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Contents

Influence of modified starches on the state of water in sponge cakes

Iryna Strilets

National University of Food Technologies, Kyiv, Ukraine

Corresponding author:

Iryna Strilets
E-mail:
irina_sam@bk.ru

Abstract

Introduction. This article describes the effect of modified cold swelling starches on the redistribution of moisture in the sponge cakes. In order to predict product storage process investigated their sorption properties.

Materials and methods. The amount of free and bound water was calculated on the basis of derivatographic analysis with considering the effect of layered warming of dough pieces. The study was carried out on a sorption and vacuum devices of Mak Ben at 20 ºC temperature using the traditional methods. Water vapor was used as an adsorbtive.

Results and discussion. We have studied influence of crosslinked types of cold swelling starches: hydroxypropylated distarch phosphates (Microlys FH 02), acetylated distarch phosphates (Swely Gel Soft), acetylated starch adipate (Cold Swell 5771) to changes in water conditions in the sponge cakes.

Studies have shown that cross-linked modified starches cold swelling, thanks to its ramified spatial structure, are able to rapidly bind and retain moisture. The adding of 1% of starches to flour weight to an increase in amount of bound water in the product up to 7.17...13.23%.

Sorption properties of sponge cakes with the addition of modified starch significantly improved. Due to the interaction of starch with the components of flour and the formation of stronger ties with the water, the improvement of the sorption properties of the sponges with added modified starch was noted. The total amount of adsorbed water for modified starch products increased up to 3.14 cm^3 / 100g «Cold Swell 5771», up to 5.67 cm^3 / 100g «Swely Gel Soft» and up to 18,97 cm^3 / 100g «Microlys FH02».

Conclusion. Positive impact of crosslinked modified starches on moisture distribution in the finished product, which improves the extension of fresh sponge cakes, was proved.

Introduction

In the process of development of new types of flour products and improvement of existing technologies, one of the main objectives is to extend the shelf life of the finished product. For sponge cakes an important parameter is the content of moisture in the finished product, as well as the ratio of free and bound water and sorption properties of the product, since it is known that these parameters affect the shelf life of products of flour group [1].

In the production of semi-finished sponge cakes important role have supplements, which can retain moisture and reduce staling of finished products. Among hydrocolloids, which influence the redistribution of moisture in the product separate a group of modified starches. Thanks to its properties modified starches is widely used for production of various food stuffs [2, 3, 4, 5].

We have conducted research on the study of influence of crosslinked types of starches: hydroxypropylated distarch phosphates (Microlys FH 02), acetylated distarch phosphates (Swely Gel Soft), acetylated starch adipate (Cold Swell 5771) to changes in water conditions in the sponge cakes.

Analysis of recent research and publications

Staling products is a significant problem for manufacturers of flour products. It is held a number of studies, the purpose of which is to study the staling process of products and find ways to maximize time to preserve their freshness. It is known that bread staling is a complex phenomenon in which multiple mechanisms operate and water plays an important role in the process, causing staling [6, 7].

To improve the quality of the finished product and maintain its freshness researchers use various additives and raw materials.

To reduce staling of bread it was studied the usage of combination of chitosan with ascorbic acid. Changes of tightly and loosely bound water relative content in bread were studied using differential scanning calorimetry method. The authors recorded a decrease rate of staling of bread, which is explained by the decrease of free water in the bread. [8]. Earlier studies have also talked about the fact that the structural changes in bread during storage connected with the loss of 'free' water. These results have also been confirmed using differential scanning calorimetry [9]. Many researchers say that the ratio of free and bound water has an impact on the speed of staling of bakery products. Therefore, to reduce staling rate there are offered various additives capable of binding free moisture.

Recently, in the food industry it has been widely used modified starches. Among them are a special group – cross-linked starches. Properties of cross-linked starch types were widely studied by scientists for their practical application in industry [10, 11]. Various kinds of modifications have different effects on the properties of starch. Often, to obtain the desired characteristics of modified starch they use dual modification. It is proved that the procedure used to prepare dual-modified starches also affected the product properties [12, 13].

Change in functional properties of starches depends on source and granule morphology of native starch. Scientists have found out that among the starches from different cultivars, the change in the rheological parameters after acetylation differed to a significant extent. The retrogradation was observed to be negligible in the 4acetylated cooked starch pastes [14, 15].

In scientists' research [16] was studied the effects of degree of modification on the physico-chemical properties of hydroxypropylated potato di-starch phosphates. It has been

discovered that cross-linking improves the texture and temperature resistance of native starches. The effects of degree of modification on the physico-chemical properties of chemically modified starches (hydroxypropylated potato di-starch phosphates) are studied by dynamic viscoelasticity measurements and differential scanning calorimetry (DSC). Even a slight modification can retard the retrogradation remarkably.

Study of properties of distarch adipate showed that solubility in water and swelling power of the cross-linked preparations of distarch adipate, as well as pasting temperature and viscosity of produced pastes, all decreased along with the increasing degree of substitution with adipic acid residues. Scientists discovered that esterification with acetic anhydride and adipic anhydride (E 1422 starch) caused the most pronounced changes in physicochemical parameters compared with native potato starch powder. In native and E 1422 starches, mean granule diameter changed from 23.1 to 25.4 μm, shape factor from 1.47 to 1.33, specific surface from 0.2115 to 0.1695 m2 g−1, porosity from 41.31% to 45.29%, water absorption increased up to 50%.

In order to use a distarch phosphates in sponge cake technology were studied hydrophilic and sorption properties of cross-linked types of starches: hydroxypropylated di-starch phosphates (Microlys FH 02), acetylated di-starch phosphates (Swely Gel Soft), acetylated starch adipate (Cold Swell 5771). The results showed that it is advisable to use those starches in the preparation of sponge cakes [18].

The aim of this work was to study influence of the di-starch phosphates the number of bound and free water in biscuits, as well as their sorption properties. hydrophilic and.

Materials and methods

The calculation of bound and free water. To calculate the amount of free and bound water a method developed by the authors [Strilets I., Koretska I., Mank V., Zinchenko T., Patent 98522 U, A21D 13/00 (2015.04), Sposib rozrakhunku volohy v boroshnianykh vyrobakh], which is based on derivatografic analysis, was used. This analysis is based on the simultaneous measurement of mass and enthalpy of the studied material during heating process. During derivatographic analysis for a single sample simultaneously are recorded four curves: DTA - enthalpy change, TG - mass change, DTG - the rate of weight change and T - temperature (Pic. 1, a). For the calculation of the values DTG curve.

The first bend (A) corresponds to a decrease in the speed of removal of free moisture, and the peak of the curve (point B) shows a decrease in the rate of evaporation of moisture-related. On the DTG curve it is proposed to conduct a baseline CD, find the peak and inflection that characterize the change of physical and chemical changes in the product (Pic. 1b).

A   **B**
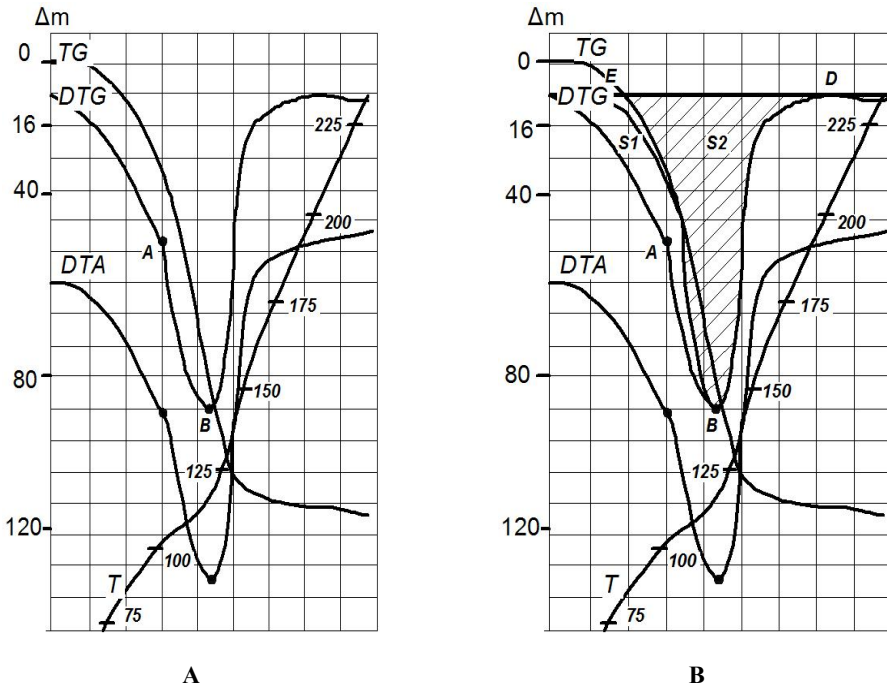
Figure 1. Thermogram of the test sample:
A - basic curves obtained as a result of derivatographic analysis;
B - receiving Area S_1 and S_2 on the line DTG

It is known that free water in the product is removed by layers. Therefore, at point A (the top of the first bend) the rate of removal of free water is decreses, but not completely stop. Given the emergence of a parallel process of evaporation of various forms of water, from the point of the main peak (B) we offer to hold the curve BE symmetrical to the line, which characterizes the decrease in the rate of mass change of the BD, and assume, that the EBD figure area (S_2), which is obtained as a result, represents the amount of bound water in the sample. We'll also assume that the area of the formed curve CBE (S_1) corresponds to the amount of free moisture removed. To calculate the total amount of moisture removed (as an absolute value in mg) it can be used TG curve. For the calculation of the total area, which characterizes the entire removal of moisture (in relative terms), you can use the sum of the areas S_1 and S_2. Estimates provide a graph (Pic. 2), which shows the dependence of the rate of removal of free and bound moisture from temperature (the temperature at a certain point can be found in a way of designing a line of temperature change T (Pic. 1)).

For the calculation of S_1 and S_2 areas let's use the integration on the respective intervals. But since the function is specified in tabular form (no analytic form), then to find the exact integral is not possible (Pic. 2). Roughly calculate the integral is possible by means of quadrature formulas of Newton-Cotes. To calculate these functions, we used the method of Simpson, which is considerably more accurate in comparison with other:

$$\int_{x_0}^{x_n} f(x)dx = \frac{h}{3}[f_0 + f_n + 2(f_2 + f_4 + ... + f_{2k-2}) + 4(f_1 + f_3 + ... + f_{2k-1})]$$

(1),

where $x_1, x_2...x_n$ – arguments of function are used as interpolation points;

$[x_0...x_n]$ – function interval;

h – step size for measuring argument (in this case, is constant for all measurements);

$f_0...f_n$ – values of the functions at the nodal points stated in a particular table.
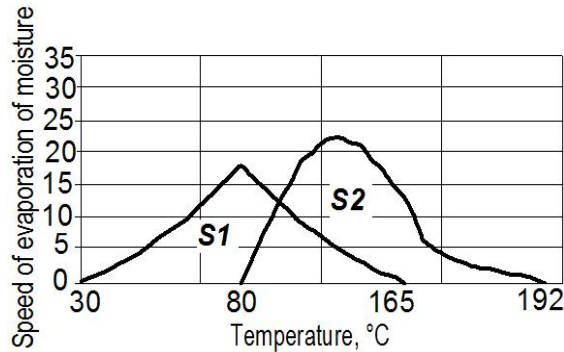
Figure 2. Functions that characterize the removal of free (S_1) and bound (S_2) water obtained from curve derivateur DTG

To determine the relative value of free and bound moisture of values of the areas calculated by the formula, compare.

Sorption-desorption properties of the sponge cakes were determined on Mac Ben's sorption-vacuum system, where on previously dehydrated samples at 20 °C and under pressure 0...18 mm Hg sorption and desorption of water vapor in equilibrium conditions were conducted. When analyzing the adsorption-desorption isotherms of water Langmuir equation was used to calculate the amount of adsorbed moisture in monolayer

$$a = a_m \cdot B \cdot a_w / (1 + B \cdot a_w), \ mole\text{-}rat/g \tag{2},$$

where a - number of substance, which was adsorbed for some water activity, mmol /g; a_m – the amount of adsorbed substances needed to cover the surface layer of dense monomolecular, mole-rat /g; B - constant, which is characterized by the interaction energy of adsorbate and adsorbent (adsorption energy); a_w - water activity, directly connected with the relative equilibrium vapor pressure of water $a_w = p/p_s$.

To describe the phenomena of adsorption for secondary humidities empirical Freundlich equation was used

$$a = K \cdot (a_w)^{1/n}, \ mole\text{-}rat/g \tag{3},$$

where a - number of adsorbed water mmol /g; K - constant characterizing the adsorption energy; a_w - activity of adsorbed water; 1/n - constant characterizing intensity of adsorption.

Water activity was established by graphical approximation out of Freundlich equation

$$lg \ a = lg \ b + 1/n \cdot lg \ a_w , \tag{4},$$

where a - is adsorption figure (mmol / g); b and n – activity of water (fixed values); a_w - equilibrium concentration of substances in solution (water activity) mmol /dm^3.

Result and discussion

To conduct the analysis the sponge cakes were prepared with addition of 1% of modified starch to flour weight. As a control, there was used a biscuit without adding additives. Thus obtained sponge cakes were examined for derivatograph. The processed data of derivatograms, obtained data by the method described above, got the features, which characterize the rate of removal from the product of free and bound water when heated (pics.3-6).
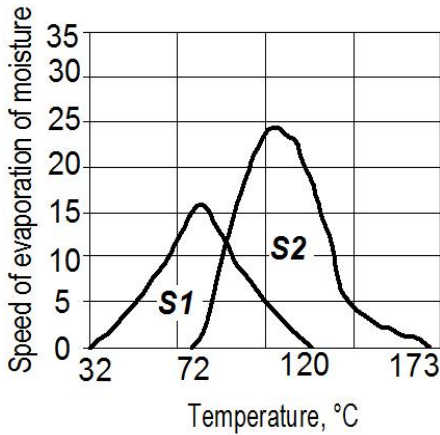
Figure 3. Graphic representation of evaporation free (S₁) and bound (S₂) moisture for Control sample
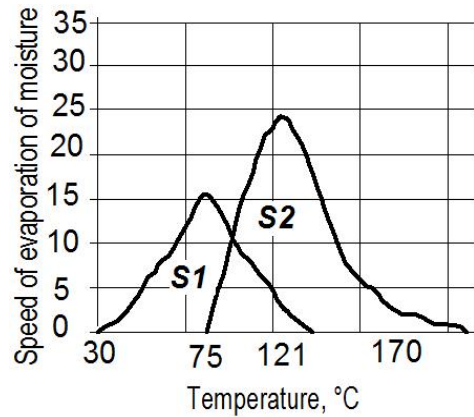
Figure 4. Graphic representation of evaporation free (S₁) and bound (S₂) moisture for «Microlys FH 02»
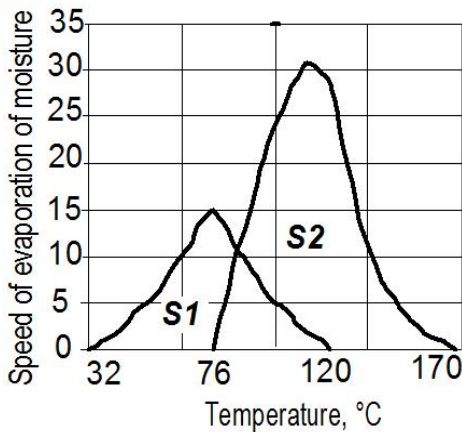
Figure 5. Graphic representation of evaporation free (S₁) and bound (S₂) moisture for «Swely Gel Soft»
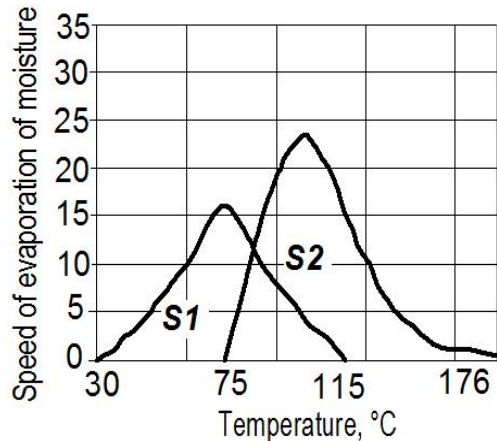
Figure 6. Graphic representation of evaporation free (S₁) and bound (S₂) moisture for «Cold Swell 5771»

As it can be seen from the pictures, the amount of bound water in biscuits exceeds the number of free water. According to pictures, the evaporation of the bound water starts when the temperature reaches above 75 ° C, the rate of free water evaporation reduces.

The calculation results are shown in Table 1.

