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Contents

Impact of pumpkin as a nutritional supplement on the physico-chemical and organoleptic characteristics of a puncake

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Abstract

Introduction. Studies have been conducted to determine the influence of nutritional additives on the basis of pumpkin on the energy value, physico-chemical and organolleptic properties of confectionery flour products.

Materials and methods. The samples of cupcake with the addition of raw and blanched pumpkins in quantities of 8, 16, 24 and 32% were studied. Rheological parameters have been investigated using rotational viscometry.

Results and discussion. The most successful formulation is to replace the classical components of the muffin with a functional additive of 24% blanched pumpkin. The use of various forms of pumpkin as a food additive in the manufacture of cakes is appropriate in view of the enrichment of the product with biologically valuable components, vitamin and mineral complexes and compounds of antioxidants contained in this raw material.

Having analyzed the physical and chemical parameters of the samples, the following results can be made: on the curves of viscosity with an increase in P, Pa from 0 to 6000 η increases from 0 to 450 for a parabolic dependence, with the most intense growth – in the range of P in 5000. Increase of the additive from 8% to 32% increases η on average 2-3 times. Similarly, with an increase in P, the flow curves ε increases from 0 to 800 with the highest peak at 640 and then decreases.

According to the analyzed organoleptic indicators, the most successful are formulations with the addition of 16% and 24% blanched pumpkin.

Creating a new type of cupcake will help expand the range of specialty pastry flour confectionery.

Conclusions. It is rational to replace traditional components of cupcake with pumpkin with the quality assurance of products by physical and organoleptic characteristics.

Introduction

Flour confectionery products occupy an important place in the diet of the population and are in great demand. The essential disadvantage of this product group is the low content of essential substances (vitamins, minerals, food fibers, etc.) and high content of carbohydrates and fats. Therefore, a significant demand for these products necessitates the adjustment of their chemical composition. Taking into account the requirements of the science of nutrition, using non-traditional ingredients, the recipe of this group of products may be able to model and create nutritionally enriched foods with biologically active substances. One of the ways to create such products is to use additives with significant content of essential substances. As such raw can be used pumpkin[1].

The development and introduction of the newest technologies of flour confectionery with the use of functional ingredients is relevant in our time, contributes to the improvement of nutritional value, organoleptic parameters, and reduction of caloric content[2].

An overview of literary sources on assortment, technologies for the production of cakes showed that today there are no industrial technologies and formulations of carotinoid additives, such as pumpkin and cupcakes, with their use for health nutrition, both in restaurants, as well as in bakery. The assortment of cakes enriched with natural carotenoid herbal supplements abroad is also limited. An effective way to improve the vitamin content of the population is the additional enrichment of vitamins in food products of mass consumption.

The aim of research is to determine the impact of pumpkin as a nutritional supplement on the physico-chemical and organoleptic characteristics of a puncake.

Analysis of recent researchs and publications

Pumpkin (Cucurbita) – generic name of annual and perennial plants of the pumpkin family. Varieties of pumpkins differ in shape, size and color of the fruits. Some varieties of pumpkin breed for the sake of delicious and useful edible fruits, others – as decorative plants, and from the third, they make utensils and musical instruments [3,5].

Pumpkin – a natural vitamin and mineral complex. The champion among the vitamins contained in the pumpkin is beta-carotene. For comparison: in orange varieties of beta-carotene several times more than in carrots. In addition, the pumpkin is rich in vitamins C, B1, B2, PP, that is, it contains a lot of potassium, calcium, iron, magnesium, copper, zinc, cobalt, silicon, fluorine.

1. Calorific value 21.4 kcal
2. Carbohydrates 4.4 g
3. Fat 0.1 gr
4. Proteins 1.0 g
5. Water 91.8 gr
6. Mono and disaccharides 4.2 g
7. Starch 0.2 g
8. Nutrient Fibers 2.0 g
9. Organic acids 0.1 g
10. Ash 0.6 g
11. Vitamins:
    Vitamin A 1.5 mg
    Vitamin B1 0.05 mg
    Vitamin B2 is 0.06 mg
    Vitamin B3 0.4 mg
    Vitamin B6 0.1 mg
    Vitamin B9 14.0 μg
    Vitamin C 8.0 mg
    Vitamin PP 0.5 mg

Blanching is a culinary method that involves the rapid boiling of products in boiling water. Sometimes this term means scalding with boiling water. In the process of blanching,

some of the products begin to bilelit – hence the characteristic name of this culinary admission. By the way, the very word "blanching" comes from the French blanchir, that is, "whitewash"[4].

Blanching is carried out as follows: in boiling water, the products are placed and they expect to re-boil water. From this moment it is accepted to deduct the time required for blanching – as a rule, about 2–3 minutes. If the products remain in boiling water longer, in this case it is a different culinary process – cooking.

Blanching is used to disinfect the products and, in addition, it also replaces cooking for some vegetables that are tender. Thus, the prolonged processing of vegetables, for example, hot water contributes to the loss of most of the vitamins, and blanching, in turn, relates to the fruits of the sparing, softening them. In addition, using a blanching on vegetables, a protective film is created, which helps to keep the products juicy and give them a more vivid taste [6].

Material and methods

Materials

Pumpkin and cupcakes were researched. Physical and chemical properties, organoleptic characteristics of made cupcakes with the addition of functional additives and without were analyzed.

Four formulations of cupcakes were developed with the addition of various forms of pumpkin.

Table 1

Classic cupcake recipe

Component	Quantity, g	Quantity, %
Butter	200	26,4
Egg	120 (3 pcs)	15,8
Flour	200	26,4
Sugar	200	26,4
Vanilla	15	2
Ripper	15	2
Salt	7,5	1
Total	757,5	100

Table 2

Developed cupcake recipe with addition of 8 % of pumpkin

Component	Quantity, g	Quantity, %
Butter	180	23,8
Egg	120 (3 pcs)	15,8
Flour	180	23,8
Sugar	180	23,8
Vanilla	14,7	1,9
Ripper	14,7	1,9
Salt	7,5	1
Pumpkin	60,6	8
Total	757,5	100

Table 3

Developed cupcake recipe with addition of 16 % of pumpkin

Component	Quantity, g	Quantity, %
Butter	160	21,1
Egg	120 (3 pcs)	15,8
Flour	160	21,1
Sugar	160	21,1
Vanilla	14,6	2
Ripper	14,6	2
Salt	7,1	0,9
Pumpkin	121,2	16
Total	757,5	100

Table 4

Developed cupcake recipe with addition of 24 % of pumpkin

Component	Quantity, g	Quantity, %
Butter	140	18,5
Egg	120 (3 pcs)	15,8
Flour	140	18,5
Sugar	140	18,5
Vanilla	14,4	1,9
Ripper	14,4	1,9
Salt	6,9	0,9
Pumpkin	181,8	24
Total	757,5	100

Table 5

Developed cupcake recipe with addition of 32 % of pumpkin

Component	Quantity, g	Quantity, %
Butter	130	17,2
Egg	80 (2 pcs)	10,6
Flour	140	18,5
Sugar	130	17,2
Vanilla	14,2	1,8
Ripper	14,2	1,8
Salt	6,7	0,9
Pumpkin	242,4	32
Total	757,5	100

Methods

The study of structural and mechanical properties of the samples were performed on viscometer (Figure 1).

Each of the samples under study, in the amount of 30–40 cm^3, is introduced into the stationary outer cylinder of the device (1). After the test samples are applied, the inner cylinder S2 (2) is worn on the axle (3), which is connected to the electric motor. The outer cylinder (1) with the sample is worn on the fixed inner cylinder S2 (2) and lifted to the stop. The position of the outer cylinder is fixed with the help of a nut. The investigated sample is evenly distributed in the gap (4) between the coaxial cylinders – external 1 and internal 2. Next, the potentiometer readings for each test sample are removed at various twelve strain rates.

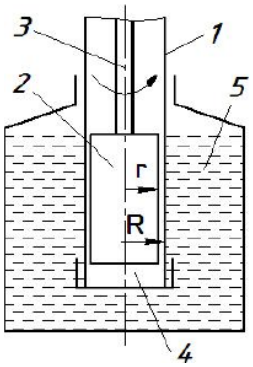

Figure 1. Chart of device

The stresses of the displacement P, which arises in the system, is calculated by the equation:

$$P = Z \cdot \alpha$$

where Z – has become an internal cylinder; a – value of the scale on the indicator device (potentiometer);

The values of deformation gradients for each speed (12 values) were taken from the passport data.

By the values of the shear stress P and the deformation gradient, calculate the dynamic viscosity η by the Newton equation:

$$\eta = P / \dot{\varepsilon}$$

where η is the dynamic viscosity, Pa × s; P – shear stress, Pa; $\dot{\varepsilon}$ – shear rate, s^{-1}.

According to the calculated data, construct complete rheological curves of viscosity and fluidity.

An organoleptic assessment of the quality of toothpastes is carried out using the descriptor-profile method [12].

Were offered a list of organoleptic indicators:

1. Shape
2. Surface
3. Color
4. View in fault

A 5-point scale was created and profiles of quality indicators were performed on scale. This made it possible to systematically approach the quality assessment and clearly assess the quality of indicators and determine the level of quality. Also, identify indicators with significant deviations.

Organoleptic evaluation of cakes should be given in accordance with the Table 6.

Table 6

Organoleptic evaluation of cupcakes

Indicator	Characteristic	
	Cupcakes without stuffing	**Cupcakes with filling**
Shape	Correct, that corresponds to the form, established according to the formulation, without breakages	Round, rectangular, not deformed, without inflow, is inherent in the form in which products are baked, without contamination
Surface	Not burned. The glazing of cupcakes should not have marks of "graying" and stains. The surface of cupcakes made on chemical rashes may be due to the presence of cracks and gaps that do not alter the product's appearance. Glaze should not be sticky.	With the presence of insignificant cracks and gaps that do not change the product's appearance without burning. It is permissible to adhere to the packaging material on the side and side of the product, the sinking hole, as well as a small amount of filling on the surface of the cupcake.
Color	From light brown to dark brown. The color of the lower crust may differ from the color of the upper side.	From light yellow to brown, the bottom and the side surface are lighter.
View in fault	A well baked cupcake, no hardening and no traces.	Well cooked, without hardening and traces of overshoot, with the inside of the product.

Results and discussion

The organoleptic and physico-chemical properties of various recipes with the addition of raw and blanched pumpkins have been developed and investigated.

Quality of control of cupcakes begins with an organoleptic evaluation: assessing the conformity of the form, surface condition, color, appearance to breakage, taste and smell. The surface of cupcakes should be non-flammable, and manufactured on chemical rashes may have cracks and gaps that do not alter the product's appearance. The color is from light to dark brown[7,8].

Cupcakes should be well baked, without hardening and traces of non-mushrooming; additives are evenly distributed in the products [9,11].

Table 7

Organoleptic evaluation of cupcakes without pumpkin and with the addition of raw pumpkin

Indicator	Without pumpkin	8%	16%	24%	32%
Shape	The shape is slightly disturbed	The shape is slightly disturbed	The shape is broken, the dough is licked when cooking	The shape is broken, the dough is licked when cooking	The shape is broken, the dough is licked when cooking
Scores	4	4	3	3	3
Surface	Not burnt, without cracks and breaks	Not burnt, without cracks and breaks	Not burnt, without cracks and breaks	The surface is slightly uneven	The surface is slightly uneven
Scores	5	5	5	4	4
Color	Light brown	Brown	Light brown	Scorched, dark brown	Really bright, hardly yellow
Scores	4	5	4	3	3
View in fault	Well baked cupcake	Well baked cupcake	Well baked cupcake	Not all parts are baked	Not all parts are baked
Scores	5	5	5	4	4

Table 8

Organoleptic evaluation of cupcakes without pumpkin and with the addition of blanched pumpkin

Indicator	Without pumpkin	8%	16%	24%	32%
Shape	Correct shape	Correct shape	Correct shape	Correct shape	Correct shape
Scores	5	5	5	5	5
Surface	Not burnt, without cracks and breaks	Not burnt, with characteristic cracks	Not burnt, without cracks and breaks	Not burnt, without cracks and breaks	The surface is slightly uneven
Scores	5	5	5	4,5	4
Color	Light brown	Light brown	Light brown	Scorched, dark brown	Really bright, hardly yellow
Scores	4	4	4	3	3
View in fault	Well baked cupcake	Well baked cupcake	Well baked cupcake	Not all parts are baked	Not all parts are baked
Scores	5	5	5	4	4

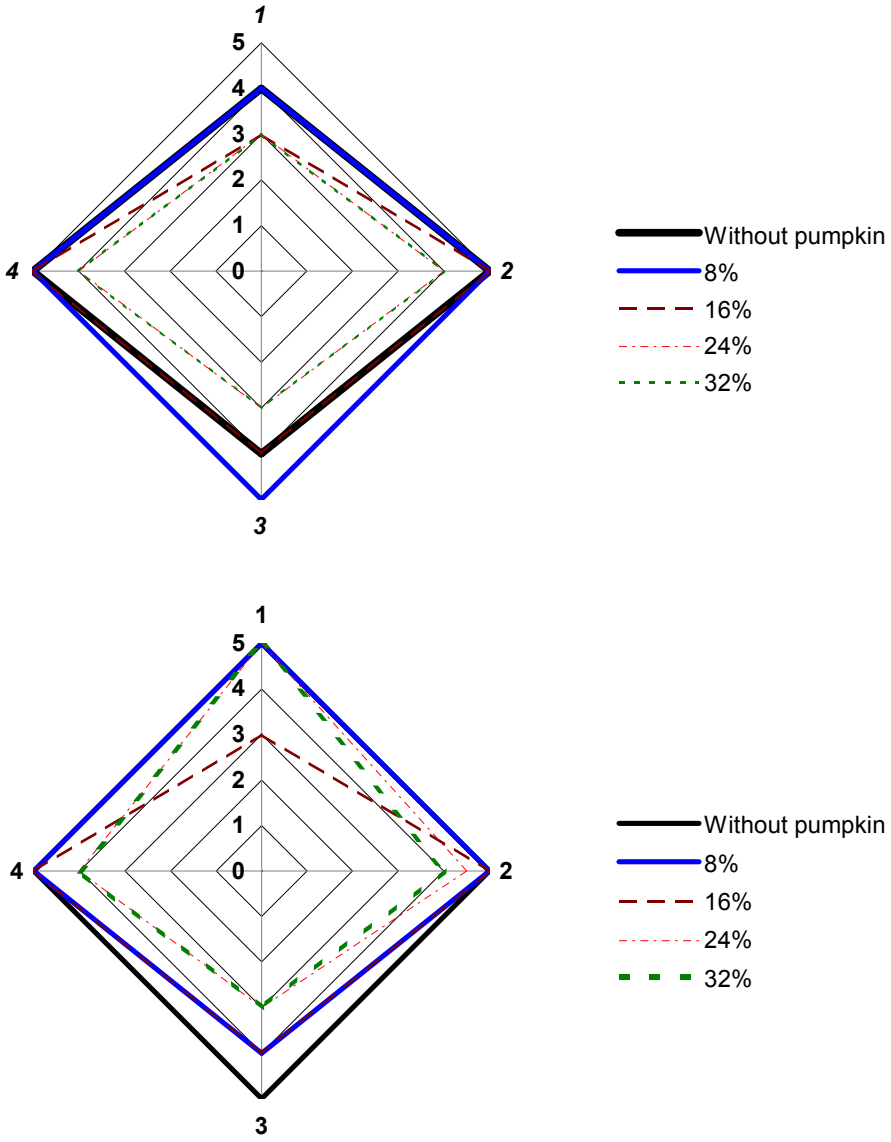

Figure 2. Profileratives of the organoleptic quality assessment of cakes with the addition of raw pumpkin and blanched pumpkin respectively

The results of rheological researches of the physical and chemical properties of various recipes with the addition of raw and blanched pumpkins are given below.

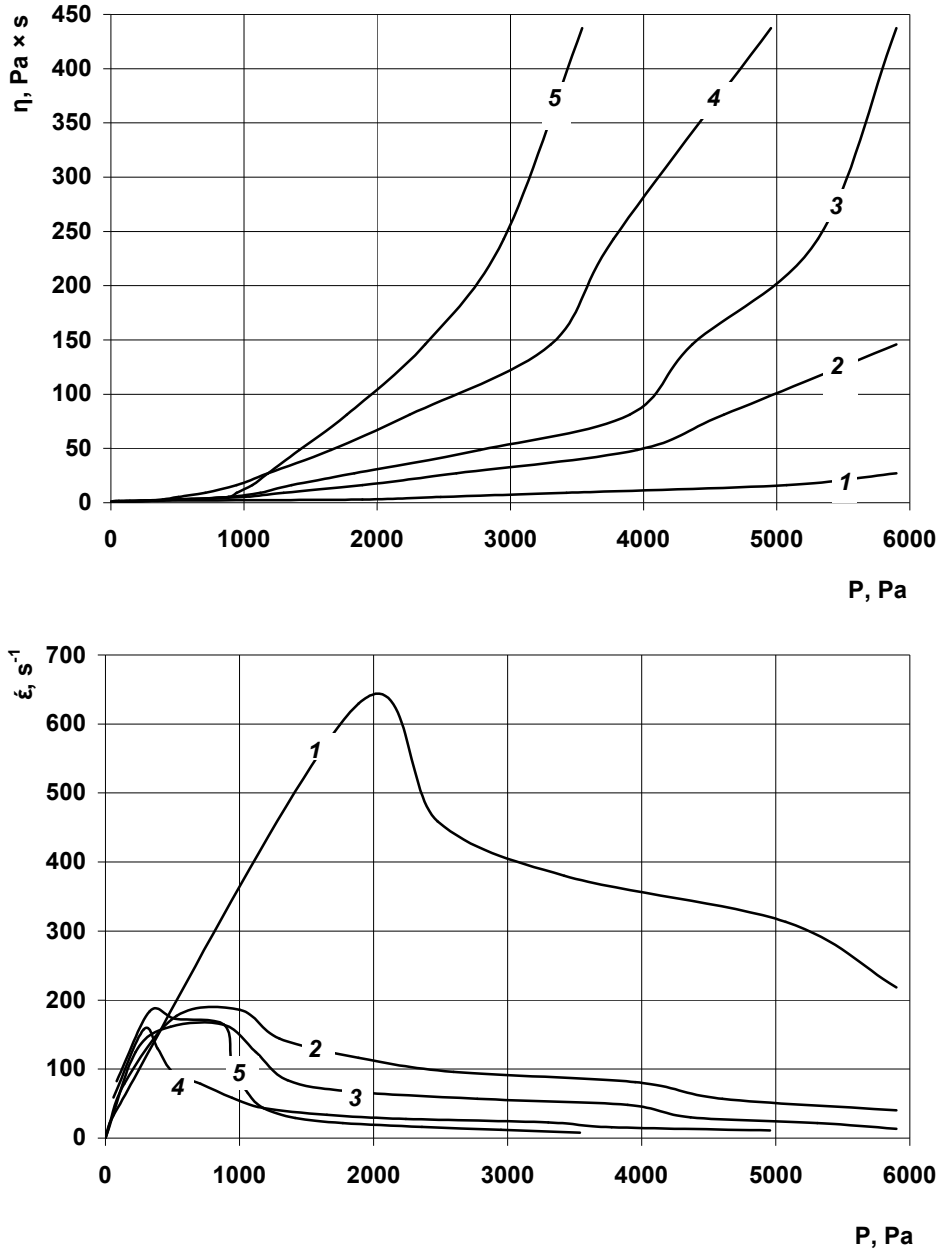

Figure 3. Rheological curves of viscosity and flowing of dough with the addition of raw pumpkin:

1 – classical recipe;
2 – recipe with adding 8% of pumpkin;
3 – recipe with adding 16% of pumpkin;
4 – recipe with adding 24% of pumpkin;
5 – recipe with adding 32% of pumpkin.

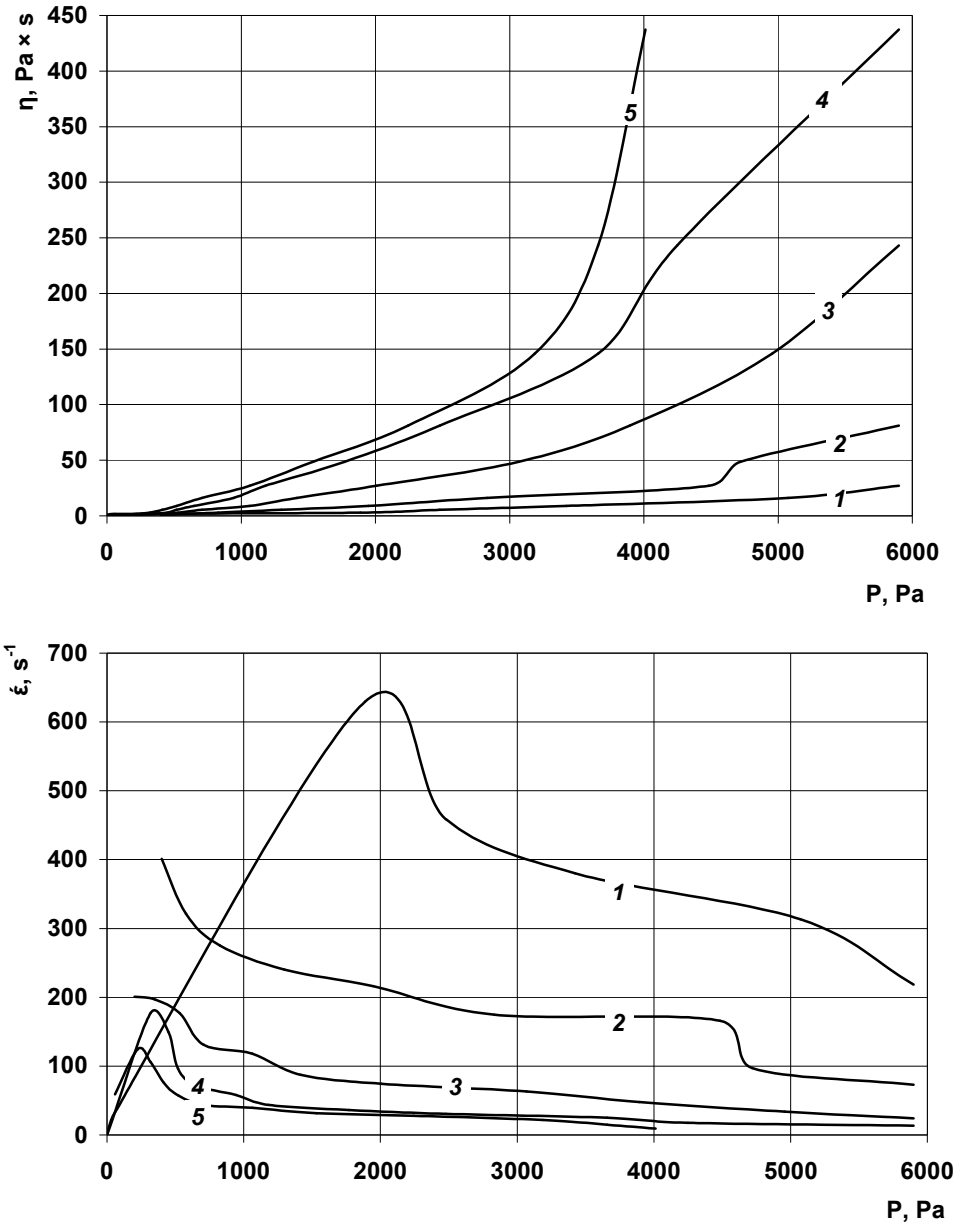

Figure 4. Rheological curves of viscosity and flowing of dough with the addition of blanched pumpkin

1 – classical recipe;
2 – recipe with adding 8% of pumpkin;
3 – recipe with adding 16% of pumpkin;
4 – recipe with adding 24% of pumpkin;
5 – recipe with adding 32% of pumpkin.

By viscosity, the most similar to the classical receipe is a sample containing 24% blanched pumpkin.

With the help of conducted organoleptic and physicochemical studies, we can conclude that the formulation with the addition of 24% blanched pumpkin is the most successful.

Creation of a new type of cupcake will promote the expansion of the range of flour confectionery products of functional action. Has been proven that adding the pumpkin to cupcake leads to the enrichment of the product with biologically valuable components, vitamin and mineral complexes and compounds of antioxidants contained in this raw material [9].

Conclusions

The use of pumpkin in the manufacture of cupcakes is appropriate in view of the enrichment of the product with biologically valuable components, vitamin-mineral complexes and compounds of antioxidants contained in this raw material. Creation of a new type of cupcake will contribute to the expansion of the range of flour confectionery products of functional action.

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Determination of molecular weights of biologically active fragments of colostrum by electrophoresis method

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Abstract

Introduction. The objective of the present article is to determine the molecular weights of the protein mixture of the cow colostrum. This will lead to the development and production of immuno-prophylactic products for maintaining immunity human body.

Materials and methods. Bovine milk was the main material for the study. The test samples have been selected from the first day of calving and during the following three days. Specimen 1 represented the colostrum of the cows from Zhytomyr region (Berdychiv town). Specimen 2 represented the bovine colostrum from Kyiv region (Tetiiv town). Electrophoresis method in the polyacrylamide gel in the Laemmli system.

Results. It has been determined that high molecular weight fractions of colostrum contain protein molecules with molecular weights of 160-190 kDa, among which are immunoglobulins. Separate parts of immunoglobulins and other proteins, namely, IgG (55kDa) and IgA (62kDa) heavy chains, secretory component of sIgA, and lactoferrin, have also been found out.

The test samples of high molecular weight peptides of colostrum contain the biologically active fragments among which there are mostly immunoglobulins, their parts, proteins-abzymes, other protein fragments. The proteins with the molecular weight of 80, 62, 55 kDa are also determined, they can represent heavy chains (55 kDa) and light chains (25 kDa) of IgG and sIgA. In particular, sIgA is a supermolecular complex consisting of H- and L-chains of IgA (62, 25 kDa, respectively) and a secretory component (80 kDa). Apart from the secretory component of IgA, the protein molecules with the molecular weight of 80 kDa can be halves of the molecules of immunoglobulins or lactoferrin.

Conclusion. The presence of a large quantity of proteins allow using the colostrum in the production of childhood, functional, medical, and prophylactic nutrition; in biotechnologies for the manufacturing of other food products with a special composition; in medicine and pharmacology to produce food-grade coats and capsules for medical substances, dietary food supplements.

Introduction

Studying the interrelation between the immune response and nourishment is one of the actual issues as it allows determining the possible reasons of the development of immune deficiency states in a human organism. The main role of nutrition is in a trophic, plastic, and energy support of the functional activity of the body, including the immune system. The components of food products show the immunomodulatory properties in terms of the acquired cell and humoral immunity, and nonspecific factors of the inborn immunity. It is known that the nutritional disorder also leads to the change of the operation of the immune system.

In this respect, the development of a balanced immune diet represents a new trend in the modern nutraceuticals. It has been proven that due to the consumption of nutraceuticals the increase of phagocytosis and bacterial activity of neutrophils is observed, as well as the growth of the general number of lymphocytes, activated T-lymphocytes, NK cells, and IgA, IgM, IgG [1, 11].

Cow colostrum is a well-known evolutionally balanced food product, because it contains all necessary components to maintain the active immunity and to renew and activate the weakened immune system.

Colostrum is vital for newborn calves. This is conditioned by the presence in its composition of a large number of the mother's antibodies that strengthen the immunity of a newborn calf and protect it from various disease producing microorganisms, which attack a calf's organism since the first months of its life [2, 10].

The digestive tract of newborn calves is characterized with high permeability enhancing the direct delivery of antibodies and different nutritive substances of colostrum to the blood flow. Besides, colostrum contains two times more dry substances, 100 times more vitamin A, and six times more protein, and 3 times more mineral substances than the ordinary milk [13].

Alongside with the advantages of the colostrum over the ordinary milk, there are a number of problems related to its storage and disposal. This is explained by the inability of the newborn calves to consume all the colostrum of the cows as its quantity exceeds the needs of the calves that consume only 30-50% of the total quantity of colostrum [3]. Due to its physical and chemical properties, the excess of colostrum cannot be used to produce dairy products. It has a thick consistency, salty taste, and specific smell, it coagulates during the thermal treatment. The dairy products produced from milk acquire an unpleasant taste and quickly spoil during storage even with the smallest addition of colostrum [4]. Therefore, the issues related to the processing of the excess of colostrum remain relevant.

Materials and methods

To extract and refine proteins, the test colostrum was divided into 2 test specimens.

The received colostrum samples from different regions have been distributed in the following way:

- Sample 1 – the bovine milk of Specimen 1, taken on the first day in two hours after calving;
- Sample 2 – the bovine milk of Specimen 1, taken on the first day in 12 hours after calving;
- Sample 3 – the bovine milk of Specimen 1, taken on the second day in 24 hours after calving;

- Sample 4 – the bovine milk of Specimen 1, taken on the second day in 36 hours after calving;
- Sample 5 – the bovine milk of Specimen 1, taken on the third day in 48 hours after calving;
- Sample 6 – the bovine milk of Specimen 1, taken on the third day in 60 hours after calving;
- Sample 7 – the bovine milk of Specimen 2, taken on the first day in two hours after calving;
- Sample 8 – the bovine milk of Specimen 2, taken on the first day in 12 hours after calving;
- Sample 9 – the bovine milk of Specimen 2, taken on the second day in 24 hours after calving;
- Sample 10 – the bovine milk of Specimen 2, taken on the second day in 36 hours after calving;
- Sample 11 – the bovine milk of Specimen 2, taken on the third day in 48 hours after calving;
- Sample 12 – the bovine milk of Specimen 2, taken on the third day in 60 hours after calving;
- Sample 13 – milk (control).

Biologically active fragments of colostrum were obtained according to the diagram below, Figure 1.

In the result of the gel filtration, two fractions have been obtained: the high molecular weight peptides and low molecular weight peptides of colostrum (Table 1).

Determination of molecular weights of the refined protein solutions of bovine colostrum and milk was carried out by the electrophoresis method in the polyacrylamide gel in the Laemmli system [5]. Electrophoresis was conducted by means of Hoefer apparatus (Amersham Biosciences, USA) with the current of 19 mA for the concentration gel and 36 mA for the separating gel [6,12]. PageRuler Plus Prestained Protein Ladder were used as markers with such proteins as 250 kDa, 130 kDa, 100 kDa, 70 kDa, 55 kDa, 35 kDa, 25 kDa, 15 kDa, 10 kDa (Thermo Fisher Scientific, USA).

To prepare samples for the electrophoresis, the buffer for samples was added to the protein solution, which contained 5% of saccharose (for more thickness); 2% of SDS (for the decomposition of protein associates into separate polypeptide chains and change of the molecule charge into negative); bromophenol – before the colouring. The samples were heated in the water bath.

The colouring of the gel was carried out in the solution of 0,01% Coomassie G-250, in 25 % isopropanol, and 10% acetic acid during 10 minutes. To eliminate the remains of the colouring agent, 2-8% solution of acetic acid was used. The resolution of the method is 1 μg of protein.

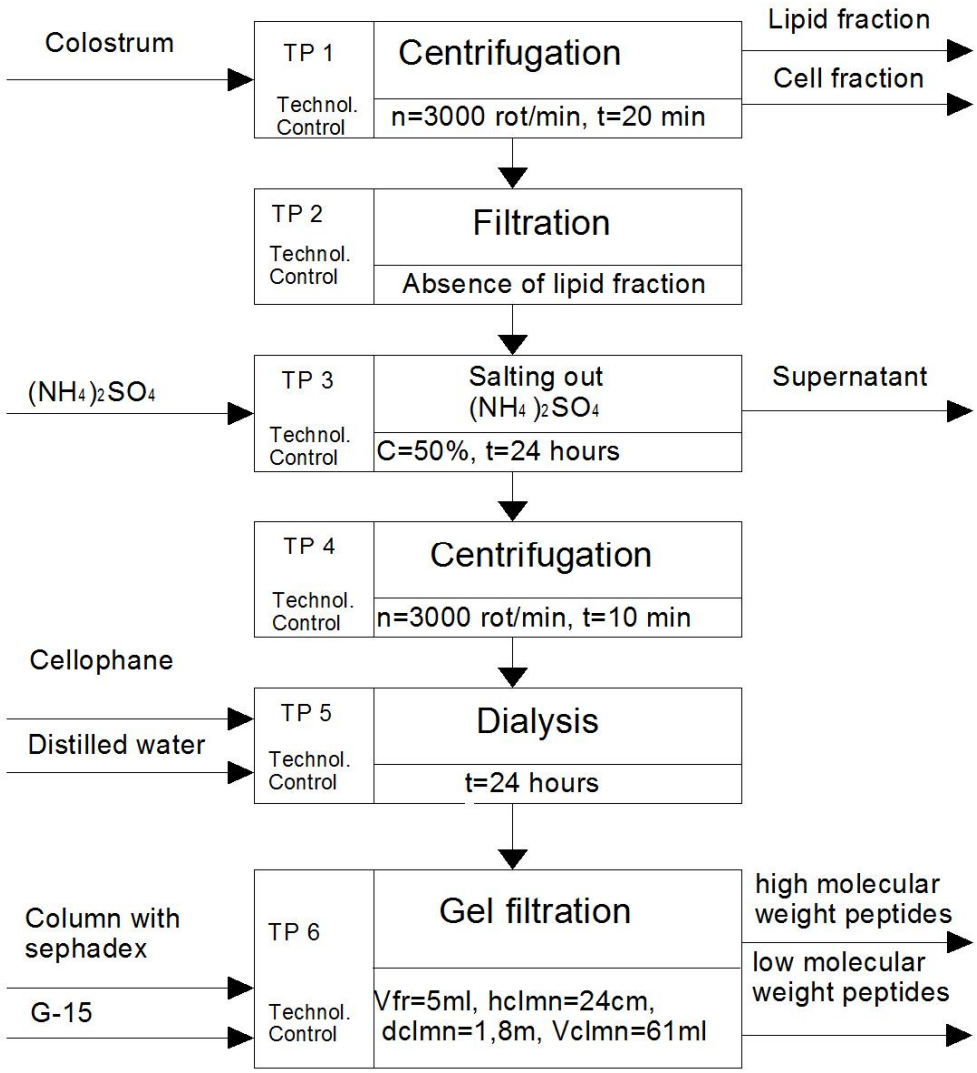

Figure 1. Diagram for the extraction and refinement of the milk and colostrum proteins

Table 1

Characteristic of the biologically active fragments of colostrum under study

Name	Fraction No	Remark
Sample 1: Day 1 in 2 hours after calving (calving on 10.02.2016)	1	high molecular weight peptides
	2	low molecular weight peptides
Sample 2: Day 1 in 12 hours after calving (calving on 10.02.2016)	3	high molecular weight peptides
	4	low molecular weight peptides
Sample 3: Day 2 in 24 hours after calving (11.02.2016)	5	high molecular weight peptides
	6	low molecular weight peptides
Sample 4: Day 2 in 36 hours after calving (11.02.2016)	7	high molecular weight peptides
	8	low molecular weight peptides
Sample 5: Day 3 in 48 hours after calving (12.02.2016)	9	high molecular weight peptides
	10	low molecular weight peptides
Sample 6: Day 3 in 60 hours after calving (12.02.2016)	11	high molecular weight peptides
	12	low molecular weight peptides
Sample 7: Day 1 in 2 hours after calving (calving on 21.01.2016)	13	high molecular weight peptides
	14	low molecular weight peptides
Sample 8: Day 1 in 12 hours after calving (calving on 21.01.2016)	15	high molecular weight peptides
	16	low molecular weight peptides
Sample 9: Day 2 in 24 hours after calving (22.01.2016)	17	high molecular weight peptides
	18	low molecular weight peptides
Sample 10: Day 2 in 36 hours after calving (22.01.2016)	19	high molecular weight peptides
	20	low molecular weight peptides
Sample 11: Day 3 in 48 hours after calving (23.01.2016)	21	high molecular weight peptides
	22	low molecular weight peptides
Sample 12: Day 3 in 60 hours after calving (23.01.2016)	23	high molecular weight peptides
	24	low molecular weight peptides
Sample 13. Reference (milk)	25	high molecular weight peptides
	26	low molecular weight peptides

Results and discussion

According to the classification of the Committee for nomenclature and methodology of milk proteins of the American Dairy Science Association, milk proteins are divided into caseins, the molecular weight of which is 14-22 kDa, and whey proteins [7]. Whey proteins comprise β-lactoglobulins and α-lactoalbumins, the molecular weight of which is ≈ 18 kDa and 14 kDa, respectively, also, lactoferrin (80 kDa), lysozyme (15 kDa), and immunoglobulins.

The major classes of the secretion of the mammary gland of the cattle and human are IgM, IgG, IgA, IgE, IgD. The full major molecule of Ig has Y-like structure and molecular weight of about 160 kDa [8,9].

IgG is a monomer, the molecular weight of which is ≈ 160 kDa. Isotype G1 represents the major weight of Ig as it contains 70-80% of all serum immunoglobulins. IgA is a monomer with the molecular weight of about 170 kDa. It contains approximately 10-15% of all serum Igs. This immunoglobulin also exits in the secretory form (sIgA). Secretory sIgA exits in the polymeric form like di- or trimer connected by J-chain (15 kDa), it also contains S-component (a secretory component – glycoprotein with the molecular weight of 80 kDa). The molecular weight of the secretory IgA is 350 kDa and more.

Immunoglobulin of class M. The largest molecule of all Igs is a pentamer with the molecular weight of about 900 kDa. It contains about 5-10% of all serum Igs.

Class D immunoglobulin is a monomer with the molecular weight of 160 kDa. It accounts for about 0,2% of the total number of circulating Igs.

Class E immunoglobulin is a monomer with the molecular weight of ≈ 190 kDa. It accounts for about 0,002% of all circulating Igs.

The electrophoretic separation was carried out under the following conditions: 1) the test samples were treated with SDS to decompose the protein molecules into the separate peptide chains, they acquired the negative charge, which significantly exceeds the own charge of the protein molecule; 2) to study the protein mixture in the samples, the 8% distribution gel was prepared.

At the first stage of work, we studied the high molecular weight and low molecular weight peptides of the colostrum of Specimen 1, which were extracted and selected on the first day immediately after calving and after 12 hours (*Fig. 2*), and the high molecular weight peptides of the second day (samples taken 24 hours after calving). The high molecular weight peptides (No 25) and low molecular weight peptides (No 26) of milk (control) were used as reference samples.

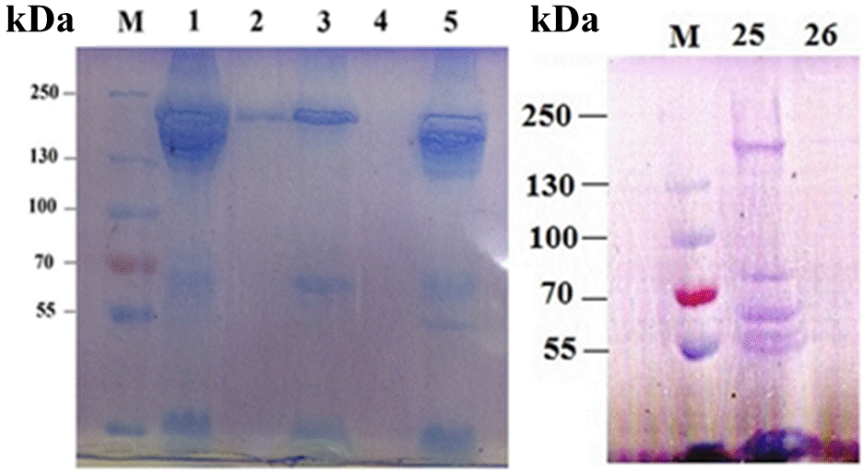

Figure 2. Electropherogram of the proteins of the colostrum of the first and second days after calving and cow milk

*Note. No 1-No 5 – the test samples of Specimen 1 of the colostrum of the first and second days after calving; No 25, 26 – the reference samples, high molecular weight and low molecular weight peptides respectively, extracted from milk (control); M – the protein markers of molecular weights: 250 kDa, 130 kDa, 100 kDa, 70 kDa, 55 kDa, 35 kDa, 25 kDa, 15 kDa, 10 kDa.

After the electrophoresis of the protein solutions of colostrum, four protein lines were determined in the electropherogram. Samples 1, 2, 3, 5, and 25 (reference sample) showed the lines that corresponded to the molecular weights of 160-190 kDa.

The weights typical for IgG and IgA (160 kDa and 170 kDa, respectively). Samples 4 and 26 (reference sample) did not show any protein molecules.

Samples 1, 3, and 5 demonstrated the proteins with the molecular weight of 60 kDa, and Reference Sample 25 – the molecular weights of 55 kDa, 60 kDa, and 80 kDa. On the basis of the obtained results, one can assume that the determined proteins can be IgG (55 kDa) and IgA (62 kDa) heavy chains, and the proteins with the molecular weight of 80 kDa can comprise a half of the Ig molecule which is composed of one heavy chain with the molecular weight of 55 kDa and one light chain with the molecular weight of 25 kDa. Secretory component sIgA (80k Da) and lactoferrin (the molecular weight of which is 80 kDa) can also be possible.

At the second stage of work, we studied high molecular weight and low molecular weight peptides of the colostrum of Specimen 1, extracted and selected on the first and third days after calving (*Figure 3*). The reference samples represented high molecular weight (No 25) and low molecular weight (No 26) peptides of milk (control).

The obtained results demonstrate that high molecular weight peptide fractions No 7, No 9, No 11, No 25 contain proteins with the molecular weight of 160-190 kDa. It corresponds to IgG and IgA, the molecular weight of which is 160 kDa and 170 kDa, respectively. Protein molecules were not determined in low molecular weight peptide fractions No 6, No 8, No 10, No 12, and reference sample No 26. Sample 7, 9, 11 showed proteins with the molecular weight of 60 kDa. Reference Sample 25 demonstrated the presence of proteins with the molecular weight of 55 kDa, 60 kDa, 80kDa.

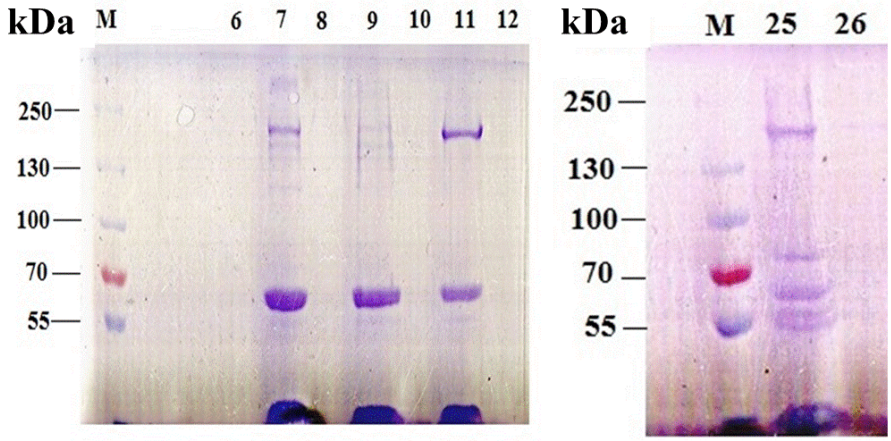

Figure 3. Electropherogram of the proteins of the colostrum of the second and third days after calving and bovine milk

*Note. No 6-No 12 – the test samples of the colostrum of Specimen 1 on the second and third days after calving; No 25, 26 – the reference samples, high molecular weight and low molecular weight peptides respectively, extracted from milk (control) ; M – the protein markers of molecular weights: 250 kDa, 130 kDa, 100 kDa, 70 kDa, 55 kDa, 35 kDa, 25 kDa, 15 kDa, 10 kDa.

One can assume that the identified proteins can be IgG (55 kDa) and IgA (62 kDa) heavy chains. The protein molecules with the molecular weight of 80 kDa can comprise a half of the Ig molecule, which is composed of one heavy chain with the molecular weight of 55 kDa and one light chain with the molecular weight of 25 kDa. Secretory component sIgA (80k Da) and lactoferrin (80 kDa) can also be possible.

At the third stage of work, we studied high molecular weight and low molecular weight peptides of the colostrum of Specimen 2 selected on the first day immediately after calving and 12 hours after calving and on the second day (*Fig. 4*). The reference samples represented high molecular weight (No 25) and low molecular weight (No 26) peptides of milk (control).

The electropherogram (*Fig. 4*) shows that Samples 13, 15, 16, 17, 19, 25 contain the lines similar to the molecular weights of 160-190 kDa. According to published articles such molecular weights belong to the immunoglobulins of IgG and IgA classes (160 kDa and 170 kDa, respectively). Samples 14 and 18 did not show any presence of protein molecules.

Examining Samples 13, 15, 17, 19, the lines, which corresponded to the molecular weights of 60 kDa and 55 kDa, were determined. Reference Sample 25 contains a line, which represents the molecular weight of 80 kDa. The identified proteins can represent IgG (55 kDa) and IgA (62 kDa) heavy chains. The protein molecules with the molecular weight of 80 kDa comprise a half of the Ig molecule, secretory component sIgA, and lactoferrin.

At the final stage of work, we studied the high molecular weight and low molecular weight peptides of the colostrum of Specimen 2, selected on the third day after calving, and the low molecular weight peptides, which were selected on the second day in 36 hours after calving (*Fig. 5*). The reference samples represented high molecular weight (No 25) and low molecular weight (No 26) peptides of milk (control).

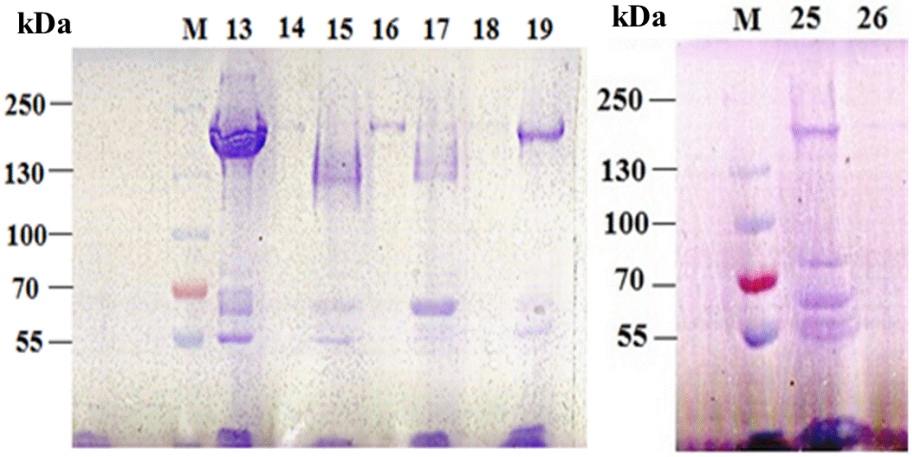

Figure 4. Electropherogram of the proteins of the colostrum of the first and second days after calving and cow milk

*Note. No13-No 19 – the test samples of Specimen 2 of the colostrum of the first and second days after calving; No 25, 26 – the reference samples, high molecular weight and low molecular weight peptides respectively, extracted from milk (control).; M – the protein markers of molecular weights: 250 kDa, 130 kDa, 100 kDa, 70 kDa, 55 kDa, 35 kDa, 25 kDa, 15 kDa, 10 kDa.

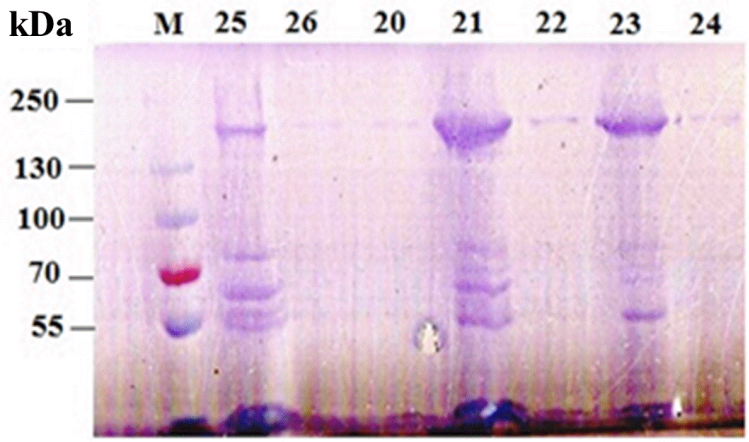

Figure 5. Electropherogram of the proteins of the colostrum of the second and third days after calving and cow milk

**Note. No20-No24 – the test samples of the colostrum of Specimen 2 of the second and third days after calving; No 25, 26 – the reference samples, high molecular weight and low molecular weight peptides respectively, extracted from milk (control); M – the protein markers of molecular weights: 250 kDa, 130 kDa, 100 kDa, 70 kDa, 55 kDa, 35 kDa, 25 kDa, 15 kDa, 10 kDa.*

According to the results of the electropherogram for Samples 20-24 and Reference Sample 25, the obtained lines match the molecular weights of 160-190 kDa. Such results indicate the presence of IgG and IgA, the molecular weight of which is 160 kDa and 170 kDa, respectively.

The analysis of Samples 21, 23, 25 showed the presence of three lines of 60 kDa, 55 kDa, and 80 kDa.

These results let assume that the lines with the molecular weights refer to the heavy chains IgG (55 kDa) and IgA (62 kDa), and the protein molecules with the molecular weight of 80 kDa refer to a half of the molecule of immunoglobulin or secretory component sIgA (80 kDa), or lactoferrin (80 kDa).

Conclusions

Thus, multifunctional content of colostrum makes it a promising raw material to develop diverse products of general and special purpose. Besides, from the practical point of view, only the colostrum selected on the first days after calving represents a special interest as, after a while, the level of proteins, namely, immunoglobulins, rapidly decreases in it.

The data above emphasize the relevance of the studies, selection and refinement of the high molecular weight biologically active protein fragments of colostrum for the purposes of its use in child nutrition, addition into milk powders. This will lead to the development and production of immuno-prophylactic products for maintaining immunity and preventing and reducing the occurrence of immunodeficiency states in the human body.

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Resource saving wool washing technology

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Abstract

Introduction. Washing of wool is carried out in an aqueous environment in order to remove contaminants and wool fat (zhyropit). Remove sewage from sewage. The purified fat of wool (food additive E–913, lanolin) is widely used in the production of food, perfumery, cosmetics and specialty products and preparations.

Materials and methods. Sles 70 was washed with wipes. To find rational wool washing parameters, the mathematical planning of the experiment was performed using Latin squares. Experimental data was processed using mathematical statistics in the Matcad package.

Results and discussion. The influence of Sles 70 concentration in the washing solution in the range of 0.5–3.5 g/dm^3, the hydromodule 10–50, the temperature 20–50 °C and the duration of washing 2 to 32 minutes were determined for extraction of extractives from sheep wool into a washing solution.

The rational parameters of washing of fine-wool hair are revealed, influential factors are determined. The possibility of reducing the amount of water used during washing is studied. A regression equation is obtained that approximates the effect of normalized factors on the refractive index n (n_D^{20}) of waste water. Three essential and significant factors on the amount of extracted substances extracted in the washed solution are selected. The most influential factor on the refractive index of the spent washing solution is the temperature. Further on the significance of the effect is the hydromodule, with the temperature and the hydraulic module exhibit a measurable effect on the refractive index. The less important factor is the duration of the washing process. The concentration of detergent Sles 70 was an ineffective factor in the process of washing the wool, since the detergent was sufficient to form a micelle in a clean solution.

Conclusions. It is determined that within the limits of the investigated range, the rational mode is as follows: washing at a temperature of 40 °C and a hydromodule of process 10 (the ratio of aqueous solution: wool 10:1) for a duration of 10 minutes washing solution Sles 70 at a concentration of 1 g/dm^3.

Introduction

Purified wool grease (E-913 lanolin) is widely used in the manufacture of food, perfume and cosmetics and special products and preparations [1, 2].

The sheep's wool is trimmed after trimming and sent for purification on the primary treatment. The primary treatment of wool includes dry and wet stages [1, 8]. The dry stage of primary treatment is intended to remove dry particles from the runes: lumps of earth or sand, straw. Dry cleaning is carried out on tipping machines, which do not loosen the fleece's fibers but only shaking, reducing the contamination of the wool. Wet cleansing involves the sequential movement of wool in several baths (barks) with detergent solutions for the removal of such substances: vein of wool, sand, residues of feed and excrement, pigments and other dirt [6–8].

Washing the wool can be done in washing machines that use a different washing principle. For a van washing machine, it is important to maintain the ratio of water: wool or hydromodule of the washing process. For a reciprocating machine, the pressure of the water at the outlet of the nozzles is important, however, the fiber is dumped under the high pressure of water. Better washing of dirt from wool is characteristic for the bathroom machine. The mixing of the contents of the bath with the robbery mechanism is more intense than with the harrow mechanism, due to the reduction of the number of so-called "dead" zones with standing liquid detergent [14].

Primary treatment of wool includes tepid, wet cleaning, which involves soaking, washing and rinsing, and drying. Washing of wool is carried out in aqueous solution of soap and soda for dipping the wool into a solution and successively moving in several baths, which change the temperature regime and the concentration of detergent solutions. Soaking is carried out in 0.1–0.2% solution of sodium carbonate (soda ash) with a temperature of 35–40 °C for 30–40 minutes for the mass ratio of the solution to the wool from 25 to 30 to 1. After soaking the wool is pressed. Washing is carried out sequentially in two working chambers of a washing machine in 0,2–0,3% solution of commercial soap and 0.2–0.3% solution of sodium carbonate at a temperature of 45–50 °C for 5–10 minutes for a mass ratio of solution to wool 25 to 30 to 1. After washing in each cell wool is pressed. Next, rinsing is carried out sequentially in two working chambers of the washing machine and spin after passing the wool of each chamber, and rinsing is performed at a temperature of 35–40 °C for 5–7 minutes in the first chamber and at a temperature of 20–25 °C for 3 to 5 minutes in the second chamber. After wet processing, the wool is dried in the dryer at an air temperature of 75–85 °C to a final moisture content of wool of 12–18 %. The spent cleaning solutions of the final stages of processing after filtration are used for further wool washing [UA 55426 U, 10.12.2009]. In this way, the waste water that contains grease, dirt and which consumes 125–150 parts by weight to 1 part by weight of wool is obtained.

In order to increase the capacity of the washing machine and reduce the hanging particles in the next bath, in comparison with the previous one, it is suggested before irrigation with a washing solution with a temperature of 1–25 °C above the solution temperature in the washing machine chamber and to prevent free draining of the excess portion of the solution towards the spindle shafts [RU 2193081 C1, 20.11.2002].

The reaction movement of the wool and the detergent solution reduces the amount of waste (waste water) and increases the concentration of suspended particles of dirt in the first chamber of the washing machine [RU 2228975 C1, 20.05.2004]. Moreover, the amount of waste water is regulated by the concentration of dirt in the first chamber of a washing machine [RU 2365685 C1, 27.08.2009], or by the size of the counterflow, which is

set by adjusting the flow through the overflow pipes and visually fixed on the calibration openings of the drain tank installed at the beginning of the first washing machine chamber [RU 2441946, 10.12.2012].

During intense mechanical mixing during wool washing can be dumped. Washing dirty wool requires the use of water, which, after wool cleaning, requires additional treatment to separate fat from dirt. Reducing water consumption and preventing the removal of fibers was achieved by mechanical additional extraction of wool in a washing liquid [9].

Intensification of wool washing was carried out by repeated pressing of wool while washing and loosening it, bubbling the solution with air. Washing the wool in a bath with multiple pressing allows you to reduce the volume of sewage twice [10].

Extrusion of wool after each technological operation (soaking, washing, rinsing) reduces the consumption of water and detergents in 1.2–1.5 times. A small-sized plant for primary wool processing for agricultural enterprises has been developed, which includes a spinning roller for pressing wool after soaking and a washing machine, in which there are two washing chambers and two for rinsing, and moves the wool from the chamber to the next chamber after it is squeezed [12].

The reduction of the number of baths for washing the wool reaches the previous one before washing with wool treatment by high voltage electrical discharges [UA 38562 U, 12.01.2009; 16].

Intensification of wool cleaning is carried out by lowering the temperature of the detergent solution and water for rinsing the wool and simultaneously treating the wool with high voltage electric discharges [UA 48930 U, 12.04.2010]. Also, the processing of wool fibers is carried out by high voltage electrical discharges before washing and dyeing to increase the sorption properties of wool, although, after processing with electrond rigid nonlinear volumetric cavitation, the weight of wool is reduced [UA 111316 U, 10.11.2016; 11].

During the washing of wool, an electro-hydraulic impact is used which is created in the field between the grounded conveyor which is immersed in the washing solution and by which the wool is transported, and the electrodes supplied with current pulses from the pulse current generator [RU 2049178 C1, 27.11.1995].

When wool is washed, an ultrasound of 5–22 kHz with an intensity of 1–2 W/cm^2 using at least two hydrodynamic magnetostrictive transducers is used, and the washing solution is applied to the washing chamber under pressure of 4–7 atm, which provides mixing of the solution and the wool [UA 35834 A, 16.01.2001].

Wool washings are carried out using ultrasound in a V-shaped cylinder with a hollow shaft, with flat acoustic emitters fixed on the acoustically rigid walls of the cylinder, as well as initiating the washing of the dirt, replacing the washing solution and then removing the wool oil from the wool [UA 30059 A, 15.11.2000]. The use of flat hydrodynamic emitters in industrial washing machines is placed over a layer of wool immersed in a washing solution and placed between the mesh bands of two conveyors that move the wool in a washing machine [UA 54270 U, 10.11.2010; 13].

There are several interpretations of the use of ozone or air ions in air to improve the quality of wool due to the restoration of cross-fiber fiber bonds and the increase of urea-bisulfite solubility of wool [RU 2228974 C1, 20.05.2004] or for destruction of zhiropt and organic pollutants [UA 56564 A, 15.05.2003].

Washing of wool is carried out in an alkaline fraction of hydrolyzed water at pH 9.0–9.5, followed by treatment in an acidic fraction of hydrolyzed water at pH 5.0–6.0 and at a temperature of 45–50 °C without the use of detergents [UA 29671 A, 15.11.2000].

For washing the wool use 2–3 % water mildew solutions [UA 55426 U, 10.12.2010; 8] and aqueous solutions with synthetic detergents [UA 32398, 12.05.2008; UA 32960 U, 10.06.2008; UA 57000 U, 10.02.2011].

Consequently, wool washing is carried out in a water environment in order to remove contaminants and wool grease (zhiropot). After washing the wool accumulates the waste water that is treated to remove from it the wool fat.

Cleaning the wool is necessary for the removal of mineral and organic contaminants, adhered to woolen fibers. Apply drying (dry mechanical cleaning from dust, earth, straw, forage) and soaking and washing (wet cleaning). Washing is carried out necessarily. While washing with dirt, they take off part of the wax, or the so-called zhiropt, from the surface of the fiber [UA 105905 U, 11.04.2016; UA 105906 U, 11.04.2016; UA 114836 C2, 10.08.2017; UA 114837 C2, 10.08.2017]. Search for detergents for washing wool is also relevant today. Requirements for detergent are as follows: the product should not reduce the quality of the wool fiber (to be chemically inert to the wool), its consumption should be minimal (critical concentration of micelles – as small as possible) [3, 5].

Materials and methods

Sles 70 was washed with wipes. In order to find rational wool washing parameters, the mathematical planning of the experiment in Latin squares was used. This plan of experiment declares the absence of inter-factor influences. This involves the choice of independent factors and the use of the regression equations of the response of the change in factors to find the optimal value of the factor in the selected range of variation. Each experiment experiment performed in triple repetition. Among the factors that were used to clean the wool during soaking, the concentration of Sles 70 in the washing solution, the hydrodilution (water ratio: dry wool), temperature, and duration was investigated. In response to changes in factors, the refractive index of waste water was chosen.

Experimental data was processed using mathematical statistics in the Matcad package.

Results and discussion

The purpose of our study was to find the rational parameters of washing fine-wool hair. To achieve the goal, the factors influencing the process of extracting extractives in the washing solution were determined, and the possibility of reducing the amount of water used during washing was studied. The washing solution was prepared by dissolving an anionic detergent sodium laureth sulfate (Sles 70), replacing the classical alkaline solution solution with a solution with a neutral pH of the medium. Solutions up to 3 % Sles 70 have a pH of 6.5–9.5. The critical concentration of micelles (CCM) at a temperature of 20 °C for Sles 70 is 0.55 g/dm^3 [4, 15]. Sles 70 is the main ingredient in the hair shampoo formulation.

The influence of Sles 70 concentration in the washing solution in the range of 0.5–3.5 g/dm^3, the hydromodule 10–50, the temperature 20–50 °C and the duration of washing 2 to 32 minutes were determined for extraction of extractives from sheep wool into a washing solution.

The plan of incomplete factor experiment is presented in the table 1.

Table 1

Planning a partial quotient experiment in Latin squares in physical quantities of factor levels

Experiment No.	Concentration Sles 70, g/dm^3	Hydraulic Module	Temperature, °C	Duration, min.
1	1.5	55	40	2
2	3.5	25	20	22
3	0.5	40	30	32
4	2.5	10	50	12
5	3.5	55	50	32
6	1.5	40	20	12
7	2.5	25	30	2
8	0.5	10	40	22
9	1.5	10	30	22
10	0.5	25	50	2
11	3.5	40	40	12
12	2.5	55	20	32
13	0.5	55	20	12
14	2.5	40	40	22
15	1.5	25	50	32
16	3.5	10	30	2

The results of a partial factor experiment are presented in the table 2.

Table 2

Average response to changing factors in the selected range

Experiment No.	Refractive index
1	1.3340
2	1.3338
3	1.3338
4	1.3344
5	1.3340
6	1.3336
7	1.3340
8	1.3342
9	1.3342
10	1.3336
11	1.3340
12	1.3336
13	1.3340
14	1.3340
15	1.3338
16	1.3342

To compare the influence of the investigated factors, the values of the levels of factors were normalized.

Correlation and regression dependence of the index of refraction on the change of factors in the studied range was established.

The regression equation, which approximates the effect of normalized factors on the refractive index n of the treated wastewater:

$$n = -0{,}0001x_1^2 - 0{,}0007x_1 - 0{,}0001x_2^2 + 0{,}0006x_2 - 0{,}00007x_3^2 + 0{,}0003x_3 + 4{,}0016,$$

where x1 – wool wash temperature in the normalized sense; x2 – hydrological washing hair in normalized terms; x3 – the duration of wool washing in the normalized sense.

The coefficients in the regression equation are congruent and significant. The effect of the duration of wool washing is less significant, albeit an influential factor, in comparison with the influence of temperature and the hydromodule of washing in the studied range of variation of factors. The obtained regression equation describes the effect of temperature on extracting extractives in a washing solution with a determination coefficient of 99.4 %, the effect of the hydrodule represents 89.6 % of the experimental data, and the effect of duration in the regression equation reproduces 87.1 % of the actual values of the factor response.

From the regression equation, it follows that the influence of extracting extractives during washing in the solution of solutions can be ranked in order of decreasing their effect on the process: washing temperature, hydromodule (ratio of water: wool), duration of washing process. The concentration of detergent in the solution exceeded its CCM, so the effect of this factor did not manifest.

On the basis of the regression equation, the surface of the response was constructed, considering the factors that are in pairs, which have an influence on the extraction of the extractives in the washing solution during washing.

In Figure 1 shows the response plane for the change of the hydromodule and the temperature taken in the normalized form. On the plane of the same color, the areas with the same range of refractive index values of the worked-out detergent solution were observed.

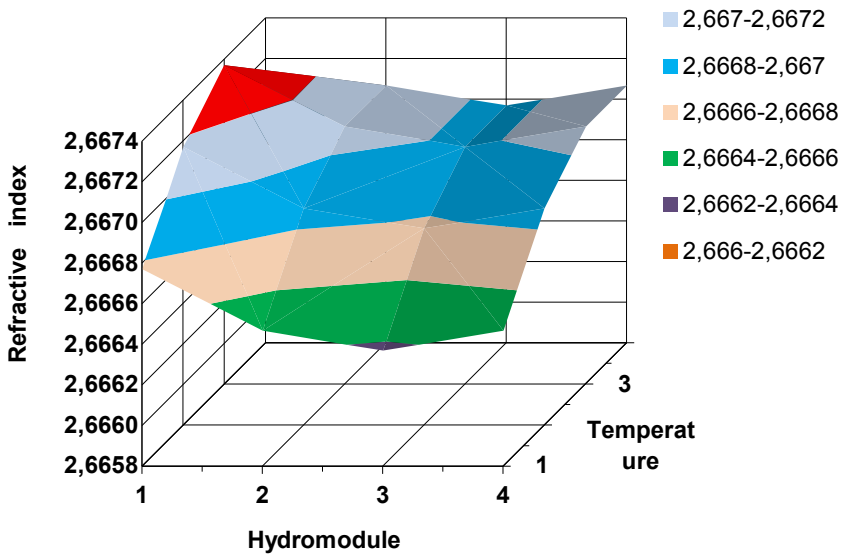

Figure 1. The response plane of the values of the refractive index of the spent washing solution for the change of hydromodule and temperature taken in the normalized form

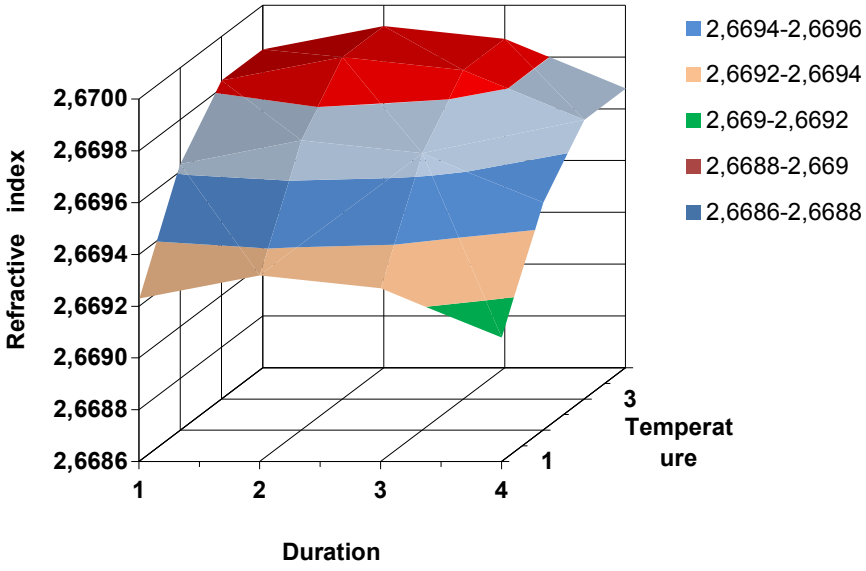

Figure 2. The response plane of the values of the refractive index of the spent washing solution for the change of temperature and duration of washing taken in the normalized form

From Figure 1 shows that the greatest value of the refractive index of the detergent solution is achieved for the normalized values of the hydromodule 1 and temperature 3, which correspond to the physical values of the hydrodule 10 respectively and the temperature of 40 °C. Consequently, the most extractive substances in the washing solution accumulate in the hydromodule 10 and the temperature of 40 °C.

Wool wash for 22 minutes reaches equilibrium values of the content of extractives in the washing solution. Extending the duration of washing does not increase the refractive index of the detergent solution, as seen from the Figure 2. Wool washing in Sles 70 solution at temperatures in the range of 20–44 °C for 22 minutes and extracts most of the extractives for longer.

The hydromodule 10 removes the most extractive substances from the wool in the washing solution. Consideration of the effects of the hydromodule and the duration of washing on the value of refractive index of the detergent solution revealed the sufficiency of varying the duration of the washing process in the range of 12–22 minutes for the hydromodule 10 (Figure 3).

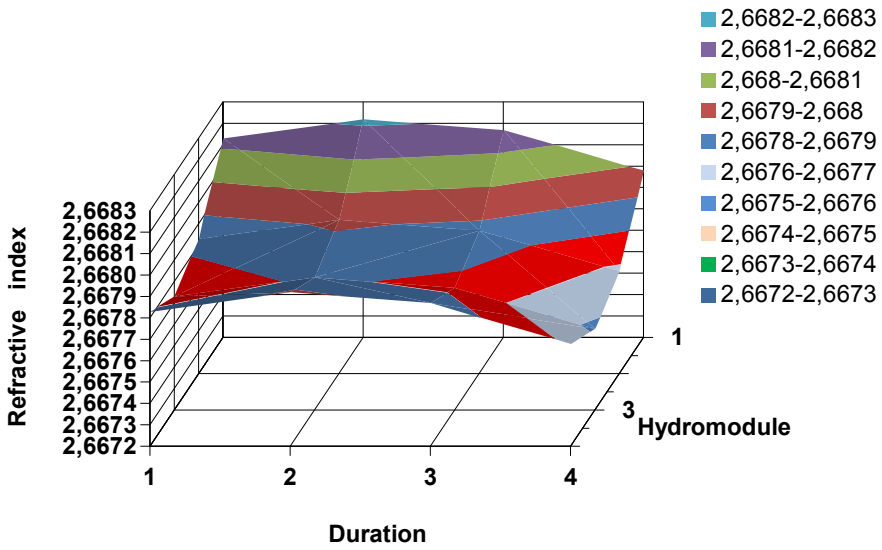

Figure 3. The response plane of the values of the refractive index of the spent washing solution for the change of hydromodule and duration of washing taken in the normalized form

Consequently, the use the ratio of aqueous solution: wool 10:1 is optimal, which indicated the expediency reducing the amount o water during wool washing.

Conclusion

The influence of the concentration of detergent in the washing solution, the hydromodule, the temperature and duration of washing on the refractive index of the washed waste solution obtained after wool washing was investigated. The refractive index indirectly indicates the amount of extracts extracted from the wool removed from the wool.

Three essential and significant factors on the content of recovered extractives in the washed solution were identified. The most influential factor on the refractive index of the spent washing solution is the temperature. Further on the significance of the effect is the hydromodule, with the temperature and the hydraulic module exhibit a measurable effect on the refractive index. The less important factor is the duration of the washing process. The concentration of detergent Sles 70 was an ineffective factor in the process of washing the wool, since the medium was taken sufficiently to form a micelle in a washing solution.

According to the results of the mathematical processing of the incomplete factor experiment planned by the Latin squares method, it is determined that within the limits of the investigated range, the rational mode of washing is as follows: washing at a temperature of 40 °C and the hydromodule of the process 10 (ratio of aqueous solution : wool 10:1) for a duration of 10 minutes washing solution Sles 70 at a concentration of 1 g/dm^3.

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Effect of natural dye from beetroot juice on antioxidant properties and nutritional values of fondants

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Abstract

Introduction. It was performed a research the physical and chemical, antioxidant and nutritional properties of the fondants with beetroot juice addition.

Materials and methods. 3 samples of fondants with juice obtained from raw (1), boiled (2) and baked (3) beetroot were used in this study. Methods: sensory analysis with the help of 15 subjects, the antioxidant activity assessment through DPPH method, and the chemical test, which refers to moisture, ash, mineral and reducing sugar determinations.

Results and discussions. Sample 1, which are fondant candies with juice obtained from fresh beetroot, was the most appreciated with a total ranking of 8,92, and sample III, fondant candies with juice obtained from baked beetroot, was the least appreciated with a result of 8,55. Sample II, fondant candies with juice obtained from boiled beetroot, had an overall assessment of 8,59.

Highest antioxidant capacity occurs in the case of fondant candies with red juice obtained from raw beetroots (sample 1), with an overall performance of 93,22%. A rather lower result had the sample 2 with 92,84%. Sample 3 showed the lowest result of 91,49%.

The highest results in the matter of moisture content (94,20%) and reducing sugars (14,20%) had the sample 3. On the contrary, the lowest results for both moisture content and reducing sugars was shown by sample 2 with 93,2% and 12,1%.

The highest value of ash content was shown by the sample with raw beetroot juice, 5,66%. Sample 3 had the lowest level of ash content, 1,18%, five times lower comparing to the first sample.

Conclusions. The fondants obtained from raw beetroot juice has the most pronounced antioxidant capacity and the betaine content is almost double compared with other analysed samples.

Introduction

Fondants are types of confectionery. They are categorized based products called fondanterie flux. Besides fondants in this category are included sherbet, marzipan and other confectionery [6].

Natural dye is used in both commercial production of food and the cooking class. Due to their safety and general availability, natural dyes are used in a variety of non-food applications, for example in handicrafts and educational kits. By the mid 1800s the only source of dyes used in foods were natural, extracted from saffron, carrots, dude, beetroot etc. [2] [3].

Manufacturers continue to seek solutions for natural ingredients for the development of new products, particularly for products that are marketed as "better for consumption". As costumers demand for healthy food and healthy increases, so does the use of natural colors [1] [4].

Also, natural colors must be declared on the product label. If the red beet juice is used to shade a foodstuff (sweets, jellies, etc.), it should be indicated as an additive color [4] [5].

It was discovered that in 2010 only 1.6% of confectionery products contained natural colorants; this number has increased and is estimated to account for over 10% of all confections in 2020 [13].

An interesting use of natural coloring aids is that many are bioactive and have a strong antioxidant capacity; for example, betaine extracted from red beet is one of the most powerful natural antioxidants [2].

A study by a group of UK researchers in 2012 compared the antioxidant activity of betaine extracted from red beetroot Detroit Dark Red, with the antioxidant capacity of betaine extracted from an unknown variety.

It has been found that betaine extract obtained from the Detroit Dark Red variety has higher salt antioxidant capacity (DPPH) than the other extract; 3.28 times greater packing capacity, and ORACs 20 times higher.

It has been demonstrated in the same study that betaine remains stable in the gastrointestinal tract without any significant loss of antioxidant properties, which makes its value as a food additive increase.

Betaines are divided into two groups: betaxanthines and beta-cyanines, due to their chemical structure. Betaxanthines are condensation products of betalamic acid, they have a deep violet color [12].

The purpose of this research is the assessment of the physical and chemical behavior of the beetroot juice added in the product, as well as its properties changes after heat treatment application. Plus, another intent of this paper is to find if there can be found any correlation between sensorial and chemical performances of the samples.

Materials and methods

For this study were analysed the following samples:
Sample 1 – fondant candies with beetroot juice, obtained from fresh beetroot;
Sample 2 – fondant candies with beetroot juice, obtained from boiled beetroot;
Sample 3 – fondant candies with beetroot juice, obtained from baked beetroot.

Sensory analysis

For the sensory analysis has been used the method with hedonic scale (hedonic test). This method is used for the purpose of introducing a new product on the market, by assessing the consumer's reaction to the organoleptic properties of the product [7].

The hedonic test allows to determinate both the best sample and the degree of preference of certain factors such as the packing method, the modification of the recipe as well as the shelf life [7].

For this method 15 subjects were selected with the help of which were performed the following determinations: appearance, colour, taste, smell, flavour and texture. [7]

The experiment was held in the laboratory with specific conditions of light, ventilation and temperature.

Antioxidant activity

This test was performed using the DPPH reagent and a spectrophotometer.

DPPH (2,2-diphenyl-1-picrylhydrazyl) is one of the most stable and commercially available organic radionuclides and has a maximum UV-VIS absorption at 517 nm. DPPH method is based on the generation of free radicals, from a methanol solution of 2,2diphenyl -1- picrylhydrazyl, which absorption disappears in the presence of an antioxidant [8]

Preparation of the solid samples. In three volumetric flasks were introduced 2,5 mg of each sample, followed by bringing to the mark with methanol. The flasks were agitated vigorously and left in the dark for 15 minutes, after which the content was filtered through filter paper. The obtained extracts were used for the calibration curve [8].

Establishment of the calibration curve. For this determination, firstly, was used a blank sample, namely a methanol solution, used as a standard, for which was determined the absorbance ($A_{standard}$). The calibration curve for each sample was traced based on 10 solutions containing different amounts of the certain sample extracts and methanol, to which was added 500 µl of DPPH reagent in every test tube right before the cuvette should have been placed in the spectrophotometer. These manipulations were followed by the absorbance determination for each concentration (A_{sample}) [9].

Antioxidant activity value calculation. The inhibition percentage of the free radicals (I%) was obtained with the equation [8]:

$$I\% = \frac{A_{s\tan dart} - A_{sample}}{A_{s\tan dart}} 100$$

Chemical analysis

Moisture determination. Moisture content of each fondant candy with beets juice was performed by using the digital moisture analyzer at 100 °C. The total soluble solids were determined using a Digital ABBE Refractometer and expressed using a Brix degree scale (°B) [10].

Ash determination. The classic calcination method was used. In a porcelain crucible, weighed in advance, was introduced the sample. The crucible was placed on the flame of a gas lamp until the smoke appeared [11].

This procedure was followed by the insertion of the crucible in the electric furnace set

at 750˚C and left the necessary time there until a pale white or gray residue with no traces of charcoal was obtained [11].

The crucible was cooled in a desiccator until it reached the room temperature, then it was weighed.

The ash content was determined with the formula [11]:

$$Ash\% = \frac{m_1}{m}100$$

where m_1 - is the amount of ash in g, which is deduced from the difference between the weight of the crucible with ash after calcination and the empty crucible

m - the amount of sample taken into work, this being calculated from the difference between the weight of the crucible with sample before calcination and the empty crucible [11]

Quantitative determination of mineral substances (EDX spectroscope). Rontgen energy-dispersive fluorescence spectroscopy is based on measuring discrete energy of each Rontgen wavelength as expression of concentration and composition. With the emergence of discrete radiant energy on a semiconductor detector it produces a certain number of pairs of voids and through them a certain electrical pulse. Current pulses, according to the current value, are distributed by a multichannel analyzer (about 1000 channels) and give a specific spectrum that has the order of pulses and the energy abscissa.

All Rontgen fine analysis procedures, whether refractive or spectroscopic, are analytical and control procedures that act completely non-destructively on the subject matter under investigation.

Determination of reducing sugar (Schoorl method). Reducing sugars reduce the copper-tartaric alkaline solution (Fehling's reagent) to Cu_2O, which is indirectly quantitatively determined by iodometric measurement of copper sulphate in the Fehling solution before and after reduction. The difference obtained is the amount of copper reduced by sugar.

- Extraction. An amount of 5-25g of the sample evenly blended, it is placed in a 150-200ml vial where was added 70-80 ml of distilled water heated to 85-90 °C, then placed on a water bath, and from the moment the water begins to boil for 30 minutes, started the stirring. The extract is filtered in a 100 ml volumetric flask and washed with hot distilled water.
- Dosage of reducing sugars. In a 300 ml Erlenmayer flask, 20 ml of the flaky extract was introduced, then Fehling I solution 10 ml and Fehling II solution 10 ml, the pot was heated on an asbestos sieve, the boiling time was exactly 2 minutes. The flask was cooled in a stream of water, then 20 ml of potassium iodide solution and 15 ml of sulfuric acid was added.

The liberated iodine is titrated with 0.1N sodium thiosulfate in the presence of starch as an indicator. The solution of starch is added to the end of the titration when the solution had a pale yellow color. Titration is continued until the blue color disappears due to the presence of iodine.

The amount of copper reduced by sugar is determined by the amount of 0.1 N sodium thiosulphate used for titration based on the equation:

$$V = V_1 - V_2$$

where V_1 - the volume of 0.1 N sodium thiosulphate used to titrate the blank sample (ml)

V_2 - the volume of 0.1 N sodium thiosulphate used to titrate the actual sample (ml)

There is the amount of reducing sugar in the analyzed samples based on the equation:

$$g\% = \frac{z \cdot d}{g} 100$$

where z is the quantity of inverted sugar from the corresponding table for V ml of $Na_2S_2O_3$ 0,1 N;

d is dilution cipher;

g is weight of analyzed sample (g).

Results and discussions

1. Sensory analysis

Following the sensory analysis on each of the three samples were obtained the following results.

Graphical interpretation of sensory analysis:

1.1. Appearance assessment

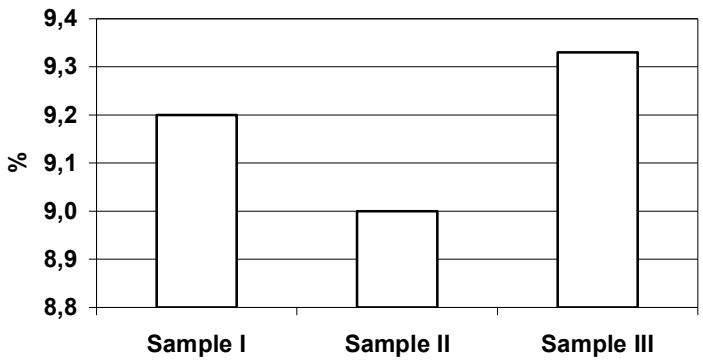


Figure 1.1. Appearance assessment of the fondant candies with beetroot juice

As results from this graph, sample III, namely candies containing juice obtained from baked beetroots, has the highest value for appearance 9,33. The lowest value of 9 has the second sample.

1.2. Colour assessment

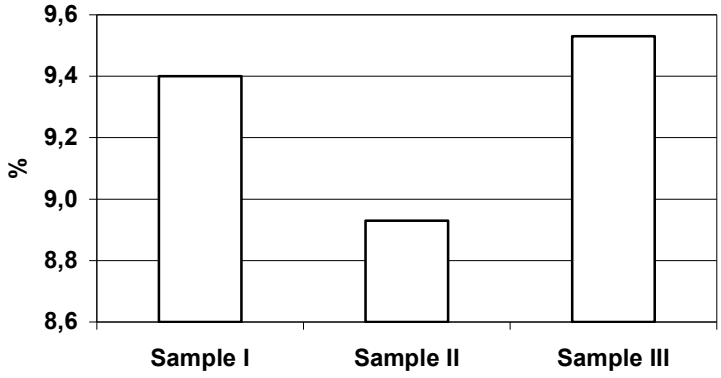


Figure 1.2. Colour assessment of the fondant candies with beetroot juice

Following the completion of the colour graph, sample III has the highest result of 9,53 compared to the other 2 samples.

1.3. Taste assessment

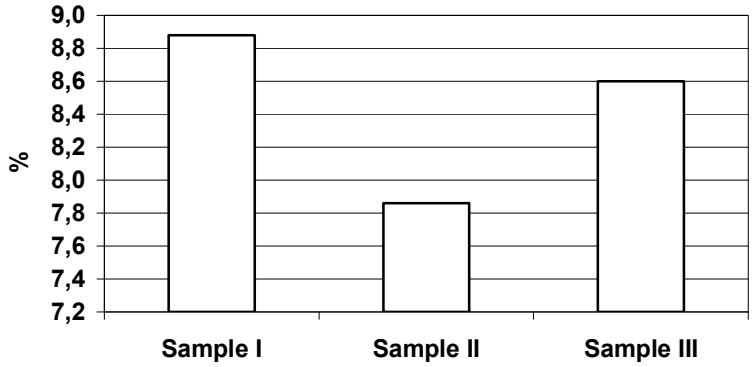


Figure 1.3. Taste assessment of the fondant candies with beetroot juice

Fondant candies with juice obtained from fresh beetroot have the highest grade in the taste category, 8,88. Meanwhile sample II was ranked with 7,86.

1.4. Smell assessment

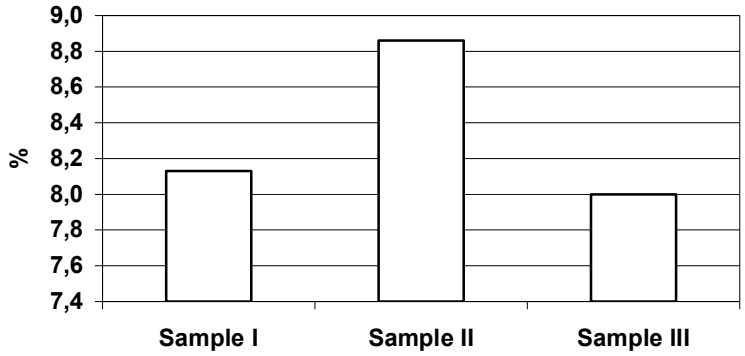


Figure1.4. Smell assessment of the fondant candies with beetroot juice

According to this graph, candies made with juice obtained from boiled beetroots are the most appreciated in terms of smell, with a 8,86 appreciation. Sample I and II had slightly the same results: 8,13 and 8.

1.5. Flavour assessment

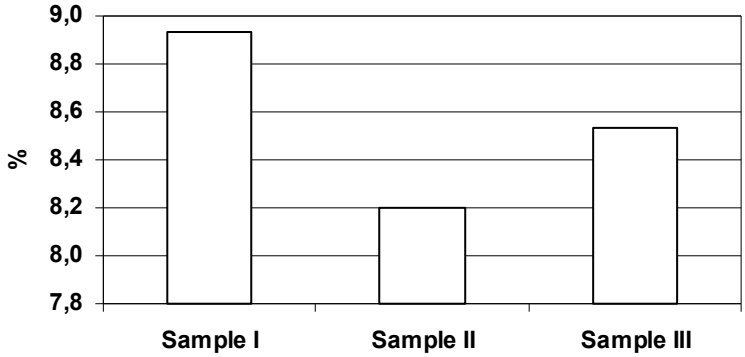


Figure1.5. Flavour assessment of the fondant candies with beetroot juice

According to graph 5, candies with juice obtained from raw beetroots have the most pronounced flavour, with a rank of 8,93. The lowest result, 8,20, was obtained by sample II.

1.6. Texture assessment

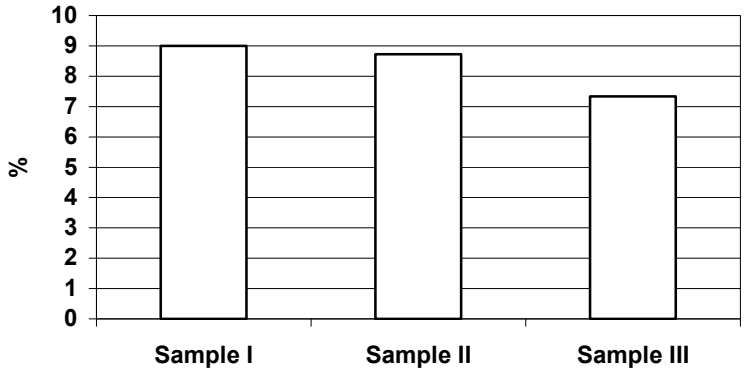


Figure 1.6. Texture assessment of the fondant candies with beetroot juice

In the matter of texture, samples were ranked as follows: 9 for sample I, 8,73 for sample II and 7,33 for sample III.