Table 1

Characteristics of water state in sponge cakes samples

Name	Amount of free water (on surface S_1), conventional units	Amount of free water as fot the total amount, %	Amount of bound water (on surface S_2), conventional units	Amount of bound water as fot the total amount, %
Control	241,3	44,15	305,2	55,85
Sponge cake with MS «Microlys FH 02»	203,0	36,98	346,0	63,02
Sponge cake with MS «Swely Gel Soft»	199,0	30,92	444,5	69,08
Sponge cake with MS «Cold Swell 5771»	209,3	35,19	385,5	64,81

The water state analysis showed that, due to addition of the studied starches, the amount of bound water in the sponge cakes increases. When adding MS «Microlys FH 02» the number of bound water increases by 7.2%. When adding MS «Swely Gel Soft» and MS «Cold Swell 5771» it increases by 13.2 and 9% respectively. Due to its branched structure of spatial data modified starches are able to quickly associate the cold water, as well as interact with the particles of flour, which has a positive effect on the formation of stronger bonds with water in the system.

It is known that the increase of the number of bound water will help to reduce drying of products during storage. One of the methods, that allows to predict the behavior of water in the product during storage, it is the study of sorption-desorption properties.

The study of sorption-desorption properties gives an idea about the changes in the finished product during storage, in particular, the rate of water loss or its absorption. The rate of water loss affects the staling process.

Considering the water adsorption isotherms of finished products as a process that takes place in several stages, we characterized isotherms by three conventional zones of sorption. In the analysis of adsorption isotherms calculations were performed of absorbed water equivalent to 100 g for dry matter. Also, the calculation was performed on 100 g of semi-product under conditions, that are close to the conditions of storage (Aw = 0,7...075). The calculated data are presented in Table 2.

Number of adsorbed water in different samples of biscuit

Name	Amount of water, c3/100g					
	I zone $Aw = 0\ 0,2$ $W = 0...20\%$	II zone $Aw = 0,21...0,65$ $W = 21...65\%$	III zone $Aw = 0,65...1,0$ $W = 65...100\%$	Amount of adsorbed moisture under $Aw = 0.75$	Total amount of adsorbed moisture	Remainder after moisture adsorption
Sample of «Microlys FH02» (W = 25,4)	3,68	13,37	64,72	23,01	81,77	1,30
Sample of «Swely Gel Soft» (W = 25,1)	3,16	11,01	54,30	18,95	68,47	1,58
Sample of «Cold Swell 5771» (W = 25,3)	3,22	10,94	51,78	18,72	65,94	1,46
Control (W = 25,0)	3,02	9,99	49,79	17,52	62,80	1,37

The obtained isothermal data suggest that most of the moisture is absorbed into the third zone. In the first zone (monomolecular adsorption), which is characterized by the most tightly bound water, the percentage of absorbed water is minimal.

In the second zone (multimolecular layer) absorption of moisture is increased. Biscuits, containing modified starch, absorb more of its amount compared with the control. With the addition of MS «Microlys FH02» amount of absorbed moisture in polylayer increases by 3.38 cm^3 / 100g of dehydrated product. With the addition of MS «Swely Gel Soft» and MS «Cold Swell 5771» at 1.02 and 0.95 cm^3 / 100g of dehydrated product, respectively.

In the third zone, which is characterized by less bound water, the amount of adsorbed moisture is 78.5...79.3% of the absorbed water. We believe, that during the storaging of biscuits, first will be deleted any water that is the least mighty bound. Studies show, that, when adding «Microlys FH02» the amount of sorbed water in the third zone increased compared to control at 14.93 cm^3 / 100 g, while by adding «Swely Gel Soft» and IC «Cold Swell 5771» to 4.51 cm^3 / 100 g and 1.99 cm^3 /100 g, respectively.

Distarch phosphates positive impact on the increase in the number of bound water in biscuits and improvement of their sorption properties is explained due to high kinetics of swelling in cold water and hydrophilic of stated starches, which were studied previously. The branched spatial data structure of starches allows them to interact with the particles of flour and form a strong bond with water (increasing of the binding energy) that is capable of holding more moisture due to a hydrogen bonding, and mechanical (spatial) binding.

Conclusions

On the shelf life of bakery products affects their drying speed rate, which depends on the state of water in the food system. Identifying of forms of water into the product is critical to its quality management.

Ability of studied starches rapidly bind large amounts of water will have positive impact in the production of sponge cakes, as the increased percentage of bound water has a positive impact on the performance of the finished product quality and reduce drying of products during storaging.

Researching states of water in sponge cakes with addition of modified cold swelling starches showed increasing of bound water quantity in the product up to 7.17...13.23%.

During study of the sorption properties of the finished sponge cakes it was set that sorptive capacity of sponge cakes, which were prepared with the addition of modified starch, improved. The total amount of adsorbed water for products with modified starch increased up to 3.14 cm^3 / 100g for «Cold Swell 5771», up to 5.67 cm^3 / 100 g for «Swely Gel Soft», and up to18, 97 cm^3 /100g for «Microlys FH02».

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Determination of antioxidant activity of solids extracts obtained from sunflower cakes

Dmytro Dobrunov, Leonid Perevalov, Olena Piven

National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine

Abstract

Introduction. The aim if this work is to determine the antioxidant properties of extracts obtained from sunflower cakes processed in the cavitation facility.

Materials and methods. Sunflower seeds (breeded NK-Brio) were cooled with liquid nitrogen then dehulled. Further dehulled sunflower kernels were pressed using an extruder. Obtained sunflower cakes were processed in the cavitation facility (with solvents – hexane and ethanol), where 4 samples of "Solids extracts obtained from sunflower cakes" (SESC) were derived.

Results and discussion. Due to unknown nature of the antioxidants present in the obtained SESC the authors could only expect the certain composition of the obtained SESC (tocopherols, chlorogenic acid, phospholipids, etc.). On that basis, the calculations of inhibitor concentrations ([*InH*]) were made in α-tocopherol equivalent. To determine the antioxidant properties of SESC a series experiments initiated oxidation of the model hydrocarbon with addition of SESC and without them. To determine the antioxidant properties of SESC a series of experiments with the initiated model hydrocarbon (cumene) oxidation with the addition of SESC and without SESC was carried out. The obtained experimental data confirmed the presence in SESC of substances with antioxidant properties such as: tocopherols, sterols, chlorogenic acid, and phospholipids. The presence of phospholipids in the obtained SESC was confirmed by the fact that the residue oil in the meal obtained after processing in the cavitation facility was 0.9%. Moreover, the extruded oil contained only 0.05% of phospholipids. That means that almost all of the phospholipids were extracted to the obtained SESC. The composition of SESC was investigated by HPLC. The constants of chain termination (k_7) of 4 SESC samples ranged from $1.0 \cdot 10^5$ l/mol·s to $1.6 \cdot 10^5$ l/mol·s. For the most known natural antioxidant − tocopherol k_7 ranges from $0.7 \cdot 10^5$ to $3 \cdot 10^5$ l/mol·s. The meanings of the constants of chain termination (k_7) show that all of the SESC samples are the inhibitors that are close to tocopherol. That means that all of the obtained SESC are oxidation inhibitors and slow down the chain reaction during the propagation step.

Conclusions. SESC can be used to prevent the oxidatidative deterioration of different oil-containing foodstuff and increase their shelf-life.

Introduction

Increasing of shelf-life of different foodstuff is one of the crucial aims of modern food industry.

Addition of substances that cause slow-down of oxidative deterioration of different fat-containing foodstuff (especially during their storage) is one of the effective methods that help manufacturers to increase the shelf-life of that foodstuff. These substances can be of antioxidants nature. [2]

The aim of this work is to research antioxidant activity of solids extracts obtained from sunflower cakes by using cavitation facility.

Literature review

Antioxidants are substances that when present in foods or in our body at low concentrations compared with that of an oxidizable substrate markedly delay or prevent the oxidation of that substrate.

Antioxidants are known to act at different levels in the oxidative sequence involving lipid molecules. They may act by decreasing oxygen concentration, intercepting singlet oxygen, preventing first-chain initiation by scavenging initial radicals such as hydroxyl radicals, binding metal ion catalysts, decompressing primary products to non-radical compounds, and chain-breaking to prevent continued hydrogen abstraction from substances. The extent to which oxidation of lipids occurs also depends on the chemical structure of the fatty acids involved as well as other factors related to the storage of foods and reaction conditions. [1, 3]

Lipid oxidation has been recognized since antiquity as a challenging problem in the storage of fats and oils and lipid-containing foods. Characteristic changes associated with oxidative deterioration of vegetable oils and animal fats include development of unpleasant tastes and odors as well as changes in color, viscosity, specific gravity and solubility [2].

Autoxidation is a natural process that takes place between molecular oxygen and unsaturated fatty acids. Autoxidation of unsaturated fatty acids occurs *via* a free radical process whose basic steps are initiation, propagation, and termination. Initiation starts with the abstraction of a hydrogen atom adjacent to a double bond in a fatty acid (RH) and this may be catalyzed by light, heat, or metal ions to form a free radical. The resultant alkyl free radical (R*) reacts with atmospheric oxygen to form an unstable peroxy free radical which may in turn abstract a hydrogen atom from another unsaturated fatty acid to form a hydroperoxide (ROOH) and a new alkyl free radical. The new alkyl free radical initiates further oxidation and contributes to the chain reaction. The chain reaction (or propagation) may be terminated by formation of non-radical products resulting from the combination of two radical species [4].

The mechanism of lipid autoxidation has been described in [2]. The propagation step in the autoxidation process includes an *induction* period in which hydroperoxide formation is minimal [2, 4]. The rate of oxidation of fatty acids increases in relation to their degree of unsaturation. The relative rate of autoxidation of oleate, linoleate, and linolenate is in the order of 1:40-50:100 on the basis of oxygen uptake and 1:12:25 on the basis of peroxide formation. Therefore, oils that contain relatively high amounts of polyunsaturated fatty acids (PUFA) experience stability problems. The breakdown products of hydroperoxides such as alcohols, aldehydes, ketones, and hydrocarbons generally possess offensive off-flavors. These compounds may also interact with other food components and bring about changes in their functional and nutritional properties [4]. A generalized scheme for

autoxidation of food lipids which also illustrates some of its possible consequences is shown in Fig. 1.

Antioxidants work by different mechanisms. These involve inactivation of prooxidants in the medium such as carotenoids that scavenge singlet oxygen or chelators that inactivate metal catalysts. These reactions lead to a delay in the onset of oxidation and the extension of the induction period. Antioxidants may also donate a hydrogen atom or an electron to radicals formed from unsaturated lipids, thus imparting stability to food lipids [2, 3, 5].

RH

Initiation | Abstraction of H atom

Initiators (UV light, $^1O_2$, metal catalysts, heat, etc.)

R*(lipid free radical) ———→ Termination

$^3O_2$

ROO* ———→ Dimers, polymers, cyclic hydroperoxides, hydroperoxy compounds

RH

Cleavage

ROOH (Hydroperoxides) ———→ Aldehydes, ketones, hydrocarbons, furans, acids

ROOR, ROR, dimers ←——— RO* ———→ Keto, hydroxy and epoxy compounds, etc.

Cleavage

Aldehydes | Semyaldehydes or oxo esters | Alkyl radicals

O_2 | Condensation | Hydrocarbons | O_2

Alkyltrioxanes and dioxolanes

Terminal ROOH

Hydrocarbons, shorter aldehydes, acids, epoxides

Hydrocarbons, aldehydes, alcohols

Fig. 1. Generalized scheme for autoxidation of unsaturated lipid fatty acids and its consequences [2].

Nowadays one of the perspective sources of natural antioxidants is secondary oil-containing stock-material such as sunflower meal. Defatted meals are the source of edible proteins. But according to the nature of sunflower seeds a group of additives which can show antioxidant properties can be obtained while processing.

Phospholipids. Phospholipids compose the structural lipids of the plant cell membrane. Phospholipid content of seed oil can be up to 10% of total lipids depending on the type of seed. Several studies have indicated that phospholipids chelate trace metals, thus acting as a secondary antioxidant, and subsequently increase oxidative stability of the oil. Acidic phospholipids such as phosphotidylinositol can form inactive complexes with metals but not with phosphotidylcholine or phosphatidylethanolamine. However, it has been well established that phospholipids can act as synergists with tocopherol and flavonoids. Therefore, it has been suggested that phospholipids may act as antioxidants by releasing protons and bringing about rapid decomposition of hydroperoxides without the formation of free radicals. It should also be noted that surface activity of phospholipids at the air-oil interface or water-oil interface might also be involved in antioxidative activity of phospholipids in bulk oils and emulsion systems. The residual amount of phospholipids can be found in sunflower meal after sunflower oil processing [2].

Phenolic compounds. The most active dietary antioxidants belong to the family of phenolic and polyphenolic compounds [1]. It was determined that the presence of phenolic compounds in sunflower meal is ranging from 1 to 4% [6].

Tocopherols occur widely in plant tissues and are monophenolic as well as lipophilic compounds. Tocopherols and tocotrienols, collectively referred to as tocols, are classified into α, β, γ, or δ depending on the number and position of the methyl groups attached to the chromane rings. In tocopherols, the side chain is saturated whereas in tocotrienols it is unsaturated. Tocopherols are important biological antioxidants with vitamin E activity. α-Tocopherol, which exhibits maximum vitamin E activity, prevents oxidation of lipids in vivo including polyunsaturated fatty acids and lipid components of cells and organelle membranes. [3]

Chlorogenic and *Caffeic acids* are the dominant polyphenolic compounds in the sunflower protein isolates. These substances cause significant changes in color of the meal, proteins and food matrices during their extraction and use as food additives. Moreover, these substances reduce the nutritional value of the end product due to their interaction with some of amino acids such as lysine and methionine. Thus, the removal of these undesirable substances is important to enable the use of sunflower meal in different food applications and replacing more expensive protein sources such as soy protein [6−9]. That's why removing of Chlorogenic and Caffeic acids and other polyphenols and additives from sunflower meal can solve two different problems: the removal of undesirable components from sunflower meal and obtaining of antioxidants for different uses [10, 11].

Sterols. Sterols are components of the unsaponifiable fraction of plant lipids. Although not effective as traditional antioxidants at room temperature sterols (α3-avenasterol, fucosterol, citrostadienol) are reported to have antipolymerization activity in heated oils. The unsaponifiables isolated from olive, corn, wheat were effective in protecting safflower oil from oxidative polymerization during heating at frying temperatures. It has been suggested that donation of a hydrogen atom from the allylic methyl group in the side chain of sterols, followed by isomerization in a relatively stable tertiary allylic free radical represents the mode of activity of sterols as antioxidants [2]

Antioxidative compounds of oilseeds can be of great value as natural antioxidants. The safety of these compounds has been proven by prolonged and continuous use. Antioxidants

of oilseeds can be considered in two ways. They can be used to prevent oxidation of fat-containing foodstuff, thus replacing synthetic antioxidants. Similarly, these compounds, once incorporated into living cells, enhance the antioxidative status of the body, thus improving its defense capability against oxidative damage [2].

The knowledge concerning extraction of the antioxidants from sunflower cakes using cavitation method is highly limited [12].

To provide the cavitation treatment of sunflower cakes (protein extraction) the authors used the described below *cavitation facility*. It is now common knowledge that controlled turbulence and cavitation in a circulating fluid flow are attended with a heat evolution, so the cavitation facility is suitable for dispersing plant seeds and simultaneously heat treating the resulting dispersions. Nevertheless, where the hydrodynamic cavitation stimulator is connected to the upper portion of the flow-through vessel having an invariable cross section adjacent its symmetry plane from top to bottom, the dispersing action practically ceases within the vessel to necessarily result in a dead zone adjacent to the bottom and in a sediment of coarse particles. Prolongation of the dispersing action in turbulent flow (due to collisions of particles in a vortex like motion) and a substantial decrease in sediments at the bottom (due to partially stirring it up) have been to some extent gained by way of whirling the flow of the liquid medium. This has been achieved in a flow-through device having an axially symmetric process chamber (Patent No. US 7,428,797 B2, *Method for Dispergating Plant Seeds And Device for Carrying Out Said Method*, Published on Sep. 30, 2008).

Materials and methods

Materials. Sunflower seeds used in the frame of this work were of breeded NK Brio line delivered from the *private farm* (Maliye Prohody, Ukraine). Seeds with initial moisture content of 7% (wet-basis) were separated from the additives on the sieves.

The solvents used in this work were: hexane (chemically pure, produced by Brenntag, AG.) and ethanol (96%, produced by "PRIME" Distillery, Ltd., Malinivka, Ukraine.)