1.7 Overall sensory analysis performance

After performing the sensory analysis on all three different samples the following general graph was established:

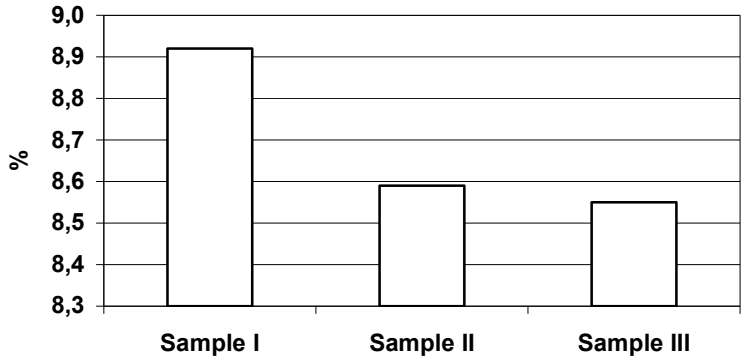


Figure 1.7. General graph of the sensory analysis performance

As a result of the overall chart, sample I was the most appreciated with a total ranking of 8,92, and sample III was the least appreciated with a result of 8,55. Sample II had an overall assessment of 8,59.

2. Antioxidant capacity determination

2.1. Graphical interpretation of antioxidant capacity

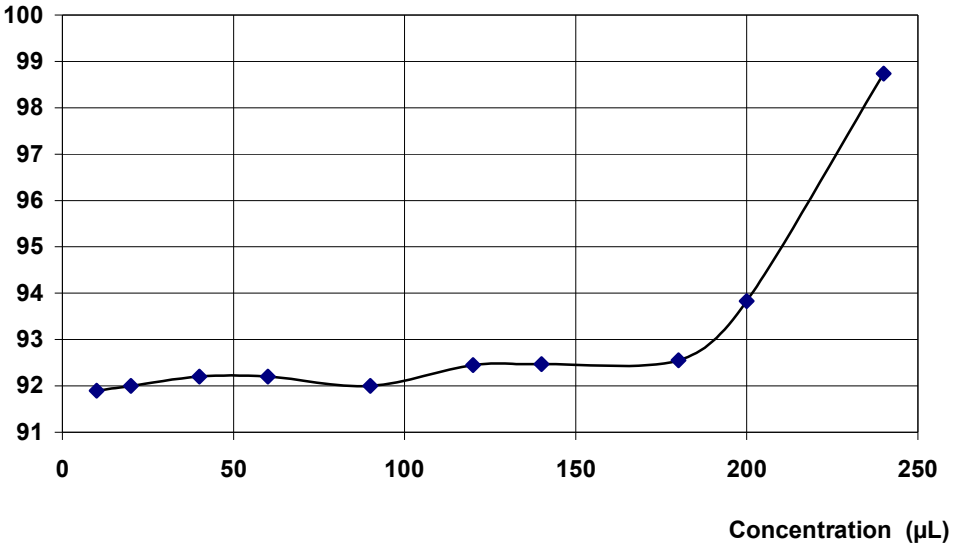


Figure 2.1.1. Sample 1 – Fondant candies with juice obtained from raw beetroots

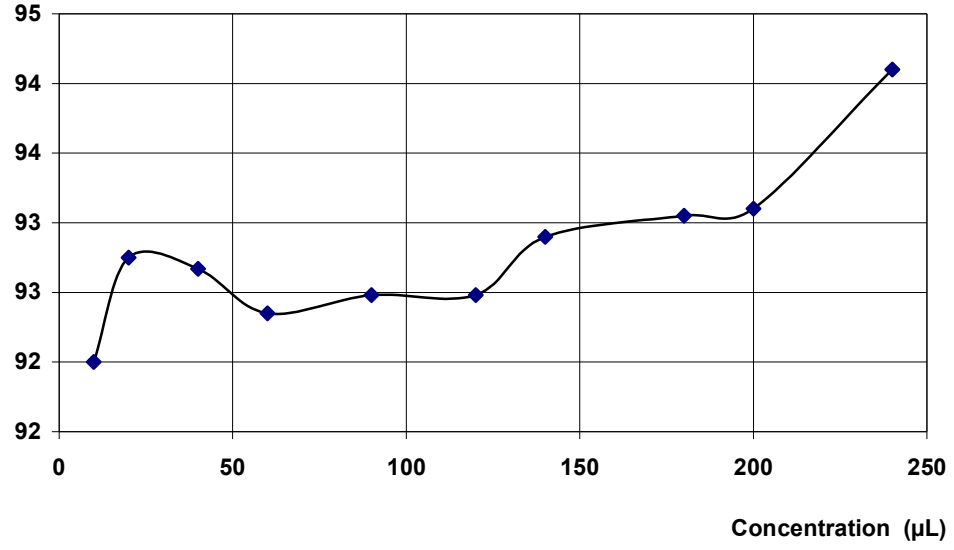


Figure 2.1.2. Sample 2 – Fondant candies with juice obtained from boiled beetroots

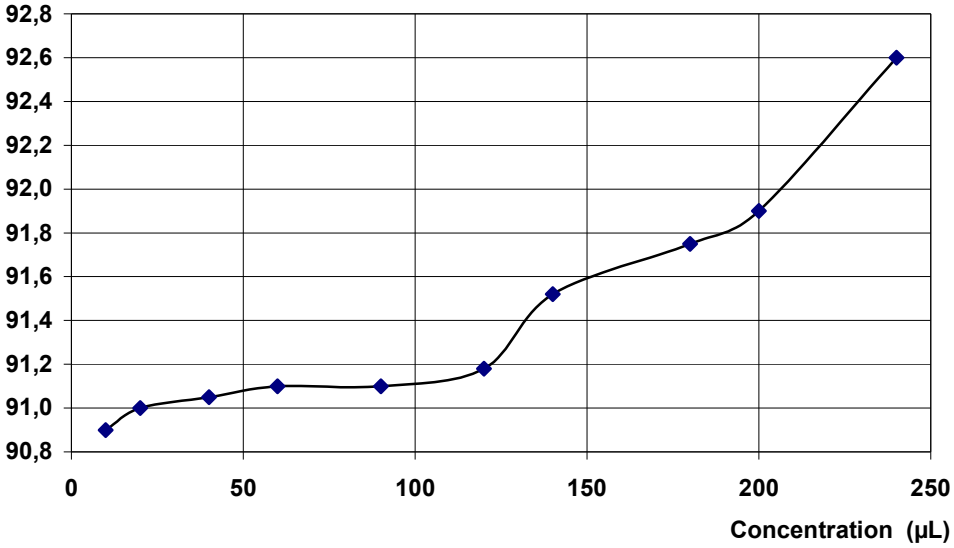


Figure 2.1.3. Sample 3 – Fondant candies with juice obtained from baked beetroots

2.2. Overall antioxidant capacity performance

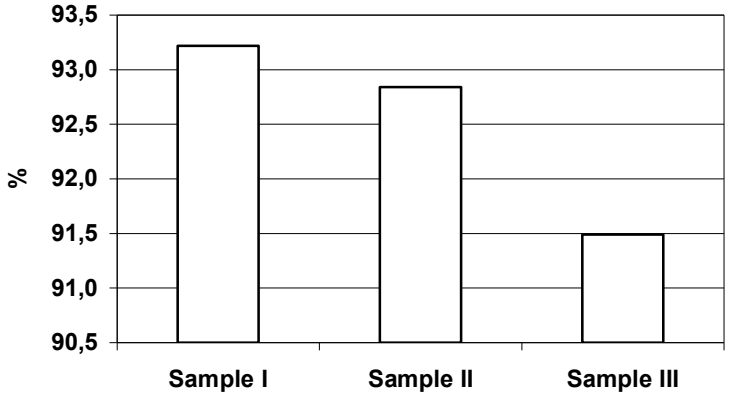


Figure 2.2.1. General graph of antioxidant capacity

The highest antioxidant capacity occurs in the case of fondant candies with red juice obtained from raw beetroots (sample I), with an overall performance of 93,22%. A rather lower result had the sample II with 92,84%. Simultaneously, sample III showed the lowest result of 91,49%.

It is also noted that with the absorbance decrease the antioxidant activity decreases.

3. Chemical analysis of the fondant candies with beetroot juice

3.1. Moisture determination

After keeping the samples in an oven at constant 100 °C for 5 hours, the following results were obtained:

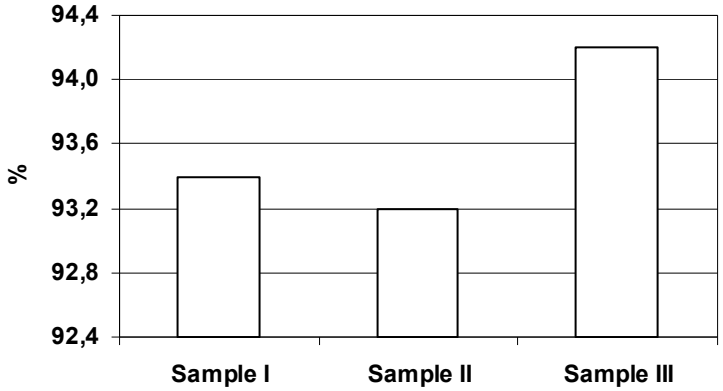


Figure 3.1. Graphical interpretation of moisture

Sample III has the highest result of 94,20%, meanwhile samples I and II showed a slightly equal result of 93,4% and 93,2%.

3.2. Ash content

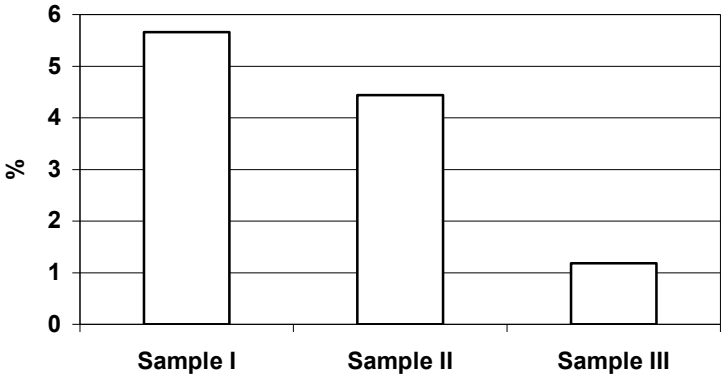


Figure 3.2. Graphical interpretation of ash content

As a result of this graph, sample I, fondant candies with juice obtained from raw beetroots has the highest ash content of 5,66%. Sample III showed a five times lower result, 1,18%.

3.3 Quantitative determination of mineral substances with EDX method

Based on the quantitative determination of mineral substances from fresh beetroot juice were highlighted the following elements:

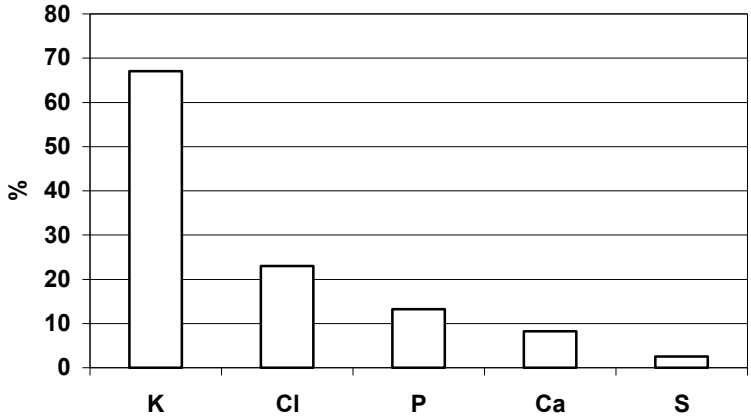
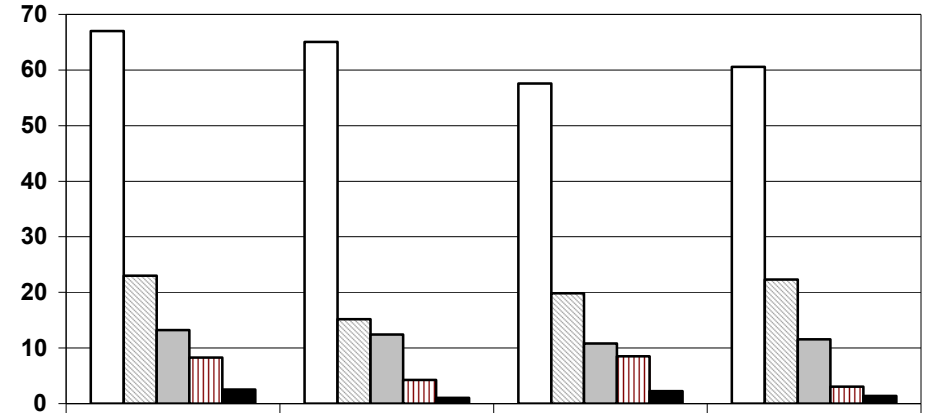


Figure 3.3.1. Graphical interpretation of mineral substances from fresh beetroot juice

According to the graph, following the quantitative determination of the mineral substances in the fresh beetroot juice, it contains an amount of 67,0% K that passes into ash, but also other elements such as: Cl (23.01%), P (13,24%), Ca (8.26%), S (2.52%).

A significant proportion of these elements and minerals are found in the 3 fondant candy samples. The results are as follows:



	FRESH JUICE	SAMPLE I	SAMPLE II	SAMPLE III
K	67,02	65,08	57,57	60,58
Cl	23,01	15,2	19,87	22,3
P	13,24	12,4	10,84	11,58
Ca	8,26	4,26	8,52	3,06
S	2,52	1,02	2,22	1,4

Figure 3.3.2. General graphic of mineral substances content

Mineral substances pass into the three samples of fondant candies to some extent, as follows:

- Potassium (K) is found in the highest quantity in sample 1 (65.08%) and the smallest quantity in sample 2 (57.57%);
- Chlorine (Cl) passes to the highest amount in sample 3 (22.3%), and the smallest quantity is found in sample 1 (15.2%);
- Phosphorus (P) is found in the highest quantity in sample 1 (12.4%), and the smallest quantity in sample 2 (10.84%);
- Calcium (Ca), sample 2 has the highest amount of calcium (8.52%), and sample 3 - the smallest amount (3.06%);
- Sulfur (S) migrates to the largest quantity in sample 2 (2.22%), and the smallest quantity passes to sample 1 (1.02%).

3.4. Determination of reducing sugars. The Schoorl method

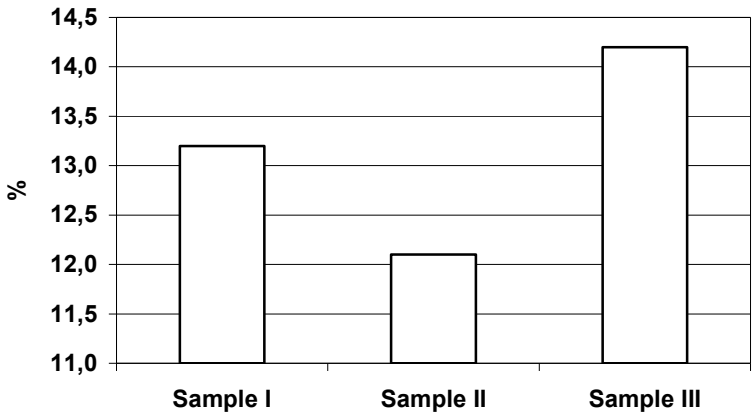


Figure 3.4. Graphical interpretation of reducing sugars content

Sample III has the highest amount of reducing sugars (14.2%). Sample II has the lowest amount of reducing sugars (12.1%). An amount of 13.2% was presented by sample I.

Conclusions

- Betaine (beetroot natural dye) can be used in both its liquid and powder form;
- Sample I (fondant candies with fresh beetroot juice) had the highest antioxidant activity and ash content;
- The highest moisture and amount of reducing sugars is given by sample III. Beetroot juice contains a high amount of mineral substances, but the heat treatment applied to the fondant candy affects the amount of minerals that migrate from the juice in the final product.

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Features and prospects of using collagenase-containing enzyme compositions in the meat-based products technology

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Abstract

Introduction. The research problem of synergistic effects that can be observed on parallel or sequential fermentation of meat and vegetable raw materials is not widely presented and requires a more detailed consideration of these issues.

Materials an methods. The object of research is the technology of meat-based products. Substance – low-grade fermentation. The methods of analysis and synthesis were used, literature sources, presented by publications of leading scientists, whose works are devoted to processes of fermentation of animal and plant raw materials and synergistic effects in these processes, are considered.

Results and discussion. The possibility of simultaneous hydrolysis of proteins of the main meat raw material makes it possible to modify the biological value of the product within wide limits. Barely only of the limiting factors here are the biological activities of individual amino acids. All amino acids are biologically active substances and excessive amount of them in the free state in an unbalanced ratio with others can have a negative effect. This question is more relevant to the medical and biological, but should be taken into account when evaluating and modeling the composition and fermentation of new meat-containing products. The fermentation regimes of raw materials can vary in time and space. In many cases, it is rational to use certain processes for the fermentation of plant and meat raw materials in order to avoid excessive microbiological insemination and overlay effects of different groups of enzymes. This issue is to be dealt with separately for each particular formulation and enzyme combination, but in many cases it is more appropriate to separate the fermentation of meat and vegetable raw materials with the further inactivation of enzymes at high temperatures and the addition of minced meat with inactivated enzymes. Synergistic effects between different types of proteolytic enzymes are studied mainly for meat products. The course of fermentation processes under influence simultaneously on meat and vegetable raw materials is poorly investigated. As has been said above, in many cases, such studies are not feasible due to the effectiveness of separating fermentation of meat and vegetable raw materials, however, in many cases, these synergistic effects should be explored.

Conclusions. The processes of fermentation and proteolysis in the meat raw material can be carried out with the use of a number of enzymes of both natural and synthetic origin. Fermentation of plant material can be carried out in parallel (simultaneously) or separated in time and space with enzymatic treatment of meat raw materials.

Introduction

The world market of meat products is in an unstable state in recent years. This is due to an increase in demand and total consumption in one group of countries and to a decrease in the other. It should be noted that the global level of world consumption of meat products is increasing, given the growing population and economic development of Africa and Asia [1]. However, it is worth analyzing the trends in the qualitative composition of meat products. WHO official publications, according to which meat products from the "red" (beef, pork) meat are classified as "potentially carcinogenic" products affecting a large number of consumers in the countries of Europe and North America [1, 2]. Current research shows that there are certain chemicals in red and processed meats – both added and naturally occurring – that cause these foods to be carcinogenic. For example, when a chemical in red meat called haem is broken down in the gut, N-nitroso chemicals are formed and these have been found to damage the cells that line the bowel, which can lead to bowel cancer. These same chemicals also form when processed meat is digested. In addition, the nitrite and nitrate preservatives used to preserve processed meat produce these N-nitroso chemicals and can lead to bowel cancer. Therefore, it is highly probable that this trend will take place in the domestic market. Analyzing the reasons for changing the structure of the domestic meat market, it is worth pointing out as the main factors a sharp increase in prices for pork, beef and poultry meat. The causes of these phenomena – the epidemiological pattern of disease of pigs and poultry market monopolization [3, 4].

Taking into account the given trends, development and improvement of technologies of meat-based products will solve several problems of the market and industry at once. First, it will reduce the cost of production by reducing the share of the most valuable raw materials (veal beef, pork and lamb of the highest and first grades). Secondly, it will expand the range of products, which will positively affect the development of the market and industry. Third, increase the rationality of processing low-grade meat raw materials, by combining it with plant raw materials rich in protein [5, 6].

However, this direction of technology requires improvement. When developing new and application of known technologies for the production of meat-based products, some disadvantages are becoming apparent. The first drawback is the complexity of supply and primary processing of plant raw materials. This raw material has a high moisture content, which negatively affects the shelf life and structure of the product when it is introduced without proper treatment. Ways of solving this problem – application of extruders, drying of raw materials with pre-shredding, lyophil drying, heat treatment under specific conditions [7]. The second disadvantage is the low biological value of plant material. As a result, the restriction of the use of low-grade meat raw materials due to the general value of the product.

To address these issues, it is advisable to use targeted fermentation. Fermentation can increase the biological value of low-grade raw meat and plant material generally by acting on peptide bonds in proteins and monomerizatsiyi amino acids and peptides. As a result, due to the formation of free amino acids and peptides, the content of all essential amino acids in the product is achieved. According to Mitchell's law, this will lead to an increase in the absorption of other amino acids that contain large amounts of plant and collagen-containing raw materials [8].

The use of collagenase in the technology of meat-based products has advantages not only in increasing the biological value of the product, but also increases the technological characteristics (positively affects the structure, rheological characteristics and homogeneity of the forage system) product [9]. However, the created kind of apple systems requires the

use of enzymes for the processing of plant raw materials. Also, it is worth considering other types of enzymes that may exhibit positive (or synergistic) effects when making meaty products in the formulation in combination with collagenase. Among several enzymes should be identified such as fitsyn, papain and bromelin.

These enzymes belong to the class of proteases (proteolytic enzymes) and act on peptide bonds between amino acids in proteins, channeling their hydrolysis. Ficcin, papain and bromelin have isoelectric points, which are achieved at high (8 and higher) pH values. Therefore, suitable for use in the meat industry.

Material and methods

The object of research is the technology of meat-based products. Substance – low-grade fermentation.

During the writing of the article the methods of analysis and synthesis were used, literature sources, presented by publications of leading scientists, whose works are devoted to processes of fermentation of animal and plant raw materials and synergistic effects in these processes, are considered.

Results and discussion

The aim of the work was to consider the relevance, prospects and peculiarities of the technology of meat products with the use of fermentation, analyze the publications on the chosen topic and draw a conclusion on the prospects of combining collagenase with other enzymes in meat-based products technology, to consider the available types of enzymes and their application technologies on the market, to identify the disadvantages of the technological process of meat products production and the prospects for their elimination.

In general consumer perception towards the intake of meat and meat products is unhealthy because it may increase the risk of diseases like cardiovascular diseases, obesity and cancer, because of its high fat content (especially saturated fat) and added synthetic antioxidants and antimicrobials. Addition of plant derivatives having antioxidant components including vitamins A, C and E, minerals, polyphenols, flavanoids and terpenoids in meat products may decrease the risk of several degenerative diseases. To change consumer attitudes towards meat consumption, the meat industry is undergoing major transformations by addition of nonmeat ingredients as animal fat replacers, natural antioxidants and antimicrobials, preferably derived from plant sources.

Fitsin belongs to the group of papainases. According to Liner, it contains in its molecule at least two sulfhydryl groups, of which only one is in the catalytic region of the enzyme. In addition, ficin contains one disulphide group that is not essential for its activity. By its action on ficin proteins, pepsin resembles that, since its protein splitting catalyzes proteins to the stage of polypeptides that have an amine nitrogen ratio of up to 25% overall. In the technology of meat products, ficin is used to soften the main raw material along with papain and bromelin (bromelain).

The research has found that the introduction of the enzyme complex on the basis of ficin, pineapple and papaya processing products increases the overall efficiency of the process and reduces the strength of the raw material for compression from 17.45 kPa (for the use of mono-enzyme mixtures) to 16.45 kPa (for a combination of enzymes) [10].

Papain – a plant enzyme derived from the fruits of the evergreen tropical papaya tree. In addition, the pulp of papaya fruit itself is tasty, which makes these fruits every year more and more popular in our country, it contains milk juice, rich in many useful substances and trace elements. To get juice you need to use only immature fruits. It appears after a cut of the skin of the fetus. But this is not the only way to get a papain – in addition to natural origin, the enzyme is also produced by the chemical synthesis of papain.

An important alternative to papaya and ficin in meat products is fungal and bacterial proteases. Studies of a team of scientists from New Zealand have compared the effects of different protease types on the characteristics of protein of meat raw material (first class beef and extracts of the tendons of cattle and pigs) [11]. The authors conclude that such optimal regimes for the hydrolysis of the investigated raw material, in which there is a significant synergistic interaction of papain-collagenase – 45 °C, pH ranges from 5.2 to 7.5. From this we can draw conclusions about the effectiveness of the joint application of these enzymes in meat products technology, as these regimes are fully implemented during the initial processing of raw materials.

In the work of the team of scientists on the influence of papain and collagenase on the fascia and intramuscular connective tissue, it was established that the introduction of this combination allows the release of insoluble collagen in the intercellular plasma, which greatly affects the structure of the final product [12].

Microbial collagenases are important and promising enzymes, taking into account the industrial and biological perspectives for their application. Recent work on their potential use in the food industry and the benefits of health effects have shown that microbial collagenase has significant prospects as a major component for biologically active functional ingredients and for peptides. Collagenases are important virulence factors that play a decisive role in the global degradation of extracellular animal protein matrices due to their ability to split collagen. There is no scientific consensus on the well-defined and proper screening of collagenase produced by micro-organisms. A lot of discussions can be found in the literature on the correct identification of microbial collagenase. Modern technologies and strategies used to improve the screening, production and purification of microbial collagenase with full detail, especially with regard to the classification, structures and mechanisms of collagen-cleavage of the representatives of collagenases of the M9 family. The potential of microbial collagenase in the development of a process of softening meat and bioactive "true" collagen peptides or obtaining hydrolyzates. In addition, critical issues and different strategies for potential uses of collagenase in the food, food, biotechnology and medical sectors are underlined. [13].

To study the effect of enzymes on monomerization of plant proteins, it is important to understand the process of decomposition of homologagacturonan (HG) (the most common pectin polymer) by specific enzymes. HG, a polymer that can be methylated or acetylated. Both the degree of substitution (methylation and / or acetylation) and polymerization can be controlled by specific enzymes such as pectin methyl esterase (PME), pectin acetyl esterase (PAE), polygalacturonase (PG), or pectinal lysis (PLA). Over the past 10 years had been achieved in the biochemical and functional description of these enzymes [14].

In the work of the team of scientists from the United States conducted comparative studies of the impact of two types of microbiological enzymes on the monomerization of protein and carbohydrate soybeans simultaneously [15]. Soy protein is a valuable nutritional supplement for animal feed. While the protein is ~ 50% skimmed soy flour, it coexists with complex carbohydrates (30–35%), which may have a negative effect on the nutritional value. The enzymatic process can remove carbohydrates and produce a protein-rich soy product. Hydrolyzate with monomerised carbohydrates is a valuable enzyme raw

material. In this study, the enzymes of the micro-organisms of the species Aspergillus niger and Trichoderma reesei were compared with respect to the use in the hydrolysis of carbohydrates. To determine the enzymatic conversion, the following conditions were applied: pH 3.2–6.4, temperature (40–60 °C). The effects of factors and interaction between them are investigated. The optimal pH and temperature were virtually identical for both enzymes: pH 4.8 and 50–51 °C for the first strain and pH 5.1–5.2 and 48–51 °C for the second one. Both enzymes also provide similar protein content in soy protein concentrates, ie 74–75% versus the indicator of 64–68% for most concentrates in the market. The A. niger enzyme was significantly more effective in converting carbohydrates, reaching efficiency up to 75%.

The feasibility of concurrent monomerization of proteins and carbohydrates is not always justified. The reason for this is the ability of monosaccharides to shift the pH of the environment and influence the autolytic processes in the main raw materials of meat products. Also, the lack of the presence of monosaccharides is the acceleration of the development of undesirable microflora due to the presence of nutrient medium for micro-organisms. It is worth noting the deterioration of organoleptic properties – the taste of the finished product.

According to the given literary sources – results of researches and publications on the chosen theme, it is possible to make a number of conclusions about the current state and problems in the technology of meat-based products and the application of enzyme combinations in this direction.

The possibility of simultaneous hydrolysis of proteins of the main meat raw material makes it possible to modify the biological value of the product within wide limits. The limiting factor here is the biological activity of individual amino acids. All amino acids are biologically active substances and excessive amount of them in the free state in an unbalanced ratio with others can have a negative effect. This question relates more to the biomedical, but should be taken into account when evaluating and modeling the composition and fermentation of new meat-based products.

It should be remembered that the fermentation of raw mode can be varied in time and space. In many cases, it is rational to use certain processes for the fermentation of plant and meat raw materials in order to avoid excessive microbiological insemination and overlay effects of various groups of enzymes – those used for monomerization and responsible for the polymerization of carbohydrates. This issue is to be dealt with separately for each specific formulation and enzyme combination, but in many cases it is more appropriate to separate the fermentation of meat and plant raw materials with the further inactivation of enzymes at high temperatures and the addition of minced meat with inactivated enzymes.

The expediency of using collagenase in combination with other enzymes is appropriate in the vast majority of cases when using low-grade meat raw materials. Factors limiting the use of this enzyme are primarily economical – in many cases it is impractical to use collagenase for the hydrolysis of raw materials if the proportion of such raw material in the formulation is too small. Or the opposite – it is inappropriate to introduce additional enzymes if the basis of the formulation is only collagen-containing raw materials.

Synergistic effects between different types of proteolytic enzymes are studied mainly for meat products. The course of the fermentation process when subjected to both meat and plant material is less explored. As has been said above, in many cases, such studies are not feasible due to the effectiveness of separating fermentation of meat and plant raw materials, however, in many cases, these synergistic effects should be explored [16 , 17].

Bioactive peptides are short amino acid sequences, that upon release from the parent protein may play different physiological roles, including antioxidant, antihypertensive,

antimicrobial, and other bioactivities. They have been identified from a range of foods, including those of animal origin, e.g., milk and muscle sources (with pork, beef, or chicken and various species of fish and marine organism). Bioactive peptides are encrypted within the sequence of the parent protein molecule and latent until released and activated by enzymatic proteolysis, e.g. during gastrointestinal digestion or food processing. Bioactive peptides derived from food sources have the potential for incorporation into functional foods and nutraceuticals. The aim of fermentation process in technology of meat-based products is also to rise the intake of muscle-derived bioactive peptides, especially those of fermented meats and the potential benefits of these bioactive compounds to human health [18, 19].

Ability to use bacterial and other enzymes of microbiological origin is closely related to the type of a specific producer organism, and therefore requires further research. The given publications show high enzyme activity of enzymes of microbiological origin, but there are some restrictions in their application which can have both economic and logistic character [20]. These issues require further consideration and concretization for domestic conditions.

Conclusions

According to the analysis of publications, the results of leading research, market trends and WHO recommendations, the production of meat-based products is feasible and promising given several factors.

The first factor is the lack of research data, which are aimed to meat and plant fermentation process during the processing of meat-based products. Many scientific articles are aimed to meat and collagen-containing stuff fermentation that is caused by high biological value of these types of stuff. But also fermentation of the plant and vegetable stuff wasn`t considered in equial level and need to be estimated better.

The second factor is the possibility of simplifying the technological process of processing plant and collagen-containing raw materials with increasing its full value.

The use of enzyme compositions comprising collagenase is effective in view of the synergistic effects that have been proven by the experimental method for meat raw material. Synergistic effects and qualitative composition of enzyme compositions in their interaction in the meat-stuff minced meat system require further research, but even for negative results, it is possible to solve the problem by the method of separate fermentation of meat and plant raw materials.

Among the types of enzymes, it is worth highlighting the most effective enzymes that have the maximum effect on the meat raw material. According to the analyzed publications, it is worth allocating ficin, bromelin, papain and proteases of microbiological origin. According to the results of studies, these enzymes exhibit high activity separately and do not reduce it in absolute majority of cases and with a consistent application, have an isoelectric point, optimal temperatures and pH levels that are easy to provide in the meat processing industry. it can be concluded that further research is needed on the processes of fermentation of meat and plant raw materials and the synergistic effects between enzymes in these systems.

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Effect of processing conditions on chemical composition and consumer acceptability of cocoyam (colocasia esculentus) elubo

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Abstract

Introduction. The effect of two processing conditions on chemical and consumer acceptability of cocoyam (taro) elubo was investigated.

Materials and methods: Fresh taro tubers were processed into elubo using traditional method of four treatments ($P_{50}S_{12;}$ $P_{50}S_{24;}$ $P_{60}S_{12}$ and $P_{60}S_{24}$) from parboiling at 50^0C for 3h and at 60^0C for 1h; steeping in water for 12h and 24h. Standard methods were used to determine the proximate and mineral composition of the elubo samples. A stiff gel (amala) was prepared from the elubo samples to evaluate the sensory quality and consumer acceptability.

Results and discussion: The proximate composition of the taro elubo samples revealed that the processing treatments had no significant ($p<0.05$) effect on the crude fibre (3.80 to 3.83%), carbohydrate (77.50 to 78.80%), and calories (345.32 to 349.47K), while, significant ($p<0.05$) effects were observed on the moisture (8.39 to 9.30%), ash (1.56 to 2.98%) and protein (5.08 to 6.26%) contents. Parboiling at 50^0C resulted in lower moisture content, though all the values are still within the acceptable level for storage of food flour. The ash content of the taro elubo was significantly ($p<0.05$) influenced by steeping at 12h with elubo sample obtained from $P_{60}S_{12}$ treatment having the highest value. Stepping at 12h also favoured the protein content, the $P_{50}S_{12}$ recorded the highest value. The usual lost of minerals through heat treatment (parboiling) and leaching (stepping) was observed as the fresh taro had significantly ($p<0.05$) high mineral composition. Elubo sample obtained from $P_{50}S_{12}$ and $P_{60}S_{12}$ treatments the highest value for calcium (30.87mg/100g) and potassium (47.00mg/g) respectively. Increase in steeping time caused a significant ($p<0.05$) reduction in the values obtained for calcium, potassium and sodium. There was no significant ($p<0.05$) effect on the iron and manganese contents of the elubo samples. The sensory qualities of the amala samples showed that parboiling of taro at 50^oC resulted in amala having no significant ($p<0.0$) difference in colour, taste, aroma, consistency and general acceptability with yam amala (the reference sample). This indicates that low heat treatment is required for processing of taro corms.

Conclusions. The study showed that the parboiling at 50^oC and stepping at 12h favoured the chemical and sensory qualities and consumer acceptability of taro elubo than parboiling at 60^oC and stepping at 24h.

Introduction

Cocoyam commonly called taro is an underutilized crop mainly grown for its edible corms. Taro (*Colocasia esculenta*) and Tannia (*Xanthosoma sagittifolium*) are the two most important genera of the family *Aracea* [40, 14, 2]. They constitute one of the six most important root and tuber crops worldwide [13]. Although, they are less important than other tropical root crops such as yam, cassava and sweet potato, they are still a major staple in some parts of the tropics and sub-tropics [38]. Taro is produced in abundance in Nigeria, but less valued as it is regarded as staple food for rural dwellers, the poor and the less privileged in society [20, 34]. The nutritional and chemical composition as reported by FAO [15] shows that cocoyam if fully exploited would enhance the food security of people living in the tropics [14].

Corms of taro have generally been reported to contain digestible starch which is an important factor when selecting a starchy food that will not be cumbersome on the digestive system [19] protein of good quality, ascorbic acid, thiamin, riboflavin, niacin and high scores of amino acids [32]. Report shows that 70 – 80% starch content is with small size granules [37, 8, 34], which result in high digestibility. According to [22] starch derived from taro corm is unique because of its very small granular size ranging from 1–5 μ, significantly smaller than that of corn and wheat. The protein and amino acids content are also higher than other tropical root crops [24, 7]. It is also rich in dietary fibre, thiamine, calcium, niacin, manganese, magnesium, copper and riboflavin. Consuming nutrients-packed food like taro is vital for maintaining a healthy immune system, which helps our body to make use of protein, carbohydrates and other nutrients in the food [36].

Processing greatly increase the utilization of root crops and reduces annual post-harvest loss of about 30% [23]. Cocoyam flour (*elubo*) like yam *elubo* is a major form in which the tuber could be preserved and consumed during the periods preceding yam harvest and this underscores its importance as a possible substitute for yam in Nigeria [1,18, 4]. The processing method however affects final product quality [29, 30, 32].

In the traditional production of *elubo*, the major processing units of critical control include; parboiling, steeping, and drying [31, 11, 30]. Parboiling and steeping improve the digestibility, promote palatability, improve keeping quality, reduces anti-nutritional factors and have effect on the major nutrients, including proteins, carbohydrates, minerals and vitamins [29, 28, 30, 32], hence appropriate processing conditions are required to ascertain quality of the final product. The study was designed to determine the effect of parboiling and steeping conditions on for proximate, minerals and acceptability of taro elubo.

Materials and methods

The cocoyam corms were obtained from the local food market in Osogbo, Osun State, Nigeria.

Production of cocoyam *elubo*

The method reported by [29] was adopted for production of the cocoyam *elubo*. Clean cocoyam corms were sorted from infected tubers. The selected tubers were peeled and reduced into even chips (150±3g). The chips were divided into for parboiling at 50^0C for 3h and at 60^0C for 1h, steeped in the warm water for 12h and 24h resulting into four treatments. The parboiled chips were later sun-dried till a constant weight was obtained.

The dried chips were milled into flour (*elubo)* using attrition mill and sieved with 0.25um sieve. The *elubo* samples were packaged in high density polyethylene bags (10mm thickness) for further analysis.

Proximate Analysis

Proximate composition of the taro *elubo* samples were determined using the method described by AOAC [9]. Moisture, ash, crude fat, protein and crude fibre were determined, while carbohydrate content was determined using difference method.

Mineral Analysis

The mineral content of the *elubo* was determined using the method described by [27]. *Elubo* sample of 0.5g was weighed into a clean ceramic crucible. A blank was prepared with empty crucible. The crucible was placed in a muffle furnace at 50^0C for 4 h. The sample was allowed to cool down in the oven after which it was removed carefully. The ashed sample was poured into already labeled 50ml centrifuge tube. The crucible was rinsed with 5ml of distilled water into the centrifuge tube. The crucible was rinsed again with 5ml of aqua regia. This was repeated to make a total volume of 20ml. The sample was mixed properly and centrifuged (ICE Centra GP8) for 10 minutes. The supernatant was decanted into clean vials for mineral determination. The absorbance was read on atomic absorption spectrophotometer (Buck Scientific Model 200A) at different wavelength for each mineral element (copper -324.8nm, zinc -213.9nm, calcium -422.7nm, iron -248.3nm, magnesium-285.2nm, manganese -279.5nm, sodium -589nm and potassium -766.5nm).

Preparation of *amala*

The procedure described by [10] was adopted for the preparation of taro *amala.* About 50g taro *amala* was added to 200ml boiled water. The paste was stirred manually with a wooden spoon over a low flame until a smooth consistency was obtained.

Sensory evaluation and consumer acceptability test

The sensory quality [1] and consumer acceptability of *taro amala* was evaluated using 50 panelists that were familiar with *yam amala.* A nine point hedonic scale as described by [21, 19] was adopted. The scale ranged from like extremely (9) to dislike extremely (1). Each of the samples was rated for appearance, aroma, taste, texture, mouth feel and overall acceptability

Statistical analysis

Data were subjected to multiple analyses of variance (MANOVA) at 5% significance level, and mean of samples separated by Duncan multiple range test (DMRT) using statistical package for social sciences (SPSS) version 20.0.

Results and Discussion

Proximate composition of taro *elubo*

The result of proximate composition of fresh taro and taro *elubo* is presented in Table 1. The two varied processing units (parboiling and steeping) were observed to have significant ($p<0.05$) effect on the taro *elubo* samples. Fresh taro corms constitute majorly of moisture with other macronutrients in low concentration [34]. The apparent increase in protein, fat, crude fibre and carbohydrate contents observed in taro *elubo* samples could be as a result of the removal of moisture and processing conditions which tend to increase the concentration of nutrients [26].

The moisture content ranging from 8.39 to 9.30% was significantly ($p<0.05$) affected by the processing conditions. *Elubo* from $P_{50}S_{24}$ treatment had the lowest moisture content, while the highest value was observed in *elubo* from $P_{60}S_{12}$ treatment. The results revealed that parboiling at 50°C and steeping for 24h resulted into lower moisture content compared to parboiling at 60°C and steeping for 24h. This could be as a result of more dissociation of the starch granules, easing heat transfer and surface evaporation of moisture. Moisture content of food or processed products give an indication of its anticipated shelf life. High moisture content enhances microbial contamination and reduces food quality and stability [5], therefore the lower the moisture content of a sample, the more its storability. The values are lower than the values (9.43 – 10.47%) reported for cocoyam flour by [31], however the values fall within the acceptable limit of not more than 10% for long term storage of flour [33, 12].

The fresh corm had the significantly ($p<0.05$) highest ash content, which indicates that taro in their fresh state is rich in minerals [7, 14]. The effect of parboiling and steeping conditions is thus significant ($p<0.05$) on the ash contents of the *elubo* samples. Parboiling and steeping conditions have been reported to reduce ash content of processed food products [6, 11]. The ash contents of the taro *elubo* are higher than the value reported for yam *elubo* (1.84%) by [25] and [11]. While, the range of 1.56 to 2.98% reported by [39] for cocoyam flour is similar to the values obtained from the study. The result indicates that the taro *elubo* could be a good source of essential minerals and trace elements.

The protein content of root and tuber crops is generally low. Processing of taro into *elubo* influenced the protein content due to concentration of the nutrient upon drying. The highest value (6.45%) was obtained from *elubo* from $P_{50}S_{24,}$ treatment, while *elubo* from $P_{60}S_{12}$ had the lowest value (5.06%). The variation in protein content consequently was due to the effect of the processing conditions. Heat application denatures proteins [26, 19, 24]. At higher parboiling temperature (60°C), lower protein content was obtained, which may be as a result of heat denaturation of protein. Parboiling has been found to decrease protein content due to leaching of nitrogenous substances during steeping and rupturing of molecules during steaming [35] and this might be the reason for the observed effect. Also decrease in protein content probably occurred as a result of Maillard reaction, which occurs between carbohydrates and protein [2, 41]. Browning of *elubo* is responsible for the characteristic colour of the cooked paste (amala). The result is similar with the values reported by [29] and greater than the values reported by [3, 1, 28] for yam *elubo*. This explains that taro has higher protein content (thermo-stable) than yam.

There was no significant difference ($p<0.05$) between the fat contents of the taro *elubo* samples. Fat content in flour explains storability of the flour due to various chemical reactions associated with lipid oxidation [38]. Fat also serve as energy store in the body

when is broken down to release glycerol thereafter converted into glucose (energy) by the liver. It has been reported that 1g of fat provides 37Kcal of energy [16]. The low fat content of taro *elubo* may make it suitable for diabetics and people suffering from cardiovascular diseases.

The crude fibre content is similar to the ash content. The effect of the processing conditions were not significant ($p<0.05$) on the fibre content. These values compared well with values reported for cocoyam flour by [28, 29, 18]. Crude fibre represents the content of the non-digestible components of food, such as lignin, cellulose and hemicelluloses. These are essential in human nutrition, since they enhance the transit time through the bowels, facilitates bowels movement thus reducing the risk of colon cancer. The results indicate that taro *elubo* is rich in insoluble dietary fibre. This may be relevant in African's food and nutritional security. The high carbohydrate content of fresh taro was reflected on the values obtained from the *elubo* samples (77.50 to 78.80%). There was no significant ($p<0.05$) effect of the processing conditions on the carbohydrate content. However, the values are slightly higher than values obtained for yam flour from the study reported by [2] and cocoyam flour by [29]. Carbohydrate supplies energy to the body, contributes to fat metabolism, spares proteins as an energy source, act as a mild natural laxative for human beings and generally add to the bulk of the diet [16].

All the calorie contents of all the taro *elubo* samples are higher and significantly ($p<0.05$) different from the value of the fresh corm. The *elubo* from $P_{50}S_{24}$ treatment had the highest calorific value. The result revealed that taro *elubo* though is a good source of carbohydrate, can be consumed in large amount without a substantial increase in the glycemic load in the body.

Mineral composition of fresh taro and taro *elubo*

The ranges of the mineral composition of taro *elubo* were: calcium (23.28 to 53.64 mg/100g), potassium (21.45 to 79.53 mg/100g), sodium (15.33 to 65.22 mg/100g), magnesium (8.38 to 26.2 mg/100g), phosphorus (0.43 to 1.31 mg/100g), iron (0.22 to 1.53 mg/100g), zinc (0.10 to1.32mg/kg), and manganese (1.10 to 3.48 mg/100g) as shown in Table 2. The nutritional potential, health and food security benefits of taro are justified with the rich essential mineral content [41].The variation in the mineral composition might have been influenced by the processing conditions as higher values were obtained for the fresh taro corm. Minerals are usually lost through heat treatment and leaching during parboiling and stepping, most especially with potassium, calcium and magnesium [41, 18]. The processing methods had significant effect on potassium, calcium, sodium, magnesium and phosphorus, while no effect was obtained for iron and manganese contents. According to Hassan *et al.*, [17] during processing the nutritive value and antinutritional components of roots and tubers may be adversely affected. Calcium is important in the body as it helps to build and maintain bones and teeth [41].

Sodium and potassium are water soluble and are sensitive to high heat processing. Increase in steeping time caused a significant reduction in the values obtained for potassium and sodium. Also, *elubo* samples obtained from steeping of taro for 12h showed better values for potassium and sodium. *Elubo* sample from $P_{60}S_{12}$ treatment had the highest sodium content while *elubo* sample from $P_{50}S_{24}$ treatment had the lowest value. Potassium and sodium are important in the diet as they help to regulate acid-base equilibrium and osmotic pressure of body fluid.

The values obtained for magnesium, phosphorus, iron, zinc and manganese are lower than the values reported by Hassan *et al*. [17].

Table 1

Proximate composition of Fresh taro and taro *elubo*

Samples	Moisture (%)	Ash (%)	Crude Protein (%)	Fat (%)	Crude fibre (%)	Carbohydrate (%)	Calorie (KJ)
Fresh Taro	$48.93^{a}\pm0.42$	$5.17^{a}\pm0.27$	$2.08^{c}\pm0.22$	$0.63^{a}\pm0.01$	$2.30^{b}\pm0.17$	$40.90^{b}\pm0.53$	$177.54^{b}\pm1.34$
$P_{50}S_{12}$	$8.82^{b}\pm0.74$	$1.98^{bc}\pm0.14$	$6.26^{b}\pm0.44$	$1.34^{a}\pm0.32$	$3.83^{a}\pm0.00$	$77.77^{a}\pm1.20$	$348.78^{a}\pm3.72$
$P_{50}S_{24}$	$7.95^{b}\pm0.90$	$1.70^{c}\pm0.07$	$6.45^{a}\pm0.51$	$1.28^{a}\pm0.77$	$3.81^{a}\pm0.00$	$78.81^{a}\pm1.24$	$352.52^{a}\pm0.06$
$P_{60}S_{12}$	$9.30^{b}\pm0.37$	$2.20^{b}\pm0.07$	$5.86^{b}\pm0.80$	$1.32^{a}\pm0.47$	$3.82^{a}\pm0.04$	$77.50^{a}\pm1.52$	$345.32^{a}\pm1.33$
$P_{60}S_{24}$	$8.39^{b}\pm1.02$	$1.82^{bc}\pm0.58$	$5.08^{c}\pm0.77$	$1.23^{a}\pm0.64$	$3.80^{a}\pm0.00$	$79.68^{a}\pm2.29$	$349.47^{a}\pm0.31$

Mean values with different superscripts within the same column are significantly different at $p< 0.05$

$P_{50}S_{12}$: parboiled at 50°C, steeped for 12h

$P_{50}S_{24}$: parboiled at 50°C, steeped for 24h

$P_{60}S_{12}$: parboiled at 60°C, steeped for 12h

$P_{60}S_{24}$: parboiled at 60°C, steeped for 24h

Table 2

Minerals composition of fresh taro and taro *elubo*

Samples	Calcium (mg/100g)	Potassium (mg/100g)	Sodium (mg/100g)	Magnesium (mg/100g)	Phosphorous (mg/100g)	Iron (mg/100g)	Zinc (mg/kg)	Manganese (mg/100g)
Fresh	53.64^{a} ±1.03	79.53^{a} ±0.96	65.22^{a} ±0.40	26.2^{a} ±0.53	2.03^{a} ±0.10	1.53^{a} ±0.05	1.32^{a} ±0.03	3.48^{a} ±0.78
$P_{50}S_{12}$	30.87^{b} ±0.72	$26.33^{c\backslash}$ ±1.14	23.15^{c} ±1.15	8.67^{bc} ±0.16	0.88^{c} ±0.18	0.22^{b} ±0.04	0.15^{b} ±0.01	1.15^{b} ±0.18
$P_{50}S_{24}$	25.30^{cd} ±0.11	21.45^{c} ±1.76	$15.33^{d\backslash}$ ±1.15	8.38^{c} ±0.07	0.92^{b} ±0.48	0.42^{b} ±0.29	0.15^{b} ±0.01	1.15^{b} ±0.00
$P_{60}S_{12}$	26.31^{bc} ±1.16	47.00^{b} ±2.86	31.63^{b} ±1.38	8.72^{b} ±0.26	0.43^{d} ± 0.25	0.44^{b} ±0.07	0.10^{c} ±0.03	1.10^{b} ±0.02
$P_{60}S_{24}$	$23.2\ 8^{d}$ ±0.10	27.79^{c} ±1.58	18.59^{cd} ±1.38	8.56^{bc} ±0.12	0.57^{cd} ±0.27	0.51^{b} ±0.02	0.12^{c} ±0.00	1.23^{b} ±0.13

Mean values with different superscripts within the same column are significantly different at $p< 0.05$

$P_{50}S_{12}$: parboiled at 50°C, steeped for 12h

$P_{50}S_{24}$: parboiled at 50°C, steeped for 24h

$P_{60}S_{12}$: parboiled at 60°C, steeped for 12h

$P_{60}S_{24}$: parboiled at 60°C, steeped for 24h

Sensory properties of taro *amala*

The mean sensory scores of *amala* produced from the taro *elubo* samples varied significantly ($p<0.05$) as shown in Table 3. The *amala* prepared from sample $P_{50}S_{24}$ treatment had the highest mean score of 7.70 for colour and was more preferred than the reference sample (*amala* from yam *elubo*). The aroma values ranged from 7.55 to 6.20 with *amala* prepared from *elubo* of $P_{50}S_{12}$ treatment having the highest score and *amala* from $P_{60}S_{24}$ treatment having the least score. The reference recorded 7.05 for taste which were lower than some scores obtained for the taro *amala* samples. This indicates that on the average level, the taro *amala* samples had better scores than the yam *amala*. Parboiling of taro at 50°C influenced the consistency quality and mouth feel qualities. Consistency of *amala* explains the firmness and viscosity quality. This is one of the major acceptable characteristics of the stiff dough [3, 1, 23]. In generally, yam *amala* was most accepted than the taro *amala* samples. However, the *amala* obtained from taro *elubo* parboiled at 50°C were not significantly different from the reference. This indicates that low heat treatment is required for processing of taro corms.

Table 3

Sensory Quality and Consumer Acceptability scores of taro *amala*

Samples	Colour	Taste	Aroma	Mouth feel	Consistency	General Acceptability
Reference	7.65^{a}±1.18	6.89^{b} ± 1.73	7.05^{cd} ± 1.42	7.40^{a} ± 1.79	7.0^{b} ± 1.45	7.71^{a} ± 1.14
$P_{50}S_{12}$	7.67^{a}±1.40	6.97^{ab} ±1.69	7.55^{a} ± 1.74	7.05^{b} ± 1.62	7.08^{ab} ± 1.84	7.67^{a} ± 1.56
$P_{50}S_{24}$	7.70^{a} ±1.56	7.00^{a} ± 0.73	7.15^{c}± 0.99	7.15^{ab} ± 1.04	7.15^{a} ± 0.93	7.60^{a} ± 0.73
$P_{60}S_{12}$	7.15^{b}±1.46	6.65^{c} ± 1.76	7.30^{b} ± 1.87	6.65^{c} ± 1.47	6.13^{e} ± 1.80	6.85^{b} ± 1.69
$P_{60}S_{24}$	6.25^{c} ±1.21	6.05^{cd} ±1.54	6.20^{f} ± 1.47	6.95^{bc} ± 1.40	6.38^{d} ± 1.46	6.70^{d} ± 1.38

Mean values with different superscripts within the same column are significantly different at $p< 0.05$
Reference: Amala prepared from yam *elubo*
$P_{50}S_{12}$: Amala prepared from taro *elubo* parboiled at 50°C and steeped for 12h
$P_{50}S_{24}$: Amala prepared from taro *elubo* parboiled at 50°C and steeped for 24h
$P_{60}S_{12}$: Amala prepared from taro *elubo* parboiled at 60°C and steeped for 12h
$P_{60}S_{24}$: Amala prepared from taro *elubo* parboiled at 60°C and steeped for 24h

Conclusion

The study has shown that the chemical qualities of taro *elubo* are significantly influenced by the processing conditions. Parboiling at 50°C and stepping at 12h favoured the chemical qualities than parboiling at 60°C and stepping at 24h. *Amala* from elubo produced from parboiling at 50°C and stepping at 12h was also found to have similar sensory qualities and consumer acceptability with yam amala.

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Composition and properties of peanut and sunflower oil blends

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Abstract

Introduction. Investigation of the properties of refined deodorized peanut and sunflower oil blends has been carried out in order to influence the indexes of their antioxidant properties on the basis of acid and peroxide numbers.

Materials and methods. The vegetable oils parameters were determined: acid number by titrometric method, the peroxide number by the iodometric method, iodine number by the Weiss method. Fatty acid composition was studied by gas-liquid chromatography on a Hewlett Packard HP-6890 chromatograph using a HP-88 capillary column.

Results and discussion. The antioxidant properties of vegetable oils were depended on the fatty acid composition, the natural properties and the method of obtaining. Analysis of the fatty acid content of peanut oil shows that it contains, among others, about 60% oleic, 19% linoleic and 9% palmitic fatty acids. Composition and properties of blends are regulated by peanut and sunflower oil ratio. Acid number of refined sunflower oil have increased from 0.3 to 0.6 mgKOH/g during 7 months storage. Such growth indicates rapid oxidation. Increasing the content of peanut oil in the blends leads to an increase of antioxidant stability. The peroxide number of the blend of 30 % and 70 % was lower than sunflower oil by 25%. The acid number increase of this blend is significantly slower compared with others. This result is due to the fact that the composition of blends is abounded by fraction of monounsaturated fatty acids of peanut oil, which contains up to 60% of fatty acids Omega-9 family addition.

Conclusions. Peanut and sunflower refined deodorized oil blends samples have better antioxidant properties than sunflower oil it self. The best ratio is a blend of 30:70 peanut and sunflower oil.

Introduction

The consumption of vegetable oils increases annually in the world that is why the development of new oil and fat products of high quality is important.

The use of peanut oil is multifaceted [1]. The consumption of peanut oil is known both in food industry and in medicine and cosmetology.

Peanut oil after the composition has a significant amount of vitamins, especially group B. This oil contains numerous microelements such as polyphenols, phospholipids, and phytosterols.

Peanut oil [2] contains to 60% of monounsaturated oleic acid Omega-9, also to 30% of unsaturated fatty acids Omega - 6, which contributes to a significant strengthening of the immune system, improve the system of sexual rights, normalize hormonal balance and blood cholesterol levels.

In particular, peanut oil is rich in folic acid that plays an important role in the regeneration and growth of cells with antioxidants reduce free radicals. Thus, the processes of organism aging are slowed. In addition, regular consumption of peanut oil improves the process of removing toxins and speed up metabolism in the body, which is considered the most important feature of food product.

The refined peanut oil is mostly used in confectionary [3]. This foodstuff sufficiently often consume with a large vitamin component and vitamin-rich energy value. Peanut oil even at the insignificant food consumption adds a feeling of satiety for a long time. Consumer properties of this oil are revealed when it is used for filling various salads and cold vegetable dishes. For deep-frying cooking consumption of peanut butter is two times lower than when using other oils. Peanut oil does not smoke.

The chemical composition and other characteristics of peanut oil is similar to olive, known for unique curative properties. However, the price of peanut oil significantly lower. Compared with the degree of saturation sunflower oil fatty acid peanut oil higher. In comparing to sunflower-seed oil, the degree of saturation of fat acids of peanut oil is higher. In Ukraine sunflower oil is the most widely used in mayonnaise recipes.

It is possible to assume that the development of technology blends with refined deodorized peanut and sunflower oils will allow taking advantage of the peanut butter along with the attractive price of sunflower oil and getting better quality characteristics of new oil fatty products [4].

Materials and methods

Blend of refined deodorized peanut and sunflower oils were prepared by mixing in the appropriate ratio of refined deodorized peanut oil of Swiss production and refined deodorized sunflower oil of Ukrainian origin.

Fatty acid composition of refined deodorized peanut oil compared with unrefined peanut oil was checked and obtained by its pressing from peanut kernels beans on laboratory screw press [5] and refined deodorized sunflower oil.

Fatty acid composition of oils was studied by gas-liquid chromatography on a Hewlett Packard HP-6890 chromatograph using a HP-88 capillary column [6].

Sensory properties of oils were evaluated for original appearance, color and smell of tasting technique [6,8].

Determination of the acid number was performed according to the titration methodologies.

Determination of the peroxide number was conducted according to iodometric methodologies.

Results and discussion

Comparative analysis of the fatty acid composition of refined deodorized and unpurified peanut oil, and sunflower oil is in Table 1.

Table 1

Comparative description of fatty acid composition of vegetative oil

Fat acid	Sample 1	Sample 2	Sample 3
Myristic	-	-	-
Palmitic	9,1	9,2	7,1
Palmetelaidic	0,1	0,1	0,1
Stearin	3,3	3,5	3,4
Oleic	61,2	62,4	25,0
Linoleic	19,2	17,6	62,9
Arachic	1,5	1,4	0,2
Eicosanoid	1,2	1,4	-
Gadoleic	-	-	
Behenic	2,6	2,4	0,7
Eicosatetraenoic	-	-	-
Erucic	-	-	-
Lignoretic	1,4	1,5	0,13
Eicosapentaenoic	-	-	-
Nervonic	-	-	-
Docosahexaenoic	-	-	-
Total	**100,0**	**100,0**	**100,0**

Sample 1 - Press unrefined peanut oil got in laboratory terms,
Sample 2 - Refined deodorized peanut oil (Erdnussöl) (Switzerland)
Sample 3 – Refined deodorized sunflower oil (Ukraine)

Table 2

Comparative sensory evaluation of the quality of oils

Name of quality indexes, description	Estimation	Sample 1	Sample 2
Taste and smell			
With the poorly expressed aftertaste of feedstock. Tastes and smells are not allowed	10	9	10
With a strong taste of raw materials. Tastes and smells are not allowed.	10	-	-
Transparency			
Transparent	10	10	10
Transparent, allowed a slight turbidity	10	-	-
Color			
According to normative documents	10	10	10

Sample 1 - Refined deodorized peanut oil (Erdnussöl) (Switzerland),
Sample 2 - Refined deodorized sunflower oil (Ukraine)

Analysis of fatty acid composition of peanut and sunflower oils shows that peanut oil has a very high ratio ω 3: ω 6 polyunsaturated fatty acids, which shows its high biological value. Peanut oil is balanced for fatty acid composition and is more intense than sunflower oil.

Refined deodorized peanut is oil of Swiss production is similar in fatty acid composition of peanut press unrefined oil received in the laboratory condition. Feature of peanut oil is also high in oleic acid, which provides a high antioxidant stability of sunflower oil blends.

Comparative Sensory evaluation of the quality of refined deodorized peanut and unflower oils is in Table. 2.

Refined deodorized peanut and sunflower oils were investigated with physical and chemical indexes (Table 3)

Table 3

Comparative description of physical and chemical indexes of refined deodorized peanut and sunflower oils

Indexes	Norm	Sample 1	Sample 2	Sample 3
Acid value, mg KOH/g no more	0,5	0,38	0,25	0,37
Peroxide number ½ mmol / kg, no more	10	1,2	2,0	1,1
Iodic number, g J2/100g, no more	83-105	94	125-145	136

Sample 1 - Refined deodorized peanut oil (Erdnussöl) (Switzerland),
Sample 2 -Refined deodorized sunflower oil,
Sample 3 - Refined deodorized sunflower oil (Ukraine)

According to the research of sensory characteristics, we can conclude that refined deodorized peanut oil satisfies the requirements. And according to data presented in Table 3, it is shown that refined deodorized peanut oil of Swiss production for its physical and chemical rates do not exceed the norms and for those indexes it is like a refined deodorized sunflower oil of Ukrainian origin.

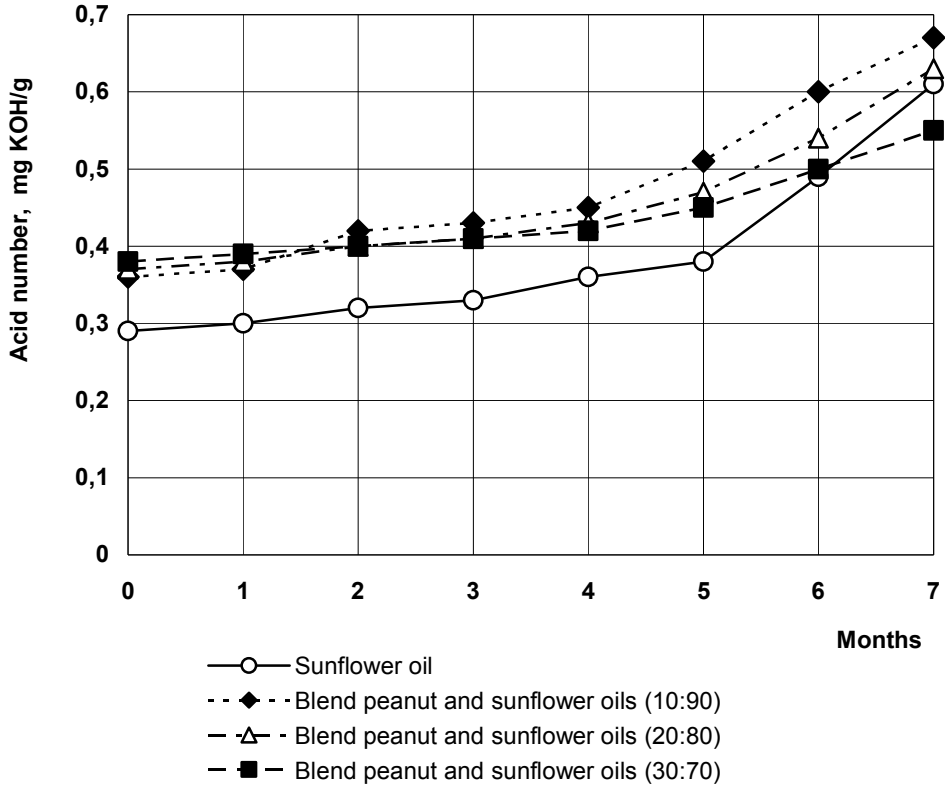

Figure 1. The change in acid number blend peanut and sunflower oils during 7 months' storage

On this basis, it was proposed to use peanut refined deodorized oil for developing blends of the given oil with refined deodorized sunflower oil.

Blends from peanut and sunflower oils were worked out at correlation according to 10:90, 20:80, 30:70, as a norm does not provide blends recipes with peanut oil. For this purpose the recommended correlations of oils to olive or rape oil blends with sunflower oil. A study of changes of acid and peroxide numbers blends refined deodorized peanut and sunflower oil at the ratio of 10:90 respectively, 20:80, 30:70 under the influence of atmospheric oxygen during the blends storage at room temperature compared with sunflower oil. Curves changes in these indicators are presented in Figure 1 and Figure 2.

According to our data, we can conclude that the change of acid and peroxide numbers in 7 months' storage the developed blends of peanut and sunflower oils does not exceed the norm and change similarly with acid and peroxide numbers of sunflower oil. Developed blends can be used in the formulations of other food products (the rational ratio peanut and sunflower oils is 30:70) [6].

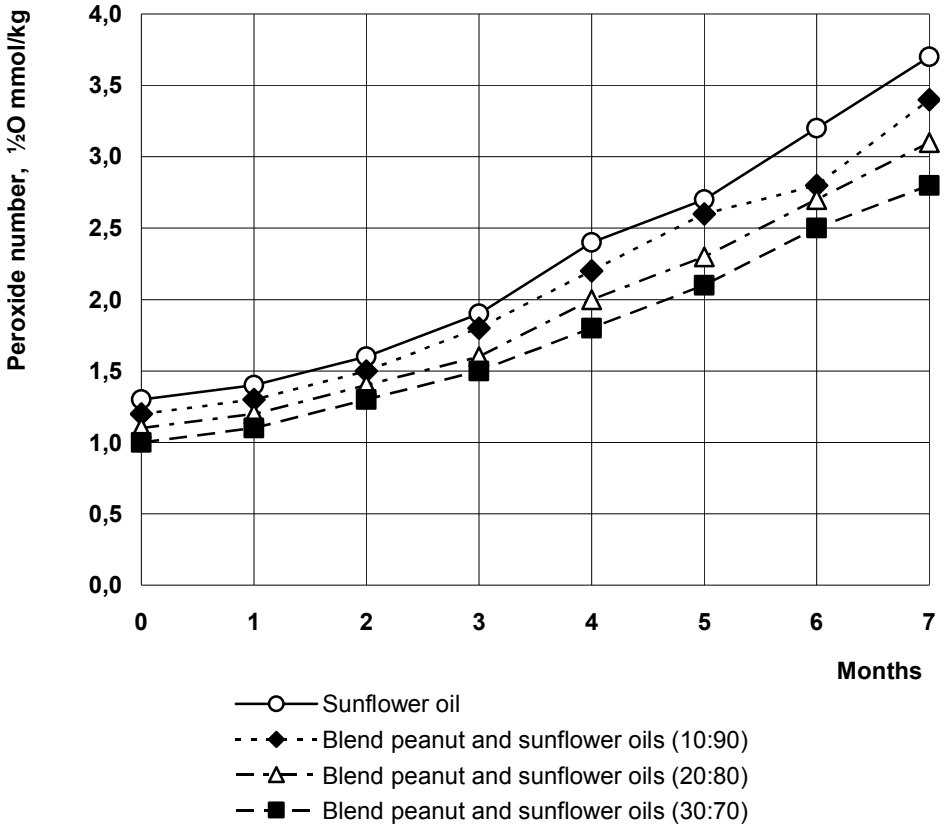

Figure 2. The change in the number of peroxide blend peanut and sunflower oils during 7 months' storage

Conclusion

Use of method of the mathematical planning of experiment in this work the optimal compounding of peanut and sunflower blends refined deodorized oils were developed. Our studies showed that the blend peanut and sunflower oils have high biological value as a new type of oil and fat products [7]. Developed blends of peanut and sunflower oil recipes can be used for food production [8–10].

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Synthesis of robust interconnected power system stabilizers for turbine generators in sugar factories

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Abstract

Introduction. This research aims to develop the method of synthesis of interconnected robust power system stabilizer (IRPSS) for power supply systems of sugar factories with own turbine generators.

Materials and methods. The mathematical tools of H_∞ synthesis with pole placement and the linear matrix inequalities (LMI) are used for developing the method of IRPSS synthesis. MATLAB Simulink is used to verify synthesized regulator by computer simulation.

Results and discussion. A model of power supply system with own generator, automatic exciter regulator, turbine and speed governor is constructed. The controlled object nonlinear differential equations model is linearized and simplified by reducing of its order using Schur's method. The model is extended with chosen weighting functions preparing for H_∞ synthesis procedure. The LMI region is chosen in the form of a conic sector for satisfying condition of lower oscillability of transient process, which is the main goal of such a regulator to optimize turbine generator operation process.

The IRPSS for extended model was synthesized, using H_∞ synthesis procedure with poles placement. The regulator is presented in the form of matrix continuous transfer function.

The transition process of 3-phase short-circuit fault behind the transformer and subsequent automatic re-closing is simulated with full-order nonlinear model with IRPSS and compared with standard system stabilizer and the system without stabilizer. The graphs of modelled transients demonstrate effectiveness of IRPSS.

Conclusion. The developed method can be used for operation process optimization of turbine generators in sugar factories. The synthesized IRPSS was found to have satisfying robust stability and performance qualities for given structure of power system.

Introduction

A power supply system of a sugar factory may enclose the turbine generators to cover the electricity requirements during peak loads. The availability of its own turbine units allows saving the heat and electrical energy in both production and standing periods of manufacturing process. As turbine generators in such a scheme work a lot of time in a state of transient processes, it is important to ensure their stable operation using power system stabilizers [10, 13].

In the mathematical model of electrical turbine generators connected to an electrical system, it is not always possible to determine exactly all the parameters. Moreover, because of simplification and linearization of models there is the so-called unmodeled dynamics [11, 12]. This leads to the fact that the system stabilizers that are synthesized for one set of model parameters do not always provide the desired level of stability and quality control for other parameters values within the permissible limits.

There are techniques to synthesize controllers that are insensitive to changes of model parameters in certain ranges, which are called robust control design methods. In works [1, 6, 9] some variants of the synthesis of robust controllers for power systems were proposed. In this work, the goal is to expand these results and apply these techniques for controllers that stabilize the operation of the turbine unit, using not only the traditional channel of excitation system, but also an additional channel of the steam turbine governing system.

Materials and methods

The method of H_∞ synthesis with pole placement. Stability of the synthesized controller in this paper is based on the small gain theorem [7].

Let RH_∞ be the space of stable proper rational functions, i.e. functions of the form $G(s) = A(s) / B(s)$, where A is the polynomial, B – a polynomial with roots with negative real part, and $\deg A \le \deg B$. If $M(s)$ is the matrix with elements $m_{ij}(s)$, the expression $M(s) \in RH_\infty$ means that $m_{ij}(s) \in RH_\infty$ for all i, j.

The norm $\|\cdot\|_\infty$ in space RH_∞ is defined as $\|W(s)\|_\infty = \sup_{\omega \in R} \|W(j\omega)\|_2$, where $\|\cdot\|_2$ – is the spectral norm of the matrix, which is equal to its largest singular value $\bar{\sigma}$.

The small gain theorem states, that if $M(s) \in RH_\infty$, then matrix $\left(I + M(s)\Delta(s)\right)^{-1}$ is exists and belongs to RH_∞ for all $\Delta(s) \in RH_\infty$, $\|\Delta(s)\|_\infty \le 1/\gamma$ if and only if, when $\|M(s)\|_\infty \le \gamma$. From this theorem appears that if we take the additive model of uncertainty $G_{pert} = G + \Delta W_2$, where G is the model with nominal parameters, Δ is an arbitrary stable transfer function that corresponds to the condition $\|\Delta\|_\infty < 1$, and W_2 is weighting function, which generally belongs RH_∞, the robust stability of the closed-loop system with the controller $K(s)$ for all $\|\Delta(s)\|_\infty \le 1$ takes place if $\|W_2 KS\|_\infty \le 1$, where $S = \left(I + M(s)K(s)\right)^{-1}$ is so called output sensitivity function.

Based on the above, one of the quality criteria, which appears to be the condition of searching for the optimal robust controller, will be the criterion $\min\|W_2KS\|_\infty$. It should be noted that this criterion is responsible for control signal bounds. Consequently, if there are clear requirements to the control signal, such that they expressed the weighting function W_2', then for the specified criteria the weighting function which is need to be selected among W_2 and W_2', will be that the graph of maximum singular number $\bar{\sigma}(i\omega)$ of which is greater.

To meet the requirements of the usual performance specifications there is another criterion that should be optimized along with the above one: $\min\|W_1S\|_\infty$, where $W_1 \in RH_\infty$ is the another weighting function. It follows from requirements of minimisation of the control error and, as a rule, should provide a high quality of tracking and disturbance attenuation at the object's output.

But using the weighting function W_1 is very difficult to specify some transient process specifications, for example, its dumping coefficient, so in addition to the restrictions that can be put together in this way: $\min\left\|\begin{matrix}W_1S\\W_2KS\end{matrix}\right\|_\infty$, in [1] it was proposed to introduce an additional constraint on the poles of the closed-loop system in the form of regions that can be described in the form of linear matrix inequalities (LMI).

A region in the complex plane can be described using expressions of the form

$$D=\left\{z\in C \mid L+zM+\bar{z}M^T<0\right\},$$

where L is some symmetric matrix $m\times m$, M is an arbitrary matrix $m\times m$. Here the matrix-valued function $f_D=L+zM+\bar{z}M^T$ is denoted as the characteristic function of the LMI region D.

Consider an example of such a region, which limits the dumping coefficient of closed-loop object (Fig. 1). This area is called conic sector and guarantees that the damping ratio is not less than $\xi=\cos\theta$ or the oscillability is not more than $\mu=\mathrm{tg}\theta$, where $\mu=\frac{\beta}{\alpha}$ and $a+j\beta$ are the complex roots of the closed-loop system. The region D of the conic sector can be written as

$$D=\left\{z \mid \mathrm{Re}\,z<0, \frac{|\mathrm{Im}\,z|}{|\mathrm{Re}\,z|}<\mathrm{tg}\theta\right\},$$

or through matrix inequalities

$$D=\left\{z\in C \mid \begin{pmatrix}\sin\theta & \cos\theta\\ -\cos\theta & \sin\theta\end{pmatrix}z+\begin{pmatrix}\sin\theta & -\cos\theta\\ \cos\theta & \sin\theta\end{pmatrix}\bar{z}<0\right\}.$$

where the matrix $L=0$ and $M=\begin{pmatrix}\sin\theta & \cos\theta\\ -\cos\theta & \sin\theta\end{pmatrix}$.

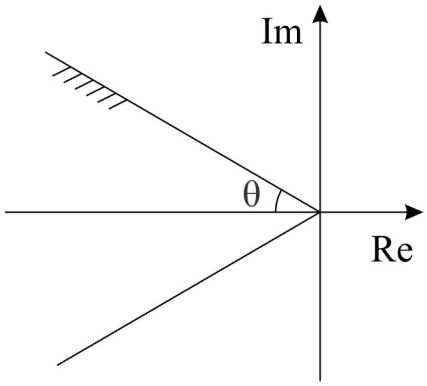

Figure 1. LMI region – conic sector

Mathematical model of controlled object

Steam turbines mathematical models in calculations of transients in electrical systems should reflect the impact of speed governing system to turbine output power when rotational frequency is changing [3]. The models of steam turbines are generally based on the assumption of the constancy of the steam pressure before the control valves. Thus the control system of the boiler is not taken into account. This determines the scope of the mathematical model of the steam turbine: it is adequate to those transients which endure no more than 5-10 seconds from the moment of frequency change.

The equation of steam turbine governing system [8]

$$\frac{d\mu_*}{dt} = \frac{1}{T_c}\left(\frac{s}{\sigma} - \mu_* + \mu_{0*}\right);$$

$$\mu_{\min} \le \mu_* \le \mu_{\max};\ \mu_* = \mu / \mu_{nom};\ \mu_{0*} = \mu_0 / \mu_{nom};\ s = \left(\omega_{nom} - \omega\right) / \omega_{nom},$$

where σ – the droop of the governing system of the turbine; T_c – time constant of the servomotor that moves the valves of the turbine; μ_* – the current value of the servomotor displacement that equals in per unit system to the displacement of equivalent responsive valve of the turbine; μ_{nom} – is the nominal value of the servomotor displacement that corresponds to the nominal power of the turbine at the nominal mode parameters of the unit; μ_{0*} – the initial value of the servo motor position; s – slip; ω, ω_{nom} – current and nominal frequency value; $\mu_{\min}$, $\mu_{\max}$ – the restrictions of the servomotor displacement, minimal and maximal respectively.

The equation of the turbine

$$D = \mu_* p_T;\ P_{HP} = Dk_{HP};\ \frac{dP_{LMP}}{dt} = \frac{1}{T_{PP}}\left(D\left(1 - k_{HP}\right) - P_{LMP}\right);\ P_T = P_{HP} + P_{LMP},$$

where D – the current value of the flow rate of steam passing through the turbine; p_T – steam pressure before the turbine; T_{PP} – time constant of intermediate steam reheater; k_{HP}

– part of the power that produced by turbine high pressure stage; P_{HP} – output power of the turbine high pressure stage; P_{LMP} – output power of the turbine middle pressure and low pressure stages; P_T – full output power of the turbine.

The equation of the turbine speed governor simplistically describes the measuring part of the governor (assuming ideal and is replaced by the gain *1/σ*) and hydraulic servomotor of turbine control valves [transfer function $1/(T_c p+1)$]. The input of the unit is a signal of the slip *s*, the output is a signal of displacement of the servomotor. The displacement of the servomotor has upper and lower limits.

Turbine with intermediate steam reheating, which has a large storage capacity, is modelled by two parallel elements, one of which is the gain block, and the second is first-order system. The gain block is related to the turbine high pressure stage (HP), which is located between the control valve and the intermediate reheater. Variation of power P_{HP} by changing the position of HP control valves actually lasts for 0.2-0.4 s, which is determined by volume of steam behind the valve, but in this simplified model this time lag is ignored and the transfer function is taken to be equal k_{HP}. The other part of the power which is produced by turbine middle pressure and low pressure stages changes with a time lag determined by the capacitance of the intermediate reheater. This part of the turbine's dynamic property is modelled as the first-order system $(1-k_{HP})/(T_{PP}p+1)$.

The mathematical model of turbine generator with a rigid shaft can be represented as follows:

$$U_{gd}=r_s i_d+\frac{d\psi_d}{dt}-\omega\psi_q;\ U_{gq}=r_s i_q+\frac{d\psi_q}{dt}+\omega\psi_d;\ U_f=r_f i_f+\frac{d\psi_f}{dt};$$

$$0=r_{kd}i_{kd}+\frac{d\psi_{kd}}{dt};\ 0=r_{kq}i_{kq}+\frac{d\psi_{kq}}{dt};$$

$$\psi_d=x_d i_d+x_{ad}i_f+x_{ad}i_{kd};\ \psi_q=x_q i_d+x_{aq}i_{kq};\ \psi_f=x_{ff}i_f+x_{ad}i_d+x_{ad}i_{kd};$$

$$\psi_d=x_d i_d+x_{ad}i_f+x_{ad}i_{kd};\ \psi_q=x_q i_d+x_{aq}i_{kq};$$

$$J\frac{d^2\theta}{dt^2}=M_t-(\psi_d i_q-\psi_q i_d);\ \frac{d\theta}{dt}=\omega,$$

where x_s, r_s – stator resistance, $M_T=P_T/\omega$ – turbine torque.

The model of external power system:

$$E_s\cos(\Theta)=x_v\frac{di_q}{dt}+r_v i_q+\omega x_v i_d+U_{gq}$$

$$E_s\cos(\Theta)=x_v\frac{di_q}{dt}+r_v i_q+\omega x_v i_d+U_{gq}$$

where x_v, r_v – resistance of external power system, E_s – external system electromotive force.

The model of automatic excitation proportional regulator without stabilization channels, dynamics of the exciter is ignored:

$$U_g = \sqrt{U_{gd}^2 + U_{gq}^2}\ ;\ \ E_f = -K_{0u}\left(U_g - U_{gnom}\right).$$

Model linearization and simplification

First step of robust control system design is linearizing of turbine generator model with automatic excitation regulator (AER) and a turbine speed governor (TSG) in the neighbourhood of the nominal operation point to obtain the linear system G with inputs $u1$ and $u2$ to AER and TSG, respectively, and with the output y as slip $d\omega$ (Fig. 2).

As a result of the controller synthesis for complex high-order models with the help of robust methods one can usually obtain the high-order regulators. Such regulators are not only difficult to implement but sometimes overly precise. There are different ways to obtain a lower-order controller [2]: to lower the order of the original object model with subsequent synthesis of controller, to synthesize the controller for the initial model and then reduce its order or to synthesize at once a reduced order controller for the full model.

In this work we have chosen the method of lowering the order of the original model. First we simplify the model to a 4-th order with the help of Schur's method [2]. The resulting transfer matrix G is:

$$G = \left(\frac{-0.005465s^3 + 0.1145s^2 + 1.295s + 1.001}{s^4 + 6.899s^3 + 168.9s^2 + 794.4s + 4231} \quad \frac{0.000057s^3 - 0.818s^2 - 34.45s - 11.73}{s^4 + 6.899s^3 + 168.9s^2 + 794.4s + 4231} \right)$$

The model can be represented schematically as shown in fig. 2.

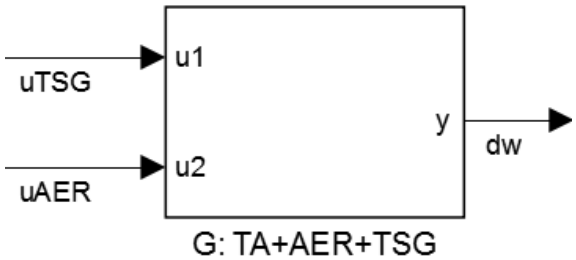

Figure 2. Schematic representation of the model

Uncertainty of the model

In the model of power system with turbine generators there are many sources of uncertainty. In this study, for example of using the method we will consider model uncertainty with respect to one parameter –AER gain for voltage channel K_{0u}, which can range from 50 to 150 p. u. Nominal value is selected to be K_{0u}=100. We accept the model of unstructured additive uncertainty which was described above. The weighting function W_2 in this model is chosen based on the model uncertainty and ranges of parameters in such a way: we build a set of frequency response of difference $G_{param} - G_{nom}$ with the parameters from the range of their variations, in this case for $K_{0u} \in [50,150]$. By the maximum of this frequency response family we can restore a minimum-phase transfer

function w_2, which makes a matrix weighting function $W_2 = \begin{pmatrix} w_2 & 0 \\ 0 & w_2 \end{pmatrix}$. Another simplification could be the replacement of w_2 with a constant function that equals to the maximum point of the set of frequency response of differences $G_{param} - G_{nom}$.

For application of the H_∞ norm optimization theory we construct extended model *P* based on the original system *G*, which is shown in Fig. 3.

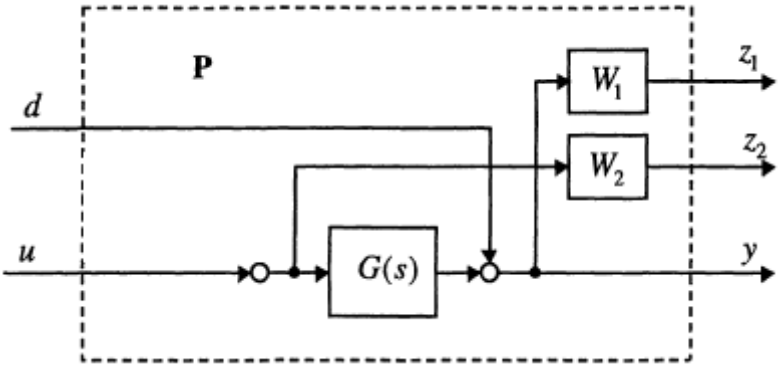

Figure 3. Extended model

The place of the controller *K* in the system is shown in Fig. 4.

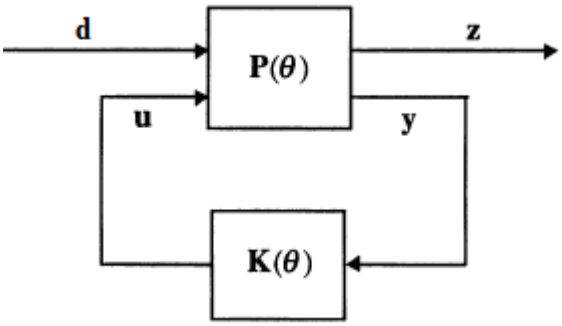

Figure 4. Closed-loop model with controller *K*

The function W_1 is responsible for the constraint on the sensitivity function *S* and has the form [5]:

$$W_1 = \frac{1}{S_\infty} \frac{s + \omega_1}{s + \omega_\varepsilon}.$$

We select the region of the poles placement in the form of a conic sector with an angle $\theta = 30^\circ$ from requirements of reducing process oscillability and the existence of a stable transient process in the simulation on the original model that is found by numerical calculations.

Results and discussion

Controller synthesis. We synthesize the controller K by the procedure described above using the MATLAB function hinfmix. The form of the obtained regulator is:

$$K = \begin{pmatrix} \dfrac{15.33s^5 + 4.535\cdot10^5 s^4 + 1.018\cdot10^7 s^3 + 4.622\cdot10^7 s^2 + 1.691\cdot10^8 s + 1.69\cdot10^7}{s^5 + 3782s^4 + 1.786\cdot10^5 s^3 + 2.956\cdot10^6 s^2 + 5.535\cdot10^5 s - 5240} \\ \dfrac{-89.17s^5 - 5.623\cdot10^5 s^4 + 1.826\cdot10^6 s^3 + 2.716\cdot10^6 s^2 + 1.311\cdot10^8 s - 2.772\cdot10^8}{s^5 + 3782s^4 + 1.786\cdot10^5 s^3 + 2.956\cdot10^6 s^2 + 5.535\cdot10^5 s - 5240} \end{pmatrix}$$

Pole-zero map of the closed-loop system (Fig. 5) shows that the poles of that system with nominal parameters lie within the selected sector.

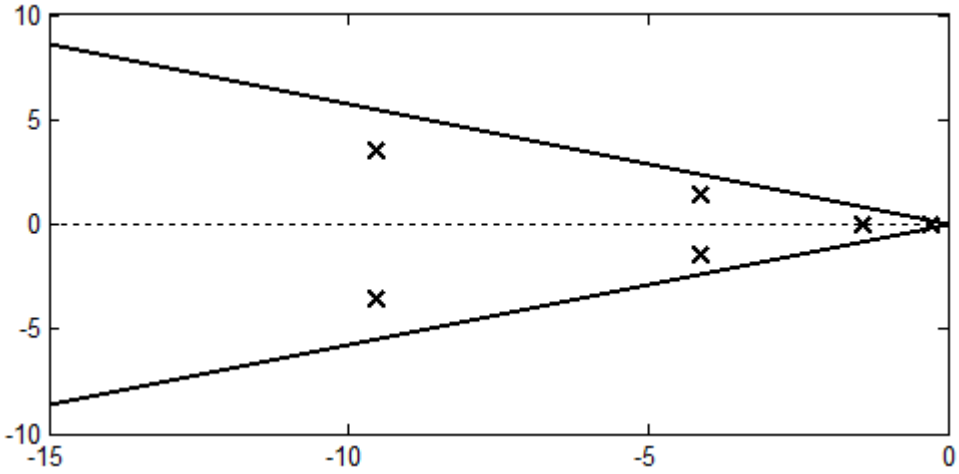

Figure 5. Pole-zero map of the closed-loop system

Simulation of the transient process on the full-order nonlinear model. The scheme of simulation of transient processes with interconnected system stabilizer is shown in Fig. 6.

We simulate the transient process of 3-phase short-circuit fault (0.2 s) behind the transformer and subsequent automatic re-closing for the system with the turbine generator without stabilizer, with the standard [4] and interconnected robust system stabilizer, drawing them on the same graph (Fig. 7). This graph shows lower oscillability of transient process with the use of robust controller with poles placement technique. To demonstrate the robust properties of the synthesized controller, the graphs were generated for different values of K_{0u}. In Fig. 7 a) for K_{0u} 100 and 150, b) K_{0u} 100 and 50.