Samples preparation. Sunflower seeds were cooled with liquid nitrogen at a temperature of -30°C. Then the seeds were dehulled using centrifugal dehulling machine [13]. Further obtained dehulled kernels (phospholipids content, in stearo-oleo-lecitin equivalent, 0.7%) were pressed at an extruder. After that stage the extruded oil (phospholipids content, in stearo-oleo-lecitin equivalent, 0.07%), and sunflower cakes (oil content 8.5%, moisture content 4.5%) were obtained. Further, the cakes were processed with solvent (ethanol [14], hexane) or mixture of solvents in the *cavitation facility* (Patent No. US 7,428,797 B2, *Method for Dispergating Plant Seeds And Device for Carrying Out Said Method*, Published on Sep. 30, 2008). After that the suspension obtained from the cavitation facility was divided into three fractions: filtered and dried meal (residue oil content 0.9%, moisture content 1.6%), miscella and extracted sunflower oil. Finally miscella was divided by solvent evaporation and the residue was dried. The obtained residue was named as "Solids extract obtained from sunflower cakes" (SESC).

The obtained samples of SESC differed in follows:

Sample No.1 − SESC obtained after solvent mixture (hexane/ethanol 1/9 vol./vol.) evaporation;

Sample No.2 – SESC obtained after ethanol evaporation;

Sample No.3 – SESC obtained after solvent mixture (hexane/ethanol 1/1 vol./vol.) evaporation;

Sample No.4 − SESC obtained after solvent mixture (hexane/ethanol 9/1 vol./vol.) evaporation.

Oxidation rate determining. This method is used to determine the concentration of inhibition groups of antioxidants present in oils, fats, margarines and other model systems ranging from 10^{-5} to $5 \cdot 10^{-3}$ mol/kg and absolute error $0.2 \cdot 10^{-3}$ mol/kg.

Also, together with the inhibition potency determining, this method allows to determine the quality indicators of the antioxidants – the constants of chain termination (k_7).

The method is based on the gasometric measuring of oxygen amount absorbed by the model hydrocarbon during the oxidation. The oxidation reaction rate is determined by the amount of oxygen absorbed per the unit of time.

Choosing the Model System for Determination of Antioxidant Properties. Cumene (isopropylbenzene) was used as a model hydrocarbon. It was necessary to prove the purity of the model hydrocarbon before the main research.

Cumene Purifying. Cumene purifying was performed in several stages:

1. Repeated shaking with 10, 15, and 25% oleum solution in sulfuric acid until the mixture becomes transparent. During this operation a part of the initial hydrocarbon can sulphonate (up to 30%).
2. Flushing sequentially with 6% solution of sodium metabisulphite, and 4% solution of potassium permanganate in 8% alkali solution.
3. Flushing with with distilled water and drying over metallic sodium and distillation under vacuum at a temperature of about 60°C.

To check the purity of cumene the rate of its oxidation is determined. The process is carried out at 60°C, in the volume of 10 ml, and with addition of 10 mg of the initiator – 2, 2-Azobisisobutyronitrile (AIBN). The oxidation rate has to range from 6.3 to $7.9 \cdot 10^{-6}$ mol/l·s, or from 92 to 116 mm³/min.

AIBN Purifying

The AIBN initiator was sequentially recrystallized from ethanol and benzene and then dried up to constant weight under vacuum. There is no expiry date to the purified this way initiator.

Cumene Oxidation Carrying Out. Determination of cumene oxidation rate was carried out at the volumetric facility. The principal scheme of the volumetric facility is shown in Fig. 2.

Cumene oxidation was carried out according to following procedure:

Before every observation the volumetric facility is ventilated with oxygen. For this purpose the facility is connected with vacuum pump by valve (4).At this time valve (5) is closed. It is important to watch the changes in the height of the liquid column in the jacketed drop tube (7) while ventilating the facility. The volume mustn't change. Then valve (4) is closed and valve (6) is opened to fill the facility with oxygen. This operation is repeated for 5-6 times. Valve (3) is used when it is needed to throw off the vacuum (if valve (5) doesn't provide vacuum sealing).

According to the aim of research the oxidation temperature is chosen (in our case the temperature was set at the meaning of 75°C or 348 K), and the reaction vessel (1) working mode is set. The temperature in the drop tube (7) jacket sets at 25°C (298 K). 2 ml of the researched substance (cumene) pour into the reaction vessel (1). After that AIBN is added in the amount ranging from $2 \cdot 10^{-3}$ to $10 \cdot 10^{-3}$ mol/l. The amount of AIBN depends on the desirable oxidation speed. The reaction mixture (cumene + AIBN) is ventilated with oxygen (through specialized capillary) for 0.5-1 minute and quickly install into the pre filled (with oxygen) volumetric facility.
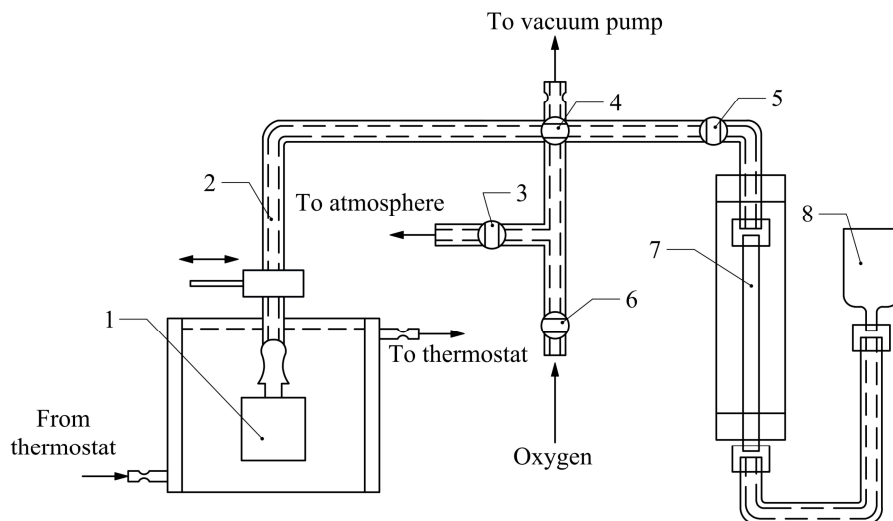
Fig. 2. Volumetric facility:
1 – Reaction vessel; 2 – Glass capillary; 3, 5, 6 – One-way valves; 4 – Triple valve;
7 – Jacketed drop tube; 8 – Leveling vessel

Observations carrying out. The reaction vessel (1) and the attached to the reaction vessel part of the glass capillary (2) of a 2 cm length are steeped into the thermostat where the temperature of the experiment is kept. The vessel is shaken at the frequency of 5 times per second to provide the oxygen saturation of the reaction mixture. When the vessel starts shaking the timer is turned on. At this time valve (3) is opened to provide the excess pressure drop off. After 2 minutes of thermostating the reaction vessel (1) and the jacketed drop tube (7) are turned off the atmosphere (valve (3) closed) and connected to each other with the triple valve (4) and valve (5). Then the oxygen absorption volume is measured by changes in the height of the liquid column in the jacketed drop tube (7).

Observations analysis. The speed of the liquid meniscus lifting in the drop tube is proportional to the rate of cumene oxygen uptake. After measuring the time in minutes and the volume of absorbed oxygen in ml the dependence between the amount of absorbed oxygen and time of the absorbtion ($\Delta O_2 / t$) is plotted. The cumene oxidation rate can be found as the tangent slope to the curve at the point corresponded to the time point. If the speed is constant, the dependence between the amount of the absorbed oxygen and the time is a straight line, and the reaction rate is equal to the slope ratio of this line. The calculated in this way reaction rate is written in mm^3/min or mol/l using the conversion factor

$$1 mm^3/min = \frac{2.7 \cdot 10^{-7}}{V_0} mol/l \,, \qquad (1)$$

where V_0 – volume of the reaction mixture, ml [15]

Determining of SESC antioxidant properties. The next step of the work was to study the effect of SESC on the oxidation rate of cumene. For this purpose, a series of

experiments with the initiated cumene oxidation with the addition of SESC and without SESC was carried out. The initiated oxidation of cumene was assessed by the speed of oxygen feed rate at the volumetric facility according to abovementioned method. To initiate the reaction of oxidation the initiator – 2,2-Azobisisobutyronitrile (AIBN, 0.1M solution) was used. The initiator was added in amounts of $4\cdot10^{-3}$ mol/l, $6\cdot10^{-3}$ mol/l, and $8\cdot10^{-3}$ mol/l respectively. Cumene oxidation was carried out at the temperature of 348 K. The obtained SESC were added in amount of 2% vol./vol.

The determination of the antioxidant properties was calculated according to the equation [17]

$$\frac{W_o}{W_i} = \frac{k_2 \cdot [RH]}{k_7 \cdot f \cdot [InH]}, \qquad (2)$$

where:

W_o – oxidation speed (mol/l·s)
W_i – initiation speed (mol/l·s)
k_2 – constant of chain propagation (l/mol·s)
k_7 – constant of chain termination (l/mol·s)
[RH] – concentration of hydrocarbon (mol/l)
[InH] –concentration of inhibitor (mol/l)
f – inhibition factor.

Results and discussion

Due to unknown nature of the antioxidants present in the obtained SESC the authors could only expect the certain composition of the obtained SESC (tocopherols, chlorogenic acid, phospholipids, etc.). That's why the calculations of [InH] were made in α-tocopherol equivalent (as most expectable). The results of the antioxidant properties are shown in tab. 1.

Table 1

Constants of chain termination for initiated cumene oxidation with addition of SESC

Sample No.	Constant of Chain Termination k_7, l/mol·s
1	$1.4\cdot10^5$
2	$1.6\cdot10^5$
3	$1.0\cdot10^5$
4	$1.0\cdot10^5$
α-tocopherol [16-17]	0.7-$3\cdot10^5$

According to tab. 1 all the constants of chain termination (k_7) of the SESC samples are close to those of the α-tocopherol. The meanings of the constants (k_7) are ranging from $1.0\cdot10^5$ l/mol·s to $1.6\cdot10^5$ l/mol·s. For tocopherol these meanings range from $0.7\cdot10^5$ to $3\cdot10^5$ l/mol·s. That means that all of the obtained SESC terminate the chain reaction which occurs at the propagation step.

The composition of the obtained SESC was investigated by using HPLC-method. The presence and composition of tocopherols and sterols were investigated. The results of HPLC are shown in Tab. 2 and Fig. 3.
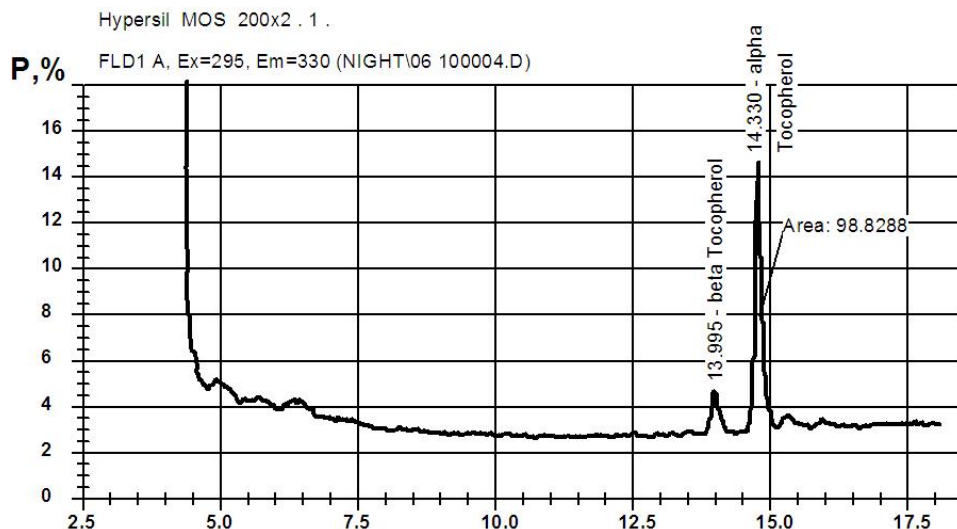
Fig. 3. HPLC for tocopherol composition of the obtained SESC

Table 2

HPLC for sterol composition of the obtained SESC.

Parameter	Amount,% wt./wt.	Relative error,%
Kampesterol	10,7	4
Stigmasterol	12,6	4
D-7-kampesterol	2,6	8
P-sitosterol	57,9	4
D-5 -avenasterol	3,7	8

Obtained experimental data confirms the presence, in the composition of the SESC samples, of substances such as: tocopherols (Fig. 3), sterols (tab. 2), chlorogenic acid [18], and phospholipids. The presence of phospholipids in the obtained SESC is confirmed by the fact that the residue oil in the meal obtained after processing in the cavitation facility was 0.9%. Moreover, the extruded oil contained only 0.05% of phospholipids. That means that almost all of the phospholipids were extracted to the obtained SESC.

Conclusions

In the frame of this work the antioxidant activity of 4 SESC samples was investigated. The obtained data shows the presence of different substances with antioxidant properties such as: tocopherols, sterols, chlorogenic acid, and phospholipids. All the constants of chain termination (k_7) range from $1.0 \cdot 10^5$ l/mol·s to $1.6 \cdot 10^5$ l/mol·s (for tocopherol (k_7) range from $0.7 \cdot 10^5$ to $3 \cdot 10^5$ l/mol·s) and show that all of the SESC samples terminate chain reaction during the model hydrocarbon oxidation and they show relatively strong

antioxidant properties. According to the obtained data all of the SESC samples contain antioxidants and can be used to prevent the oxidative deterioration of vegetable oils, confectionary fats, and other fat-containing confectionary foods [10, 11], and increase their shelf-life up to two times.

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Improving efficiency of the dry protein preparations hydrated with the electro activated water

Liudmyla Vinnikova, Kseniia Pronkina, Andrii Kyshenya

Odessa National Academy of Food Technologies

Corresponding author:

Kseniia Pronkina
E-mail:
pronkinakseniya@
gmail.com

Abstract

Introduction. In the contemporary production of the meat products there is a concern of the raw material quality. Development of the new technologies for production of the meat products using protein supplements is a promising and cost-effective trend.

Materials and methods. The dry protein preparations of different origin were studied: protein from the pig skin "Progel C-95" and soy protein "Supro 500E". The basic functional and technological properties of the protein preparations when hydrated with the electro activated water fractions were determined.

Results and discussion. Shifting the pH hydration medium of the dry protein preparations to the alkaline one using catholyte allowed improving the viscosity of the supplement samples, but the protein preparation of vegetable origin "Supro 500E" showed the best efficiency. The viscosity of this preparation was 35% greater than that of the reference sample.

Determination of the water-retaining and fat-retaining capacities of the supplements showed the best efficiency of catholyte in the supplement of animal origin "Progel C-95", which amounted to 95% and 42%, respectively.

Use of catholyte for hydration allowed increasing the emulsion capacity and stability of the emulsion in the most effective way in the protein supplement samples of animal origin "Progel C-95". The emulsion stability increased by 8% compared with the reference sample.

One measure of the economic efficiency of using the dry protein preparations is the critical gelling concentration. Efficient use of the supplements is inversely related to the critical gelling concentration index. In general, the use of catholyte reduced this index in all the preparations, but in the pig skin supplement sample "Progel C-95" it reached minimum, which amounted to 5%.

Conclusions. The proposed method to increase the functional and technological properties of the dry protein preparations using the alkaline fraction of the electro activated water proves its efficiency. The best results of improved efficiency of the supplements are determined by a number of indices in the preparation of animal origin "Progel C-95".

Introduction

In developing formulations for the meat products, the research investigations are of great importance, which study the functional and technological properties of the protein supplements of animal and vegetable origin. These investigations are a basis not only for making and improving the formulations, but also for reasoning the processes and modes for processing of the protein containing raw materials.

Analysis of literature

The problem of the low raw meat quality is most commonly found at the meat processing plants. Using PSE and DFD meat with the high fat and connective tissue content after the long-term storage of the poultry meat after mechanical deboning results in the lower quality and yield of the finished products, increased losses during the heat treatment. The water and fat pockets occur in the meat products, and the finished product has a loose or soft consistency. The most popular and effective way to improve the quality and reduce the cost of the meat products, primarily made of the low-grade raw meat, is adding extra proteins into the minced meat or pumping pickle. [3,5,8]

Proteins bind moisture, strengthen the protein matrix and allow to get a stable water-fat emulsion. In processing of meat and poultry, the proteins of animal and vegetable origin are used. [5,8,10]

Using the connective tissue proteins (collagen containing raw pork, pig skin powder) allows to compensate for the lack of the muscle proteins, increase the finished product yield and its strength while reducing the costs for the raw meat, stabilize the product quality, reduce losses during the heat treatment, the raw material and finished product prime cost, increase the nutrition and biological value of the meat products. [5,8,10,12]

Isolates of the connective tissue proteins are produced in the form of powder of the varying grinding degrees. As a rule, the fine powders are notable for their ability to evenly distribute in the cold water not forming gel. This advantage is used when preparing the pumping pickle. Powders with larger particles are used in the production of the minced meat products. They can be added to the minced meat as gel prepared both, by hot and cold method, in the form of a protein emulsion, protein-fat emulsion or granules. [12,14-17]

Essential are the components of the soy protein preparations. They are used in production of the cooked sausages, frankfurters, meat loaves, boiled-smoked and smoked sausages, different types of ham, pate, broth jelly, whole muscle products of beef, pork and poultry, canned meat and chopped half-finished products. The soy protein products are the most popular way to improve the quality of the meat products made of the low-grade raw meat. [14,16,19]

At the present stage of the meat production development, the most of the used supplements require prior hydration to get the stable emulsions, suspensions and multi-component systems. Improvement of the meat products manufacture technologies is stipulated by the use of the multi-component protein systems having the broad functional properties. [5,15,19]

Hydration of the protein supplements is a key stage in the formation of their functional properties, and, as a result, quality of the finished products. The quality of water used for hydration is decisively important in determining further functional properties of the supplements. [1,2,4,6]

The scientific reasoning for using the non-chemical methods to process water used for the technological purposes, offers great opportunities to improve the meat products

manufacture processes. Electro activation is the most environmentally friendly method to treat water because it does not require introducing any foreign chemicals into water. [4,6,7,9]

During the electro activation in the cathode chamber, water is enriched with the high-performance reducing agent, leading to formation of insoluble metal hydroxides, which precipitate. The light metal hydroxides (Na, K) do not precipitate and remain 100% dissolved. In addition, the direct recovery of the polyvalent cations takes place in the cathode chamber (deposition of the metal molecules). These processes manifold reduce the toxicity of water caused by presence of the heavy metals. In the anode chamber, water is saturated with the high-performance oxidizing agents. We know that anode has the most powerful electrolytic oxidation of all the organic matter destruction processes in water. The gases formed during electrolysis (destruction of microorganisms, salts decomposition) dissolved in water (CO_2, SO_2, NO_2, N_2, H_2S, Cl_2, O_2, H_2) evaporate in the electrode area. The final water electro activation products are the two factions - catholyte and anolyte. [9,11,13]

Catholyte has an alkaline pH, the oxidation-reduction potential (ORP) decreases, the surface tension reduces, the amount of oxygen dissolved in water decreases, hydrogen and hydroxyl ions (OH-) concentration increases, water conductivity decreases, the structure of water changes. In its extrinsic properties, catholyte is soft light water with the alkaline taste, sometimes with white residue; its pH = 10-11, ORP = -200 ...- 800 mV. In its physical and chemical parameters, catholyte is a solution with the advanced electron-donor properties able to enhance the electron-donor background by a few tens of millivolts when getting into the physiological fluids. The antibacterial action of catholyte is differentiated: it has bactericidal effect against the enterobacteria, group B enterococci and streptococci are resistant to it, and against the gram-negative microorganisms it has bacteriostatic effect only. [11,13]

Anolyte has an acidic pH, ORP increases, the surface tension of water slightly decreases, conductivity increases, the number of oxygen and chlorine dissolved in water increases, hydrogen concentration decreases, the structure of water changes. In its extrinsic properties, anolyte is brownish sour liquid with a characteristic odor and taste with pH of 2.3 and ORP = + 500 + 1100 mV. When heated to 50°C, the bactericidal anolyte activity increases by 30-100%. [11,13]

Materials and methods

The objective of the research was the technology of using the protein preparations of animal and vegetable origin. The subject studied was the protein preparations of animal and vegetable origin hydrated with the electro activated water fractions - anolyte and catholyte. The objectives assigned in the work were solved experimentally using the functional, technological and rheological methods. The protein preparations of animal and vegetable origin brought to the Ukrainian meat processing industry market and commonly used in the cooked sausages manufacture were involved in the research. In particular, protein from the pig skin "Progel C-95", and "Supro 500E", a protein preparation of vegetable origin - soy protein. As reference samples, ordinary tap water for drinking was used for hydration of the aforementioned supplements. Hydration was performed as recommended by the manufacturers and the viscosity, pH, water and fat retaining capacity, emulsion stability and critical gelling concentration were estimated.

The active acidity (pH) was determined by the potentiometric method using the laboratory pH meter. The viscosity of the dry preparations was determined using a rotational viscometer BCH-3.

The water-retaining capacity of the preparations (WRC) was determined as follows. A test portion of the hydrated preparation was placed in a thermostat with the temperature of 75 ± 1° C for 15 minutes. After that, the test portions were transferred into the centrifuge grids and centrifuged for 15 minutes at 1000 rpm. WRC was calculated by the following formula:

$$WRC = \frac{W_1 - W_2}{W_2}$$

where W_1 – hydrated preparation weight, g; W_2 – dry preparation weight, g.

The fat-retaining capacity of the preparations (FRC) was determined as follows. A test portion of the hydrated preparation was dispersed in 10 ml of vegetable oil for 1 hour. Then the cups were placed in a thermostat with the temperature of 75 ± 1° C for 15 minutes. After that, the test portions were transferred into the centrifuge grids and centrifuged for 15 minutes at 1000 rpm. FRC was calculated by the following formula:

$$FRC = \frac{W_1 - W_2}{W_2}$$

where W_1 – dispersed preparation weight, g; W_2 – hydrated preparation weight, g.

The stability of the emulsion (ES) was determined by heating the emulsion at the temperature of 75 ± 1° C for 15 minutes. Then the emulsions were water cooled to the room temperature and hold for 2 hours. The resulting emulsions were centrifuged at 2500 rpm. The stability of the emulsion was calculated by the following formula:

$$\eta = \frac{V_1}{V_2} \cdot 100$$

where V_1 - emulsified oil volume, cm^3; V_2 – total emulsion volume, cm^3.

Determining the critical gelling concentration (CGC) of the dry protein preparations was carried out by the standard method of gel destruction with a lead ball weighing 0.53 g. The method included making 10 suspensions for each hydrated preparation according to their water duty. The suspension concentration interval was 1%. The minimal concentration of the preparation where there was no gel destruction under pressure of a lead ball was taken for the critical concentration.

Results and discussion

According to the objective of the work, the basic functional and technological properties of the protein preparations hydrated with the drinking tap water (benchmark) and fractions of the electro activated water were determined. Such indices as the supplement's viscosity, water-retaining and fat-retaining capacity, stability of the emulsion and critical gelling concentration were estimated.

It is known that the dietary supplements "Progel C-95" and "Supro 500E" are the protein supplements of different type. "Progel C-95" is a protein preparation made from collagen, dry pig skin protein, and "Supro 500E" is a vegetable protein preparation made from soy protein. In the hydration they form colloidal solutions of different viscosity, so it is advisable to conduct a study and determine the change in the viscosity of these supplements when hydrating them with the electro activated water. Results are presented in Table 1.

Table 1

Change of the supplements' viscosity when hydrated with the electro activated water

Protein supplement	Viscosity, mPa·s			pH		
	Tap water (benchmark)	Catholyte	Anolyte	Tap water (benchmark)	Catholyte	Anolyte
Progel C-95	7,55	9,12	7,2	6,6	7,05	6,4
Supro 500E	4,95	6,68	4,62	6,7	6,9	6,6

The obtained data analysis showed that after hydration with catholyte, the viscosity index of "Progel C-95" increased by 21% and that of "Supro 500E" - by 35% compared with the benchmark. When anolyte was used, the viscosity of both supplements decreased compared with the reference samples, as follows: "Progel C-95" by 4.8% and "Supro 500E" by 7%. This effect can be explained by better solubility of proteins by changing the active acidity level of the protein preparations.

Studying the water-retaining capacity of the supplements is fundamental. This parameter is indicative of the supplement's efficiency.

The results of studying the water-retaining capacity of the hydrated protein supplements are given in Figure 1.
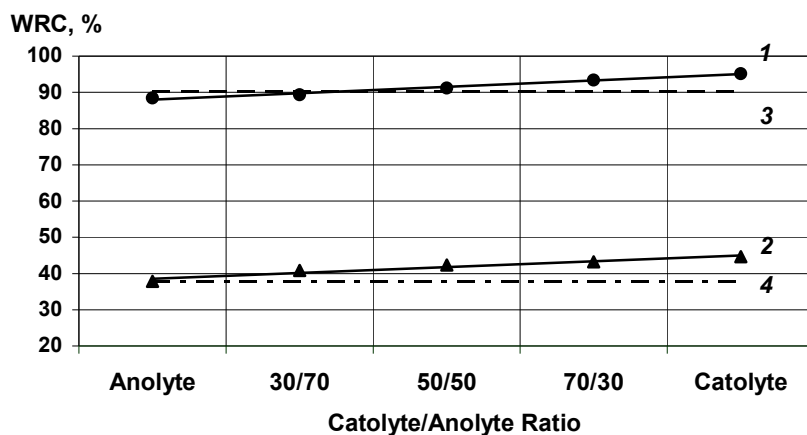
Fig.1. Change of the water-retaining capacity of supplements after hydration with the electro activated water: 1– Progel, 2 – Supro, 3 – Benchmark Progel, 4 - Benchmark Supro

The obtained data analysis, shown in Figure 1, indicated that the increase in the water-retaining capacity was evident in all the samples hydrated with catholyte. Also, the highest water-retaining capacity was noted in the "Progel" protein supplement. It was 95% for the catholyte hydration, while that of the benchmark sample appeared to be 90%. The lowest WRC index was observed in the "Supro" supplement which amounted to 44.7% for the catholyte hydration. In the samples with anolyte, a drop of WRC index compared to the benchmark was observed. Hydration with anolyte did not reduce WRC in the "Supro" supplement samples and amounted to 37.9%.

The fat-retaining capacity of the dry protein preparations is important for production of the cooked sausages since this index affects the consistency of the finished product and occurrence of the fat pockets. Low fat-retaining capacity of the protein system can cause deterioration of the organoleptic and rheological parameters of the finished products.

The results of studying the fat-retaining capacity of the hydrated protein supplements are given in Figure 2.

Fig. 2. Change of the fat-retaining capacity of supplements after hydration with the electro activated water: 1– Progel, 2 –Supro, 3 – Benchmark Progel, 4 - Benchmark Supro

The comparative analysis of impact of the protein supplements hydrated with the electro activated water on the fat-retaining capacity showed that when the "Progel" supplement was hydrated with catholyte, its FRC increased by 5.2% compared with the reference and by 6.1% compared to the sample hydrated with anolyte. The use of anolyte for hydration slightly reduced FRC compared to the benchmark, by 0.8%. The lowest fat-retaining capacity, compared with other supplements, was noted in the "Supro" supplement samples. When hydrated with catholyte, its FRC was 12.7%, while in the benchmark sample this figure was 4.8% lower. Hydration with anolyte decreased FRC by 1.2% compared with the benchmark sample.

The stability of the protein system emulsion is an important parameter forming the quality indicators of the finished meat products. Advanced stability of the emulsion improves the structural and mechanical properties.

The changes in the stability of the studied supplements emulsions are shown in Figure 3.

ES, %

Fig.3. Change of the supplement emulsion stability after hydration with the electro activated water: 1– Progel, 2 –Supro, 3 – Benchmark Progel, 4 - Benchmark Supro

The results suggested improving the stability of emulsions in all the supplement samples hydrated with catholyte. The highest emulsion stability was observed in the "Progel" supplement samples. Hydration with catholyte allowed to improve the stability of this supplement's emulsion by 8% of the benchmark sample and amounted to 98%. In the samples hydrated with anolyte, the emulsion stability was 87%. Regarding the "Supro" supplement, hydration with catholyte increased the emulsion stability index by 7% compared to the benchmark samples. In the samples hydrated with anolyte, ES decreased by 6% of the benchmark one.

The most important functional characteristics of the protein preparations of animal and vegetable origin include the critical gelling concentration, when homogeneous gel is formed. The lower CGC, the more efficient gelling agent the supplement is, therefore, less protein is required to form gel.
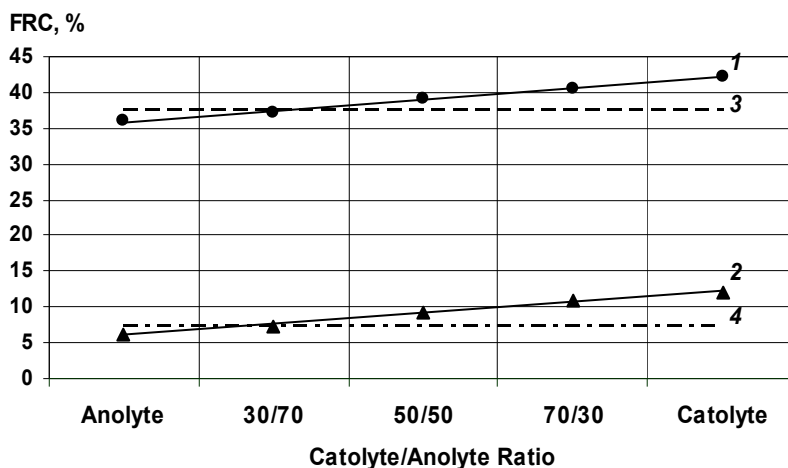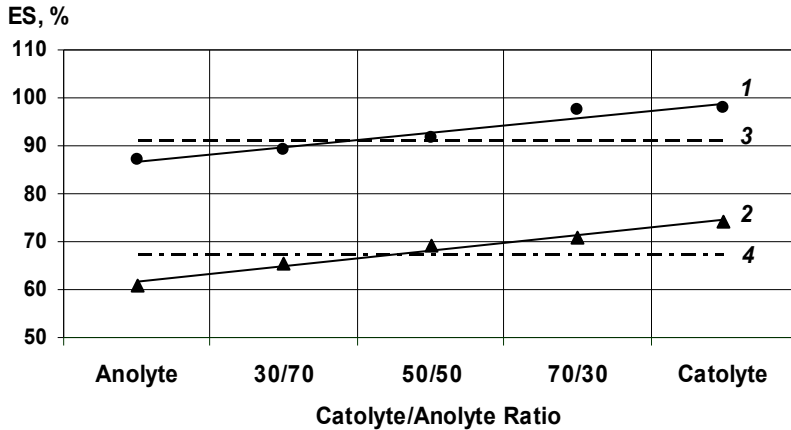
CGC, %
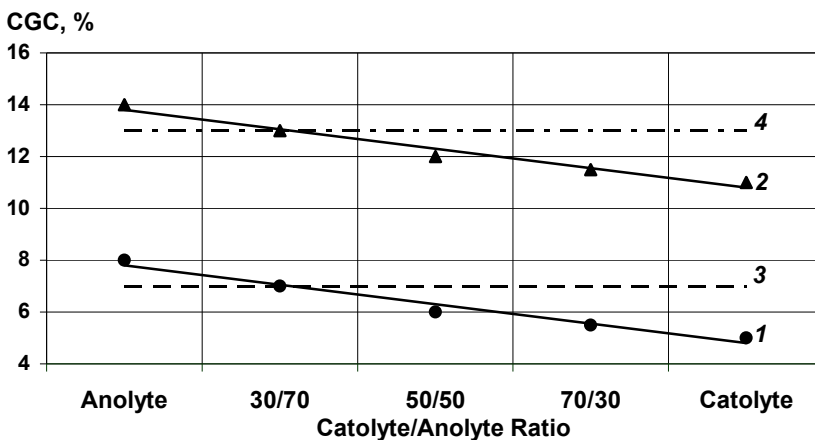
Fig.4. Change of the critical gelling concentration of supplements after hydration with the electro activated water: 1– Progel, 2 –Supro, 3 – Benchmark Progel, 4 - Benchmark Supro

The data in Figure 4 showed that the most critical gelling concentration was observed in the "Supro" supplement samples hydrated with anolyte, which was 14%. That is, that very sample has the worst gelling capacity. If we compare the samples hydrated with catholyte only, we see that the "Progel" supplement has the best gelling capacity with CGC is 5%.

Conclusion

Summing up the results obtained, we can conclude that using the alkaline fraction of the electro activated water - catholyte - for hydration of the supplements of different origin (animal and vegetable), allows to improve their functional and technological properties. Namely, increase the water-retaining capacity of the protein preparations as much as 7%, the fat-retaining capacity as much as 5.2%, and the emulsion stability of the emulsion as much as 7%. The critical gelling concentration in the catholyte hydration lowered, thereby reducing mass share of the supplements in the meat products keeping their yield unchanged. In turn, this proves the feasibility of using the alkaline fraction of the electro activated water to improve the quality characteristics and points to the possibility of increasing the economic feasibility of the electro activated water.