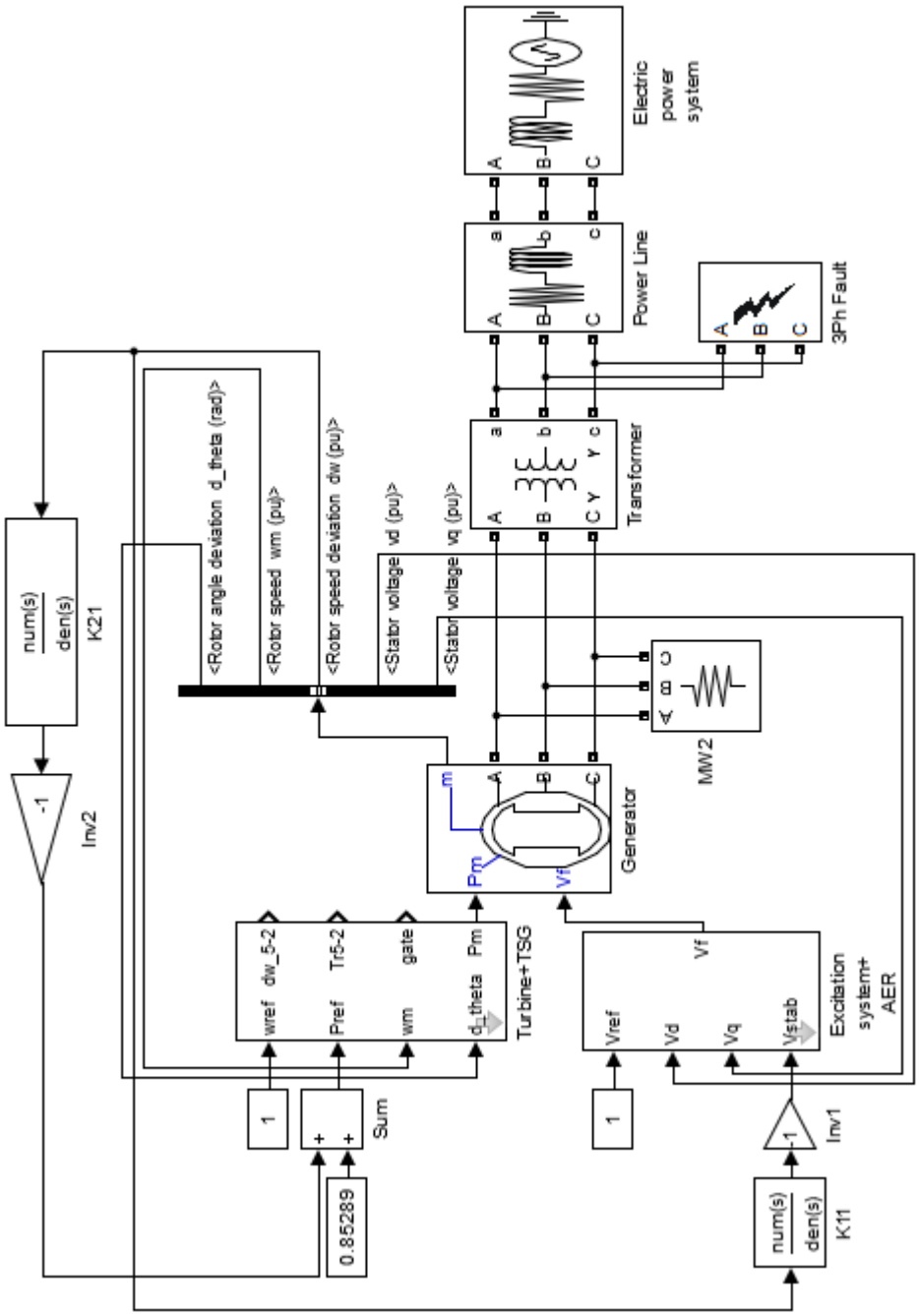

Figure 6. Simulation scheme

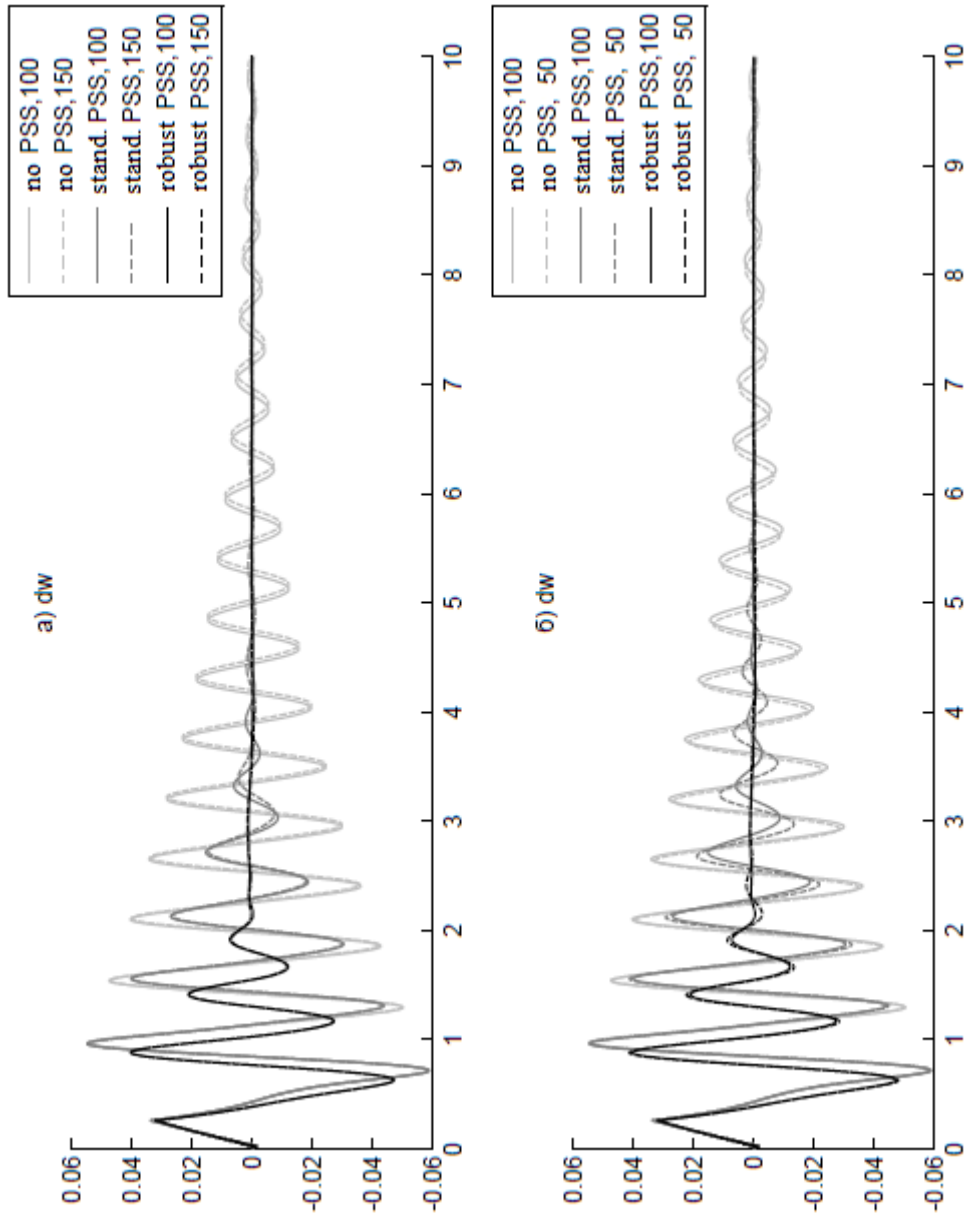

Figure 7. Simulation graphs

Conclusion

To ensure the performance specifications of automatic control of the turbine-generator unit it is expedient to use interconnected robust controller, which is synthesized using H_∞-optimization method with the closed-loop system poles placements with the linear matrix inequalities regions. As numeric simulation graphs show this kind of controller has better performance specifications of transients than the standard power system stabiliser which was reported by P. Kundur in [4].

It was shown that the method of model simplification before the synthesis of controller can produce sufficient accuracy for resulting system stabiliser. In addition, the selection method of weighting functions for chosen uncertainty model leads not only to robust stabilization of closed-loop system but to robust satisfying of performance specifications of transients for different model parameters within their predefined ranges.

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Methods and algorithms of food industry enterprises electrical energy consumption control

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Abstract

Introduction. The conducted researches of the food industry enterprise electrical energy consumption control with the aim of electrical resources efficiency increase by electricity consumption control methods and algorithms developing.

Materials and methods. The researches are made on the base of control processes system analysis methods.

Results and discussion. The analysis of the food processing enterprise (FIE) electrical energy consumption control has allowed to determine the main stages of the control process: the basic control functions are electric energy (EE) consumption registration , forecasting of EE consumption, calculation of EE consumption norms, consumers – regulators (CRs) list formation; control functions support conditions – EE consumption information, restrictions and rates, electricity consumption forecasting accuracy requirements; organizational and technical mechanisms of control functions implementation - information and computing system, electric power dispatcher, process operator, electrical supervisor; basic information flows which provide electrical energy consumption control - predicted temperatures values, EE consumption and production output current data, decisions settled on EE consumption. Represented methods and algorithms of FIE electrical energy consumption management with use of CRs. When creating a FIE EE consumption management forecasting mathematical model an artificial neural network in the form of a multilayer perceptron was used. In order to study the artificial neural network is used the combined training method based on the back error propagation method and the Cauchy method. The organizational and technical FIE EE consumption management requirements are formulated. It is determined that taking into account the technological process and the EE consumption process mutual connection for EE consumption control it is necessary to use a dialogue system.

Conclusion. FIE EE consumption control is realized with the use of forecasting values received via artificial neural network by the optimal EE consumers composition forming on the base of the heuristic algorithm. This allows to ensure the high efficiency and to take into account damages caused by CRs disabling.

Glossary

ACSFIE – automated EE consumption control system of food industry enterprise;
EE – electric energy;
FIE – food industry enterprise;
CR – consumer-regulator.

Introduction

The electric energy (EE) consumption reducing problem is relevant for the food industry, since it allows to increase the generating capacities use efficiency and to reduce EE consumption during its transmission and the energy intensity of production outputted by enterprises. For ensuring of rational EE consumption levels by food industry enterprises (FIE), it is necessary to forecast its consumption and use consumers-regulators (CRs).

The electric energy control issues are devoted a number of works [1–6]. Let us look at some of them. In the article [1] the software of commercial EE accounting systems and the technical facilities complex "Energomira" is represented. It is represented by the software modules set for the commercial EE accounting organization on energy sites. As such objects can be used energy companies, electricity grid areas, substations and other EE consumers.

The technical facilities complex "Energomira" software includes:

- automatic dispatcher workplace, which realizes the data processing from the data collection device and from data collection and transmission device, their representation in form of charts and tables;
- report generator for creating various documents forms;
- data collection and database development programs;
- technical facilities complex administering programs for the system devices parameters determining.

The works analysis [1, 2] showed that the software presented in them was created by various organizations, which did not interact with each other when it was created. This condition causes significant complications with this software sharing.

The article [3] represents a two-level automated EE consumption accounting system "E1 – Energy-accounting". The lower system level contains electronic counters "Euro Alpha" and "Alfa Plus" with digital communication channels, and the upper - modern computers with automatic dispatcher workplaces. The system is based on the client-server architecture. It allows to support an arbitrary number of client computers with automatic dispatcher workplaces. However, at present, this system solves only the EE accounting problems.

Recently, more and more automated new generation control and accounting EE systems are used, which are developed on the basis of modern industrial controllers [4]. These systems are aimed at solving the problems of commercial EE accounting and capacity consumption, as well as technical accounting and monitoring of industrial enterprises electrical loads in real time mode.

The works analysis [4–6] shows that the systems presented in them are performing functions of electric capacity and EE control. These systems do not realize the EE valuation, planning, forecasting and control optimization functions of industrial enterprises, which allows to obtain the main economic effect.

The aim of the research consists in the automated synthesis of food industry enterprise EE consumption control and supply system on the base of the transmission control process systematic analysis, EE distribution and consumption.

Materials and methods

Research materials

The food industry enterprise electrical energy consumption control process is studied.

Research methods

Researches were conducted in the following order:

- it was made a systematic analysis of the electrical energy consumption process;
- it was developed the FIE electrical energy consumption control algorithm with the use of consumers-regulators;
- it was developed the mathematical model of electrical energy consumption forecasting with the use of an artificial neural network;
- it was developed the consumers-regulators choice;
- it is developed the electrical energy consumption automated control system on the basis of the forecasted values of the enterprise electrical energy consumption using the decision-making dialogue subsystem.

Results and discussion

The automated EE consumption control system of food industry enterprise (ACSFIE) is created with the purpose of the electric resources efficiency use increasing and the production energy intensity reducing due to the EE consumption predicted values use, EE consumption regulatory values, analysis of arising production situations and the assessment of production energy efficiency improving measures [8].

The system synthesis is based on the subsystem representation in the form of a interconnected structures set: decision making support, as well as, functional, organizational, technical and informational support.

Let us formulate requirements for creatable subsystem:

- efficiency (system construction and operation costs should be lower than the
- results obtained);
- adaptability (the system should be simple in construction and mastering);
- scalability (the ability to change the coverage breadth.

The enterprise EE consumption control process will be represented in the form of a interconnected depictions set:

$$\forall b_n \; \exists \; \chi_n\left(K_n, T_n\right): \quad P_n \to P_{n+1}$$

$$\mathrm{B_l} \in \mathrm{B} = \left\{\mathrm{b_l}, \mathrm{l} = 1,\ldots,\mathrm{L}\right\};$$

$$\mathrm{K_n} \subset \mathrm{K} = \left\{\mathrm{k_l}, \mathrm{l} = 1,\ldots,\mathrm{L}\right\};$$

$$\mathrm{T_n} \subset \mathrm{T} = \left\{\mathrm{t_m}, \mathrm{m} = 1,\ldots,\right\};$$

$$\mathrm{P_n}, \mathrm{P_{n+1}} \subset \mathrm{P} = \left\{\mathrm{p_g}, \mathrm{g} = 1,\ldots,\mathrm{G}\right\}$$

where B means process stages of the EE consumption control: b_1 is the stage of registration and verification of the measurement information accuracy; b_2 is the stage of model choosing and enterprise EE consumption and production sections forecasting; b_3 is the stage of rationing and planning of enterprise and production sections electricity consumption on the base of forecast values, enterprise electric balance closing; b_4 is the stage of comparison of actual and planned enterprise EE consumption and production sections for a certain period and decision making on the enterprise EE consumption;

χ_n is the displaying function of the control process at the-stage b_n;

K means realization conditions of all enterprise EE consumption control functions: k_1 are normative acts on EE consumption by consumers; k_2 are terms and conditions of the contract for FIE EE supply; k_3 are metrological requirements for EE accounting devices; k_4 are requirements for the accuracy of the EE consumption forecast;

T means organizational and technical facilities and structures used for the control functions realization: t_1 is an information and computing system of electrical supervisor service; t_2 is an electric power dispatcher; t_3 is an electrical department; t_4 is electrical supervisor; t_5 are EE accounting sensors and measuring devices;

P means input and output information streams used in the control process of FIE EE consumption: p_1 are average daily environment temperature data; p_2 are enterprise and production sections EE consumption data; p_3 are data on production volumes produced by the enterprise; p_4 are enterprise EE consumption limits; p_5 is a reliable information about the average environment daily temperature; p_6 is a reliable information about the enterprise and production sections EE consumption; p_7 and p_8 are forecast and planned values of production sections EE consumption; p_9 are decisions made to control the enterprise EE consumption.

Taking into account the introduced symbols, the displaying functions of the FIE EE consumption control process will take such the form:

for the stage b_1 - the stage of registration and verification of the measurement information accuracy used by FIE EE consumption control:

$$\chi_1(k_3, t_1, t_2, t_5):(p_1, p_2) \to (p_5, p_6);$$

for the stage b_2 - the stage of model choosing and enterprise EE consumption and production sections forecasting:

$$\chi_2(k_1, k_4, t_1):(p_3, p_5, p_6) \to p_7;$$

for the stage b_3 - the stage of rationing and planning of enterprise and FIE production sections electricity consumption on the base of their forecast values :

$$\chi_3(k_1, t_1, t_2):(p_3, p_7) \to p_8;$$

for the stage b_4 - the stage of comparison of actual and planned enterprise EE consumption and production sections for a current month; decision making on the enterprise EE consumption control:

$$\chi_4(k_1, k_2, t_1, t_2, t_3, t_4):(p_4, p_6, p_8) \to p_9.$$

Interaction between the control process stages is realized with help of information flows.

Planned electric energy consumption control

The capacity planning of the FIE consumer used in the FIE is conditioned by the need to determine the possibility of load regulation in the normal mode in order to minimize the EE consumption and to identify the EE consumers-regulators in the normal mode (CRs_N) and in the forced mode, which is implemented when restrictions from the direction of the the EE supplying organization are used (definition of consumers-regulators of EE in the forced mode (CRs_F)) [3].

The classification and determination of the EE consumers-regulators formation criteria is given in [7]. Enterprise EE consumption by the technological process load regulation of consumers with the help of this process moving into energy systems minimal loads zones is proposed in work [8].

The transfer of EE consumers to the consumers-regulators mode is realized in accordance with the formalized target functions and restrictions that correspond to them, as well as taking into account the CRs CRs_j^i type and work mode (see Table 1).

Table 1

Target function	Target function restrictions	CRs type	Work mode
$W_L \to 0$	$\begin{cases} E_{addit.} = 0, y = 0 \\ E = E_{norm.}, y = 0 \end{cases}$	CR_N^I CR_N^{II}	Normal
$W_L - W_{allwb.} \to 0$	$\begin{cases} E_{addit.} = 0, y = 0 \\ E \geq E_{norm.}, y = 0 \end{cases}$	CR_N^{III} CR_N^{IV}	Normal
$y \to \min$	$W_L < W_{allwb.}, E > E_{norm.}$	CR_N^V	Forced

In this table: W_L *means* CRs electricity consumption peak load; $W_{allwb.}$ means allowable CRs EE consumption in peak load; $E_{addit.}$ means additional expenses for the off-peak work mode creation; y means the damage of the enterprise from the CRs off-peak work mode organization; E and $E_{norm.}$ mean calculated and normative efficiency coefficients.

Algorithm of food industry enterprise electric energy consumption

The satisfaction of the electric energy system EE consumption volumes

requirements and ensuring of the normative FIE EE consumption level with a minimal expenses for FIE is achieved by changing the work mode of the CRs energy consuming equipment (shutdown or transfer to a reduced work mode). The following algorithm of industry enterprise EE consumption control is proposed (Fig. 1).

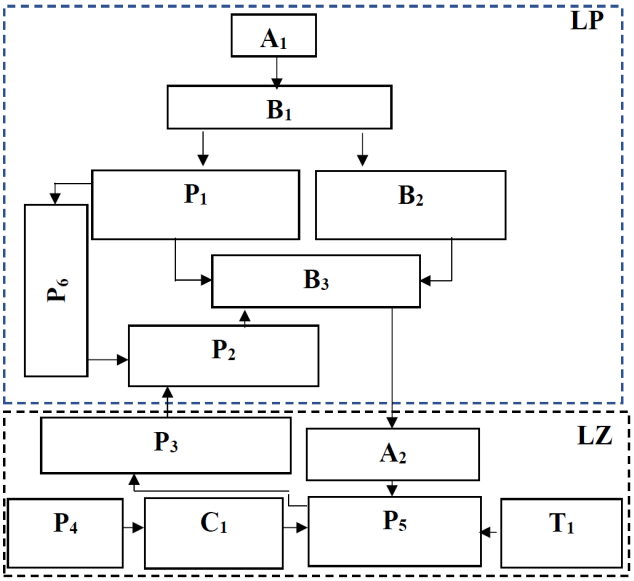

Figure 1. Algorithm of FIE EE consumption control with use of CRs

A_1 means of EE consumption data analysis; A_2 is EE consumption restrictions analysis; B_1 is of the share determination of each consumer in the total EE consumption; B_2 is consumers-regulators identification; B_3 is the EE consumption restriction setting; P_1 is EE consumption and EE consumption norms forecast; P_2 means comparison of fines and damages amount comparison; P_3 is damages results calculation; P_4 is energy inspections conducting; C_1 is damages database creation; P_5 means electrical receivers selection and damages estimation in case of their disabling; P_6 is energy system fines calculation;T_1 means technological restrictions; LP is enterprise level; LZ is section level.

In the normal work mode after fixed time intervals Δt from the initiative of information and computing system of the EE consumption control subsystem upper level is conducting the counters survey of automated EE consumption and calculation system, determination and calculation of actual current EE consumption by lower level elements of the EE consumption mode control system. Decisions are made depending on the forecasted value of EE consumption $W_{forca} \in W$.

The set of possible W values of EE consumption is divided into a range of disjoint subsets:

$$M_1 = \left\{W_{forca} \geq W_L^U\right\}; M_2 = \left\{W_L^L < W_{forca} < W_L^U\right\}; M_3 = \left\{W_L^L \geq W_{forca}\right\},$$

where W_L^L, W_L^U mean lower and upper EE consumption restriction.

Each of the selected subsets corresponds the set of controlling influences. As a EE consumption amount restriction, the FIE stated maximal EE consumption for this month $W_{\max}^k$ or the more stringent restrictions placed by energy system in the case of the scarce fuels absence, emergency situations, and so on.

The hit of a controlled parameter $W_{forc.}$ in each of the selected subsets M_1, M_2, M_3 leads

to the corresponding control influence formation.

As it follows from the given above procedure, the EE consumption mode control is leaded to:

- problems solving of EE consumption forecast and optimal CRs composition choosing (the upper level of the EE consumption mode control subsystem);
- problem solving of selected objects within a given frames during the accounting period EE consumption support (lower level of the of the EE consumption mode control subsystem).

As already was noted, the EE consumption forecast should be realized at the upper level of the of the of the EE consumption mode control subsystem with the view of possible fines determination from the energy systems and the EE consumption normalized values comparison.

The FIE EE consumption control is realized with use of EE consumption forecast values for specified times moments with the view of energy-efficient EE consumption modes providing and the energy system requirements fulfill on account of EE consumption restriction during maximal load periods. For control functions realization are used: the EE consumption forecasting model of, EE consumption control decisions making algorithms, the CRS optimal list formation and rational EE consumption modes formation.

Mathematical model of the food industry enterprise EE consumption forecasting on the base of artificial neural network

The base for any forecasts constructing, including the EE consumption forecast, is a mathematical forecast model.

The process of the forecast model building includes following steps:

- the forecasting method choice, which determines the forecast model
- essence;
- input and output model parameters choice;
- formation, training and verification of the data set accuracy;
- the forecast model internal structure construction, which determines the
- dependence of the output parameters from the input ones;
- the forecast model verification and the quality estimation of the received forecasts.

As a forecasting method during the forecast model constructing of the FIE EE consumption, it will be used forecasting on the base of artificial neural networks. This will increase the adaptability degree of the obtained model, achieve a good generalizing ability and provide the possibility of complex nonlinear dependencies setting of the output parameters from the input ones [9].

The output parameter of the forecast model will be used the hourly EE consumption W_h of the enterprise as a whole.

Let us conduct the parameters analyze that affect the FIE EE consumption at various levels of its energy supply system.

FIE energy supply work mode is characterized by the following parameters:

- active, reactive capacity and EE consumption of electrical receiver that are used for balance compilation;
- voltage in the FIE electric network nodes;
- currents in EE transmission lines;
- wastes in EE transmission lines;
- EE quality Indicators.

The main, basic parameters of FIE energy supply system work mode are the capacity consumption and EE. Depending on the capacity consumption, in the nodes of the system will change the voltage, and in the lines - currents. The FIE EE amount consists of the EE consumption w_i of all N of all electrical receivers working at current time and EE wastes ΔW in the network elements:

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

EE wastes, in their turn, in the energy supply systems main elements: lines and transformers, will depend on the electrotechnical parameters of these elements themselves (their active and reactive resistances) and the energy transmitted with their help:

$$\Delta W = f\left(W_a, W_p, R, X\right)$$

In the energy supply work process, the resistances of its elements can be considered almost unchanged. Thus, a change of the current capacity waste in the enterprise network will occur due to changes in the total capacity of the electrical during their switching on, switching off or work mode change.

The EE consumption w_i of each electrical receiver or group of ones, in their turn, can be written as follows:

$$w_i = f\left(\lambda_1, \lambda_2, \ldots, \lambda_n\right)$$

where $\lambda_1, \lambda_2, \ldots, \lambda_n$ are parameters, which influence on EE consumption.

The number of electrical receivers (primarily asynchronous and synchronous motors) at an enterprise can reach hundreds and thousands. For each electrical receiver, parameters that influence its EE consumption can be different.

It is not possible to construct FIE EE consumption forecast models that takes into account the parameters, which influence the EE consumption of each electric receiver because of the large number of interconnected input parameters in such a model. The most optimal is the electrical receivers combination in groups by any features (technological, electrical), with subsequent parameters identification that influence the EE consumption of each group. In their turn, the electrical receivers influential parameters totality of each group will be an input parameters set for the forecast model of the enterprise EE consumption as a whole.

In the general case, all electrical receivers, according to their purpose, can be divided into two groups:

- the main ones, which involve in the main production process of the enterprise. These electric receivers include electrotechnological devices (electrothermal and welding apparatuses, electrolysis baths), compressors, pumps and centrifuges drive, conveyors and other transport vehicles drive, metalcutting, woodworking and other machines, etc.

- auxiliary – that means such, which do not participate in the main enterprise production process. These include electric receivers, which are involved in the enterprise creation and support microclimate (ventilation and air-conditioning devices, air heaters), lighting devices and electrical receivers work on the enterprise sanitary and technical needs (pumps for cold and hot water supply, sewage, waste, etc.).

In their turn, electrical receivers of the main group can be grouped according to one or another area, section, production line.

Choice of structure, input parameters and methods of an artificial neural network training

In this work for the FIE EE consumption forecasting from the artificial neural network architectures set was chosen multi-layered perceptron, first proposed by Frank Rosenblatt (1957), and later generalized by David Rumelhart (1986) [9].

This choice is caused by the possibility of complex nonlinear extrapolation problems solving in spite of the relative simplicity of the perceptron.

Perceptron configuration selection

As the input and output perceptron layers dimensions determining were based the following considerations:

- the input layer contains the number of elements (neurons) that corresponds to the retrospective data total number , which include daily EE consumption and average daily temperature for the working year days, that is previous to that for which is made the forecast, as well as the volumes change coefficient of enterprise manufactured production for the previous year;
- the output layer contains elements (neurons) that determine the predicted values of EE consumption.

The change coefficient of volumes outputted by the enterprise production is calculated on the basis of the proportion

$$K_{forci} = \frac{\Phi_l}{\Phi_{l+1}},$$

where Φ_l means the production volume outputted in l year.

The choice of the intermediate (hidden) layers number and elements in them was conducted experimentally in such a way that for the various input and output data sets the minimum forecast error was reached.

It is determined that for EE consumption forecasting it is expedient to use one hidden layer with the number of elements equal to the half-sum of the input and output layers elements of the perceptron

$$n_H = \left[\left(n_X + n_Y \right) / 2 \right],$$

where n_H means number of elements in the hidden layer, and n_X and n_y mean number of elements in input and output perceptron layers.

The set of perceptron weight coefficients is represented by a synoptic map W, the weight of the relationship between each neuron of the neighboring layers is indicated as w_{ij}^1, w_{ij}^2, *where* i, j *mean* ordinal numbers of the neurons in the initial and final layers. Input values of daily EE consumption and average environment daily temperature for the last year are initialized as $W_1,...,W_N$ *and* $T_1,...,T_N$ *correspondingly,* as well as the output signals of the artificial neural network, the corresponding predicted values of EE consumption are indicated as $Y_1^{'},...,Y_{N'}^{'}$.

The EE consumption accuracy forecasting of industrial enterprises depends to a great extent on the retrospective sample volume, which is used for perceptron training. The conducted studies have shown that for the required forecasting accuracy the retrospective

sample volume of enterprise EE consumption and meteorological data for a period of four years is sufficient.

A retrospective sample of the FIE EE consumption values includes a sequence of training images pairs $L^m(K^m, Y_b^m)$:

- $K^m = \left[W_1^j, ..., W_k^j, T_1^j, ..., T_k^j\right]$ *is* input data vector, which are applied to the perceptron input (input signals);
- Y_b^m is vector of desired predictive values for $L^m, m = 1, 2, \ldots, N$ *(*N *is* training data sets number*).*

When constructing the input vector I of the retrospective sample, all daily EE consumption values, daily average temperature and illumination for each working day preceding the forecasted year are taken into account.

At perceptron output, the predicted value W^I *for* I input signals vector determines the predicted values of the enterprise EE consumption for the next year.

In connection with the conditions change of enterprise EE consumption, parameters of the forecasting model require an adaptation, which is realized at the end of the year and is accompanied by the perceptron re-training procedure, taking into account new retrospective data.

Using of unnormalized input data can cause the "saturation effect" on conditions which the element (neuron) of the perceptron is sensitive to the input values that are situated in the restricted area, that leads to its inadequate work. For the input data normalization is used the following formula

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

where $P_{\min}$ *and* $P_{\max}$ *are minimal and maximal value of* input data in this sample*, as well as* P_m *and* P_m^H *are* nonnormalized and normalized values that are applied to m perceptron entrance.

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

As activation is selected the sigmoidal function

$$f(u) = 1 / (1 + e^{-au}),$$

where a is an neuron parameter.

The sigmoidal activation function choice is caused by such fact that this function has continuous derivatives that are required for the back error propagation algorithm and that amplifies the weak signals to a greater extent than the strengths ones, what is important by high forecast accuracy.

For the adequate work of an artificial neural network is important its training algorithm, from which largely depends the network ability to solve given tasks.

The perceptron quality assessment is realized by the ratio:

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

where ε is training error, as well as $Y^j_{forc.}$ and Y^j are values of forecasted and actual perceptron exits.

The training process is completed if the error ε for the whole set of input signals does not go beyond the set value $\varepsilon \geq 0$ or reaches a predetermined training iterations number.

The perceptron training is realized by one of the fastest algorithms - an algorithm of back error propagation, which bases on the gradient descent method.

For adjusting of weight coefficients was used the expression

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

where w_{lm} is the *synaptic connection weight coefficients* between l *neuron of* $k-1$ layer and m neuron of k layer; ζ is rate training coefficient.

Despite such fact that the back error propagation method is widely used by the artificial neural network training, it has a significant disadvantage - it cope poorly with local minima [10], what can lead to their work deterioration. For exit from local minima is used a statistical training method - the Cauchy machine [9], by use of which a random change of the artificial neural network weight coefficients is conducted. However, this method is not effective because of slow convergence, since many steps of its realization are performed in the wrong direction.

The combination of the above examined method (algorithm) of the back error propagation with the Cauchy method (algorithm) allowed to obtain a combined training algorithm, which quickly finds the global training error minimum.

The trained perceptron allows not only to distinguish input data from the training sample, but also it is able to interpret the trends change in the forecasted process.

The FIE EE consumption mode control system on the base of the predicted values of electricity consumption is two-level:

- upper level (level of the main stepdown substation or input to the enterprise);
- lower level (EE consumer level).

For a compact description of this structure, the 1st level elements set will correspond certain numbers set of a natural sequence, which we shall call a 1st level indices set $L_1 = \{1, 2, \ldots, i, \ldots, m\}$. It characterizes the presence of the upper level elements number (for example, substations), which are parts of contractual relations with the energy supply organization.

The 2nd level elements set will correspond the certain natural sequence number set, which we call a 2nd level indices set $L_2 = \{1, 2, \ldots, i, \ldots, n\}$. Elements of this level relate only to certain elements of the upper level. For example, to the concrete substation concern only those consumers, who receive energy supply from this substation.

The EE consumption mode control system state at each of the fixed time moments $t = k\Delta t, \quad k = 0, \ldots, K$ (Δt is the interval of input information into a computer complex) can be characterized by a set of parameters

$$X = (W_{11}, \ldots, W_{m_n n}, \Delta W, z_{11}, \ldots, z_{m_n n}, k_{11}, \ldots, k_{m_n n}), x \in X,$$

where X is space of possible energy supply system states; W_{ij} is consume of i CR of j level; ΔW is the load excess value set by the energy system restriction; y is the CR specific damage estimation from changes in its work mode (damage per time unit), what includes fee for funds and depreciation deductions for equipment, which is disconnected, costs for capacity payment and damages from the technological process violation [8]; k_{ij} is Boolean function equal to 1, if the influence on the i CR of j level is exerted, and 0 is in other case.

Realization of control effects, which are implemented on the parameters set, is aimed

at the minima achieving:

- damages from changes in the CR work mode and deviations from the EE consumption normative values;
- fines from energy systems, in case of over contract EE consumption;
- fines from energy systems, in case of underrated EE consumption compared with the contractual EE consumption amount.

FIE EE consumption control is conducted by optimal consumers composition forming.

In systematic EE consumption reduction can not participate CRs, disconnection of which is unacceptable for safety reasons, catastrophic consequences or can lead to significant damages and equipment failure as a result of changes in technological production processes. All other consumers can be used for regulation.

When choosing of CR, is made their quality assessment for EE consumption regulation according to the vector criterion

$$F(x) = \left[F_1(x)F_2(x)\right],$$

defined in the states system space X with the components

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

where y_{ij} means the damage from use for the regulation of i CR at the j level energy supply system; k_{ij} is Boolean variable, which takes the value: - 1, if i CR of the j level is used for load regulation and 0 is used in other case; n is the consumers number allocated for regulation at the j level.

CRs composition optimization is conducted in the region

$$\sum_{j=1}^{n}\sum_{i=1}^{m_j} P_{ij}k_{ij} \geq \Delta P$$

CR composition forming for active load regulation is realized on the base of problem solving of integer programming with Boolean variables with use of the heuristic algorithm. The consumers choice for the load regulation is realized from the very top level, which contains at least one consumer with a load that is less than that, which is stepped down.

Optimization at j level was realized according to the criterion

$$\sum_{i=1}^{m_j} (y_{ij} / W_{ij})k_{ij} \rightarrow \min,$$

where W_{ij} is EE consumption of i consumer of j level of energy supply system.

As the task restriction is used the load amount restriction, that is stepped down at this level.

$$\sum_{i=1}^{m_j} P_{ij}k_{ij}t \geq \Delta W.$$

We use the heuristic algorithm of CR selection, according to which consumers-regulators of j level of the electrical network are arranged in order of the ratio increasing $y_{ij} / P_{ij.}$. The target function minimization is realized by CR successive selection, from the received series, till load restriction violation. After task completing at the j level, the last consumer from the selected ones is rejected. At the same time, load restriction is violated. The load value reduces by the total capacity amount ΔP, which will remain in the CR list and the list formation at the $j+1$ level. If the further descent by levels is not possible, then

the last of the rejected CRs is included in the list, and the algorithm work ends.

The CR choice at the enterprise network level is also conducted with help of the heuristic algorithm [8]. At the same time, for the network j level, for which the problem is solved, are given the following data: the electrical equipment units number at this level and the load reducing value ΔP. Prior also are calculated damages y_{ij} and are determined the current CR electrical loads - P_{ij}.

This algorithm allows to get the set task solution by relatively simple mathematical methods. He realized the CR choice at network individual levels with the help of an approximate method. By insignificant costs for realization, it is characterized by certain wastes of accuracy load, which is switched off.

Automated EE consumption control system construction on the base of predicted values of the enterprise EE consumption

ACSFIE is a interacting units set - forecasting, regulation and EE consumption planning, the optimal consumers composition forming and the decision-making dialogue subsystem of the enterprise EE consumption control (Figure 2).

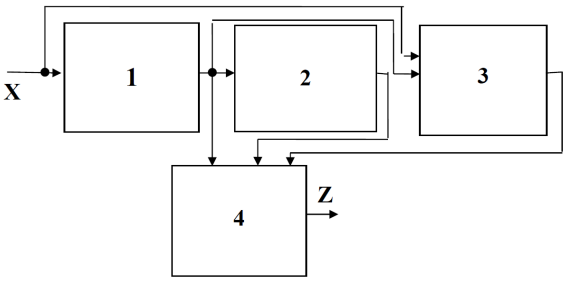

Figure 2. FIE automated EE consumption control system structure

X means input data; 1 is EE consumption forecasting unit; 2 is EE consumption expenses normalization and planning unit; 3 is forming unit of the optimal EE consumers composition; 4 is the dialogue support and decision-making subsystem; **Z** - control actions.

Let us consider the features and appointment of individual functional units **Forecasting unit.** On the basis of coming data from the databases for the EE expenses control, with the help of a three-layered perceptron, the EE consumption forecasting of the enterprise production units and the enterprise as a whole is realized. The predicted EE consumption values by data of these objects come to the EE consumption normalization and planning unit.

EE consumption **regulation and planning unit**. On the base of the obtained predicted values are determined the total expense norm and total planned EE expenses for production sections, as well as the expense norm and planned EE expense for the enterprise as a whole.

The obtained data are contained in the EE expense control databases. It also contains calculated on their base total planned EE expenses for non-production enterprise subunits.

The ACSFIE presence allows automatic and promptly compilation of annual, quarterly and monthly electrical balances of the enterprise and of the most energy-intensive installations and production subunits (sections).

On these balances base is performed an analysis of the EE consumption, are identified economy directions, opportunities for unproductive EE expenses and wastes reducing of EE and are taken measures for its consumption improving.

Optimal EE consumers composition forming unit

On the base of the information coming from the EE expenses control databases, as well as the requirements of the energy system, is formed the CRs list, which will ensure the energy system requirements compliance relative to the EE consumption. The CRs list and EE consumption volumes are transmitted in the decision-making support subsystem.

EE consumption decision-making control support subsystem

From the databases of EE expense control are received data of the actual and planned EE consumption of production subunits and the enterprise as a whole, as well as the optimal EE consumers composition.

With help of the decision-making control support subsystem is realized a comparison of the actual and planned EE consumption values of the enterprise and production subunits, the results of which are proposed solutions for the EE consumption control of an industrial enterprise, which will ensure the use of the energy system requirements.

Appropriate decision variants (control influences), which represent the organizational and technical measures set aimed at the EE consumption plans correcting of the enterprise and production subunits during the period, that remains till the end of the year, are transmitted to the person, who is makes decisions and forms the final control influences.

At the end of the calendar year, is conducted the reasons analysis for EE consumption plans exceeding of production subunits and are taken measures for their prevention.

The general scheme of the decision-making process with use of the decision-making support dialogue subsystem is presented in Figure 3

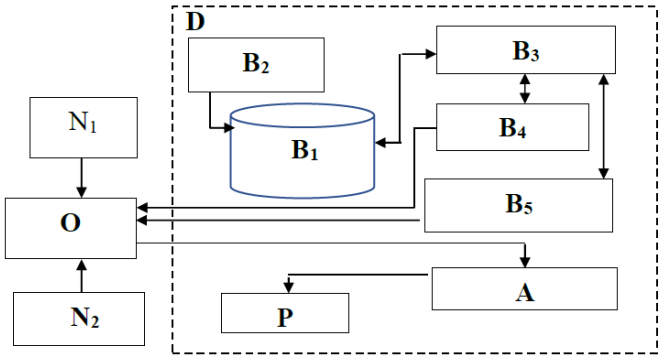

Figure 3. General scheme of the decision-making process of FIE EE consumption control with use of the dialogue subsystem

N_1 means normative data for decision-making: energy system requirements for the EE consumption volumes; duration of the production program; optimal EE consumption norms; financial expenditures on EE for the production program realization; N_2 is non-formalized criteria that take into account the specifics of a particular production and the

current situation in the internal and external environment; O is the person, who makes decision; D is the decision-making support dialogue subsystem of FIE EE consumption control; B_1 means the EE consumption database; B_2 is the EE consumption automatic information collection unit; B_3 is the interaction unit; B_4 is EE consumption forecasting and normalization unit; B_5 is the optimal EE consumers composition unit; A means the analysis of the production program variants and CRs; P is accepted CRs list and the production program variant.

Organizational and technical support of enterprises EE consumption control.

For the ACSFIE building are used modern information technology. The methods analysis of the automated control systems constructing has shown that it is expedient to realize the FIE EE consumption control on the platform of the general operating system, rather than the real-time operating system, since ACSFIE includes many "background" tasks, which are rigidly unrelated with the time of the solution: electric balance calculation tasks, normalization and planning of enterpises EE consumption and others.

Functions related with the information collection and its initial processing, are realized, as a rule, with help of programmable logic controllers. They are programmatically compatible with the MS Windows platform and are hosted on control points. Information from them is entered into personal computer.

Conclusion

The system analysis of the FIE EE consumption control process on the base of control process decomposition, allowed to determine the main control process stages; control functions conditions ensuring; organizational and technical mechanisms of the control functions realization; basic information flows, which provide EE consumption control.

When creating a mathematical forecasting model of the FIE EE consumption it is advisable to use a multilayer perceptron, which trains on the base of the back error propagation method and the Cauchy method. The FIE EE consumption volumes can be changed by forming of optimal consumers composition based on the heuristic algorithm with the use of the decision-making support dialogue subsystem.

The EE consumption control of food industry enterprises should be based on the EE consumption forecasting with help of the multilayer perceptron. Optimal EE consumption volumes can be achieved by forming of the consumers-regulators optimal composition on the basis of the heuristic algorithm with the use of the decision-making support dialogue subsystem.

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Isolation of domains of stability of linear dynamic systems with fractional regulators

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Abstract

Introduction. The research of linear dynamic systems of regulation of the process of biological purification of contaminated water with fractional regulators was conducted in order to determine the boundaries of *D*- domains of their global stability and to determine the space of the parameters of the adjustment of the fractional controller for fixed orders of the diereintegrators in its composition.

Materials and methods. Studies were conducted on the stability of the automatic control of the water treatment process. Using the *D*-split method, we obtain analytical formulas that determine the limits of the region of stable stabilization of the "object" + "fractional-regulator" system.

Result and discussion. Automatic control systems of fractional order are more precisely described by dynamic equations, in which the order of derivatives can be any number, valid and not only integer. Proportional-integral-differential (*PID*-) regulators that are widely used in practice of automation also fall under a fractional generalization, if in their structure, instead of ordinary integer derivatives and integrals, fractional analogues are used. The controllers of the fractional order denote how $PI^{\lambda}D^{\mu}$, where λ and μ are the orders of integration and differentiation of the error signal, with orders λ and μ may have valid non-integer (fractional) values.

On the basis of the *D*-split method, analytical formulas are described that describe the boundaries of global stability of linear dynamic systems of fractional order. Domains of stability are built in the space of parameters of the configuration of fractional domains $PI^{\lambda}D^{\mu}$-regulators for fixed orders of dipintegrators. An appropriate algorithmic software is developed that implements the proposed method for selecting the domain of stability. Some results of computational experiments are given, an estimation of fractional $PI^{\lambda}D^{\mu}$ - regulator efficiency is given.

Conclusions. On the basis of the D-split method, analytical expressions were obtained, which describe the boundaries of the global region of stability of linear dynamic systems of fractional order of type "input-output" with fractional $PI^{\lambda}D^{\mu}$ -regulators.

Introduction

From the beginning of the development of the theory of integro-differential calculus of fractional order [1], its first applications in control problems appeared only about 50 years ago [2]. It has been shown that fractional calculus becomes an effective tool for describing numerous dynamic systems. The classical results of the *PID* control theory have spread to the fractional order controllers, which denote how $PI^{\lambda}D^{\mu}$, where λ and μ are the orders of integration and differentiation of the error signal, with orders λ and μ may have valid non-integer (fractional) values [3,4].

Materials and methods

Studies were conducted on the stability of the automatic control of the water treatment process. Analytical studies are based on Laplace's transformation with respect to the operator of a dipintegrator, which generalizes the functions of differentiation and integration, on the use of the structural theory of closed systems and on the target mathematical transformations of the transfer functions of the object-regulator system.

On the basis of the *D*-split method, analytical formulas are described that describe the boundaries of global stability of linear dynamic systems of fractional order.

Domains of stability are built in the space of parameters of the configuration of fractional domains $PI^{\lambda}D^{\mu}$-regulators for fixed orders of dipintegrators.

An appropriate algorithmic software is developed that implements the proposed method for selecting the domain of stability.

Analytical studies and computational experiment in the MATLAB environment have been conducted. Using the *D*-split method, we obtain analytical formulas that determine the limits of the region of stable stabilization of the "object" + "fractional-regulator" system.

Result and discussion

The well-known problem of the allocation of the global region of stability (*D*-split method) required the distribution of fractional dynamic systems in the space of the parameters of the adjustment $PI^{\lambda}D^{\mu}$-regulator, depending on the value of the orders of powers λ and μ.

The purpose of the article is to study the possibility of applying the *D*-split method to automatic control systems for process control with fractional controllers.

A fundamental operator ${}_aD_t^{\gamma}$ is often referred to as a differintegrator.

$$ {}_aD_t^{\gamma} = \begin{cases} d^{\gamma} / dt^{\gamma}, & \gamma > 0, \\ 1, & \gamma = 0, \\ \int_a^t (d\tau)^{-\gamma}, & \gamma < 0, \end{cases} \qquad (1) $$

where γ – fractional order, a –constant associated with the initial conditions.

More fundamental is the definition of Grunwald-Letnikov for the order γ according to which

$$ {}_a D_t^{\gamma} f(t) = \lim_{h \to 0} \frac{1}{h^{\gamma}} \sum_{j=0}^{[(t-a)/h]} (-1)^j \binom{\gamma}{j} f(t - jh), \quad (2) $$

where $\binom{\gamma}{j} = \frac{\Gamma(\gamma+1)}{\Gamma(j+1)\Gamma(\gamma-j+1)}$, $\Gamma(x)$ – gamma Euler's function, $h > 0$ – gain of the time coordinate, $f(x)$ – the function to which the operator of the differential integration is used, $[\cdot]$ – means an integer part of the number. This definition shows that integer derivatives require the use of finite series, and fractional derivatives – an infinite number of members of a series.

It can be proved [5] that the Laplace transform, which is the basis of the definition of the concept of a transfer function, for the differintegrator has the form

$$ L\left\{ {}_0 D_t^{\gamma} f(t) \right\} = \int_0^{\infty} e^{-st} {}_0 D_t^{\gamma} f(t) dt = s^{\gamma} F(s) - \sum_{j=0}^{n-1} s^j (-1)^j {}_0 D_t^{\gamma-j-1} f(t)\Big|_{t=0}, \quad (3) $$

where $F(s) = L\{f(t)\}$ – ordinary Laplace transform function $f(x)$, n – an integer that satisfies the condition $n-1 < \gamma \le n$. Note that if ${}_0 D_t^{\gamma-j-1} f(t)\Big|_{t=0} = 0$, $j = 0,1,2,...,n-1$, then from (3) it follows that $L\left\{ {}_0 D_t^{\gamma} f(t) \right\} = s^{\gamma} F(s)$. Systems with fractional orders have transfer functions of arbitrary real order.

Consider the transfer function of fractional order, which is given by the following expression

$$ G(s) = \frac{N(s)}{D(s)} = \frac{b_n s^{\beta_n} + b_{n-1} s^{\beta_{n-1}} + ... + b_1 s^{\beta_1} + b_0 s^{\beta_0}}{a_n s^{\alpha_n} + a_{n-1} s^{\alpha_{n-1}} + ... + a_1 s^{\alpha_1} + a_0 s^{\alpha_0}} = \frac{\sum_{i=0}^{n} b_i s^{\beta_i}}{\sum_{i=0}^{n} a_i s^{\alpha_i}}, \quad (4) $$

where a_i, b_i, $\beta_n > \beta_{n-1} > ... > \beta_1 > \beta_0 \ge 0$, $\alpha_n > \alpha_{n-1} > ... > \alpha_1 > \alpha_0 \ge 0$ – arbitrary valid numbers.

In the time domain, the transfer function corresponds to an inhomogeneous differential equation of the fractional order of the form

$$ \sum_{i=0}^{n} a_i D^{\alpha_i} y(t) = \sum_{i=0}^{n} b_i D^{\beta_i} u(t), \quad (5) $$

where $y(t)$ – exit, and $u(t)$ – input of the control object, ${}_a D_t^{\gamma}$ – differintegrator.

In the general structure of the closed control system of fractional order with one input and one output is presented $y(t)$ – output, $r(t)$ – input request signal, $e(t)$ – error (mismatch), $u(t)$ – control signal, $G(s)$ – transfer function of the control object, $C(s)$ – transfer function of the fractional order controller.

Transmission function of the fractional $PI^{\lambda}D^{\mu}$ _controller has the form

$$C(s) = k_p + k_i s^{-\lambda} + k_d s^{\mu}, \tag{6}$$

where λ и μ – fractional orders whose values belong to the region $(0,2)$, k_p, k_i, k_d – adjusting parameters of the regulator.

In the time domain, the transfer function (6) corresponds to the type control

$$u(t) = k_p \cdot e(t) + k_i \cdot \left({}_0D_t^{-\lambda} e(t)\right) + k_d \cdot \left({}_0D_t^{\mu} e(t)\right), \tag{7}$$

where $-{}_0D_t^{\gamma}$ differintegrator.

The task is to find the area of stability with allowable values of the settings k_p, k_i, k_d fractional $PI^{\lambda}D^{\mu}$ - controller, which stabilize the control object. This is important when designing $PI^{\lambda}D^{\mu}$ - controllers, and then in the future and to find optimal regulators on the found parametric area of stabilization by the chosen criterion.

Transmission function of the system "object + regulator" in Fig. 1 has the form

$$W(s) = \frac{C(s)G(s)}{1 + C(s)G(s)} = \frac{Q(s)}{P(s)}, \tag{8}$$

where

$$Q(s) = \sum_{j=0}^{n} \left[k_p b_j s^{\lambda+\beta_j} + k_i b_j s^{\beta_j} + k_d b_j s^{\lambda+\mu+\beta_j} \right], \tag{9}$$

$$P(s) = \sum_{j=0}^{n} \left[a_j s^{\lambda+\alpha_j} + k_p b_j s^{\lambda+\beta_j} + k_i b_j s^{\beta_j} + k_d b_j s^{\lambda+\mu+\beta_j} \right]. \tag{10}$$

The area of stable stabilization, which we denote through S, in the space of parameters is subject to belonging to the left half-plane of the complex s - plane all real parts of the roots of the characteristic quasipolynomial $P(s)$, which for convenience will be presented in the form

$$P(s) = \sum_{j=0}^{n} p_j s^{q_j} = p_n s^{q_n} + p_{n-1} s^{q_{n-1}} + \ldots + p_1 s^{q_1} + p_0 s^{q_0}, \tag{11}$$

where q_j – ordered fractional orders of powers, and moreover $q_n > q_{n-1} > \ldots > q_0$, p_j – coefficients determined by the factors of the transfer function of the control object and the parameters of the settings k_p, k_i, k_d fractional $PI^{\lambda}D^{\mu}$ - regulator.

To select the region of stable system stabilization (control object with the controller) we use the *D*-split method, the parameters space [6].

Recall that according to this method, the boundary between the areas of stability and instability in the space of the configuration parameters is three parts: $\Gamma = \Gamma_0 + \Gamma_{\omega} + \Gamma_{\infty}$. Constituent Γ_0 is determined from the condition of intersection of the real root of the

characteristic equation of the imaginary axis s - plane with $s = 0$. That is, the component Γ_0 is found by way of substitution $s = 0$ in the equation $P(s) = 0$, where $P(s)$ which is determined by the equation (11). It follows that Γ_0 can be determined from the condition $p_0 = 0$, if the value of the smallest order q_0 equals 0, i.e. with $s^{q_0} = 1$. If $q_0 \neq 0$, i.e. $s^{q_0} \neq 1$, then the boundaries Γ_0 does not exist.

Constituent Γ_ω is determined from the condition of intersection of a pair of complex conjugate roots of the imaginary axis at $s = j\omega$, where $j = \sqrt{-1}$ – imaginary unit. So, in this case, quasipoline (11) becomes an unstable and valid and imaginary part of the equation $P(j\omega) = 0$ begin to equal zero at the same time.

Constituent Γ_∞ is determined by intersection of the real roots of the quasi-polynomial (11) imaginary axis at $s = \infty$ and can be determined from the condition $p_n = 0$.

Applying these preconditions to the investigated system "object + regulator" and analyzing the characteristic quasipolin (10), we come to the conclusion that the components Γ_0 and Γ_∞ the boundaries of the stability zone are straight lines:

$$\Gamma_0 - \text{line: } \begin{cases} k_i = 0, & \text{at } s^{\beta_0} = 1, \\ \text{not exist, at } s^{\beta_0} \neq 1, \end{cases}$$

$$\Gamma_\infty - \text{line: } \begin{cases} k_d = 0, & \text{at } (\alpha_n = \beta_n) \text{ або } (\alpha_n > \beta_n \text{ і } \mu > \alpha_n - \beta_n), \\ k_d = -a_n / b_n, & \text{at } (\alpha_n > \beta_n \text{ і } \mu = \alpha_n - \beta_n), \\ \text{not exist}, & \text{at } (\alpha_n > \beta_n \text{ і } \mu < \alpha_n - \beta_n). \end{cases}$$

To build a component Γ_ω substitute $s = j\omega$ into the equation $P(s) = 0$, where $P(s)$ – quasipolin (10). Then we will get

$$\begin{aligned} P(j\omega) &= \sum_{j=0}^{n} \left[a_j (j\omega)^{\lambda+\alpha_j} + k_p b_j (j\omega)^{\lambda+\beta_j} + k_i b_j (j\omega)^{\beta_j} + k_d b_j (j\omega)^{\lambda+\mu+\beta_j} \right] = \\ &= \text{Re}\{P(j\omega)\} + j \cdot \text{Im}\{P(j\omega)\} = 0, \end{aligned} \tag{12}$$

where $\text{Re}\{P(j\omega)\}$ and $\text{Im}\{P(j\omega)\}$ mean respectively the actual and imaginary parts of the quasipolin $P(j\omega)$.

For further transformation of the expression (12) we recall that this is not an integer degree of complex number can be calculated by the formula Muavr-Laplace

$$(\sigma + j\omega)^\gamma = \left(\sigma^2 + \omega^2\right)^{\gamma/2} \left[\cos(\gamma\varphi) + j \sin(\gamma\varphi)\right], \tag{13}$$

where $\varphi = \arctan(\omega / \sigma)$, σ – real part, ω – imaginary part and γ – fractional order of a complex number.

Expression j^{γ}, which is present in the equation (12), can be presented according to the formula (13), so

$$j^{\gamma} = \cos\left(\frac{\pi}{2}\gamma\right) + j\sin\left(\frac{\pi}{2}\gamma\right). \tag{14}$$

Further, equating to zero the real and imaginary part of the equation (12), taking into account the formula (14), we will get

$$\begin{cases} \mathrm{Re}\{P(j\omega)\} = k_p R_{1p}(\omega) + k_i R_{1i}(\omega) + k_d R_{1d}(\omega) + H_1(\omega) = 0, \\ \mathrm{Im}\{P(j\omega)\} = k_p R_{2p}(\omega) + k_i R_{2i}(\omega) + k_d R_{2d}(\omega) + H_2(\omega) = 0, \end{cases} \tag{15}$$

where

$$R_{1p}(\omega) = \sum_{j=0}^{n} b_j \omega^{\lambda+\beta_j} \cos\left(\frac{\pi}{2}(\lambda+\beta_j)\right), \quad R_{1i}(\omega) = \sum_{j=0}^{n} b_j \omega^{\beta_j} \cos\left(\frac{\pi}{2}\beta_j\right),$$

$$R_{1d}(\omega) = \sum_{j=0}^{n} b_j \omega^{\lambda+\mu+\beta_j} \cos\left(\frac{\pi}{2}(\lambda+\mu+\beta_j)\right), \quad H_1(\omega) = \sum_{j=0}^{n} a_j \omega^{\lambda+\alpha_j} \cos\left(\frac{\pi}{2}(\lambda+\alpha_j)\right),$$

$$R_{2p}(\omega) = \sum_{j=0}^{n} b_j \omega^{\lambda+\beta_j} \sin\left(\frac{\pi}{2}(\lambda+\beta_j)\right), \quad R_{2i}(\omega) = \sum_{j=0}^{n} b_j \omega^{\beta_j} \sin\left(\frac{\pi}{2}\beta_j\right),$$

$$R_{2d}(\omega) = \sum_{j=0}^{n} b_j \omega^{\lambda+\mu+\beta_j} \sin\left(\frac{\pi}{2}(\lambda+\mu+\beta_j)\right), \quad H_2(\omega) = \sum_{j=0}^{n} a_j \omega^{\lambda+\alpha_j} \sin\left(\frac{\pi}{2}(\lambda+\alpha_j)\right).$$

The system of linear equations (15) contains more unknowns (k_p, k_i, k_d), than the number of equations, one of the parameters of the system can be arbitrarily chosen for its unambiguous solution. If as a parameter, choose a coefficient k_p, then the system (15) becomes a system of linear algebraic equations of the second order with respect to unknowns k_i and k_d, the solution of which has the form

$$k_i = \frac{\Delta_i(\omega)}{\Delta(\omega)}, \quad k_d = \frac{\Delta_d(\omega)}{\Delta(\omega)}, \tag{16}$$

$$\begin{aligned} \Delta_i(\omega) &= R_{1d}(\omega)H_2(\omega) - R_{2d}(\omega)H_1(\omega) + k_p\left(R_{1d}(\omega)R_{2p}(\omega) - R_{1p}(\omega)R_{2d}(\omega)\right), \\ \Delta_d(\omega) &= R_{2i}(\omega)H_1(\omega) - R_{1i}(\omega)H_2(\omega) + k_p\left(R_{1p}(\omega)R_{2i}(\omega) - R_{1i}(\omega)R_{2p}(\omega)\right), \\ \Delta(\omega) &= R_{1i}(\omega)R_{2d}(\omega) - R_{1d}(\omega)R_{2i}(\omega) = \omega^{\lambda+\mu}\sin\left(\frac{\pi}{2}(\lambda+\mu)\right)\left(R_{1i}^2(\omega) + R_{2i}^2(\omega)\right). \end{aligned} \tag{17}$$

Note that for fractional PI^{λ} - regulator ($k_d = 0$) system (15) has a single solution

$$k_p = \frac{\Delta_p(\omega)}{\Delta(\omega)}, \quad k_i = \frac{\Delta_i(\omega)}{\Delta(\omega)}, \tag{18}$$

$$\Delta_p(\omega) = H_2(\omega)R_{1i}(\omega) - H_1(\omega)R_{2i}(\omega), \quad \Delta_i(\omega) = H_1(\omega)R_{2p}(\omega) - H_2(\omega)R_{1p}(\omega),$$

$$\Delta(\omega) = R_{1p}(\omega)R_{2i}(\omega) - R_{1i}(\omega)R_{2p}(\omega) = -\omega^{\lambda}\sin\left(\frac{\pi}{2}\lambda\right)\left(R_{1i}^2(\omega) + R_{2i}^2(\omega)\right). \qquad (19)$$

We now apply these results to highlight the stability of the biological control system for contaminated water by active sludge with fractional $PI^{\lambda}D^{\mu}$ - regulator. By the assumption that the kinetics of the growth process of biomass is described by the Mono equation [7], in work [8] the linearized model of the bioelectric system "aerotank + sedimentation tank" was obtained in the form of a model with one input and one output.

$$\frac{dx(t)}{dt} = Ax(t) + bu(t), \qquad y(t) = x_2(t) = c^T x(t), \qquad (20)$$

where $\boldsymbol{x}(t) = \left(x_1(t), x_2(t), x_3(t)\right)^T$ – state vector in which $x_1(t)$, $x_2(t)$ – respectively, the concentration of biomass and substrate in aerotanks, $x_3(t)$ – the concentration of recirculating biomass from the settling tank to the aerosol bioreactor, $u(t)$ – single-speed control function-speed of dilution (analogue of volume flow rate), $y(t)$ – the observed output of the system is the concentration of the substrate.

System matrix $\boldsymbol{A}$ and vectors $\boldsymbol{b}$ and $\boldsymbol{c}$ are defined as follows

$$\boldsymbol{A} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}, \quad \boldsymbol{b} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}, \quad \boldsymbol{c} = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix},$$

where

$$a_{1,1} = \mu_{\max}\frac{x_2^*}{k_s + x_2^*} - (1+r)u^*, \quad a_{1,2} = \mu_{\max}k_s\frac{x_1^*}{(k_s + x_2^*)^2}, \quad a_{1,3} = ru^*,$$

$$a_{2,1} = -\frac{\mu_{\max}}{Y}\frac{x_2^*}{k_s + x_2^*}, \quad a_{2,2} = -\frac{\mu_{\max}k_s}{Y}\frac{x_1^*}{(k_s + x_2^*)^2} - (1+r)u^*, \quad a_{2,3} = 0,$$

$$a_{3,1} = (1+r)u^*, \quad a_{3,2} = 0, \quad a_{3,3} = -(\beta + r)u^*,$$

$$b_1 = -(1+r)x_1^* + rx_3^*, \quad b_2 = -(1+r)x_2^* + s_{in}, \quad b_3 = -(\beta + r)x_3^* + (1+r)x_1^*.$$

It is marked here: u^* – nominal control given, $x^* = (x_1^*, x_2^*, x_3^*)^T$ – the corresponding equilibrium state vector calculated for it; $\mu_{\max}$ – maximum specific growth rate of biomass; k_s – saturation constant, determined experimentally; s_{in} – concentration of the substrate in the inlet stream; Y – the factor of output (profitability) of biomass; r, β – coefficients that determine respectively the ratio of the recirculation flow and biomass waste stream to the input stream.

Numerical simulation of a controlled biocleaning system was carried out at the following output data: $s_{in} = 200$ $[mg/l]$, $Y = 0.65$, $\mu_{\max} = 0.15$ $[h^{-1}]$, $k_s = 100$ $[mg/l]$,

$r = 0.6$, $\beta = 0.2$, $u^* = 0.05$ $[h^{-1}]$, $t_0 = 0$, $T = 1$ $[h]$, vector of the initial state of the system (20) relied on equal $\boldsymbol{x}^0 = (x_1^0, x_2^0, x_3^0)^T = (286,\ 17,\ 568)^T$ $[mg/l]$.

Note that the vector of the equilibrium state of the system (20) with this data was calculated as the solution of the corresponding system of nonlinear equations of the third order and equaled $\boldsymbol{x}^* = (x_1^*, x_2^*, x_3^*)^T = (285,\ 15.38,\ 570)^T$.

In frequency domain model (20) can be presented in the form

$$Y(s) = G(s)U(s),$$

where $U(s)$, $Y(s)$ – Laplace transforms according to input and output, $G(s)$ – transfer function of the control object.

$$G(s) = c^T \left(sE - A\right)^{-1} b = \frac{c^T adj\left(sE - A\right)b}{\det\left(sE - A\right)} = \frac{p_2 s^2 + p_1 s + p_0}{s^3 + q_2 s^2 + q_1 s + q_0}. \qquad (21)$$

Here through $adj\left(sE - A\right)$ the matrix attached to the matrix is indicated $s\boldsymbol{E} - \boldsymbol{A}$, and the coefficients p_i, q_i polynomial numerator and denominator are calculated by the formulas

$$\begin{aligned} p_0 &= b_2 a_{11} a_{33} - b_1 a_{21} a_{33} - b_2 a_{13} a_{31}, \quad q_0 = a_{12} a_{21} a_{33} + a_{13} a_{31} a_{22} - a_{11} a_{22} a_{33}, \\ p_1 &= b_1 a_{21} - b_2 a_{11} - b_2 a_{33}, \quad q_1 = a_{11} a_{22} + a_{11} a_{33} + a_{22} a_{33} - a_{13} a_{31} - a_{12} a_{21}, \end{aligned} \qquad (22)$$

$$p_2 = b_2, \quad q_2 = -a_{11} - a_{22} - a_{33}.$$

If control $u(t)$ in the time domain construct in a fractional class $PI^{\lambda}D^{\mu}$ - regulators of the form (6)

$$u(t) = -\left(k_p \cdot y(t) + k_i \cdot \left({}_0D_t^{-\lambda} y(t)\right) + k_d \cdot \left({}_0D_t^{\mu} y(t)\right)\right), \qquad (23)$$

then the transfer function of the "biocleaning" + "regulator" system will be determined by the expression $W(s) = Q(s)/P(s)$, where $Q(s) = C(s)G(s)$, $P(s) = 1 + C(s)G(s)$, $C(s)$ – transfer function of the fractional controller, determined by the formula (6), $G(s)$ – transfer function of the control object, calculated by the formulas (21), (22).

To determine the range of valid values for the configuration parameters k_p, k_i, k_d fractional $PI^{\lambda}D^{\mu}$ - regulator, which stabilizes the work of the bio-treatment system, uses the calculated formulas (16), (17) i (18), (19), that describe the boundaries of the stability regions of the system with a fractional controller. Computational experiments were carried out in the MATLAB mathematical system environment. Below are some results from computational experiments.

In figure 1 in the parameter space $Z = \{k_p, k_i\}$ the global region of stability (shaded area) of a bio-waste fractional system is presented PI^{λ} - regulator at $\lambda = 1$, that is when using the classic PI - regulator (Γ_{ω}, Γ_0 – the boundaries of the area of stability).

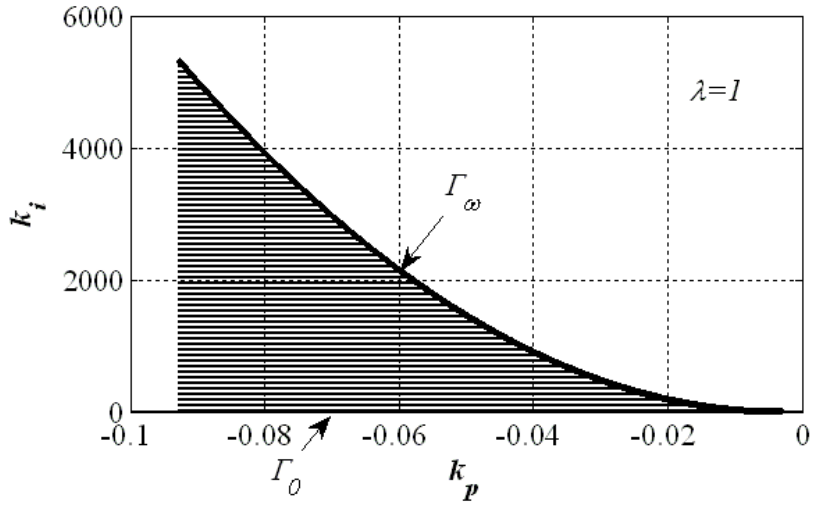

Figure 1. Global region of system stability with PI^{λ} - regulator at $\lambda = 1$

In figure 2 the areas of stability of the system of bio-purification with fractionation PI^{λ} -regulator are constructed at different values of the order of the differintegrator.

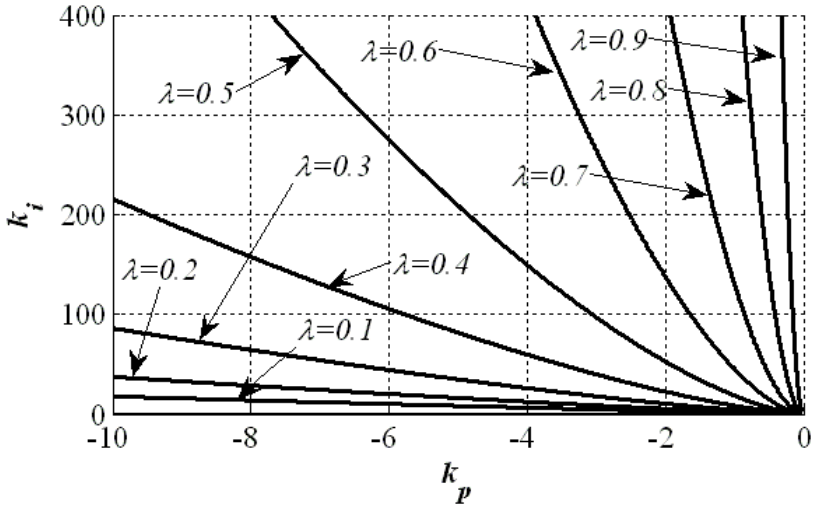

Figure 2. Global areas of stability of the biocleaning system with PI^{λ} -regulator at $0 < \lambda < 1$

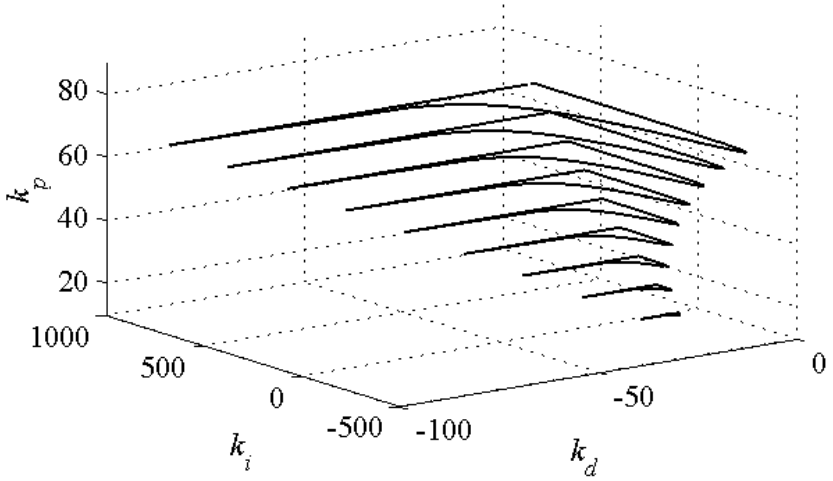

Figure 3. Global areas of stability of the biocleaning system with з $PI^{\lambda}D^{\mu}$ -regulator at $\lambda = 0.7$, $\mu = 0.1$

Here, the areas of stability are limited to the bottom of the abscissa, and on the top – the curve that matches the value of the order of the parameter. From the graphs it can be seen that with increasing order, the region of stability of the system also increases.

Then studied areas of stability of the system with fractional $PI^{\lambda}D^{\mu}$ -regulator. In fig. 3 in the parameter space $Z = \{k_p, k_i, k_d\}$ The system stability zone is depicted with $PI^{\lambda}D^{\mu}$ - regulator for fractional orders $\lambda = 0.7$, $\mu = 0.1$. In this figure, the sections of the stability region are represented by planes perpendicular to the coordinate axis. The cross sections are closed shapes whose areas increase as the setting parameter increases.

Similar areas of stability were obtained with other values of fractional orders λ and μ .

Conclusions

On the basis of the D-split method, analytical expressions were obtained, which describe the boundaries of the global region of stability of linear dynamic systems of fractional order of type "input-output" with fractional $PI^{\lambda}D^{\mu}$ -regulators. The stability areas are built on the basis of computational experiments in the space of the parameter settings for fractional $PI^{\lambda}D^{\mu}$ - regulators for fixed orders of diereintegrators in the regulator. An appropriate algorithmic software is developed.

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Hybrid expert system to model the ice cream recipes

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Abstract

Introduction. The method of ice cream recipe modeling is developed, which, unlike traditional ones, is based on the application of processing expert data and optimization methods. It allows to significantly expand the range of tasks. These tasks solutions can bring significant economic effect.

Materials and methods. To create a database and knowledge base, a relational database under the control of Firebird DBMS was used. IBExpert software tool was used to ease the database structure development. While creating a user interface, the integrated Microsoft Visual Studio software development environment is used.

Results and discussion. The hybrid expert system for modeling ice cream recipes is intended to improve the existing ones or develop new types of ice cream in a wide range of changes in the chemical composition by applying fundamentally new functional and technological ingredients. The expert system allows, in production conditions, with the minimum expense of time, to calculate the chemical composition of the ice cream recipes of guaranteed quality taking into account the available raw materials. The knowledge base formed in the expert system will improve the nutritional structure of the population due to the exclusion of chemically modified and synthesized food additives from the recipe ice cream composition and their replacement on natural, biologically complete ingredients of domestic production.

Conclusions. Using an expert system in the production environment will allow you to constantly update and accumulate knowledge of expert technicians who work in this field. The constant accumulation of new knowledge about the ice cream recipe will enable the creation and expansion of partnership programs with domestic and foreign enterprises. Using this expert system will reduce the cost of modeling new ice cream recipes.

Introduction

Providing the rhythmic production and sales of the final products, maximizing profits from their activities are the main priorities of any manufacturing.

There are some problems with the formation of complex disperse ice cream systems and frozen desserts in the low-temperature technologies of the food industry. Such food systems, in terms of colloidal chemistry, are at the same time foams, emulsions and suspensions. The continuous dispersion medium is not frozen water, which contains numerous dispersed particles of different nature – fat balls, air bubbles, ice crystals and lactose. Consistency defects are most often caused by large ice crystals that are capable of growing and forming a solid ice frame. A similar consistency defect is the reason of the formation of a too rigid product structure with tangible ice crystals during its consumption. Therefore, the first priority for the technologists is the practical solution to the mentioned problem by optimizing the recipe composition.

The product demand depends on both the price and quality, which are laid at the stage of its production. Therefore, the product profitability largely depends on its composition, namely, the cost, quantity and quality index of the individual recipe components. In today's market conditions, food industry companies in order to reduce the price try to use alternative, cheaper components instead of those that are listed in the classic recipe. The reason is that some components have a high price because they are imported from other countries or their manufacturing or cultivation require certain expenses. However, new ingredients in food systems can show unpredictable antagonistic effects and give the effect opposite to the anticipated one. Though, the synergistic manifestation of component interaction, which gives a high technological effect on the economic feasibility of such innovation, is possible [1–3].

It's easy to make a recipe if you have the whole range of high quality raw materials and relatively low cost. But this is an exception rather than a rule. If the raw material is limited in quantity and not all of it is high-quality, then there is a need to replace one raw material to another. Sometimes it is very difficult for a technologist to ensure a stable quality of products, especially if there is little time to find the recipes for the selected product. In fact, the technologist’s task is to create the recipe in such a way that the final product must have a minimum cost, but at the same time, meet all the requirements of consumer quality. Such tasks require, on the one hand, a great experience, but, on the other hand, a whole range of practical skills and information about the component behavior. The only way out of this situation is to use the modern information technology to improve the efficiency of the technological process management in the conditions of actually operating enterprises[4].

Related works

In the modern world literature, many domestic and foreign scientists are concerned with the use of information technologies and system analysis methods by controlling the technological processes of the food industry. The problem of supporting technological processes through the use of information technology is very widely investigated, but taking into account the complexity of the problem, most contemporary authors tend to use expert systems.

The literature provides a separate niche of expert systems, but based on the analysis, authors can argue that there are no expert systems in the world to support the modeling of ice cream recipes under the conditions of actually operating enterprises. For example, there is an expert system for the meat industry "FORECASTER", designed to predict new food

technologies and includes a set of functionally-oriented tasks, combined into the following structural elements: a database management group and knowledge base; information analysis group; logical and statistical flow processing group. The study of literary sources led to the construction of a hybrid expert system to support the design of ice cream recipes [5].

Materials and methods

The object of study is information technology for supporting the process of modeling food products recipe.

The subject of study is the expert system for supporting the process of modeling ice cream recipe.

To achieve the aim, Methods of system analysis, studying and modeling complex control system, operation analysis, mathematical programming, information modeling of systems, building expert systems and knowledge bases were used in the paper.

Firebird fully supports SQL-92 Entry Level 1 and implements most of the SQL-99 standard with some very useful additions. It includes the DML / DDL expression, the syntax of FULL / LEFT / RIGHT [OUTER] JOIN, UNION expression, DISTINCT, subqueries (IN, EXISTS), built-in functions (AVG, SUM, MIN, MAX, COALESCE, CASE), integrity constraints (PRIMARY KEY, UNIQUE, FOREIGN KEY), and all common types of SQL data.

Firebird also implements check constraints at the level of domains and fields, views, exceptions, roles and right of access management.

Firebird supports many ways to the server access, namely own component kits for C / C ++, Delphi, classes for ADO, ODBC, JDBC (Jaybird), drivers for Python, PHP, OLE DB driver, dbExpress, .NET data provider and direct access to use the client server library (fbclient.dll or GDS32.dll)

IBExpert software version 2017.11.5.1 was used to ease the development of the database structure[6]. IBExpert is a GUI shell intended for the development and administration of InterBase and Firebird databases, as well as for the selection and modification of data stored in databases. IBExpert supports versions Firebird 1.x, 2.x, 3.x, runs simultaneously with multiple databases and has:

- separate editors for all database objects with syntax highlighting;
- powerful SQL editor with the request history and the possibility of their background execution;
- automatic completion of the SQL code (table names, fields, etc.);
- debugger of stored procedures and triggers;
- metadata search;
- complete and partial extraction of data and metadata;
- analyzer of database object dependencies;
- metadata reports;
- user managers and user privileges;
- export data to various formats.

IBExpert has many easy-to-use components: a visual editor for all database objects, a SQL editor and script executor, a debugger for stored procedures and triggers, an area builder, a tool for importing data from a variety of sources, your own scripting language, database designer etc. IBExpert is free for Windows users with WIN1251 code page setup.

To create the user interface, the free integrated software development environment for the Microsoft Visual Studio 2015 Community using the Windows Forms technology

[5,7,10,11,20] is used. The work of Windows Forms applications for the Firebird DBMS is provided by the NuGet package manager. It implements the package connection: FirebirdSql.Data.FirebirdClient, Entity Framework, Entity Framework. Firebird.

Results and discussions

The hybrid expert system to model the ice cream recipes is designed to improve or develop new types of ice cream in a wide range of changes in the chemical composition and the application of fundamentally new functional and technological ingredients. The expert system allows, in production conditions, with the minimum expense of time, to calculate the optimal chemical composition of the ice cream recipes of assured quality by taking into account the available raw materials. The knowledge base formed in the expert system will allow to improve the nutritional structure of the population due to the exclusion of chemically modified and synthesized food additives from the recipe composition of ice cream and their replacement on natural, biologically-complete ingredients of domestic production [4, 5].

While modeling the ice-cream composition, one should take into account the fact that for this product the concept of "quality" means a complex of special requirements for sensory and physical and chemical indexes. It is understandable that the sensory and physical and chemical quality indexes are interrelated. For example overrun, the degree of air phase dispersion and resistance to thawing, in the first place, form the sensory perception of the finished product consistency.

Among the abovementioned indicators, whipping is the most important quality indicator to ensure a creamy structure of the overrun and frozen product. The recommended level of ice cream overrun is between 60 and 160%. The ice cream overrun depends on the recipe content and equipment type. If the whipping is too high (above 160%), the ice cream structure is unstable, and the taste and smell become "null". When the overrun is less than 60%, the ice cream structure becomes rough, too dense, with a very strong taste and smell. If the overrun index is in the recommended range, the ice cream will have a creamy, stable structure with a taste and smell.

First of all, the ice-cream whipping is affected by proteins, structure stabilizers (hydrocolloids), emulsifiers that strengthen free water, reduce the surface tension, and stabilize the formed foam structure. That's why the presence of the above mentioned compounds in the ice-cream recipe composition is mandatory. Except the mentioned ingredients, the technological functions of the foam formers and structure stabilizers can be performed by the raw materials of plant and animal origin – grain products, pectin containing purees from fruits, berries and vegetables, etc. But for competent correction of ice cream recipes in the conditions of industrial production, it is necessary to develop a universal and user-friendly expert system that takes into account all production experience and recommendations of scientists concerning the composition of ice cream of various kinds [2, 3].

The hybrid expert system for modeling ice cream recipes is intended to improve the existing ones or develop new types of ice cream in a wide range of changes in the chemical composition by applying fundamentally new functional and technological ingredients. The expert system allows, in production conditions, with the minimum expense of time, to calculate the chemical composition of the ice cream recipes of guaranteed quality taking into account the available raw materials. The knowledge base formed in the expert system will improve the nutritional structure of the population of Ukraine due to the exclusion of

chemically modified and synthesized food additives from the recipe ice cream composition and their replacement on natural, biologically complete ingredients of domestic production.

A hybrid expert system for modeling ice cream recipes should address the following main tasks:

- to develop recipes of new ice cream types with the given consumer characteristics and low cost;
- to substantiate the recommendations of the industry concerning the recipe ice cream composition and the possible replacement of certain ingredients without reducing the regulatory quality indicators of the finished product, in accordance with the current standards (SSU, TC, etc.) provided by the target functional and technological properties of certain components;
- to analyze a set of finished product quality indexes, to identify the technological problems and to suggest the ways to solve them [5,7].

The structure of the expert system for modeling the optimal ice cream recipes is presented in Figure 2.

To implement these tasks, application packages and knowledge manipulation tools were used. Therefore, the expert system of modeling ice cream recipes is hybrid.

The main function of the expert system is to support the implementation of the algorithm for designing the optimal ice cream recipes presented in Figure 1 [3–5].

The architecture of the hybrid expert system for the modeling of ice cream recipes consists of separate four structural blocks [5,7,8,9,13], which are designed and created separately, and then bundled into one whole interacting system through the interface: database, knowledge base, mathematical apparatus and expert system implementation of the functions of the recipe composition quality control and its technological suitability.

The database is required to provide the primary information about the recipe ingredients and their physical and chemical as well as functional and technological properties, auxiliary materials, quality indexes. It stores the recipe composition data meant for users, physical and chemical characteristics of the ingredients, the recipe status [6,16].

The knowledge base is sets of knowledge in the form of rules on the technological features of making ice cream [12, 17].

The mathematical apparatus modules are a set of applied mathematical packages to solve the optimization tasks. They are aimed at obtaining a certain universal recipe due to the possible interchangeability of certain technologically active components. It has a great practical significance in the production conditions [5, 7, 17].

The expert system provides the recipe correction by taking into account all the technological properties of multicomponent food systems. It uses the knowledge base. If to model the optimal recipe only with the help of one mathematical device, without the use of the expert system, then the received recipe is unlikely to be suitable because numerous technological properties will not be taken into account.

The EU Knowledge Base is created directly in the database in the form of individual entities. A set of these entities allows you to create research objects, rules which they meet and recommendations if the rules are met. Except the rules and facts that form the declarative part of the knowledge base, it also includes a procedural part with functions and procedures that implement optimization and calculation algorithms. The knowledge of the expert system is represented in a symbolic form (simple components of knowledge representation are texts, lists, and other symbolic structures). Thus, in the EU, the principle of the symbolic nature of estimation is realized which means that the estimation process is represented as a sequence of symbolic transformations.

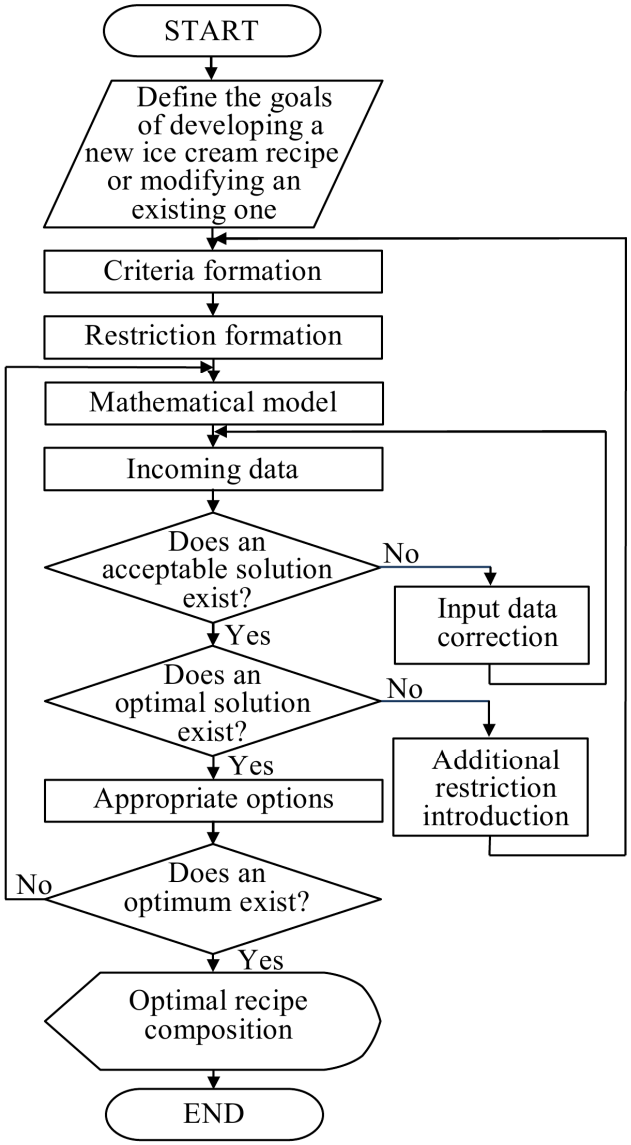

Figure 1. Algorithm for designing optimal ice cream recipes

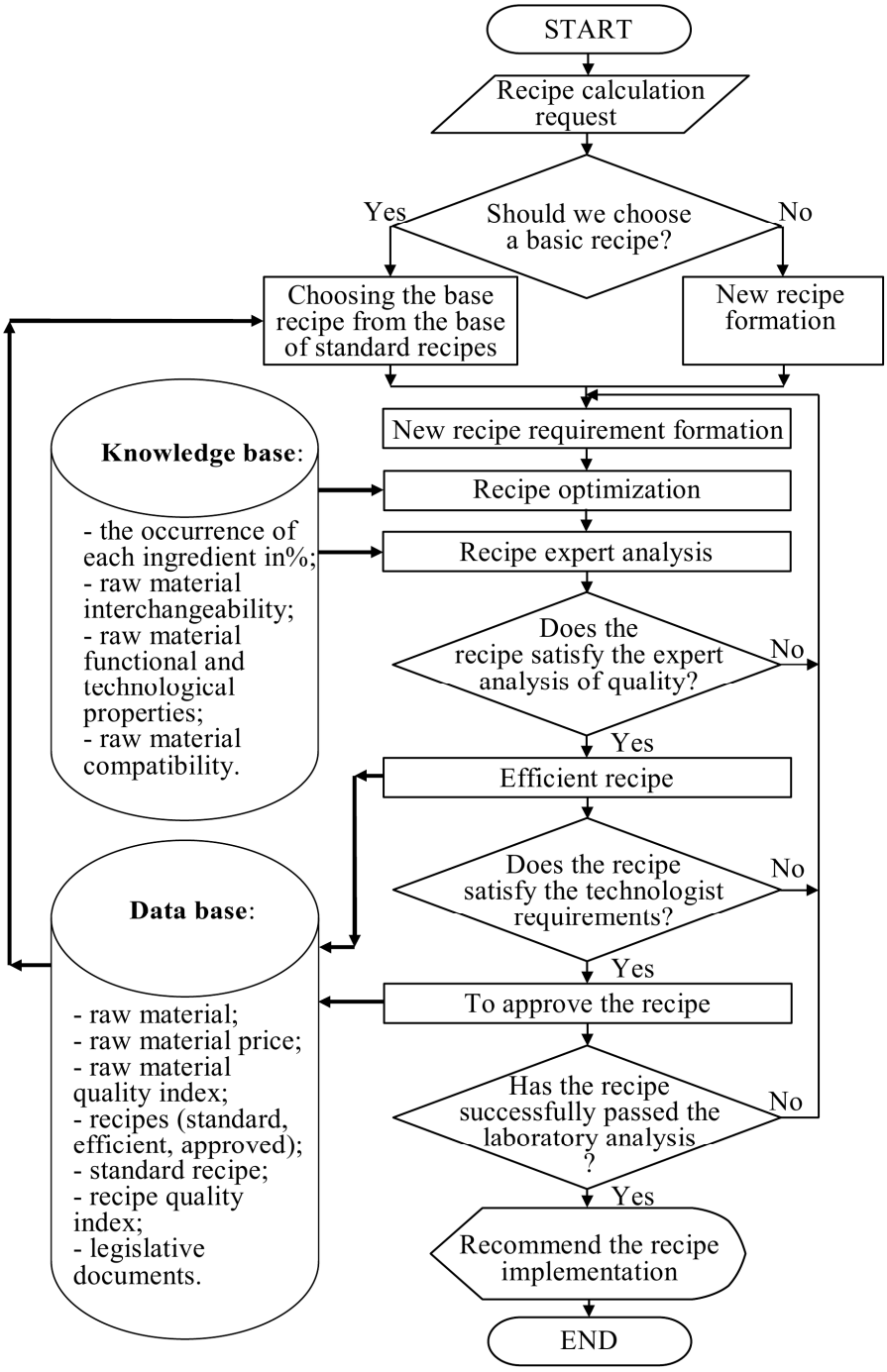

Figure 2. Structure of the expert system for optimal recipe modeling

The purpose of every essence of the knowledge base:

1. “Research objects” covers a list of objects to be analyzed in order to detect the technological deviations in the recipe.
2. "Rules" means a list of all rules which the research object can meet under those or other events. Actions included in the rules may contain new facts. When applying such rules, these facts become known to the system which means that they are included in the set of facts called the working set.
3. "Rules of the research object" are the rules relevant to the specific research object.
4. "Recommendations" is a problem description and recommendations for its solution.
5. "Recommendations of the research object" is a list of recommendations of the research object.