It is experimentally shown that hydration of the protein supplements of animal origin (pig skin collagen "Progel') with the electro activated water fractions is more effective than those of vegetable origin (soy protein "Supro").

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Impact of canning method to structural and mechanical properties fruits and vegetables

Natalia Orlova, Igor Kuzmenko, Roman Romanenko

Kyiv National University of Trade and Economics, Ukraine

**Corresponding
author:**

Igor Kuzmenko
E-mail:
Kuzmenko_Ihor@
ukr.net

Abstract

Introduction. Canned fruits and vegetables need to maintain the shape and elastic texture components. The purpose of research was to define the best way of canning fruits and vegetables, having compared tissue ultimate strength values of test samples.

Materials and methods. The samples of pumpkin, quince, plum and marrow squash canned in a different ways were analyzed. Value of continual ultimate strength of tissue was determined via penetration prototypes by cylindrical indenter needle with diameter (d) 1,4 mm, which penetrates into the sample at a speed of 3.45 mm/s to a depth of 7 mm.

Results and discussion. The value of the tissue ultimate strength canned pumpkin prototype was 1300-1500 mN/mm^2, that on three times more than control sample and quince – almost on 2 times higher than the control sample. The value of the ultimate strength canned squash and plums for test samples on average 1,8-2 times higher than figures for the control sample. These differences in value patterns of strength and fruits canned relative to control samples and caused a higher and prolonged heat treatment control of samples providing a classic technological instruction. The experimental results of structural and mechanical properties are compared with the consistence gotten by the organoleptic evaluation. The test samples of pumpkin-quince and squash-plum canned have gotten 4,81 and 4,79 accordingly; control samples 3,25 and 3,48 accordingly. Also the consistence of experimental and control samples were compared with descriptive method. Prototypes had well preserved shape, had the elastic consistence, were'nt overboiled comparatively to the control. Consistence control samples were described by descriptors "Porous, fruit peel pulp behind," "Soft, boiled." It was found that acetic acid that had been added to liquid part of control samples has'nt expected effect in stabilization of elastic tissue structure of fruits and vegetables.

Conclusions. It was established that increasing ultimate strength (penetration value) test samples shows a positive effect of the improved method of canning to preserve appearance, shape pieces of food and to form more elastic its consistence.

Introduction

Traditional processing of fruits and vegetables into canned food has a number of disadvantages, among them a heat treatment of the product, that causes a significant reduction to the biochemical, structural, and mechanical properties of raw material, including structure of canned fruits and vegetables. The thermal treatment can to improve the consistence of the finished product, and make it worse in the same time (boiled soft product, becomes a pappy viscous consistence, pieces lose its shape). That why is a need to improve some conditions of heat canned food treatment. If we understand the character and dependence of these changes, we would optimize the way of producing vegetables and fruit canned by improving technochemical mode of their production.

We have got canned squash with plum and pumpkin with quince, which had organoleptic characteristics, including consistency much better compared to sterilized canned "Squash canned" and "Canned pumpkin" (table 1, № 1), which had were produced in traditional way using acetic acid [1, pp. 43-47; 2, p. 22; 3-5].

A rational combination of raw materials, that have different chemical composition and softer heat treatment are specific features of production new canned (table 1, № 2). Method does not use of any artificially introduced preservatives – the finished product is stored entirely by organic acids of raw materials.

Table 1

Thermal modes for canned processing at traditional *(№1)* and advanced *(№2)* production methods

Kind of canned		Container		Thermal mode	Pressure in the autoclave, Pa
№1	«Squash canned»	Glass jug	I-82-500	$\dfrac{20-10-25}{105^\circ C}$	$2,5 \times 10^{-5}$
	«Pumpkin canned»		I-82-500	$\dfrac{20-15-25}{105^\circ C}$	
№2	Squash-plum canned		I-82-500	$\dfrac{10-8-20}{95^\circ C}$	
	Pumpkin-quince canned		I-82-500	$\dfrac{10-12-20}{95^\circ C}$	

Results of experimental research numbers of scholars (I. Blyznjuk, N. Komarova, A. Lylyshenceva, A. Samsonova, D. Safronova, Z. Harchenko, Abbott J., Bourne M. [6-11]) proved the possibility of mitigating thermal treatment canning under conditions of low active acidity of products (pH 3,4 ± 0,2), that provides its microbiological stability during prolonged storage.

Authors B. Emadi, V. Kosse describe similar research in source [10]. Mechanical properties of three common varieties of pumpkin were researched and statistically compared. Toughness, rupture force, shear strength and cutting force were determined for Jarrahdale, Jap, and Butternut varieties. The research was carried out in three samples (parts of pumpkin) of flesh, skin and unpeeled product, ignoring the toughness and rupture force of flesh.

Mitigated thermal treatment allows to keep a consistency of the finished product more elastic, homogeneous and not so boiled soft compared with the traditional mode of thermal sterilization.

Purpose of work is to research an effect of improved canning way on vegetable-fruit canned quality.

Main task of an experiment was to investigate component the consistency of the new pumpkin-quince canned made with pumpkin, quince with adding of cranberry juice and squash-plum canned compared with canned food made in the traditional way by determination of penetrations (ultimate strength) and surface shear stress.

Materials and methods

In accordance to purpose the objects of research were put: pumpkin-quince and squash-plum canned made by advanced (experiment) and traditional (control) methods. As an experimental samples were put components of canned food – pumpkin, quince, squash and plum. Whole or crashed into pieces canned fruits and vegetables are belong to product with an intact structure. To evaluate the consistency of the product intact structure appropriate to use devices, action principle of which is based on the using of a needle or a conical indenter.

Penetrometer operates in next way. Starting lever is pressed while achieving contact with the product. An electric motor through a reduction gear leads with an constant forward movement of a sensor platform, which is installed on the rod indenter. While the indentor contacts with the product appear indenter forces that prevent intrusions, which are compensate by elastic springs contained in the sensor. Data registration is carried out by the sensor which is graded in units of dipping indenter includes deformation strength of the spring.

Penetration resistance is defined product penetration of an indenter with known well-defined size, weight and material for particular temperature and for determinate time (fig. 1). Next figure shows forces that act in the moment of the indenter penetrate into the product.

We have determined a constant effort of the indenter penetration during immersion to a depth of 7 mm, and not the ultimate strength surface samples only. The penetration measure performed using torque sensor with a range of measurements $150^{x}10^{-5}$H price division dynamometer – $313^{x}10^{-6}$H. Measurement period – was determined at $2^{x}10^{-2}$s. Measurement data output to a graph in coordinates "force / time". The sensitive cylindrical indenter with a diameter (d) 1,4 mm, moves into the product with a speed 3,45 mm / s at a depth of 7 mm. Digital dynamometer records a value of the force as the resistance of a surface layer of the product (piercing), and in his column.

For more accurate measurement a piercing resistance piece indenter was carried out in three areas above, below and at a side of a piece. Peak resistance force divided by a square the indenter – the ultimate strength of the product, which was determined by the formula:

$$\sigma = \frac{4(F_{peak} - F_{ext})}{\pi d^2}$$

there is σ – ultimate strength, mN/mm^2; F_{peak} – peak force at moving the indenter, mN; $_{ext}$ – extra force, that occurs by uncompensated weight of the indenter, mN; d – diameter of the indentor.
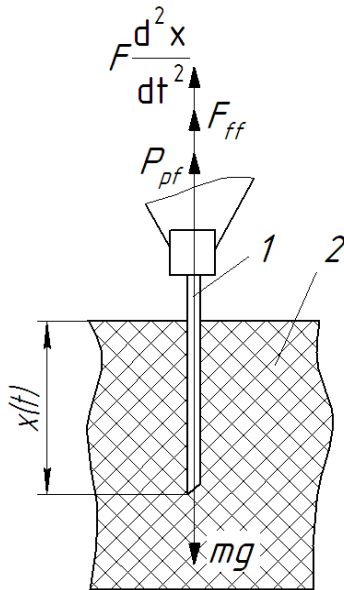
F_{ff} – a friction force

F_{pf} – a penetrating force

$F \dfrac{d^2 x}{dt^2}$ - Newton's inertial force

mg – a gravity force

Fig. 1. Forces and vectors of its action at the moment of penetration into the product

Results and discussions

To reduce the value of measurement error we have researched five samples of each item of canned. We had performed the experiment seven times measures then the smallest and largest results were rejected and calculate average value (table 2).

Average ultimate strength value of five experimental and control samples of each canned component (*fig.*2. a, b).

Table 2

Peak force resistance (F*pik*, mN) and ultimate strength value (δ, mN/mm^2) samples
(n = 7; P≥0,95)

Number of sample	Fpeak	σ	Fpeak	σ	Fpeak	σ	Fpeak	σ	F_{extra}, mH
	Quince-experiment		Pumpkin-experiment		Quince-control sample		Pumpkin-control sample		
Average value	752	1811	567	1350	415	971	182	389	26
	Squash-experiment sample		Plum-experiment sample		Squash- control sample		Plum-control sample		
Average value	131	261	103	190	87	149	73	116	27
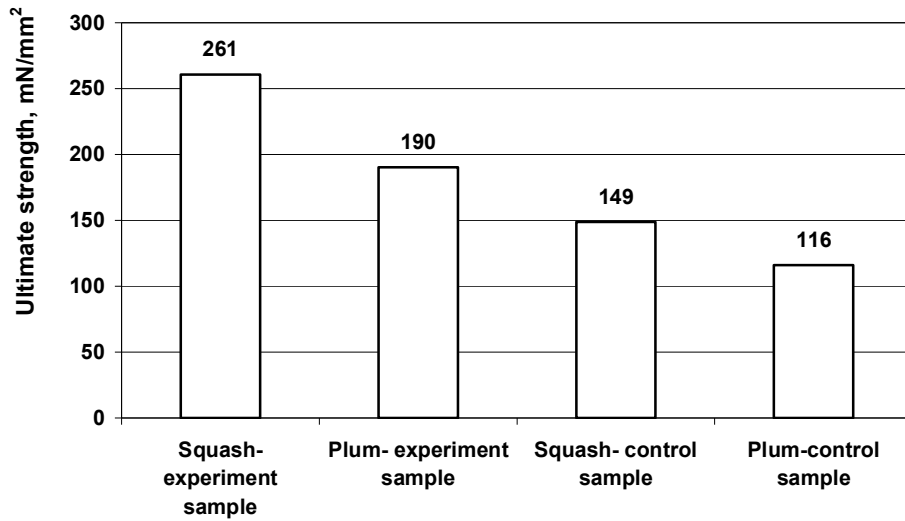
a
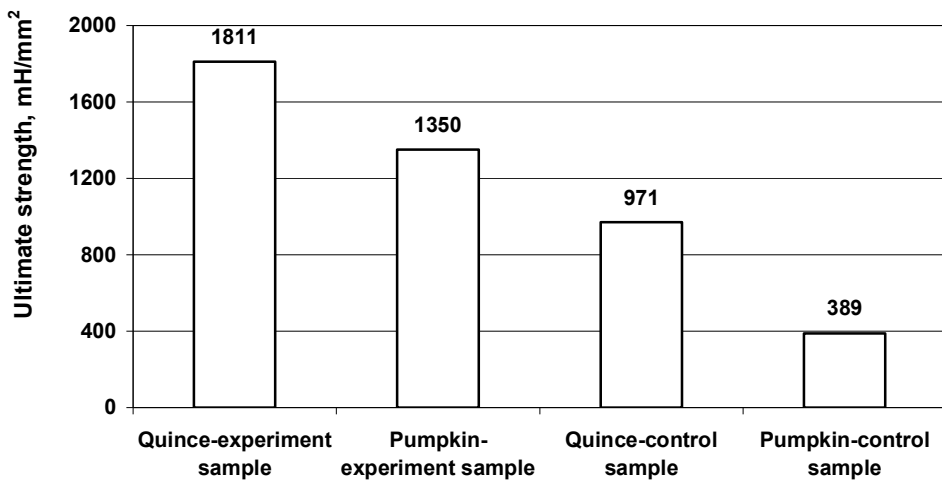
b

Fig. 2. The average ultimate strength value of experimental and control samples pumpkin-quince canned (a) and squash-plum canned (b)

The difference in had obtained values explains by heterogeneity of the test samples structure. And by the influence of unrecompensed gravity on the indenter caused by product residues that remained after each measurement. A considerable difference of a measurement data is explained by heterogeneity structure pieces of samples and an

influence of the gravity unrecompensed product residues on the indenter that were changed after each measurement.

The value of the tissue ultimate strength canned pumpkin prototype was 1300-1500 mN/mm 2, which is three times more important control and quince – almost 2 times higher than the control sample (fig. 2, a). The value of the ultimate strength canned squash and plums for test samples on average 1,8-2 times higher than for the control sample (fig. 2, b).

These differences in the value of ultimate strength of structures fruits and vegetables canned control samples with respect to research apparently caused higher and prolonged heat treatment of the product.
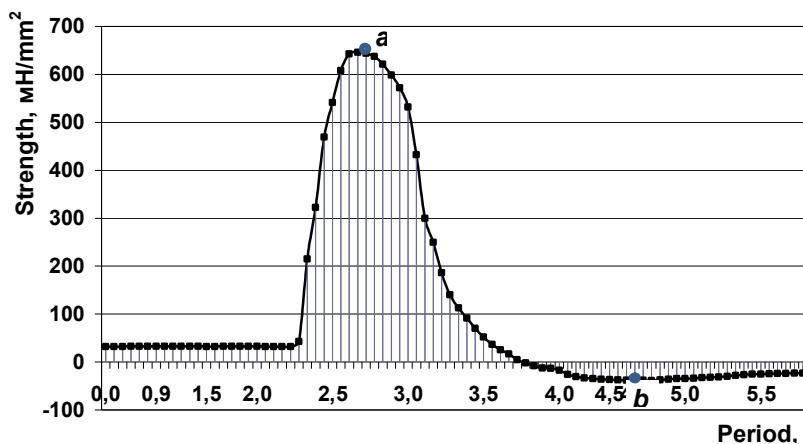
Fig. 3. The strength of tissue resistance (sample "Pumpkin test sample") on different time periods of immersion, mN

On the figure (made by special ITML-laboratory soft) the peak of a curve (point a, fig. 3) shows the highest value of resistance which makes the sample at the peak time of indenter penetration inside the product.

This figure shows that on the indenter not only tensile strength force influences. When the indenter goes back the force value of resistance decreases, and when they indenter almost leaves the body - the sensor captures negative value (point b, fig. 3). It confirms that on the indenter didn't impact strength of the tensile strength only, but forces of tissue penetration of product and its thickness also. The experimental results of structural and mechanical properties are compared with organoleptic evaluation of the consistence. The test samples of pumpkin-quince and squash-plum canned have gotten 4,81 and 4,79 respectively, control samples 3,25 and 3,48 respectively.

Also the organoleptic evaluation of canned samples was conducted by profilograph (descriptive) method to get the full qualitative and quantitative evaluation of each individual description of the consistence (fig. 4). Correlating instrumentation measurements with sensory evaluation of toughness and consistency describe in a paper [12].
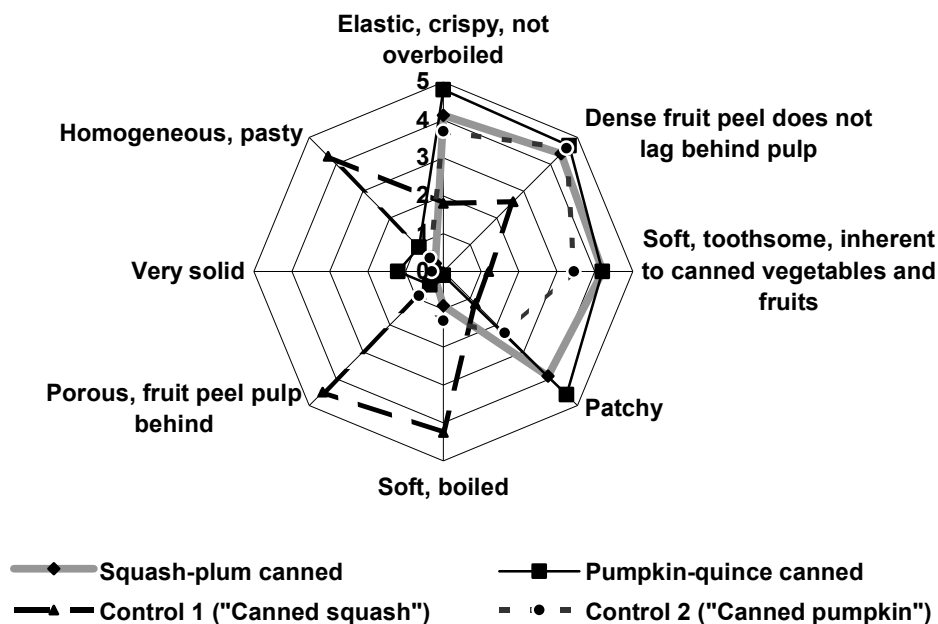
Fig. 4. The consistence sensory profilogram of new canned foods (after two weeks storage)

Profilograms of prototypes have high intensity of descriptors "elastic, crispy, not overboiled", "patchy", "dense fruit peel does not lag behind pulp". Components of the control sample "canned pumpkin" characterized by high levels of consistence comparing to prototypes. A control sample "Canned squash" had quite high intensity of descriptors characterizing porous, soft boiled the consistence. In our opinion, this is due to more stringent sterilization conditions of samples "Control 1" what were subjected to classic technology sterilization

Conclusions

Some structural and mechanical properties of fruits and vegetables which are canned in difference ways were researched.