The knowledge base of the hybrid expert system is static. In other words, it does not change with time and the facts stored in the knowledge base are static which means that they do not change in the process of solving the problem [5, 7, 12–19].

To create a databank, a relational database under the control of Firebird 2.5 was used. [6, 18]

The benefits of Firebird are that it has a multiversion architecture. It provides parallel processing of operational and analytical queries, compactness (5Mb distribution), high efficiency and powerful language support to store procedures and triggers. Firebird is completely free; it does not require any registration or payment for support. The source code of this system is open, which allows you to develop your own nonprofit projects using its base if you follow the IDPL license requirements covered by Firebird.

Also, Firebird is a database server. One Firebird server can process several hundred independent databases with a plurality of user connections. It is completely free of license deductions even for commercial use.

Table 1 presents an experimental confirmation of the efficiency of the expert system usage taking into account the calculation of a new ice cream recipe named "Milk Ice Cream with Wheat Germs". It was based on the standard milk ice cream recipe in accordance with the standard technological instruction for the ice-cream. The expert system calculated a new optimal recipe, taking into account the partial replacement of the stabilizer Cremodan SE 406 (the manufacturer is the company "Danisco", Denmark) by the natural structuring complex named wheat germ. As a result, this new recipe satisfies the quality requirements of the finished product. The cost of 1000 kg milk ice cream with wheat germs according to a new recipe made up 642,82 USD, which is 8.64% cheaper than the base one.

Table 1

The calculation of a new ice cream recipe with a partial replacement of the stabilizer

Recipe composition	Quantity 1000 kg		At 100, %		Min,%substitutes	Max,% substitutes	Price, 1 kg/$USD	Cost 1000 kg/USD
	Base	New	Base	New				
Drinking water	650,00	650,00	65,00	65,00			0,04	26,00
Milk solids non fat (MSNF)	101,00	101,00	10,10	10,10	10,10	12,00	2,39	241,39
Cream from the whole cow milk	88,00	88,00	8,80	8,80	8,80	9,00	3,11	273,86
White crystalline sugar	155,00	155,00	15,50	15,50			0,50	77,50
Cremodan SE 406	6,00	substituted	0,60	Substituted	20,00	100,00	14,16	84,87
Total (5 ingredients):	1000,00	1000,00	100,00	100,00				703,62
Recipe name	Cost 1000 kg/USD							
Base	642,82							
New	703,62							
Difference	-60,80							
At 100 %	8,64							

Calculated quality index			
Quality index	Measurement unit	Value	Description
Disperse phase content	%	76,5	The structure is moderately dense. Creamy. Durable.
Structural element dimensions of disperse systems	mkm	37,9	The air bubble size is sufficient
Structural element stability of disperse systems	second, sec	2,82	Pretty high resistance to thawing
Cryoscopic temperature	degree, C°	-2,35	Within limits
Sensory evaluation	score	9	Rather marked smell and taste

Conclusions

Expert systems are the most effective tool for calculating ice cream recipes of different groups, as well as for selecting the optimal technological regimes for its production.

An expert system developed by the authors allows purposeful management of the quality of the finished product during the technological process of its production. The greatest significance of the development lies in the possibility of replacing traditional recipe components with fundamentally new natural raw materials. The feasibility of introducing the elaborated expert system is confirmed by the possibility to prevent the most widespread ice-cream consistency and taste problems.

The use of an expert system in production conditions enables the integration of knowledge of expert technicians working in this field and the creation of appropriate partner systems.

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Innovative local control of alternating voltage

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Abstract

Introduction. It is shown the effect of low-quality current on electromagnetic and technical losses that is results in increasing expenses on power and energy, reduction of the equipment operating cycle, process losses, which include reducing production, decreasing product quality and production of low-quality products.

Research and methods. The basic aspects of the analysis are nonsinusoidal voltage that depends on the network voltage. Expediency of using Fourier series is shown.

Results and discussion. The voltage deviation is one of the major problems in power supply systems of industrial enterprises. Its solution is a priority task in the design of power supply systems. The way to improve voltage quality is suggested. The use of semiconductor devices eliminates several disadvantages of mechanical switching device (low speed, low resource) and leaves its main advantage, i.e. sinusoidal nature of voltage curve form. The possibility of using semiconductor devices to perform switching without distortion sinusoid in the time of passing zero allows eliminating the major drawback of mechanical switches their discreteness. This allows to create voltage stabilizers of any degree of accuracy, based on the principle of discrete control by switching transformer unsolders without breaking the current and distorting voltage curve. This explains the set of development directions both in this country and abroad aimed at replacement of contactor switch at currently working RUL (regulation under load) devices on thyristor.

The systematic approach to voltage regulation that allows increasing economic performance of energy sources is introduced. The most promising is the regulation method acting on voltage and reactive power.

Conclusions. We recommend using the results at food industry enterprises in order to improve the voltage quality. The diagram of the device, which could improve the quality of voltage in local area networks, is shown.

Introduction

At the change of the load value there also takes place significant change in the voltage that greatly exceeds the allowable limits. In such circumstances, it is impossible to provide admissible voltage mode only by power generators. It is necessary to apply additional regulating devices, moreover, laws of voltage regulation should be established to ensure the most economical conditions in joined work of reactive power sources, power networks and electronic devices.

Hereby the regulation in the high voltage networks, which feed distributing networks, are aimed at improving the feasibility indexes of networks performance by reducing energy losses in them. In distributing networks voltage regulation laws should ensure the optimum voltage mode at consumers' terminals. Voltage value should be determined basing on minimum losses caused by consumers in the case when the voltage at the electronic receivers terminals differs from nominal.

Materials and methods

Voltage regulation provides compensation of voltage losses in power supply systems aimed at maintaining a given voltage quality at the electronic receivers terminals (Patents of Ukraine № 47222 – Method for voltage registering at the apparatus elements, №16724 – Method pulsed AC voltage regulation with amplitude – pulse modulation, № 93131 – Method for voltage registering at the apparatus elements.

Results and discussion

Voltage deviation are caused by the slow process of load changes in the system, they have different effect on the work of individual consumers. In the case of continuous operation of the electric motor at low voltage, in particular at 90% of nominal value, life cycle of motor insulation decreases by 18-20%, which significantly reduces the efficiency of technological mechanisms that triggers this engine [2, 3, 7, 9].

If automatic voltage regulation the number of switching is 30–40 per day or 10950–14600 per year. Significant resource of most RUL devices which operate in network is 5000 switches. Examination of devices contacts should be conducted after 5000 switches, it is necessary to lead revision of switcher up to 3 times a year. This should be allowed neither under conditions of safety, no in terms of labor costs. If we take into account that the general equipment level of transformers by RUL devices is from 0 to 36%, reasons that prevent wider deployment and effective use of automatic voltage regulation will become clear. Necessary resource, sufficient for the work of devices during 20–25 years is 200–250 thousand switching, concerning the fact that with decreasing switching current resource increases. Resource of RUL device shall be not less than 500 thousand switching. For testing contacts electrical operation in the same standard 40 thousand switching are provided for reactor devices and 50 thousand for devices with active current limiting resistors. By international standards IEC 20 thousand switching is recommended [2, 4, 9].

An analysis will conduct on basis transformer – thyristor voltage regulator

The device is a system of automatic control and consists of a three-phase volt-boosting transformer VBT.

Advantages of thyristor executive branches are well-known. But the effect of regulation semiconductor significantly reduced due to distortion sine wave voltage and

current. With this in Network can be generated higher or more low harmonics (subharmonics).

One of methods of adjusting of voltage with generating of subharmonics is shown in Figure 1.

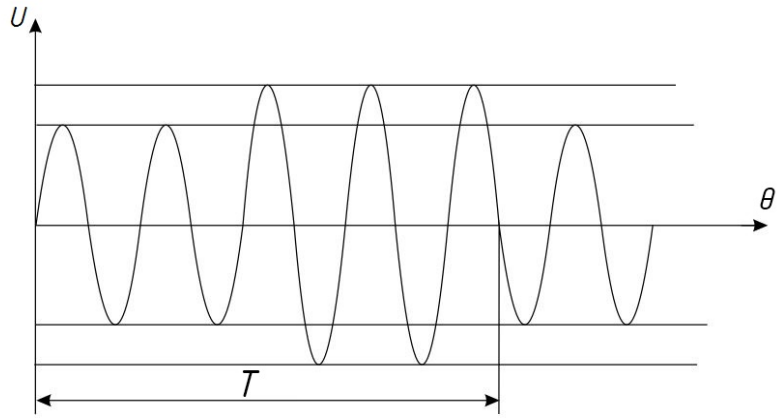

Figure 1. Principle of adjusting of voltage, in which appear subharmonics

The constituent of voltage through the consistently connected to Volt-boosting winding of VBT is directly given in the circle of voltage and not regulated (voltages U_A, U_B, U_C in Figure 2).

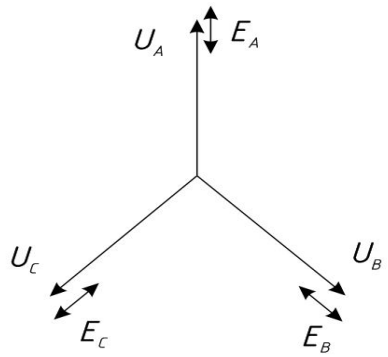

Figure 2. Principle of compensation voltage regulation.

The second component of the output voltage is fed in circle of voltage through winding excitation EW_1 and EW_2 of VBT and VBWo (Figure 3.). The change of voltage takes place by modulation of number of impulses in a package.

A method is very comfortable at presence vibrations of voltage in network. Radio interferences are absent, because opening of thyristors takes place at a zero instantaneous value of voltage. A method does not result in diminishing of power-factor, scheme, that

realize this method is very simple because thyristor is closed in natural way. But the presence of subharmonics does not allow to use the indicated method of adjusting in the electric networks of the general use.

It is necessary to search methods and devices with the small, possible for electric networks degree of distortion of sinewave by subharmonics. It is thus necessary to take into account a standard of quality of voltage.

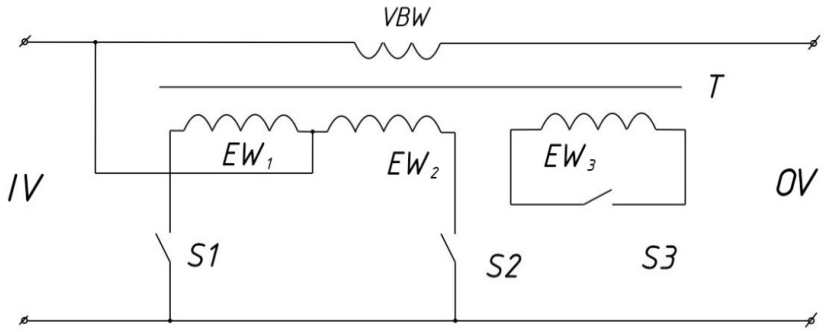

Figure 3. Principle scheme of compensating universal voltage regulator based on the VBT

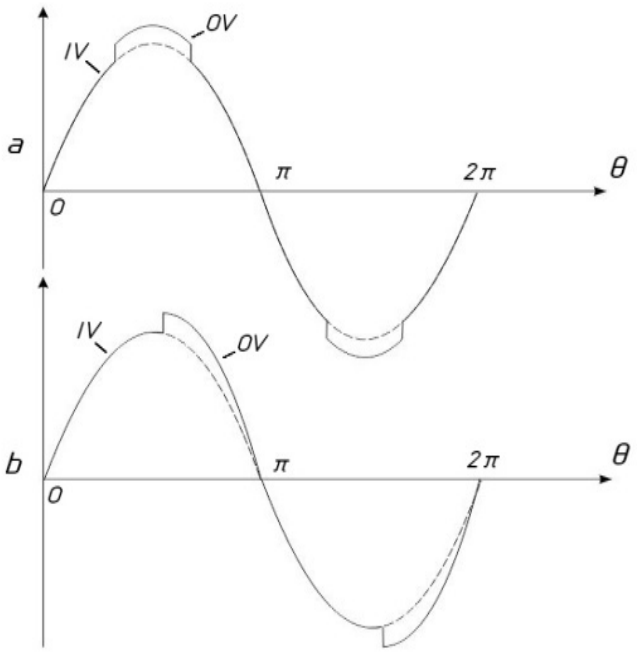

Figure 4. Basic methods of the impulse adjusting of variable voltage are with generating only of highest harmonics

Most acceptable to the electro-receivers is a method shown in Figure 5b. The phase method of adjusting which represented in Figure 5a has certain advantages before method represented in Figure 5b, a power-factor does not change in a network. But to realize it heavier, besides in three-phase networks the indicated advantages disappear.

Voltage, which is shown in Figure 5, is an sequence of impulses (Figure 5b).

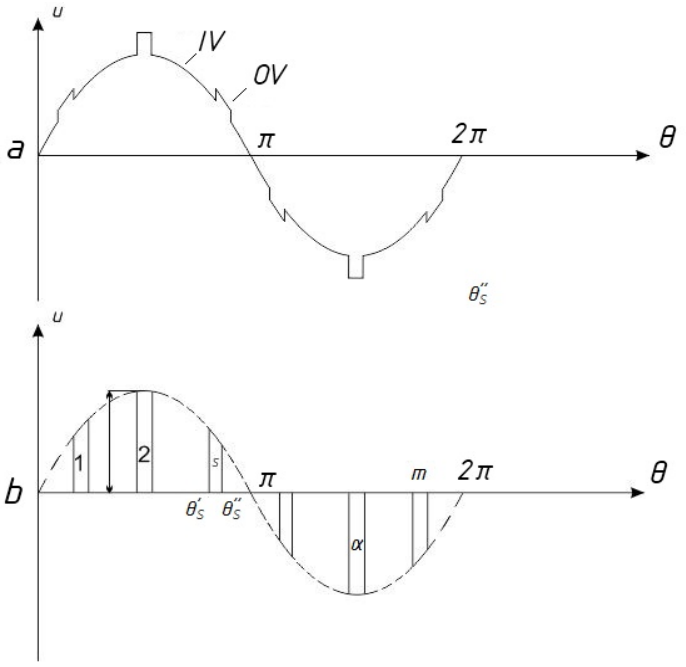

Figure 5. Voltage on the output of regulator (a) and in excitation winding (b) in the pulse method of regulation

The height of which varies by sine law, width – linearly. In accordance with the generally accepted classification this voltage can be examined as one of kinds peak – impulsive modulation (AIM) with the variable width of impulses and stable amplitude of modulating voltage (Figure 6b.). Carrying out such type of modulation is possible by VBT with an additional winding EW_3 (Figure 4.), which is closes for a short time in moments of disconnecting of Windings EW_1or EW_2 from a network. Sequential commutation of the keys S1 or S2 allows to get in a Volt-boosting winding addition of voltage as impulses 1, 2, ... (Figure 6b), whose height modulated by voltage, which induced by VBW.

Instantaneous value of the voltage

$$u_{VBW} = U_{IV} \cdot \sqrt{2} \cdot D \cdot \sin \omega t \tag{1}$$

where D – range of adjusting of device; ω – angular frequency.

The main purpose of the voltage regulator is support for a specific voltage law, voltage output by changing the input voltage, deviation and fluctuation which is a random function of time.

$$U_{OV} = U_{IV} \pm E \pm \delta \tag{2}$$

where δ – error control.

The effect of voltage regulation U_{OV} is achieved by synchronous changing the width α of all impulses, same for each of them at any time. In three limiting modes, when additive of voltage $E = \pm E_{max}$ or zero, the controller works without distortion voltage U_{OV}. In this case, connect only one excitation winding, and the output voltage of regulator.

$$U_{OV} = U_{IV} \pm U_{IV} \cdot D - \Delta U \tag{3}$$

or at zero additive

$$U_{OV} = U_{IV} - \Delta U \tag{4}$$

where ΔU – fall of voltage in regulator.

Under the keys S_1, S_2 and S_3 in the scheme of regulator (Figure 4) it is necessary to understand semiconductor key elements. The scheme (Figure 7) meets all requirements for voltage regulators on the load side. But the best technical and economic performance scheme should has, if instead of single-purpose thyristors use field effect transistors.

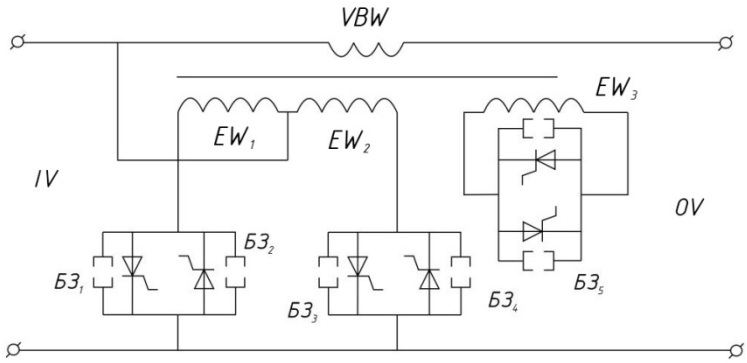

Figure 6. Connection diagram of artificial blocks for shutdown thyristors

Connection of thyristors in the diagonal of monophase bridge allows to decrease the amount of key elements in two times. In this case control unit is simplified.

A three-phase impulsive transformer – thyristor voltage regulator type, can be obtained by combining single-phase regulators in the three-phase system.

But the best technical and economic performance has scheme with three switching elements that are connected to the VBT winding through three-phase bridge rectifiers (Figure 9.). Here with the purpose of simplification of construction and increase of reliability provides simultaneous switching of currents in the three phases of the device. Switching carried by three semiconductor key elements, S_2 and S_3 on the DC side of rectifiers. The advantage of the scheme is that while commutation sum instantaneous values of electromotive force induced in VDS is zero.

This is a significant advantage over single-phase commutation that adopted for the existing thyristor – transformer (throttle) of regulators, avoids the mutual influence of phase, asymmetry current of magnetizing transformer, causing additional tension in the network.

Output voltage on regulator (Figure 6a) is the sum of two curves: sine wave voltage of network and pulse sequence (Figure 6b) the height of which varies by sine law, width – linearly. To the main parameters that characterize this type of AIM, include coefficient of a sequence of pulses equal to the number of pulses in one period of voltage modulation, frequency is equal frequency network

$$m = \frac{f_M}{f} \tag{5}$$

where f_M is modulated frequency.

Using voltage with AIM leads to distortion forms of voltage U_{OV}. The degree of distortion can be defined in several ways. The main criterion for evaluating nonsinusoidality voltage is harmonious composition of voltage on regulator output.

One of the important parameters of AIM is skvapnist:

$$Q' = \frac{t_i + t_n}{t_i} \tag{6}$$

where t_i – pulse width; t_n – length of the pause between pulses.

Skvapnist for voltage supplements can vary within $1 \le Q' \le \infty$ causing difficulties in the AIM study. Because the parameter characterizing property adjusting pulse regulator, accepted degree of regulation – quantity reverse skvapnist.

ψ – value, backward of skvapnist

$$\psi = \frac{1}{Q'} \tag{7}$$

Considering that α characterizes the pulse duration, the degree of regulation

$$\psi = \frac{\alpha m}{2\pi} \tag{8}$$

Active voltage value additives (Figure 6b) is smoothly regulated by synchronous change the width of pulses

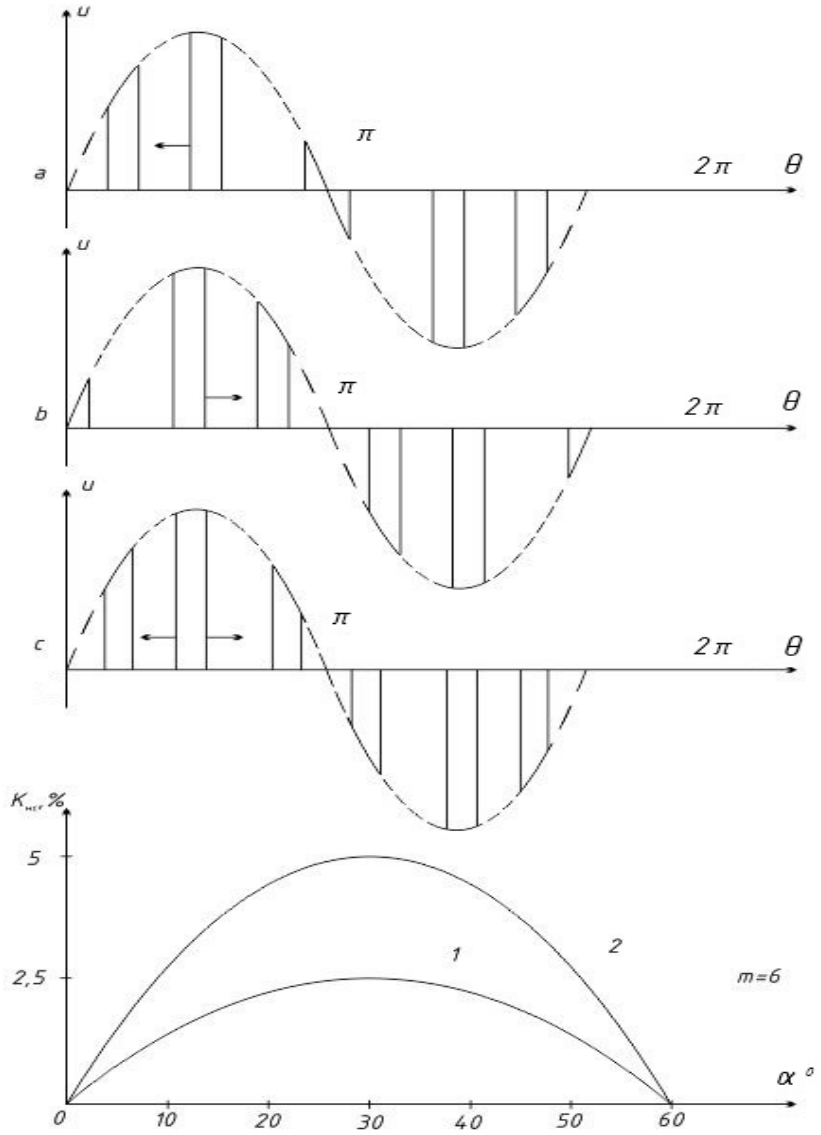

Figure 7

However, there may be three ways latitude regulation:

- unilateral, by shifting back fronts (Figure 7b.)
- bilateral, offset by simultaneous front and back fronts (Figure 7a.)
- unilateral, while shifting only the leading edge (Figure 7).

The research parameters AIM occurs at these assumptions:

- valves of the executive body are ideal
- load has linear characteristic,
- voltage of power source is sinusoidal.

All three types of regulation at $m = 6$ gave almost identical results, and three curves $\kappa_D = f(\alpha)$ at unilateral regulation by displacement of the front and rear and bilateral fronts of regulation coincide.

Based on this κ_D cannot be considered a defining characteristic when choosing a mode of regulation. Further comparison must be performed on the basis of technical and economic indicators of all types of regulation. It is important to investigate the operation of the executive body at three types of regulation and choose a way that would ensure the maximum use of capacity VBT without complications other elements of the regulator.

It is necessary to choose the optimum frequency band voltage with AIM, based on the mode of the regulator (without considering the load).

In the three-phase version of regulator create a series of pulses that form a additives tension in each phase, one key element is performed. This feature of the scheme can dramatically increase the utilization of semiconductor devices, but can impose restrictions of pulse rate sequence. The carrier frequency should be chosen to create a symmetrical system of voltage in phase and a linear voltage at the output of regulator. Also in U must be absent the constant component. These requirements are fulfilled in the case where the placement of pulses in all six half-periods of three phases will be absolutely the same, that is, should the condition at unilateral regulation by the displacement of the forward front.

$$\begin{aligned} &\frac{2\pi}{m} S_{i-} - \pi = \frac{2\pi}{m} S_{i+}; \\ &\frac{2\pi}{m} S_{iB} \pm \frac{2\pi}{3} = \frac{2\pi}{m} S_{iA}. \end{aligned} \tag{9}$$

Here S_{i-}, S_{i+} – numbers of pulses, equally placed relatively the start of negative and positive half-periods of one phase,

S_{iB}, S_{iA} – numbers impulses that equally placed relatively beginnings half-periods of two adjacent phases.

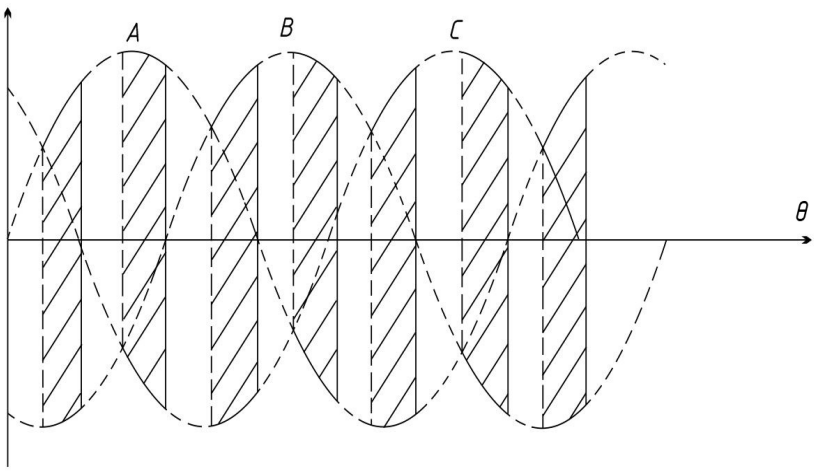

Figure 8. Principle of symmetry three-phase voltage regulation

After converting expressions, we obtain:

$$\begin{aligned} S_{i-} - S_{i+} &= \frac{m}{2}; \\ S_{iB} - S_{iA} &= \frac{m}{3}. \end{aligned} \tag{10}$$

To these conditions were kept, the coefficient sequence of pulses m must be a multiple of six, that carrier frequency $f_M = 6\kappa f$, where k = 1, 2, 3, 4, …

For bilateral regulate, symmetry condition has the form:

$$\begin{aligned} \frac{2S_{i-} - 1}{m} - \pi &= \frac{(2S_{i+} - 1)\pi}{m}; \\ \frac{(2S_{i-} - 1)\pi}{m} \pm \frac{2\pi}{3} &= \frac{(2S_{i+} - 1)\pi}{m}. \end{aligned} \tag{11}$$

For unilateral adjustment by shifting the rear edge of the pulse symmetry condition takes the form:

$$\begin{aligned} \frac{2\pi(S_{i-} - 1)}{m} - \pi &= \frac{2\pi(S_{i+} - 1)}{m}; \\ \frac{2\pi(S_{i-} - 1)}{m} \pm \frac{2\pi}{3} &= \frac{2\pi(S_{i+} - 1)}{m}. \end{aligned} \tag{12}$$

Thus, when all three types of adjustment necessary and sufficient condition for the symmetry of the output voltage regulator and no DC component in OV there is a choice of coefficient sequence of pulses m which is equal or a multiple of six.

The final selection of frequency band can be done by setting the relationship between the coefficient of sequence of pulses and sine form of output voltage.

Considering that the sinusoidal voltage can write that the voltage at the output of the regulator:

$$\sum_{\nu=2}^{\infty} U_{\nu}^2 = U_D^2 - U_{D1}^2 \tag{13}$$

Here $U_D^2, U_{D_1}^2$ – according current value of voltage induced in the VBW and the current value of the first harmonic.

Since the voltage additives pulses are modulated in sinusoid, additive rms voltage generally has the form:

$$U_D = \sqrt{\frac{1}{2\pi} \sum_{S=1}^{m} \int_{\theta_S'}^{\theta_S''} U_M^2 \sin^2 \theta \, d\theta} \tag{14}$$

After the changes, given that a m multiple of six, we get the expression which is valid for any of the three types of regulations:

$$U_D = U_M \cdot \sqrt{\frac{m\alpha}{4\pi}} \tag{15}$$

The current value of the first harmonic:

$$U_{D_1} = \frac{U_M}{\sqrt{2}} \cdot \frac{m\alpha}{2\pi} \tag{16}$$

Analysis of the impact of higher harmonic on the OV controller easier to carry, using distortion factor:

$$\kappa_d = \frac{U_1}{U}, \tag{17}$$

where U_1 – current value of voltage of first harmonic; U – effective value of nonsinusoidal voltage.

According to

$$\kappa_D = \frac{U_{IV} + U_{D_1}}{U_{IV} + U_D}, \tag{18}$$

Substituting values U_{D_1} and U_D we will obtain

$$\kappa_D = \frac{U_{IV} + U_M \cdot \frac{m\alpha}{2\sqrt{2}\pi}}{U_{IV} + U_M \cdot \sqrt{\frac{m\alpha}{4\pi}}} \tag{19}$$

Taking into account that

$$U_M = \sqrt{2} \cdot IV \cdot D \tag{20}$$

Rewrite expression for

$$\kappa_{D_{\min}} = \frac{\frac{2\sqrt{2}\pi}{\sqrt{m\alpha}} + D\sqrt{\frac{m\alpha}{4\pi}}}{\frac{2\sqrt{2}\pi}{\sqrt{m\alpha}} + D} \tag{21}$$

Taking into account the degree of regulation Ψ:

$$\kappa_D = \frac{\sqrt{\frac{2}{\psi}} + D\sqrt{\psi}}{\sqrt{\frac{2}{\psi}} + D} \tag{22}$$

Minimal distortion of coefficient determined from the equation

$$\frac{\partial \kappa_D}{\partial \alpha} = 0 \tag{23}$$

Real $\kappa_{D\,\min} = 0{,}99$ at $D = 0{,}1$. Right-wing of members of the numerator and denominator can be discarded as the value of the second order of smallness and believe, that $\kappa_D \approx 1$. If the adjustment range of the device is located within 0.10–0.15.

Thus, the higher harmonic when their amplitudes constitute up a few percent of the amplitude of the fundamental frequency, virtually hasn't impact on operating voltage:

$$OV = IV \pm U_{D_1} \tag{24}$$

The addition of the voltage regulator:

$$E = \frac{U_M\, m\alpha}{2\sqrt{2}\,\pi} \tag{25}$$

The analysis of this expression shows that adjusting characteristic of the device is linear. This is one of the benefits of AIM because it allow to simplify control scheme and increase the stability of the regulator.

Conclusions

At the reduction of power quality electromagnetic and technological losses increase. Electromagnetic power losses occur in the growth of power and energy losses, at the reducing of equipment lifecycle. Technical losses include reduction of products, manufacturing of lower quality products. Technological losses make up to 90–92% of all losses and are usually hidden in the production cost.

Voltage reduction in lamps causes decrease in luminous flux, which in turn leads to the deterioration of sanitary and hygienic conditions for workers and lower productivity. Additional costs to improve illumination are always paid off, and "bad light" is costly.

The most promising is the regulating method based on effecting voltage and reactive power.

The use of thyristors for voltage control turns economically justified if there is the need to achieve a large number (over 300 thousand) switches per year.

Given recommendations deal with voltage regulation at food industry enterprises.

After the changes, given that a m multiple of six, we get the expression this is valid for any of the three types of regulations.

Thus, the voltage deviation is one of the most important problems in power supply systems at industrial enterprises. Its solution is a priority in the design of power supply systems.

Sequence of pulses m which is equal to or a multiple of six.

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Effect of natural dye from beetroot juice on antioxidant properties and nutritional values of fondants

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Abstract

Introduction. It was performed a research the physical and chemical, antioxidant and nutritional properties of the fondants with beetroot juice addition.

Materials and methods. 3 samples of fondants with juice obtained from raw (1), boiled (2) and baked (3) beetroot were used in this study. Methods: sensory analysis with the help of 15 subjects, the antioxidant activity assessment through DPPH method, and the chemical test, which refers to moisture, ash, mineral and reducing sugar determinations.

Results and discussions. Sample 1, which are fondant candies with juice obtained from fresh beetroot, was the most appreciated with a total ranking of 8,92, and sample III, fondant candies with juice obtained from baked beetroot, was the least appreciated with a result of 8,55. Sample II, fondant candies with juice obtained from boiled beetroot, had an overall assessment of 8,59.

Highest antioxidant capacity occurs in the case of fondant candies with red juice obtained from raw beetroots (sample 1), with an overall performance of 93,22%. A rather lower result had the sample 2 with 92,84%. Sample 3 showed the lowest result of 91,49%.

The highest results in the matter of moisture content (94,20%) and reducing sugars (14,20%) had the sample 3. On the contrary, the lowest results for both moisture content and reducing sugars was shown by sample 2 with 93,2% and 12,1%.

The highest value of ash content was shown by the sample with raw beetroot juice, 5,66%. Sample 3 had the lowest level of ash content, 1,18%, five times lower comparing to the first sample.

Conclusions. The fondants obtained from raw beetroot juice has the most pronounced antioxidant capacity and the betaine content is almost double compared with other analysed samples.

Introduction

Fondants are types of confectionery. They are categorized based products called fondanterie flux. Besides fondants in this category are included sherbet, marzipan and other confectionery [6].

Natural dye is used in both commercial production of food and the cooking class. Due to their safety and general availability, natural dyes are used in a variety of non-food applications, for example in handicrafts and educational kits. By the mid 1800s the only source of dyes used in foods were natural, extracted from saffron, carrots, dude, beetroot etc. [2] [3].

Manufacturers continue to seek solutions for natural ingredients for the development of new products, particularly for products that are marketed as "better for consumption". As costumers demand for healthy food and healthy increases, so does the use of natural colors [1] [4].

Also, natural colors must be declared on the product label. If the red beet juice is used to shade a foodstuff (sweets, jellies, etc.), it should be indicated as an additive color [4] [5].

It was discovered that in 2010 only 1.6% of confectionery products contained natural colorants; this number has increased and is estimated to account for over 10% of all confections in 2020 [13].

An interesting use of natural coloring aids is that many are bioactive and have a strong antioxidant capacity; for example, betaine extracted from red beet is one of the most powerful natural antioxidants [2].

A study by a group of UK researchers in 2012 compared the antioxidant activity of betaine extracted from red beetroot Detroit Dark Red, with the antioxidant capacity of betaine extracted from an unknown variety.

It has been found that betaine extract obtained from the Detroit Dark Red variety has higher salt antioxidant capacity (DPPH) than the other extract; 3.28 times greater packing capacity, and ORACs 20 times higher.

It has been demonstrated in the same study that betaine remains stable in the gastrointestinal tract without any significant loss of antioxidant properties, which makes its value as a food additive increase.

Betaines are divided into two groups: betaxanthines and beta-cyanines, due to their chemical structure. Betaxanthines are condensation products of betalamic acid, they have a deep violet color [12].

The purpose of this research is the assessment of the physical and chemical behavior of the beetroot juice added in the product, as well as its properties changes after heat treatment application. Plus, another intent of this paper is to find if there can be found any correlation between sensorial and chemical performances of the samples.

Materials and methods

For this study were analysed the following samples:
Sample 1 – fondant candies with beetroot juice, obtained from fresh beetroot;
Sample 2 – fondant candies with beetroot juice, obtained from boiled beetroot;
Sample 3 – fondant candies with beetroot juice, obtained from baked beetroot.

Sensory analysis

For the sensory analysis has been used the method with hedonic scale (hedonic test). This method is used for the purpose of introducing a new product on the market, by assessing the consumer's reaction to the organoleptic properties of the product [7].

The hedonic test allows to determinate both the best sample and the degree of preference of certain factors such as the packing method, the modification of the recipe as well as the shelf life [7].

For this method 15 subjects were selected with the help of which were performed the following determinations: appearance, colour, taste, smell, flavour and texture. [7]

The experiment was held in the laboratory with specific conditions of light, ventilation and temperature.

Antioxidant activity

This test was performed using the DPPH reagent and a spectrophotometer.

DPPH (2,2-diphenyl-1-picrylhydrazyl) is one of the most stable and commercially available organic radionuclides and has a maximum UV-VIS absorption at 517 nm. DPPH method is based on the generation of free radicals, from a methanol solution of 2,2diphenyl -1- picrylhydrazyl, which absorption disappears in the presence of an antioxidant [8]

Preparation of the solid samples. In three volumetric flasks were introduced 2,5 mg of each sample, followed by bringing to the mark with methanol. The flasks were agitated vigorously and left in the dark for 15 minutes, after which the content was filtered through filter paper. The obtained extracts were used for the calibration curve [8].

Establishment of the calibration curve. For this determination, firstly, was used a blank sample, namely a methanol solution, used as a standard, for which was determined the absorbance ($A_{standard}$). The calibration curve for each sample was traced based on 10 solutions containing different amounts of the certain sample extracts and methanol, to which was added 500 µl of DPPH reagent in every test tube right before the cuvette should have been placed in the spectrophotometer. These manipulations were followed by the absorbance determination for each concentration (A_{sample}) [9].

Antioxidant activity value calculation. The inhibition percentage of the free radicals (I%) was obtained with the equation [8]:

$$I\% = \frac{A_{s\tan dart} - A_{sample}}{A_{s\tan dart}} 100$$

Chemical analysis

Moisture determination. Moisture content of each fondant candy with beets juice was performed by using the digital moisture analyzer at 100 °C. The total soluble solids were determined using a Digital ABBE Refractometer and expressed using a Brix degree scale (°B) [10].

Ash determination. The classic calcination method was used. In a porcelain crucible, weighed in advance, was introduced the sample. The crucible was placed on the flame of a gas lamp until the smoke appeared [11].

This procedure was followed by the insertion of the crucible in the electric furnace set

at 750˚C and left the necessary time there until a pale white or gray residue with no traces of charcoal was obtained [11].

The crucible was cooled in a desiccator until it reached the room temperature, then it was weighed.

The ash content was determined with the formula [11]:

$$Ash\% = \frac{m_1}{m}100$$

where m_1 - is the amount of ash in g, which is deduced from the difference between the weight of the crucible with ash after calcination and the empty crucible

m - the amount of sample taken into work, this being calculated from the difference between the weight of the crucible with sample before calcination and the empty crucible [11]

Quantitative determination of mineral substances (EDX spectroscope). Rontgen energy-dispersive fluorescence spectroscopy is based on measuring discrete energy of each Rontgen wavelength as expression of concentration and composition. With the emergence of discrete radiant energy on a semiconductor detector it produces a certain number of pairs of voids and through them a certain electrical pulse. Current pulses, according to the current value, are distributed by a multichannel analyzer (about 1000 channels) and give a specific spectrum that has the order of pulses and the energy abscissa.

All Rontgen fine analysis procedures, whether refractive or spectroscopic, are analytical and control procedures that act completely non-destructively on the subject matter under investigation.

Determination of reducing sugar (Schoorl method). Reducing sugars reduce the copper-tartaric alkaline solution (Fehling's reagent) to Cu_2O, which is indirectly quantitatively determined by iodometric measurement of copper sulphate in the Fehling solution before and after reduction. The difference obtained is the amount of copper reduced by sugar.

- Extraction. An amount of 5-25g of the sample evenly blended, it is placed in a 150-200ml vial where was added 70-80 ml of distilled water heated to 85-90 °C, then placed on a water bath, and from the moment the water begins to boil for 30 minutes, started the stirring. The extract is filtered in a 100 ml volumetric flask and washed with hot distilled water.
- Dosage of reducing sugars. In a 300 ml Erlenmayer flask, 20 ml of the flaky extract was introduced, then Fehling I solution 10 ml and Fehling II solution 10 ml, the pot was heated on an asbestos sieve, the boiling time was exactly 2 minutes. The flask was cooled in a stream of water, then 20 ml of potassium iodide solution and 15 ml of sulfuric acid was added.

The liberated iodine is titrated with 0.1N sodium thiosulfate in the presence of starch as an indicator. The solution of starch is added to the end of the titration when the solution had a pale yellow color. Titration is continued until the blue color disappears due to the presence of iodine.

The amount of copper reduced by sugar is determined by the amount of 0.1 N sodium thiosulphate used for titration based on the equation:

$$V = V_1 - V_2$$

where V_1 - the volume of 0.1 N sodium thiosulphate used to titrate the blank sample (ml)

V_2 - the volume of 0.1 N sodium thiosulphate used to titrate the actual sample (ml)

There is the amount of reducing sugar in the analyzed samples based on the equation:

$$g\% = \frac{z \cdot d}{g} 100$$

where z is the quantity of inverted sugar from the corresponding table for V ml of $Na_2S_2O_3$ 0,1 N;

d is dilution cipher;

g is weight of analyzed sample (g).

Results and discussions

1. Sensory analysis

Following the sensory analysis on each of the three samples were obtained the following results.