It was established that increasing ultimate strength (penetration value) test samples shows a positive effect of the improved method of canning to preserve appearance, shape pieces of food and formation a more elastic its consistency.

It was found out that acetic acid that had been added to liquid part of control samples hasn't expected effect in stabilization of elastic tissue structure of fruits and vegetables. In that the consistency of control samples components was too boiled, viscous, a fruit peel lagged behind from a pulp.

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Definition of depth for flexibility of technological system

Viacheslav Ivashchuk, Anatolii Ladaniuk

National University of Food Technologies, Kyiv, Ukraine

Abstract

Introduction. Experts are trying to use a maximal power and resources of enterprise, for increasing a total profit, when the assortment of products of production line is change.

Materials and methods. The recursion of characteristics of typical processes, which had been customized for multi-assortment production, to technological parameters and modes of equipment had been researched.For projections of consumer characteristics to depth of variation of specifications, that was desired, will be using method of quality function deployment. For estimation of necessary variations of variables, that the selected characteristics are changing by targeted, we will used Pareto diagram. We will be applying the functional analysis for estimation of possible implementations of control. For localization of necessary controlling actions we will be using the method of multiple sequential classifications. We will be using the matrix analysis for estimation the depth of technological flexibility that is needed.

Results and discussion. As a criterion of effective depth of assortment can be determined net income from losses for change settings. Incomes from investments are effectively evaluated for the number of orders, which are considered for "lifetime" of product. The initialization of flexibility are classified by operational requirements, according to schedule of production, emergencies, characteristics of raw materials The effectiveness of implementation of flexibility is associated in accordance with cumulative analysis of Pareto charts, which responsible for variation of root causes of changes for characteristics of target product. For example, the ability for problem will be solved by three coordinates of process will responsible for 70% of production efficiency had been indicated for spray dryer. In order to select the most cost-effective solution of problem for production of alternative system configurations should be evaluated by its performance. The flexibility of process is limited by degree of freedom – as a number of coordinate process and limits that will define relevant changes of characteristics of products. Limits of flexibility of technological processes are limited by power ability of equipment and by volumes of resources that will be recycled.

Conclusions. These estimates of process flexibility allow implementation of perspective program for production, optimization of technological routes and minimization costs of design for creating of product assortment.

Introduction

Private interests of producers always adhere to strategy for guaranteed profit, and thus the problem of assortment is far being solved by well known and simple methods, although the technological depth of assortment remains unchanged. These examples are changing of product portions or adding stability for technological environment fillers, which are not affecting on a basic structure or functionality of a product.

Experts are trying to maximize of capacity and resources of enterprise for changing of assortment of products for production line, for increase a total profit. Thus, methods for evaluation of effective depths become relevance flexibility within a constant range of complex assortment.

The Enterprise Resource Planning are using for maximum attraction, which, as basis, are taking expertise of specialists, who has been involved in the subject field. Thus, the methods, which have been involved, have based solely on subjective estimation, that statistically is summarizing the real characteristics of processes and resources, which have been used.

Materials and methods

The degree of flexibility of production system is the most important problem for design stage of system. While it is often considered as one of the primary requirements for competitive production, this is not always desirable characteristic for the system. Often, the examples are exist in the literature about of industrial flexibility, where the flexible manufacturing systems have not satisfactory results of work [1,2], or cases, where the available flexibility remain as unused [3], or cases, where control of flexibility are accepted as undesirable complications rather, than a potential advantage for enterprise [4].

The analysis of flexibility is often mentioned in the article about of control of production. Thus, the flexibility was defined as the ability what for changing or reacting with low losses in time, effort, stuff and productivity [5]. Many developers, who have practice of the multi-product tasks in production, are considering what the production flexibility is a strategic response for rapid changes, which are affecting for order of products [6-9]. In many cases, the analysis has been supported by empirical researches [10].

The classification of existing forms of flexibility for production management from taxonomy and conceptual bases have caused to definition [11,12] by 9 forms of flexibility: machinery, materials-handling equipment, process, routing, level, program, products and production, markets, market expansion .

From the changing concept for systematization of flexibility [13] had been proposed classification for six basic aspects of flexibility, including:
- Definition of flexibility (as general, with special attention for production);
- Factors definition, which responsible for request of flexibility (product and process variability, uncertainty of internal and external conditions);
- Classification (dimension) of flexibility (hierarchical, in phases, for a time, for variation of object or for a combination of previous measurements);
- The measuring flexibility (direct, indirect and complex indicators);
- Selecting of indicator from assessments of flexibility (which can be identified from design or technology solution and organizational or administrative units).

It was also proposed [14] division on baselines of flexibility:

- Flexible - the system has the ability for variation;
- Reconfigurable - the system may will realized the possibilities for reconfiguration by existing parts of production;
- Variability - the system has been adapted to change of settings by existing tools.

Positioning of task for research. Flexible of production is usually considered by terms for getting characteristics of product, requirements for the product, where the costs for retention driven by frequent changes of order and continuous evolution of relevant technological requirements of products.

Definition of optimal value for each of these goals can be burdensome: it often happens that the optimum values for one factor reduces the possibility of achieving optimum value for others. This situation remains relevant, because businesses often do not seek compromise between these critical factors, when are performing production tasks [15].

In addition, information, which has been related by changes of production, is often unspecified and prescriptive authority will not able to accurately estimate the probability, which have been associated of production alternatives. As a consequence of above was mentioned, the production activities of system design will very complicated and perilous.

Thus, the flexibility of production system should be rationalized and there is a need to define the best from compromise between productivity and flexibility, and the methodology for production systems designing should be filled with methods for assessing of the level of flexibility, as that are required by the task of production [16].

The implementation of degree of flexibility requires a very careful risk assessment; for this goal all measures from production strategy definition, configuration of production systems will have been strictly formalized and integrated, what are indicating above of need for unification and coordination of different types of information that is requiring what for will be gotten competitive solutions.

The first key issue of specification for develop of a flexible system arose from the need to define the relationship between different types of flexible control and technical activities, which have been performed that will be achieved them.

Therefore, the urgent task is definition of methodology and tools for design of production systems with appreciation the level that is required of flexibility for problems throughout life of system, evolution of products, processes and orders. The basic idea is that the flexibility have the own-price, so for usage of the level that needed for a present production problem, we can find the best trade-off between flexibility and productivity.

So, don't think what the topic above design of industrial systems is actually, the methods, what has existed, and tools do not provide the support systems what is necessary for developers, so as usually they operate with sub-process of all designing process. Indeed, the scope of topics, which have related from design of system, can is considered as a one from reasons for result of absence of sufficient attention for this problem, so far.

So the tasks that are scheduled for implementation are evaluating of effectiveness of product creation for a single production line, estimation of change and efficiency loss, when configuration are changing, and recursion of characteristics from typical processes to parameters of technological and modes of equipment.

Methods. As a basis of information for modeling of parameters of not determined environment of operation of flexible manufacturing systems are being examined methods of specifications formalizes for describing of objects and processes in terms of their adjustment.

For projections of consumer characteristics to depth of variation of specifications, that was desired, will be using method of quality function deployment. For estimation of

necessary variations of variables, that the selected characteristics are changing by targeted, we will used Pareto diagram.

We will be applying the functional analysis for estimation of possible implementations of control. For localization of necessary controlling actions we will be using the method of multiple sequential classifications. We will be using the matrix analysis for estimation the depth of technological flexibility that is needed.

Results and discussion

As the depth of assortment we will be designating, in terms of consumer, as the number of functions, which are characterizing a product, and relatively of function – the number of new products, which would replaced primary. Thus, the number of components that are different products can be characterized or change by the depth of assortment. Thanks to nature of any assortment, the demands of product on market are dynamically decreased, and hence the actuality of assortment remains undeniable. Static demand remains only for product, which has not alternative substitute.

Thus, the criterion of effective depth of assortment can be determined net income from losses for change settings as sequel of variation of characteristics of production assortment, which had been targeted.

$$dP = \int_{\tau_P}^{\tau_E} \frac{dS}{I_B + dI} d\tau \; , \qquad (1)$$

where dp - change of profit, ds - increment from orders, which had been realized, di-change of investments.

Incomes from investments are effectively evaluated for the number of orders, which are considered for "lifetime" of product that had been defined $d\tau = \tau_E - \tau_P$.

Thus, the sub-task for estimation of assortment production is to determine a maximum depth of assortment for new products for industrial complex that are researched. The production system can be seen as purposeful, if system is converting through changes of purpose of production (product, save resources, speed of produce).

When it changes through variation of external relations (seasonal raw materials, changes of demand, and rationality for daily variations of cost energy) it can be seen as consequence as a basis expansion of assortment will be taken a change of statistical characteristics and external factors of the production environment.

As the object initialization for flexibility can be seen next type of flexibility.
1. Exploitative flexibility is considered of availability of tools and personnel that is servicing processes and operations. This type of flexibility is convenient for to count by man-hours and is distribute by norms for maintenance according to passport of equipment.
2. Timely flexibility: seasonal, daily (different products for different times of day according to the requirements of production and consumption of raw material), serial (respectively to planned volumes of output and dimension of parties).
3. Emergency flexibility can lead to stable semi-products without a losing product.
4. Flexibility oriented on raw material – as depending of characteristics of material. For example, the state of maturity of the apples we can make the products: drying, jam and juice, pectin paste and juice drinks.

The cost of changes will be depending from complexity of system variable. If the system, that would be changed, will be requiring strong as correlation relationships for products or management characteristics from control algorithm, it change may be irrational for compare uses of a new production system. We call this the new system, which has correlated with characteristics of target products or with functional elements of existing system.

So, all factors, what do not fit to underlying causes of changes of targeted characteristics of a product, after the result of analysis of cumulative Pareto chart (Fig. 1), are making basis for election effective coordinates for a control of technological system.
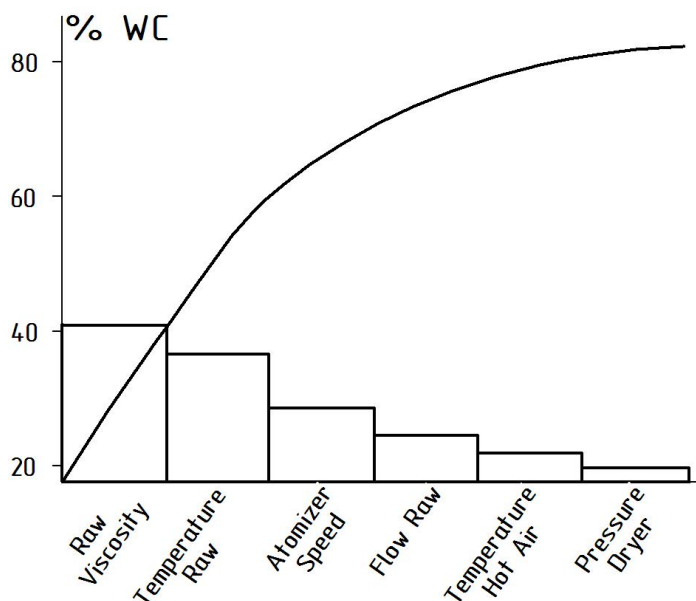
Fig.1 Pareto diagram for realized of water content via factor of drying process.

The source data of analysis of system consists of information about existing and potential products, demands for system user, availability of production units, which are characterized by range of characteristics that can be produced, possible system architecture (for example: transmission lines, flexible manufacturing systems), investment and operating costs.

The original are determined according to variation targeted program, which was scheduled, what is stipulating the depth of flexibility of technological complex, what are required. The result of analysis of system is a definition for uses flexibility, what for are solved problems of production.

If the implementation of the production plan requires involvement of flexibility, then is a necessity for define sets of resources that make up a system and the implementation of the system, by given its reconfiguration. The analysis of resources through form as acquisition of flexibility as additional features through "Active Base Costing" method, allows us to evaluate the economic advantages of flexibility in terms of cost.

The design of system, that focuses on flexibility, must be adequate to set of restrictions of equipment, that determine of production strategy for goals of implementation mode of

production (minimizing resource costs, the maximum speed of production). When alternative system configurations were been received and analyzed, the user determines a time for acquisition of resources for design of life cycle for system. Finally, in order to select the most cost-effective solution of problem for production of alternative system configurations should be evaluated by its performance, which (1) will be limited to necessary number $ds/d\tau$.

The manufacturer of means is getting as the product of analysis of alternative configurations a set of optimal and suboptimal configurations of system. The assumptions about forecasting of economic characteristics and boundary conditions for system resources are elected in next planes.

1. The cost for purchase of resources is provided as constant for time of production. If these assumptions are relaxed, then developers of flexible system will have owned a number of real problems during period of implementation of the model. In fact, the evolution of prices of resources will be able quickly calculated by system builders, but this information is not transmitted through the privacy policy. For same reason, is not transmitted sale price of resources those are considered as permanent for economic model.
2. If the production system is unable to meet demand, then company undertakes a fine or costs for outsourcing of production deficit.
3. Cash flows are discounted to consider changes in monetary value.

The cost of flexible system that consists of capital expenditures for purchase of resources will be able reduced if some resources are sold. In addition, the cost increases when the production system can not meet demands what is leading to fines or losses of costs on outsourcing. The last member of function of cost is took into account as a loss during verification of new plans.

The flexibility of production can be achieved at functional levels:
- the level of initial assessments of characteristics of product; here in conditions of flexibility can predict the presence of a set of algorithms for initial evaluating, filtering and archiving for the intended purpose or in order evaluating as depending from its importance for current mode of functioning of object;
- the level that had been designed to harmonize between parameters of processes; when the mode of operation of object is changed next subject will change too: adjust of control law, structure of control, number of parameters what had been selected for analysis, control law;
- the level that had been designed for management of relationships in a structure of production; at this level production will be able reformatted within that defined of power and functionality of hardware trim;
- the level that had been designed to provide processes of personal and economic for enterprise; at this level the company will be able reformatted within job descriptions, number of employees, external obligations of logistical chain and structure of resources for trading and supply of production resources.

Since, the level of initial estimates is most time-critical from other; it has minimal space to make adjustment of object, so as estimates of information will have able stayed in store or will have made own function. Quantitatively, the flexibility has less number of possible variations for more detail level. The obstacle here is also development of cost of flexibility for higher levels of hierarchy of production.

Higher levels will be able operated in soft real-time, so will be practically implemented numerous robust restructuring of object. Thus, for top-level already to

provide, as have been pre-prepared, set of solutions to change flexibility: state of preparation equipment, state of emergency stop for equipment, functions for integrated reservation.

$$\{da/d\tau << dA/d\tau\} \rightarrow |\vec{a}| > |\vec{A}| \ , \ |\vec{A}| = const \ , \tag{2}$$

where A - the coordinate of state, which is representing the top, relative to coordinate a, of hierarchy level.

Characteristics of system will not be able analyzed as separate from environment, raw materials or resources as they are producing the features of products as result of its number and variability characteristics. If during investigation of changes of production system from point of food production, the system loses a function for production of a base product, then should a program to expand assortment be considered as unsustainable in relation to main project of production. Thus, as the estimation of depth of flexibility will be able only relative, so the possibilities for adapting of equipment and technological process to adjacent technological units should be distributed by formally characteristics of process streams (example: processing of stone and seedless fruits, berry and citrus products). However, there is a very thin fine between flexibility and new individual technological production.

That is defining for a need to provide flexibility when replacing a percentage of processes and technological units, so as adaptation and restructuring of processes additionally burden operation, increase the cost of technological complex. Detailing processes will effectively be done by functional principle, where there is a separation of allocation of tasks for operation of process. Also to get products are expected, during detailing processes, but those products does not necessarily material resource.

The estimation of flexibility begins from lower level for characteristics as a projection of technological requirements into matrix of technological communications of object. The flexibility of the process will be able defined as the degree of freedom of coordinate of technological process, which are implemented by function of complex that it provides within sufficient to obtain a set of product characteristics of process.

Thus, the depth of flexibility will be able achieved by scale of characteristics

$$C = \left| \vec{H} \times dH_i \right|_2 \ , \tag{3}$$

where $\vec{H}$ - vector of coordinate of technological process, dH_i - variance of coordinate H_i, that will be executed by function of technological complex. As a result, correlated limits of technological characteristics are setting what bases on the finite volume and resources, which are processed and process flows; as an example - the typical processes of food technologies (Table 1).

Table 1

Distribution for to combine process of food technologies

Characteristics	Plane for to change of characteristic	
Aggregate state space	vapor	vacuum
Degree of integration of suspended particles	homogeneous product	shredded raw
Using of a process agent	warming	cooling
Direction for to absorb of environment elements	absorbing	desorbing
State of physical activity	mixing	sedimentation

For to optimize of cost range, depending of scale of complex, the function is effectively divided:

- by technological units - considered as a separate cost of unit, then the normalized value will be regarded as $I_{norm} = I_j/s_i$, so as a cost of equipment that had been attached as addition s_i ;
- by technological regimes for equipment that had been installed.

Index of raw processing power is suitable for characteristic of parameters of production line for multi-product uses. So as the regulation for processing of raw is provided as a constant for properties that had been prescribed. Because, the set of characteristics that are describing function of particular unit will have been necessary used. The consequence of realized a function is a change of characteristics which had been targeted, and therefore the set of characteristics will be represented by increments. Typical objects of food and chemical industries to include functions that to associate a group of characteristics of processed of raw materials, so the data about of this group should be presented by single indicator that would have limited for group variations.

For to change of assortment of product, those characteristics, such as efficiency and load of equipment are classified as secondary, because tasks, that had been selected, have a more significant advantage to increase of total income.

So as the equipment for to realize characteristics of efficiency changes according to a cost of providing, as a prediction of operation algorithm, so the function of cost Φ will be shared by a range of change of coordinates dH_i , according to time of equipment with additional costs (energy and materials) for order

$$\Phi = \int\limits_{\tau_0}^{\tau_0+d\tau_H} \eta_i f_{Hi} d\tau ,\qquad(4)$$

where $d\tau_{Hi}$ – variations of coordinates H_i, which are established by algorithm of equipment and are represented the appropriate form of model f_{Hi} :

- statistically form - to evaluate the cost of units;
- analytically form - if cost has strong localization, for product specification that is received, form.

The depth assessment of flexibility, for units are combined in technological plant, is analyzed by characteristics of sub-products, which had been declared. An example as an effective evaluation of flexibility can serve a combination of evaporation process of dairy products and subsequent drying in dryer column.

In this way characteristics of temperature T and moisture content, fat content of raw γ_z are adjusted. Moreover the moisture content or reverse function - density ρ should be considered in combination with temperature, as a performance of evaporation productivity of production units, also with temperature and fat content as a dynamic viscosity of raw materials μ , which is responsible for fluid motion and atomization of material.

Vector coordinates of first unit - includes evaporation characteristics that to change during implementation of its functions

$$\vec{H}_{vap} = \begin{bmatrix} dF & dT & d\gamma_z \end{bmatrix},$$

if is recorded by increments of variable characteristics that shape its problem of assortment product

$$C_{vap} = \begin{bmatrix} 0 & dT \\ dF & d\rho \\ d\gamma_z & d\mu \end{bmatrix},$$

so a change of fat $d\gamma_z$, for process of evaporation, characterizes product assortment. An adjacent production unit – a column drier, which is characterized by $\begin{bmatrix} dF & dT & d\mu \end{bmatrix}$, where $d\mu$ as a viscosity of mixture, that allow forming an effective torch of atomizing.

Thus, for realization of product range of drying process is necessary reconciliation by $d\rho$ and $d\mu$ that makes as possible to produce a product with assign moisture content or density ρ for a product fat that would be present $\gamma_z = f(\mu, T)$.

It is necessary to estimate a need for uses flexibility of technological complex, as a possibility to obtain changes that as necessary for new product. If the flexibility that is required is provided by set of state space, so the space that defines a change of coordinates of states, which is described above by a matrix of states C_i, will be assessed by the depth of matrix determinant $\det C$.

Moreover, if the depth of at least some of product

$$\det C \neq 0, \dim C > 1, \tag{5}$$

so, all objective reasons to change of production parameters to product, that is desired, within technological complex, which exist, are present.

Conclusion

These estimates of process flexibility allow implementation of perspective program for production, optimization of technological routes and minimization costs of design for creating of product assortment. So, the trend of implementation of management models in flexible manufacturing systems, which are designed to provide a level of flexibility that was assigned, is gaining actuality.

As perspective tasks remain is: to determine of purposeful detalization of experiment and characteristics of mathematical description, which will be created; to combine of characteristics for a transformation of space of coordinates of process and practical implementation of technology of algorithms of digital control.

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Fractal analysis of distillation unit time series in prediction and control problems

Nataliia Novakovska, Vasyl Kyshenko

National University of Food Technologies, Kyiv, Ukraine

Corresponding author:

E-mail:
nataliia.novak@
gmail.com

Abstract

Introduction. The behavior of distillation unit as a control object is characterized by stochastic and chaotic manifestations. This requires their identification by the nonlinear dynamics methods for organizing the specific respective control strategies.

Materials and methods. We used the synergetic methods and the theory of deterministic chaos for solving problems of distillation unit prediction and control. Time series analysis was conducted using the Rescaled Range algorithm of the analysis of Hurst, the coating method and the correlation methods. Time series are processed using the software package FRACTAN.

Results and discussion. The research of time series of distillation unit showed that distillation processes are characterized by the presence both stochastic and chaotic regimes, the dimension of attractors of which lies in the range of 3 to 8. Most of these series are fractals, that is, despite the significant instability of the process, their behavior remains the same, which makes it possible to predict change of their condition in the future. Correlation entropy index pointed to a time on which we can predict the behavior of our system. Changing regimes of distillation unit functioning is passing with various periodicity, that reaches from 4 to 10 hours.

For the analysis of chaotic state of the process in behavior of the object we used correlation dimension parameter, which showed that this object have significant trend stability (persistence), that characterized by high value of Hurst exponent in the range of 0.7 to 0.96. The predictability of distillation processes behavior is high, especially for the temperature values. It is increasing with the augmentation of attractor fractal dimension and reaching tens of minutes.

If fractal dimension is less than 1.4, then one or more of the forces affects system, which drives the system in one direction. If the dimension is about 1.5, the forces acting on the system are multidirectional, but more or less compensate each other. If the fractal dimension is much more than 1.6, the system becomes unstable and ready to move to a new state. The analysis of fractal dimension of time series of the distillation column bottom pressure showed that fractal dimension is in the range from 1.0 to 1.4, which in turn indicates that the system affects several forces that move it in one direction, that is, the system is stable.

Conclusions. The researched features of distillation unit functioning as the sophisticated nonlinear control object make it possible the realization of resource-saving control strategies based on diagnostic of its behavior by the methods of fractal analysis.

Introduction

Technological complexes of food industries, including distillation unit of the distillery are complex control objects with the characteristics of complex control systems: a high degree of uncertainty of various forms, significant noise, multicriteriality, nonlinear behavior. Decision-making on control in such circumstances is extremely difficult and time-consuming process.

In order to increase the efficiency of complicated technological complex control systems of food production is necessary to provide operational analysis of the information obtained in the operation of control systems. Thus, the development and implementation of new algorithms and models using modern methods of information analysis is actual scientific and technical problem.

The aim of the research is to improve the efficiency of alcohol production by implementing operative analytical processing of data using methods of fractal analysis, that is investigations of time series of observations using such fractal characteristics as the Hurst exponent, the fractal dimension, the correlation entropy and etc., which make it possible to assess how predictable is the control object, to detect precursors of future disasters and states of emergency of technological process and to prevent undesirable states in future.

The distillation processes on the distillery factories is complicated technological complex. Its behavior characterized by the intermittence, that is rotation of modes of stochasticity, randomness and determinism as a result of appearance of spacetime dissipative structures far from thermodynamic equilibrium in the nonlinear field at critical parameter values at the bifurcation points [1,2]. Dissipative spacetime structures are highly ordered formations because of self-organization through the exchange of energy and substance with the environment. They have a certain shape, size and characterized by resistance to small perturbations (fluctuations) [3]. The important characteristics of dissipative spacetime structures are the time of existence, the space of localization and the fractal dimension [4]. Each type of dissipative structures requires the application of specific topologically coordinated control strategies of resonance character. This provides the efficient usage of energetic and material resources. Hence follows the importance of rapid determination features of the behavior, such as type of behavior and its peculiar properties, of the distillation unit as a control object in real time scale.

The problem of the control of a technical objects condition during their functioning is the most acute became because of the transition from the concept of "scheduled and preventive maintenance" to the concept of "condition maintenance." One of the main tasks scientists face today is a necessity of a constant objective monitoring of the current state of the object and, as a consequence, strengthening requirements to monitoring and diagnostics systems [5]. Currently, the main source of information about the state of diagnostic objects is the time series of observations. Then, on this basis, are determined different process characteristics (the spectral, the correlation, the probability) [6].

These series are usually generated by sophisticated nonlinear systems, the description of which in the form of differential equations or discrete mappings are often associated with large difficulties. However, it was found, that these series are usually fractals [6]. In other words, accurate to the scale factor, such series at different scales look like approximately equally. Such a widely spread of the fractal structure is connected with the fact that in reality any irregular processes seek to find self-similar fractal structure as the most energetically favorable [7]. This means, that the nature of their behavior remains the same at all scales, down to a minimum despite the extreme irregularity. Experimentally proved that time series of data, obtained in the research of these systems, are characterized by

fractal properties (the self-similarity, the self-affinity, the fractal dimension). It makes possible to predict their dynamics, to identify hidden correlations, cycles and so on [8].

Thus, for objective reliable analysis of distillation unit as the diagnostic object by fractal time series you need use of adequate algorithms, that is fractal processing algorithms of informational signals. Today, due to the development of the stochastic fractals theory, such a characteristic of time series as an exponent of Hurst H is becoming more popular.

Analysis of different research methods

The Hurst exponent and the fractal dimension of time series determined by the method of H.E. Hurst, who experimentally found that for many of time series is true an expression [9]:

$$\frac{R}{S} = (\frac{N}{2})^{H} \tag{1}$$

$$S = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - x_{cp})^2} \quad, \tag{2}$$

where x_{cp} – the arithmetic mean value

$$x_{cp} = \frac{1}{N}\sum_{i=1}^{N}x_i \tag{3}$$

$$R = \max_{1 \leq U \leq N}(Z_u) - \min_{1 \leq U \leq N}(Z_u), \tag{4}$$

where Z_u – the accumulated deviation of series from the mean x_{cp}

$$Z_u = \sum_{i=1}^{N}(x_i - x_{cp}) \tag{5}$$

where H – Hurst exponent; R – the calculated in certain way "rescaled range" of the corresponding time series; N – the number of observation periods;
S – the mean square deviation of a series of observations X; a – a defined constant ($0.5 \div \frac{\pi}{2}$).

Thus, the Hurst exponent determines the normalized factor of amplitude (Rescaled Range) R/S of time series. Hurst exponent is associated with traditional "cell" fractal dimension D by simple correlation [10]:

$$D = 2 - H \tag{6}$$

An important indicator for the analysis is indicator of the correlation entropy, which shows the degree of divergence of close phase trajectories and allows us to estimate the amount of information required to forecast the future behavior of the object. So this coefficient shows the time on which behavior of the dynamic system can be predicted [11].

We used one of the ways of research the fractal structure of time series – calculation of their fractal dimension across the cell dimension D_2 [8].

We used test, which used in practice, to check the chaotic component in the researched time series lies in determining properties of the correlation amount $C_m(r)$ and behavior

correlation dimension $D_m(r)$ depending on the dimension of attachments m. The correlation amount $C_m(r)$ is the probability that the couples of points on the reconstructed attractor in the m-dimensional lags space are within the limits of distance r from each other. If the graph of the function $lnC_m(r)$ relatively $ln(r)$ has clearly defined linear area, this indicates to the existence of self-similar geometry of the attractor, which, in turn, points to the chaotic process. The correlation dimension D_2 of the attractor, which characterizes the dependence of the probability that two random points from attractor lie within the same cell that determines the dynamic heterogeneity of the attractorare finding as follows. We are considering the correlation integral $C(r)$, which shows the relative number of pairs of points of the attractor, which are at a distance of no greater than r:

$$C(r) = \frac{2}{m(m-1)} \sum_{i=0}^{m-2} \sum_{j-i+1}^{m-1} \theta(r - p(x_i, x_j)) \tag{7}$$

where, θ – the Heaviside function; p – the distance in n-dimensional phase space; m – the number of points x_i on the attractor. On the quite small scale lengths and when embedding dimension m not less than topological dimension of the attractor is performed dependence:

$$C(r) \approx r^{D_2} \tag{8}$$

where D_2 — the target correlation dimension of attractor. Having taking the logarithm of equation:

$$\ln C(r) \approx D_2 \ln r \tag{9}$$

The expression (9) gives the desired estimation of the attractor dimension as a tangent of slope angle of the straight line, that approximates the graph of correlation integral $C(r)$ in double logarithmic scale.

To calculate the correlation entropy we also calculated the correlation integral (7), but we consider not only its dependence on the distance r, but also on the dimension of the phase space n. In this case consider that

$$C(r,n) \approx r^{D_2} \exp(-nK_2) \tag{10}$$

whence

$$K_2(r,n) = \ln \frac{C(r,n)}{C(r,n+1)} \tag{11}$$

Entropy K_2 is approximated in an acceptable range of values r and n.

Materials and methods

The object of the research are time series of functioning of distillation unit. The researched material was the time series of distillation, rectification and epuration columns of distillation department of Krasnoslobodsk distillery. Detailed description of distillation unit are shown in [12].

The temperature of distiller's wort, the temperature at the control 16th plate of RC, the bottom and the top temperature of DC, the bottom temperature of EC, the temperature of the bottom of RC are measured by the resistance thermal converter of explosive performance TSP-1088. Conductors of resistance thermal converter to the control point are laid in metal pipes to prevent them from damage and the emergence of sparks.

For measuring pressure of the top and the bottom of distillation column, the top and the bottom pressure of epuration column (EC) and pressure of the bottom of RK is used DPP-2-13-001-0116 device. The output signal of this sensor is a standard pneumatic 20-100kPa.

The maximum error for all measurement channels is less than 1%.

The investigated materials. The fractal analysis of the functioning of distillation unit (DU) were conducted by processing of time series of the basic technological variables, such as the expenses of alcohol from rectification column (RC), the expenses and temperature of distiller's wort, the temperature at the control 16th plate of RC, the top and the bottom pressure of distillation column (DC), the bottom and the top temperature of DC, the bottom and the top pressure of epuration column (EC), the bottom temperature of EC, the temperature and the pressure of the bottom of RC.

For the processing and analysis of distillation unit are used data of 2 months of the distillery. The complete guidance of data in this article is considered inappropriate because of significant cluttering the space and for the improvement of the perception of information.

The procedure of conducting research.

We have converted the time series of technological variables to normalized form (Fig. 1) of varying duration and in different periods of DU operation, in order to establish variation of the results.

Then the time series of technological parameters processed using techniques of Hurst and the Fractan software package, which allows to conduct computation of the correlation functions, the correlation dimension, the Hurst exponent, the correlation entropy. Moreover to determine the fractal dimension and other characteristics that allow us to make conclusions about the self-similarity of the processes [13].

Processing of investigation. The correlation dimension used for the analysis of the behavior of chaotic component of the object. When the correlation dimension is not growing monotonically and has a maximum, so that indicates that the process is predictable and it defined by a certain number of parameters. This is the dimension of space of attachments m as the smallest intact dimension of the space that contains the full attractor, that is corresponds to the number of independent variables that uniquely identifies established movement of a dynamical system.