Graphical interpretation of sensory analysis:

1.1. Appearance assessment

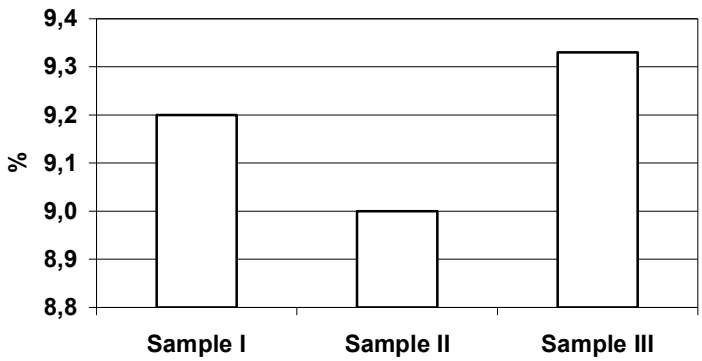


Figure 1.1. Appearance assessment of the fondant candies with beetroot juice

As results from this graph, sample III, namely candies containing juice obtained from baked beetroots, has the highest value for appearance 9,33. The lowest value of 9 has the second sample.

1.2. Colour assessment

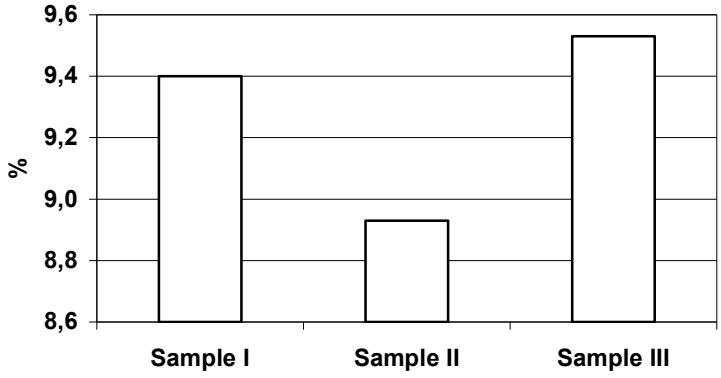


Figure 1.2. Colour assessment of the fondant candies with beetroot juice

Following the completion of the colour graph, sample III has the highest result of 9,53 compared to the other 2 samples.

1.3. Taste assessment

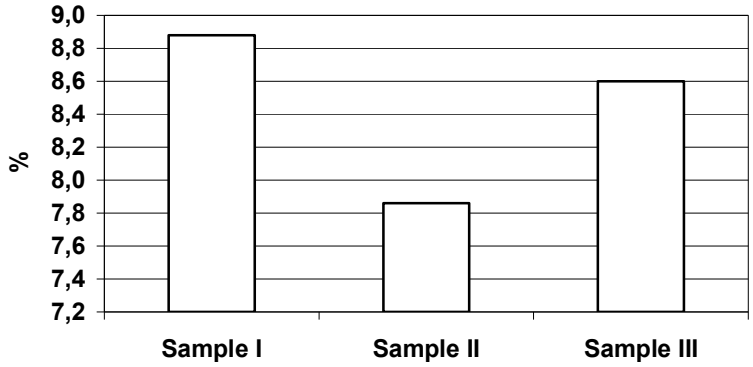


Figure 1.3. Taste assessment of the fondant candies with beetroot juice

Fondant candies with juice obtained from fresh beetroot have the highest grade in the taste category, 8,88. Meanwhile sample II was ranked with 7,86.

1.4. Smell assessment

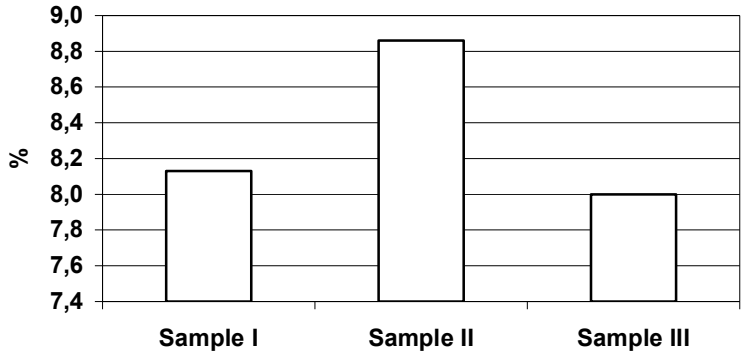


Figure1.4. Smell assessment of the fondant candies with beetroot juice

According to this graph, candies made with juice obtained from boiled beetroots are the most appreciated in terms of smell, with a 8,86 appreciation. Sample I and II had slightly the same results: 8,13 and 8.

1.5. Flavour assessment

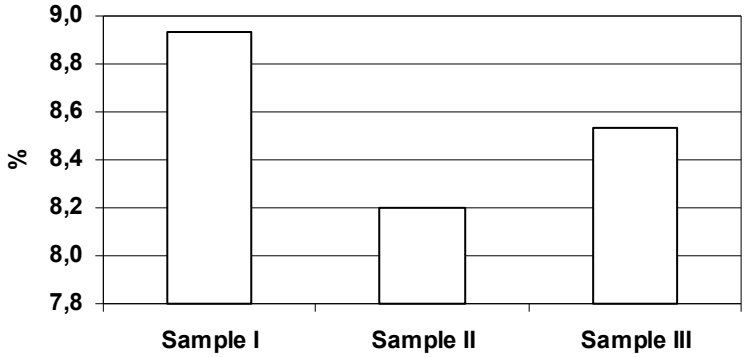


Figure1.5. Flavour assessment of the fondant candies with beetroot juice

According to graph 5, candies with juice obtained from raw beetroots have the most pronounced flavour, with a rank of 8,93. The lowest result, 8,20, was obtained by sample II.

1.6. Texture assessment

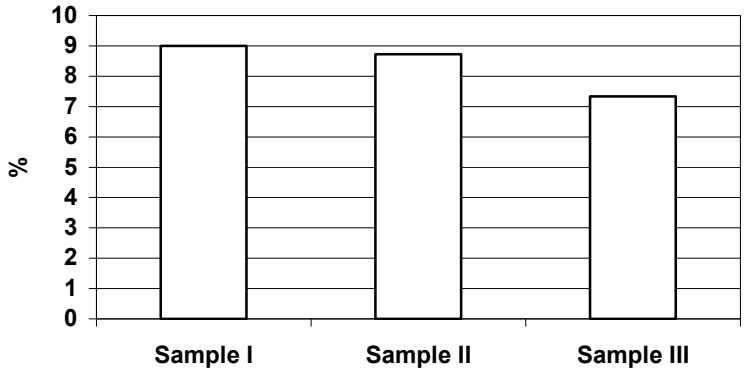


Figure 1.6. Texture assessment of the fondant candies with beetroot juice

In the matter of texture, samples were ranked as follows: 9 for sample I, 8,73 for sample II and 7,33 for sample III.

1.7 Overall sensory analysis performance

After performing the sensory analysis on all three different samples the following general graph was established:

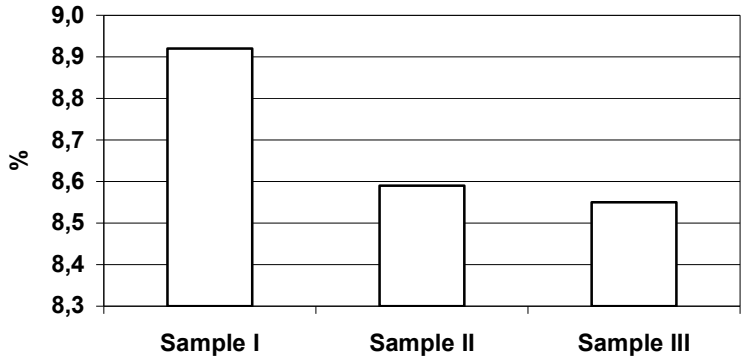


Figure 1.7. General graph of the sensory analysis performance

As a result of the overall chart, sample I was the most appreciated with a total ranking of 8,92, and sample III was the least appreciated with a result of 8,55. Sample II had an overall assessment of 8,59.

2. Antioxidant capacity determination

2.1. Graphical interpretation of antioxidant capacity

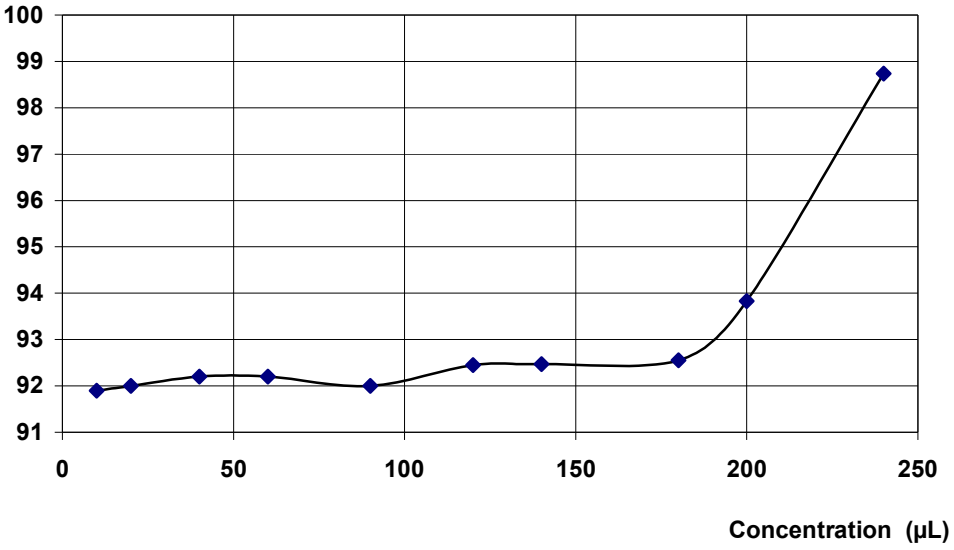


Figure 2.1.1. Sample 1 – Fondant candies with juice obtained from raw beetroots

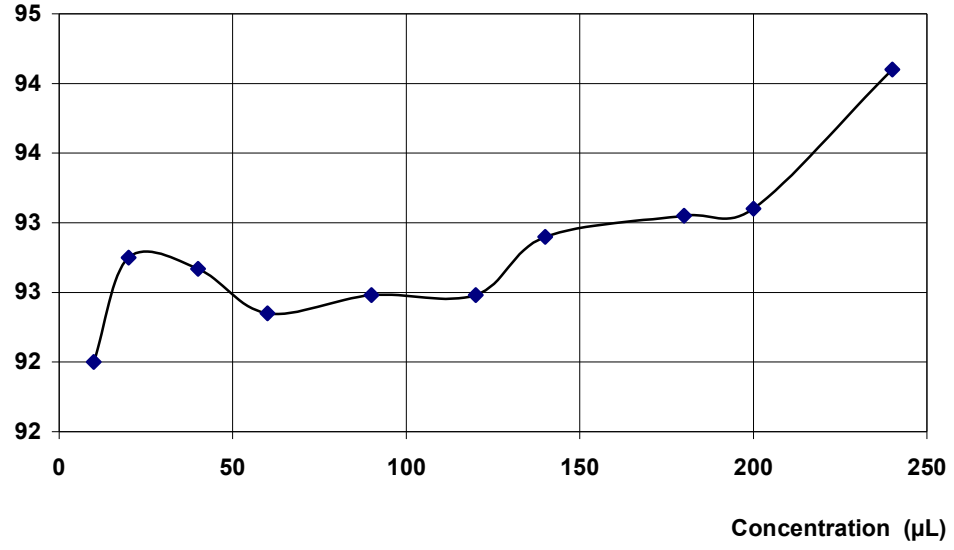


Figure 2.1.2. Sample 2 – Fondant candies with juice obtained from boiled beetroots

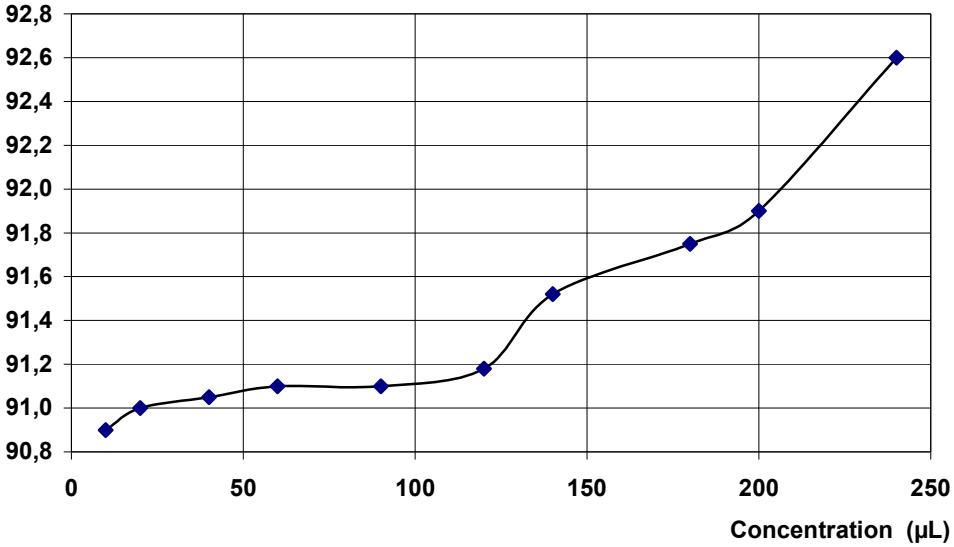


Figure 2.1.3. Sample 3 – Fondant candies with juice obtained from baked beetroots

2.2. Overall antioxidant capacity performance

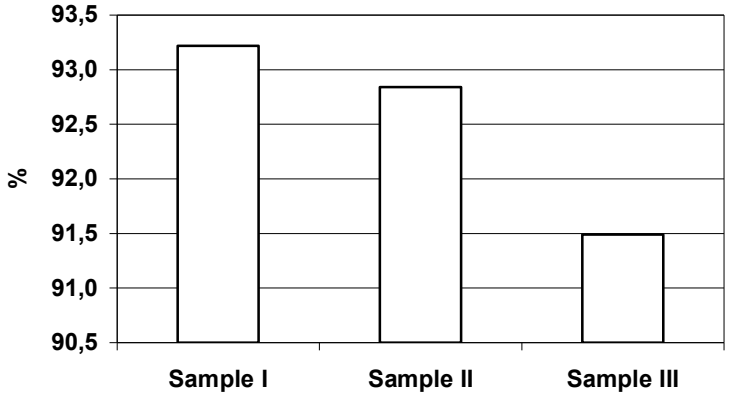


Figure 2.2.1. General graph of antioxidant capacity

The highest antioxidant capacity occurs in the case of fondant candies with red juice obtained from raw beetroots (sample I), with an overall performance of 93,22%. A rather lower result had the sample II with 92,84%. Simultaneously, sample III showed the lowest result of 91,49%.

It is also noted that with the absorbance decrease the antioxidant activity decreases.

3. Chemical analysis of the fondant candies with beetroot juice

3.1. Moisture determination

After keeping the samples in an oven at constant 100 °C for 5 hours, the following results were obtained:

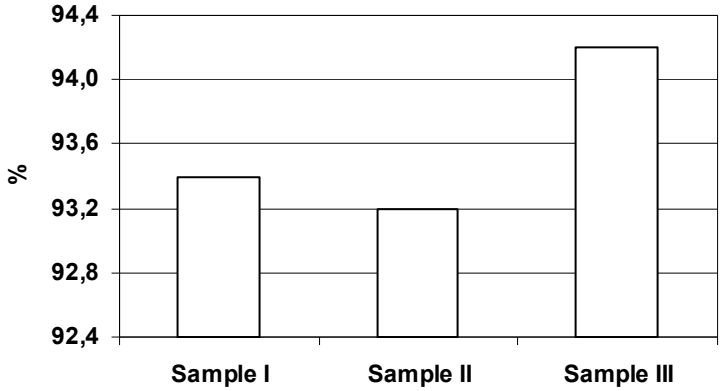


Figure 3.1. Graphical interpretation of moisture

Sample III has the highest result of 94,20%, meanwhile samples I and II showed a slightly equal result of 93,4% and 93,2%.

3.2. Ash content

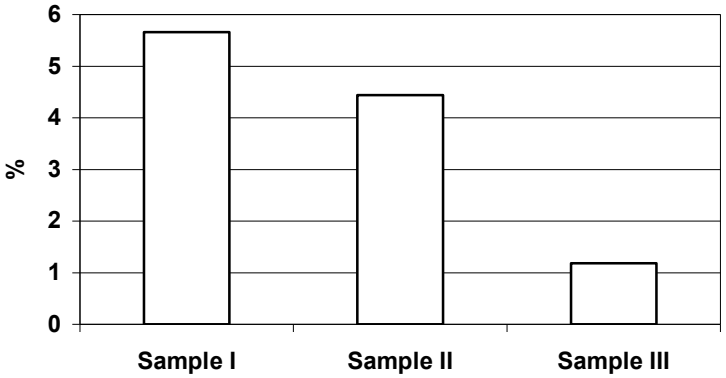


Figure 3.2. Graphical interpretation of ash content

As a result of this graph, sample I, fondant candies with juice obtained from raw beetroots has the highest ash content of 5,66%. Sample III showed a five times lower result, 1,18%.

3.3 Quantitative determination of mineral substances with EDX method

Based on the quantitative determination of mineral substances from fresh beetroot juice were highlighted the following elements:

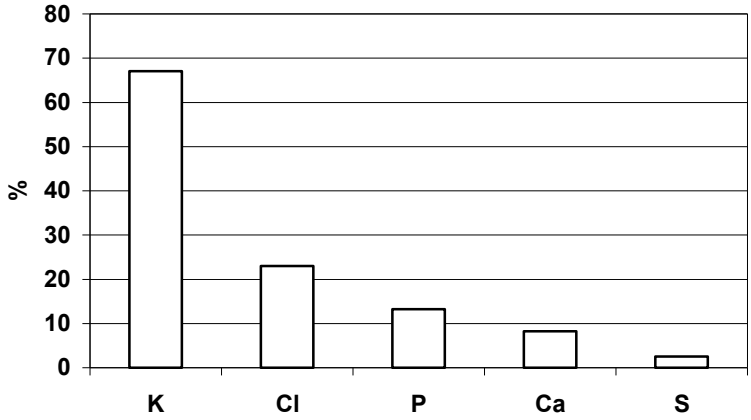
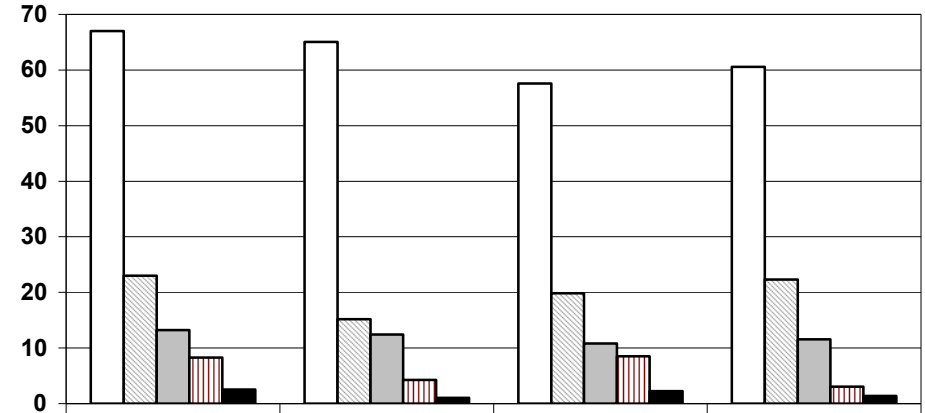


Figure 3.3.1. Graphical interpretation of mineral substances from fresh beetroot juice

According to the graph, following the quantitative determination of the mineral substances in the fresh beetroot juice, it contains an amount of 67,0% K that passes into ash, but also other elements such as: Cl (23.01%), P (13,24%), Ca (8.26%), S (2.52%).

A significant proportion of these elements and minerals are found in the 3 fondant candy samples. The results are as follows:



	FRESH JUICE	SAMPLE I	SAMPLE II	SAMPLE III
K	67,02	65,08	57,57	60,58
Cl	23,01	15,2	19,87	22,3
P	13,24	12,4	10,84	11,58
Ca	8,26	4,26	8,52	3,06
S	2,52	1,02	2,22	1,4

Figure 3.3.2. General graphic of mineral substances content

Mineral substances pass into the three samples of fondant candies to some extent, as follows:

- Potassium (K) is found in the highest quantity in sample 1 (65.08%) and the smallest quantity in sample 2 (57.57%);
- Chlorine (Cl) passes to the highest amount in sample 3 (22.3%), and the smallest quantity is found in sample 1 (15.2%);
- Phosphorus (P) is found in the highest quantity in sample 1 (12.4%), and the smallest quantity in sample 2 (10.84%);
- Calcium (Ca), sample 2 has the highest amount of calcium (8.52%), and sample 3 - the smallest amount (3.06%);
- Sulfur (S) migrates to the largest quantity in sample 2 (2.22%), and the smallest quantity passes to sample 1 (1.02%).

3.4. Determination of reducing sugars. The Schoorl method

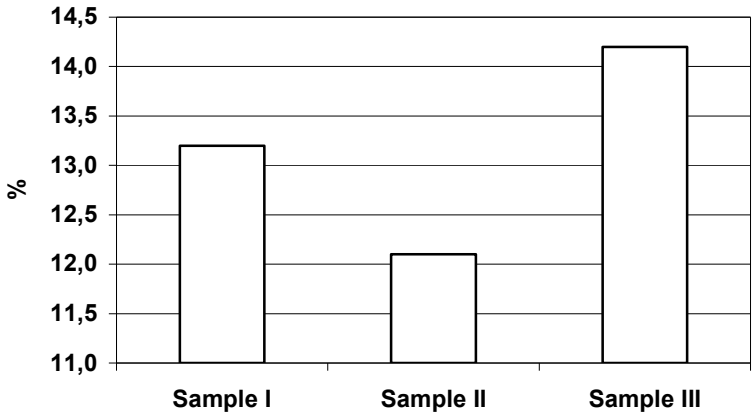


Figure 3.4. Graphical interpretation of reducing sugars content

Sample III has the highest amount of reducing sugars (14.2%). Sample II has the lowest amount of reducing sugars (12.1%). An amount of 13.2% was presented by sample I.

Conclusions

- Betaine (beetroot natural dye) can be used in both its liquid and powder form;
- Sample I (fondant candies with fresh beetroot juice) had the highest antioxidant activity and ash content;
- The highest moisture and amount of reducing sugars is given by sample III. Beetroot juice contains a high amount of mineral substances, but the heat treatment applied to the fondant candy affects the amount of minerals that migrate from the juice in the final product.

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Анотації

Харчові технології

Вплив гарбуза як харчової добавки на фізико-хімічні та органолептичні характеристики кексів

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Вступ. Проведені дослідження з метою встановлення впливу харчових добавок на основі гарбуза на енергетичну цінність, фізико-хімічні й оргранолептичні властивості кондитерських борошняних виробів.

Матеріали і методи. Досліджувалися зразки кексу з додаванням сирого і бланшованого гарбуза у кількості 8, 16, 24 і 32%. Реологічні показники досліджено методом ротаційної віскозиметрії.

Результати. Найбільш вдалою є рецептура із заміною класичних компонентів кексу на функціональну добавку 24% бланшованого гарбуза. Використання різних форм гарбуза як харчової добавки у виробництві кексів є доцільним з огляду на збагачення продукту біологічно цінними компонентами, вітамінно-мінеральним комплексами та сполуками антиоксидантами, що містяться в цій сировині.

Проаналізувавши фізико-хімічні показники зразків, можна зробити такі підсумки: на кривих в'язкості зі збільшенням Р, Па від 0 до 6000 η зростає від 0 до 450 за параболічною залежністю, причому найбільш інтенсивне зростання – в діапазоні Р в 5000. Збільшення добавки від 8% до 32% збільшує η в середньому у 2–3 рази. Так само при збільшенні Р на кривих плинності ɛ зростає від 0 до 800 із найбільшим піком у 640 і подальшим спаданням.

За проаналізованими органолептичними показниками найбільш вдалими є рецептури із додаванням 16% та 24% бланшованого гарбуза.

Створення нового виду кексу сприятиме розширенню асортименту борошняних кондитерських виробів спеціального призначення.

Висновки. Заміна традиційних компонентів кексу гарбузом є раціональним для забезпечення якості продукції, фізико-хімічних та органолептичних характеристик.

Ключові слова: *кекс, гарбуз, органолептика, добавка, реологія.*

Визначення молекулярних мас біологічно активних фрагментів молозива методом електрофорезу

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Вступ. Метою статті є визначення молекулярних мас білкової суміші молозива корів. Дослідження актуальне для розробки та виробництва імунопрофілактичних препаратів і підтримки імунітету людини.

Матеріали і методи. Об'єкт досліджень – молоко корів. Досліджувані зразки відбирали з першого дня після отелення і впродовж наступних трьох діб. 1 проба являє собою молозиво корів із Житомирської області (місто Бердичів). 2 проба – молозиво корів із Київської області (м. Тетіїв). Дослідження проводили методом електрофорезу в поліакриламідному гелі в системі Laemmli.

Результати. Визначено, що високомолекулярні фракції молозива містять білкові молекули з молекулярною масою 160–190 кДа, серед яких – імуноглобуліни. Виявлено також окремі частини імуноглобулінів та інших білків, зокрема важкі ланцюги IgG (55kDa) та IgA (62kDa), секреторний компонент sIgA та лактоферин. Досліджувані зразки високомолекулярних пептидів молозива містять біологічно активні фрагменти, серед яких переважно імуноглобуліни, їхні частини, білки-абзими та інші білкові фрагменти. Окрім імуноглобулінів у складі досліджуваних зразків також виявлено інші білки з молекулярною масою 80, 62 та 55 кДа. Таким білкам можуть відповідати важкі (55 кДа) та легкі (25 кДа) ланцюги IgG та sIgA. У свою чергу, sIgA є надмолекулярним комплексом, який складається із H- і L-ланцюгів IgA (62, 25 кДа відповідно) та секреторного компонента (80 кДа). Окрім секреторного компонента IgA, білкові молекули з молекулярною масою 80 кДа можуть бути половинками молекул імуноглобулінів або лактоферину.

Висновок. Наявність великої кількості білків дає змогу використовувати молозиво у виробництві дитячого, функціонального, лікувального та профілактичного харчування; у біотехнології при виробництві інших продуктів харчування спеціального складу; у медицині і фармакології для виготовлення харчових оболонок і капсул для лікарських речовин, біологічно активних та харчових добавок.

Ключові слова: *молозиво, білок, імуноглобулін, електрофорез, імунітет.*

Ресурсоощадна технологія миття овечої вовни

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Вступ. Миття вовни здійснюють у водному середовищі з метою видалення забруднень і вовняного жиру (жиропоту). З відпрацьованої мийної води вилучають жир. Очищений вовняний жир (Е–913, ланолін) широко використовують під час виготовлення харчових, парфумерно-косметичних і спеціальних продуктів та препаратів.

Матеріали і методи. Досліджували миття овечої вовни мийним засобом Sles 70. Для пошуку раціональних параметрів миття вовни застосували математичне планування експерименту за латинськими квадратами. Експериментальні дані обробляли методами математичної статистики у пакеті Matcad.

Результати і обговорення. Визначали вплив концентрації Sles 70 у мийному розчині у діапазоні 0,5–3,5 г/дм^3, гідромодуля 10–50, температури 20–50 °С і тривалості миття 2–32 хв на вилучення з овечої вовни екстрактивних речовин у мийний розчин.

Виявлено раціональні параметри миття тонкорунної вовни, визначено впливові фактори. Вивчено можливість зменшення кількості води, яку використовують під час миття. Отримано рівняння регресії, що апроксимує вплив нормалізованих факторів

на показник заломлення n_D^{20} відпрацьованої мийної води. Відібрано три суттєво впливові та значущі фактори на кількість вилучених екстрактивних речовин у мийному відпрацьованому розчині. Найвпливовішим фактором на показник заломлення відпрацьованого мийного розчину є температура. Далі за значущістю впливу є гідромодуль, причому температура і гідромодуль виявляють сумірний вплив на показник заломлення. Менш впливовим фактором є тривалість процесу миття. Невпливовим фактором на процес миття вовни виявилася концентрація мийного засобу Sles 70, оскільки мийного засобу було достатньо для утворення міцел у мийному розчині.

Висновки. У межах дослідженого діапазону найбільш раціональний режим такий: миття за температури 40 °С і гідромодуля процесу 10 (співвідношення водний розчин : вовна 10:1) тривалістю 10 хв мийним розчином Sles 70 концентрацією 1 г/дм^3.

Ключові слова: *вовна, жир, миття, ресурсозбереження*.

Особливості та перспективи використання колагеназовмісних ферментних композицій у технології м'ясомістких продуктів

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Вступ. Проблематика дослідження синергетичних ефектів, що можуть спостерігатись при паралельному або послідовному проведенні ферментації м’ясної та рослинної сировини не є широко представленою і потребує більш детального розгляду цих питань.

Матеріали досліджень. Об’єкт дослідження – технологія м’ясомістких продуктів. Предмет – ферментація низькосортної сировини. Використано методи аналізу та синтезу, розглянуто літературні джерела, що представлені публікаціями провідних науковців, чиї роботи присвячені процесам ферментації тваринної й рослинної сировини та синергетичним ефектам у цих процесах.

Результати і обговорення. Можливість одночасного гідролізу білків основної м'ясної сировини дає можливість модифікувати біологічну цінність продукту в широких межах. Чи не єдиним обмежувальним фактором тут є біологічна активність окремих амінокислот. Усі амінокислоти є біологічно-активними речовинами і надмірна їх кількість у вільному стані при незбалансованому співвідношенні з іншими може мати негативний вплив. Це питання відноситься скоріше до медико-біологічних, проте має бути враховане при оцінці й моделюванні складу та ферментації нових м'ясомістких продуктів. Режими ферментації сировини можна варіювати у часі та просторі. В багатьох випадках раціональним є застосування окремих процесів для ферментації рослинної та м'ясної сировини, щоб уникнути надмірного мікробіологічного обсіменіння та накладання ефектів впливу різних груп ферментів. Це питання варто вирішувати для кожної конкретної рецептури та ферментної комбінації окремо, проте більш доцільним у багатьох випадках є роздільне ферментування м'ясної та рослинної сировини з подальшою інактивацією ферментів при високих температурах і складанням фаршу з інактивованими ферментами. Синергетичні ефекти між різними видами протеолітичних ферментів досліджено здебільшого тільки для м'ясної сировини. Перебіг процесів ферментації при впливі одночасно на м'ясну та рослинну сировину є малодослідженим. Як було

сказано вище, в багатьох випадках такі дослідження не є доцільними через ефективність роздільної ферментації м'ясної та рослинної сировини, проте для багатьох випадків ці синергетичні ефекти варто дослідити.

Висновки. Процеси ферментації та протеолізу у м'ясній сировині можуть бути проведені із залученням ряду ферментів як натурального, так і синтетичного походження. Ферментація рослинної сировини може бути проведена паралельно (одночасно) або розмежована в часі та просторі з ферментативною обробкою м'ясної сировини.

Ключові слова: *м'ясо, ферментація, колагеназа, фермент, композиція.*

Склад і властивості сумішей арахісової та соняшникової олії

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Вступ. Проведені дослідження властивостей купажів з рафінованих дезодорованих арахісової та соняшникової олій з метою впливу на показники їх антиоксидантних властивостей при вивченні кислотного й пероксидного чисел.

Матеріали і методи. Визначення показників рослинних олій проводили: кислотного числа – титрометричним методом, пероксидне число – йодометричним методом, йодне число – методом Вайса. Жирнокислотний склад досліджували методом газорідинної хроматографії на хроматографі Hewlett Packard HP-6890 із застосуванням капілярної колонки HP-88.

Результати і обговорення. Антиоксидантні властивості рослинних олій залежать від складу жирних кислот, природних властивостей і методу одержання. Аналіз вмісту жирних кислот арахісової олії показує, що містить, зокрема, близько 60% олеїнової, 19% линолевої та 9% пальмітинової жирних кислот. Склад і властивості сумішей регулюються співвідношенням арахісового та соняшникового олій. Кислотне число рафінованої соняшникової олії збільшилася з 0,3 до 0,6 мг КОН/г протягом 7 місяців зберігання. Таке зростання свідчить про швидке окислення. Збільшення вмісту арахісового масла в сумішах призводить до збільшення антиоксидантної стійкості. Пероксидне число купажу (30% та 70%) було меншим, ніж для соняшникової олії на 25%. Підвищення кислотного числа для купажу значно повільніше. Цей результат пояснюється тим, що для складу купажу достатньо частки мононенасичених жирних кислот з арахісової олії, що містить до 60% жирних кислот додавання сімейства омега-9.

Висновки. З використанням методу математичного планування експерименту розроблені оптимальні купажі арахісової і соняшникової рафінованої дезодорованої олій. Доведено ефект уповільнення окислювальних процесів для купажу 30:70 арахісової та соняшникової олій.

Ключові слова: *арахіс, соняшник, олія, суміш, стабільність, якість.*

Автоматизація виробничих процесів

Синтез робастних взаємозв'язаних стабілізаторів турбоагрегатів на цукрових заводах

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Вступ. Метою дослідження є розроблення методу синтезу взаємозв'язаного робастного системного стабілізатора енергосистеми (IRPSS) для систем електропостачання цукрових заводів із власними турбогенераторами.

Матеріали і методи. Для створення методики синтезу IRPSS застосовується математичний апарат робастного H_∞-синтезу з розміщенням полюсів, а також лінійних матричних нерівностей (LMI). У процесі перевірки синтезованого за запропонованою методикою регулятора шляхом чисельного моделювання використано програмний пакет MATLAB Simulink.

Результати і обговорення. Побудовано математичну модель системи електропостачання з власним турбоагрегатом, яка складається з електричної системи, турбогенератора, регулятора автоматичного збудження, турбіни та регулятора швидкості турбіни. Модель об’єкта керування у вигляді нелінійної системи диференціальних рівнянь лінеаризовано та спрощено шляхом зменшення її порядку за допомогою методу Шура. Створено розширену модель з обраними ваговими функціями з метою застосування процедури H_∞-синтезу. Для розміщення полюсів обрано регіон LMI у вигляді конічного сектора для задоволення умов низької коливальності перехідного процесу, що є основною метою регулятора, який синтезується для оптимізації роботи турбогенератора.

Синтезовано IRPSS для розширеної моделі за допомогою процедури H_∞-синтезу з розміщенням полюсів. Наведено його у вигляді передавальної матричної неперервної функції.

Змодельовано перехідний процес 3-фазного короткого замикання за трансформатором і подальшого автоматичного повторного включення за допомогою нелінійної моделі повного порядку з IRPSS. Порівняно зі стандартним стабілізатором системи та системою без стабілізатора при різних значеннях коефіцієнта посилення АРЗ за каналом напруги. Отримані графіки змодельованих перехідних процесів показали ефективність застосування IRPSS.

Висновки. Розроблений метод синтезу IRPSS може бути застосований для оптимізації роботи турбоагрегата в системі електропостачання цукрових заводів з власними генеруючими потужностями. Синтезований IRPSS забезпечує задовільну стійкість та якість керування для цієї структури енергосистеми, суттєво знижує рівень електромеханічних коливань ротора генератора відносно системи.

Ключові слова: *робастний, регулятор, синтез, турбогенератор.*

Методи і алгоритми керування електроспоживанням підприємств харчової промисловості

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Вступ. Проведені дослідження процесу керування електроспоживанням підприємства харчової промисловості з метою підвищення ефективності використання електроресурсів шляхом розробки методів і алгоритів керування електроспоживанням.

Матеріали і методи. Дослідження виконані на основі методів системного аналізу процесів керування.

Результати і обговорення. Аналіз процесу керування електроспоживанням підприємства харчової промисловості (ПХП) дав змогу визначити основні етапи процесу керування: базові функції керування – реєстрація споживання електричної енергії (ЕЕ), прогнозування витрат ЕЕ, розрахунок норм витрат ЕЕ, формування переліку споживачів-регуляторів (СР); умови забезпечення функцій керування – інформація про витрати ЕЕ, обмеження та тарифи, вимоги до точності прогнозу електроспоживання; організаційно-технічні механізми реалізації функцій керування – інформаційно-обчислювальний комплекс, енергодиспетчер, оператор технологічного процесу, головний енергетик; базові інформаційні потоки, які забезпечують керування електроспоживанням – прогнозні значення температури, поточні дані про витрати ЕЕ та випуск продукції, прийняті рішення по витраті ЕЕ. Представлені методи і алгоритми керування електроспоживанням ПХП з використанням СР. При створенні математичної моделі прогнозування електроспоживання ПХП використано штучну нейронну мережу у вигляді багатошарового персептрона. Для навчання штучної нейронної мережі використовується комбінований метод навчання на основі методу зворотного поширення похибки і методу Коші. Сформульовані вимоги до організаційно-технічного забезпечення управління електроспоживанням ПХП. Встановлено, що з урахуванням взаємного зв'язку технологічного процесу і процесу електроспоживання для керування електроспоживанням необхідно використовувати діалогову систему.

Висновок. Керування електроспоживанням ПХП проводиться з використанням прогнозних значень, отриманих за допомогою штучної нейронної мережі, шляхом формування оптимального складу споживачів ЕЕ на основі евристичного алгоритму. Це дає змогу забезпечити високу ефективність енерговикористання і врахувати збитки, викликані відключенням СР.

Ключові слова: *електроенергія, керування, споживання, харчова промисловість.*

Виділення областей стійкості лінійних динамічних систем з дробовими регуляторами

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Вступ. Проведені дослідження лінійних динамічних систем регулювання процесу біологічного очищення забрудненої води дробовими регуляторами з метою виділення границь *D*-областей їх глобальної стійкості та визначення простору

параметрів налаштування дробового регулятора при фіксованих порядках диферінтеграторів в його складі.

Матеріали і методи. Використовуючи метод *D*-розбиття, отримані аналітичні формули, що визначають межі області стійкої стабілізації системи "об'єкт" + "дробовий $PI^{\lambda}D^{\mu}$-регулятор" стосовно керування біологічним очищенням забруднених вод активним мулом.

Результати і обговорення. Системи автоматичного керування дробового порядку більш точно описуються динамічними рівняннями, в яких порядок похідних може бути будь-яким числом, дійсним і не тільки цілим. Широко використовувані в практиці автоматизації пропорціонально-інтегрально-диференціальні (*PID*-) регулятори також підпадають під дробове узагальнення, якщо в їхній структурі замість звичайних цілочисельних похідних та інтегралів використати дробові аналоги. Регулятори дробового порядку позначають як $PI^{\lambda}D^{\mu}$, де λ и μ – порядки інтегрування і диференціювання сигналу похибки, причому порядки λ і μ можуть мати дійсні нецілі (дробові) значення.

На основі методу *D*-розбиття отримані аналітичні формули, які описують границі глобальної стійкості лінійних динамічних систем дробового порядку. Області стійкості побудовані в просторі параметрів налаштування дробових $PI^{\lambda}D^{\mu}$-регуляторів при фіксованих порядках диферінтеграторів. Розроблене відповідне алгоритмічно-програмне забезпечення, що реалізує запропонований метод виділення області стійкості. Наводяться деякі результати обчислювальних експериментів, дається оцінка ефективності дробового $PI^{\lambda}D^{\mu}$ - регулятора.

Висновок. На основі методу D-розбиття були отримані аналітичні вирази, що описують межі глобальної області стійкості лінійних динамічних систем дробного порядку типу «вхід-вихід» з дробними $PI^{\lambda}D^{\mu}$-регуляторами.

Ключові слова: *стійкість, система, дріб, похідна, інтеграл, регулятор, D-розбиття, диферінтегратор.*

Гібридна експертна система моделювання рецептур морозива

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Вступ. Розроблено універсальну систему моделювання рецептур морозива, яка, на відміну від традиційних, заснована на застосуванні методів обробки експертних даних і методів оптимізації, що дає змогу значно розширити коло практично значимих завдань, вирішення яких забезпечує значний економічний ефект.

Матеріали і методи. Для створення бази даних та бази знань була використана СУБД Firebird. Для зручності розробки структури бази даних використано програмний засіб IBExpert. Для створення інтерфейсу користувача використано інтегроване середовище розробки програмного забезпечення Microsoft Visual Studio.

Результати і обговорення. Гібридна експертна система моделювання рецептур морозива створена для удосконалення існуючих або розробки нових видів морозива в широкому діапазоні зміни хімічного складу шляхом застосування принципово нових функціонально-технологічних інгредієнтів. Експертна система дає змогу у виробничих умовах з мінімальними витратами часу розраховувати оптимальні за

хімічним складом рецептури морозива гарантованої якості з урахуванням наявної сировини. Сформована в експертній системі база знань надасть можливість покращити структуру харчування населення за рахунок виключення з рецептурного складу морозива хімічно-модифікованих і синтезованих харчових добавок та їх заміни на натуральні біологічно повноцінні інгредієнти вітчизняного виробництва.

Висновки. Використання експертної системи у виробничих умовах дасть змогу постійно оновлювати та накопичувати знання експертів-технологів, які працюють у даній сфері. Постійне накопичення нових знань про рецептури морозиво дасть можливість створювати та розширювати партнерські програми з вітчизняними й зарубіжними підприємствами. Експлуатація експертної системи забезпечить скорочення витрат на моделювання нових рецептур морозива.

Ключові слова: *морозиво, рецептура, експерт, система, база знань, база даних.*

Інноваційний локальний метод регулювання змінної напруги

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Вступ. Підвищити ефективність систем електропостачання доцільно шляхом імпульсного регулювання напруги.

Матеріали і методи. Базові аспекти досліджень – несинусоїдність напруги, що впливає на якість напруги в мережі. Використані ряди Фур′є для досліджень, використовувались матрична алгебра, теорія графів, положення теорії автоматичного керування.

Результати і обговорення. Шляхи підвищення ефективності виробництв за рахунок зниження технологічних втрат, викликаних неякісною напругою досліджені. Спосіб підвищення якості напруги – застосування імпульсного регулювання. Застосування напівпровідникових приладів дозволяє усунути ряд недоліків механічного перемикаючого пристрою (невисоку швидкодію, низький ресурс) і залишити основну його перевагу – синусоїдність форми кривої напруги. Можливість з допомогою напівпровідникових пристроїв здійснювати комутацію без спотворення синусоїди у момент переходу через нуль дозволяє усунути і такий суттєвий недолік механічних перемикачів – дискретність. Це дає змогу виконати стабілізатори напруги будь-якого ступеня точності, засновані на принципі дискретного регулювання перемиканням відпайок трансформатора без розриву струму і спотворення кривої напруги.

Висновки. Результати дослідження рекомендуємо застосовувати з метою підвищення ефективності використання електроенергії.

Ключові слова: *змінна напруга, гармоніка, електропостачання, регулювання.*

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Стаття виконується в редакторі Microsoft Word 2003 в форматі ***.doc**.

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Структура статті:

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3. *Установа, в якій виконана робота.*
4. Анотація. Рекомендований обсяг анотації – пів сторінки. Анотація повинна відповідати структурі статті та містити розділи Вступ (2–3 рядки), Матеріали і методи (до 5 рядків), Результати та обговорення (пів сторінки), Висновки (2–3 рядки).
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Посилання на статтю

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.

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1. Donchenko L.V. (2000), Tekhnologiya pektina i pektinoproduktov, Deli, Moscow
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Посилання на електронний ресурс

Виконується аналогічно посиланню на книгу або статтю. Після оформлення даних про публікацію пишуться слова **available at:** та вказується електронна адреса.

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
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