Correlation entropy K_2 allows to evaluate the average velocity of losing information about the state of the dynamic system over time and to determine the average time of predictability of system behavior, which also depends on the dimension of space attachments m. If $K_2=0$, the mode of oscillations of dynamic system is periodic, that corresponds to the regular process, and if $K_2>0$, then the system is in the mode of chaotic oscillations [14].
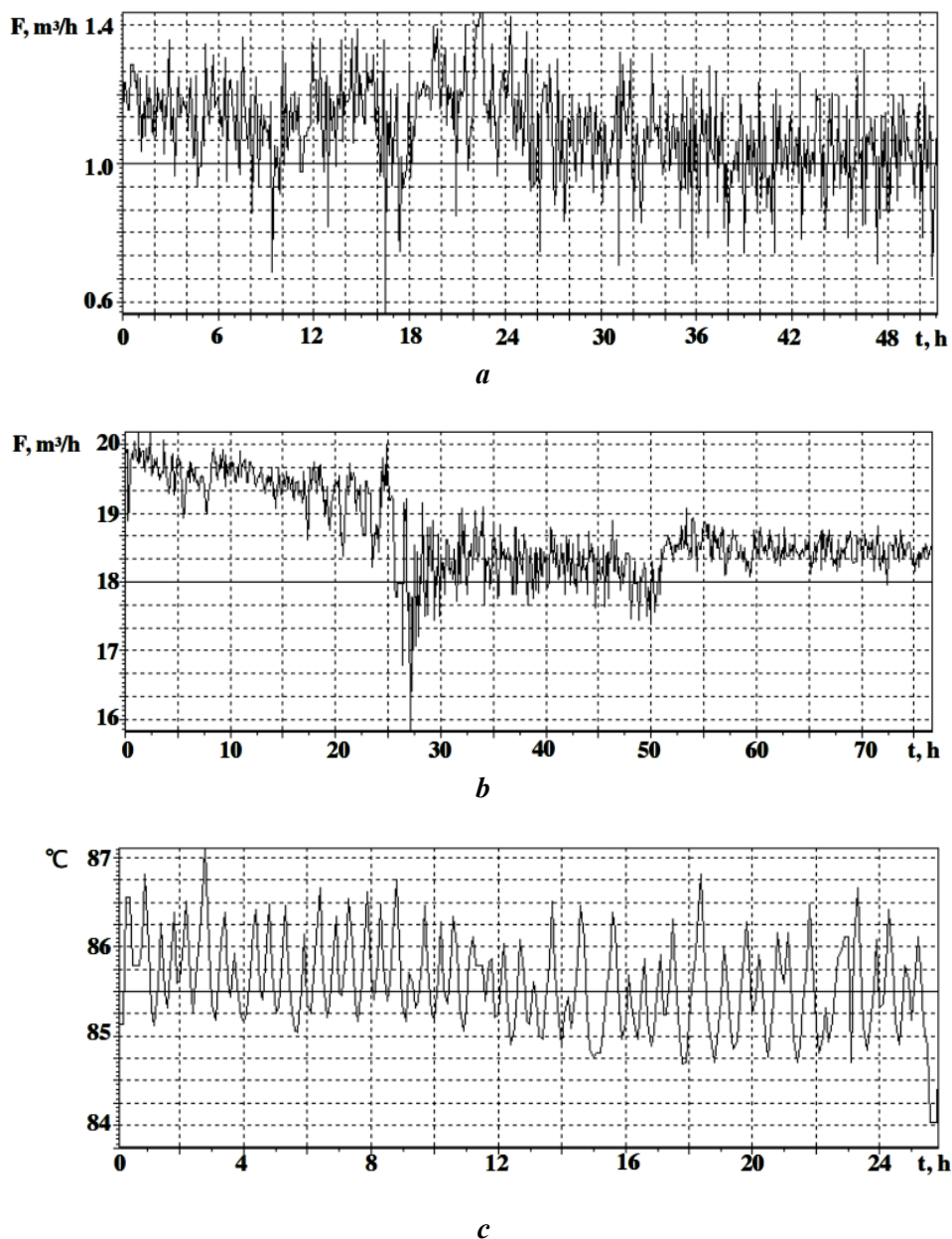
Fig.1. The normalized time-series of technological variables of DU of:
a - the alcohol expences from RC; b - the expenses of distiller's wort at DC; c - the
temperature on the 16th plate of (RC)

Results and discussion

Determination of correlation dimension is shown in Fig. 2. As seen from the graphs, the curve have a pronounced maximum indicating that the process is predictable and dependent on the completely certain number of parameters, as indicated by dimension of the space attachments, which completely corresponds to the number of variables that drive the system in a particular direction (x-axis on the graphs of Fig. 2).

a

b
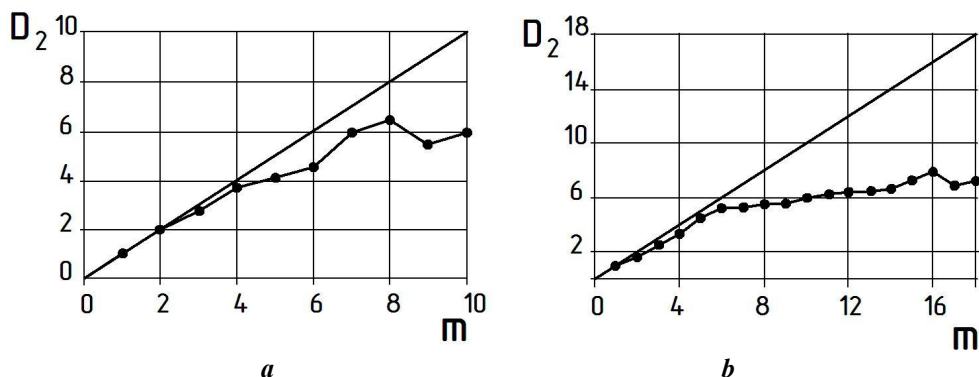
Fig. 2. The dependence of the correlation dimension D_2 from the dimension of the space attachments m for time series of:
a - the alcohol expenses from RC; *b* - the temperature on the 16 plate of (RC)

The dependence of the correlation entropy K_2 from the space dimension of attachment *m* is shown on Fig. 3

a

b
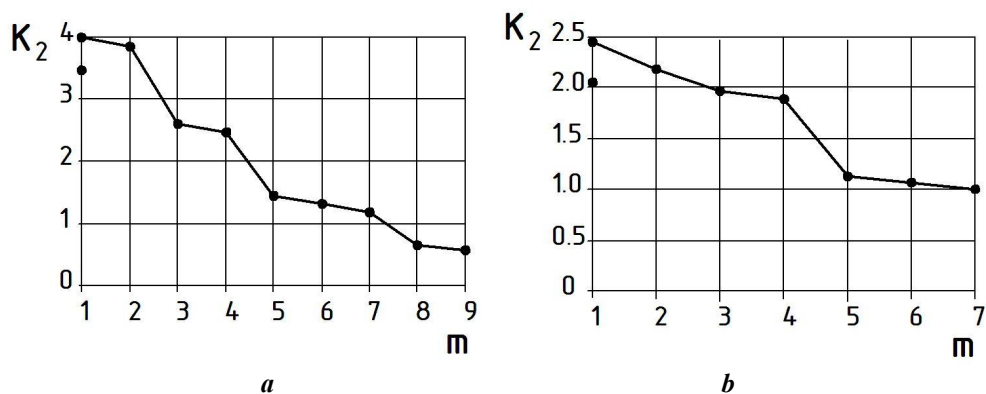
Fig.3. The dependence of the correlation entropy K_2 from the dimension of the space attachments m for time series:
a - the alcohol expenses from RC; *b* - the temperature on the 16 plate of (RC)

Particular importance of fractal time series analysis is that it takes into account not only the behavior of the system during the measurement, but also its history.
Fractal dimension is an indicator of the curve complexity of time series.

We can learn how to predict system behavior by analyzing alternation of sections with different fractal dimension. And, what is most importantly, to diagnose and predict unstable states.

The essential aspect of this approach is the availability of critical value of fractal dimension of the temporal curve, upon approaching to which the system loses stability and goes into the unstable condition, parameters quickly grow or fall, depending on current trends.

Here is analyzed the dynamics of change of time series on the example of a bottom pressure of DC.

The fractal dimension of certain size can be used as an "indicator" of disaster. Analysis of experimental data shows that the trend line for the time series is well described by the equation:

$$\overline{y}(t) = \overline{y}(t_0) + \frac{K_f(t_0)(t - t_0)}{(D - D_0)^{\beta}} , \tag{12}$$

where $\overline{y}(t_0)$ - the average value of the quantity of the period that preceding to prediction period; K_f and β coefficients; t_0 - the period of time that precedes the prediction period; t – the time for which is doing the forecast; D_0 - the fractal dimension to the period that precedes the prediction period.

Moreover, the value of fractal dimension can indicate to the number of factors that affect the system [11]. If fractal dimension is less than 1.4, then one or more of the forces affects system, which drives the system in one direction. If the dimension is about 1.5, the forces acting on the system are multidirectional, but more or less compensate each other. If the fractal dimension is much more than 1.6, the system becomes unstable and ready to move to a new state.

Fig. 4 shows the dynamics of changes in fractal dimension of time series.
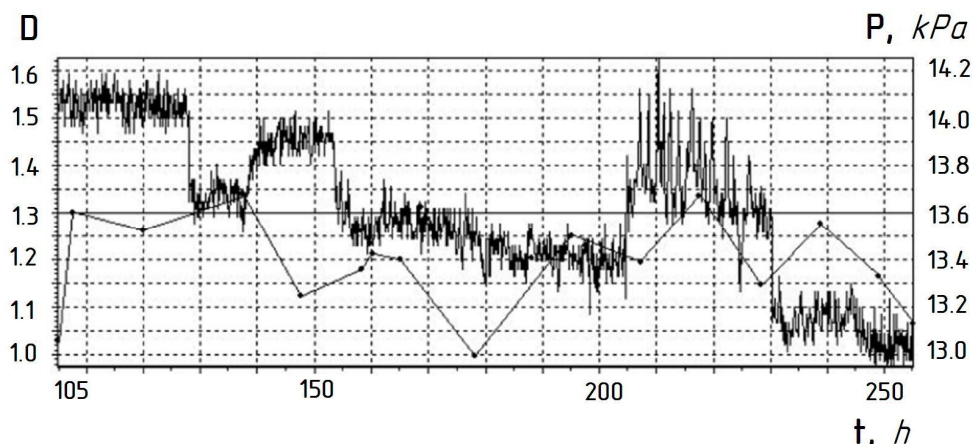
Fig.4. Dynamics of fractal dimension change of the time series of pressure in the bottom of MC

The research of the dynamics shows that during quite stable periods and slow ups the fractal dimension of the time series remains rather low, while in periods of abrupt changes the total fractal dimension is increased.

Another method of fractal analysis is based on the algorithm of *R/S* – analysis of time series.

The Hurst exponent is a measure of persistency, that is, the tendency of process to trends [7]. The value of H > ½ means that the dynamic of the process directed in a certain side in the past is likely to cause continuation of movement in the same direction. If $H <$ ½, it is predicted, that the process will change the direction. $H=$ ½ means uncertainty – Brownian motion [15].

To determine the fractal characteristics of chaotic information flows are calculated value of the Hurst exponent of time series for the main process variables of distillation department of distillery over a certain period (fig.5).
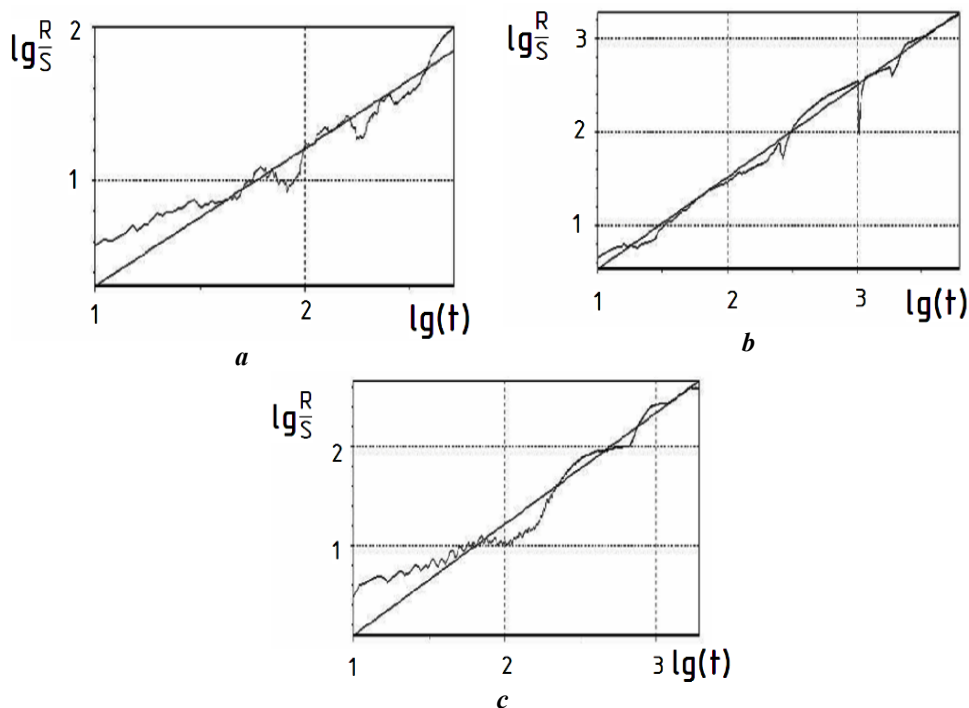
Fig.5. Calculation of the Hurst exponent of
a - the alcohol expenses (*H=0.8992*);
b - the pressure in the bottom of Distillation (Mash) Column (DC) (*H=0.9830*);
c - the temperature on the 16th plate of rectification column (RC) (*H=0.9621*)

The generalized research results are presented in Table 1.

Table 1

The generalized research results

The observed parameter	H/D	Correlation dimension, D_2	The dimension of the phase space , n
Expense of distiller's wort, F, m³/h	0,83/1,17	4.563	5
Temperature of distiller's wort, ^oC	0,84/1,16	5.468	7
Pressure of the bottom of DC P, kPa	0,809/1,19	3.233	6
Pressure of the top of DC P, kPa	0,82/1,18	2.334	4
Temperature of the bottom of DC, t, ^oC	0,76/1.24	2.474	7
Temperature of the top of DC, t, ^oC	0,725/1,275	2.205	4
Pressure of the bottom of EC P, kPa	80,86/1,14	2.185	3
Temperature of the bottom of EC, t, ^oC	0,722/1,278	5.712	7
Pressure of the bottom of RC P, kPa	0,86/1,14	5.343	3
Temperature of the bottom of RC, t, ^oC	0,73/1,27	3.873	5
The temperature in the control plate of RC , t, ^oC	0,85/1,15	4.754	6

Conclusions

The computed exponents of Hurst testify about characteristic of the persistency of considered variables and the possible sufficiently deep their predictability.

After analyzing the Hurst exponent we can conclude that the estimated indicators of Hurst show that the time series data, and in turn distillation unit itself is a complex nonlinear dynamic control object, which has persistently characteristic of temporal behavior (*0.5<H<1*) [16,17].

The results of research pointed to the presence of intermittency in the technological processes that requires the monitoring systems creation for diagnostic regimes of operation of distillation unit. The operative identification of deterministic, stochastic or chaotic regimes by the methods of nonlinear dynamic makes it possible to implement resource-saving control strategies in the algorithms of control of distillation technological processes, which will increase the efficiency of distillation unit functioning.

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Model of defect management system development for the stator of turbogenerator

Olga Mazurenko , Valerii Samsonov, Larysa Zagorovska

National University of Food Technologies, Kiev, Ukraine

Abstract

Introduction. To execute the complete list of recommendations in relation to the infinitely protracted maintainance of the absolutely in good state of technical object, including turbogenerator, is impossible in principle in connection with his complication. Therefore for providing of work of difficult technical objects it is expedient to use the checking of operating parameters, diagnostics of the technical state, management and defence work systems.

Materials and methods. By case-technologies the operating model of connections is analysed between CASS of control of parameters of work of defence and management work of turbogenerator. Investigational principles of work and informing connection between the checking of operating parameters and relay defence system, between CASS of diagnostics and management work of turbogenerator, relay defence and control system by work of turbogenerator.

Results and discussion. At informative level of the system control parameters of work and relay defence of turbogenerator system closely connected between itself. In the case when systems of defence, diagnostics and management, informing not connected between itself, in the case of defect appearance and not ability of man right to react on his appearance, the technical state of turbogenerator can attain a limiting level. In this case the consequences of development of defect will be maximally negative. In the case of formation of defect near-term, a general task for the control parameters, diagnostics and management work of turbogenerator, systems is become as possible by the rapid exposure of defect realization of necessary measures. Therefore functioning of these systems separately one from other not expediently, as a general task decides with their use. From the above it follows, that control system by development of defect combines between itself work of the control of parameters, diagnostics, management and defence of turbogenerator work systems. Maximal duration of «passive» existence of control system by development of defect, it is determined the interval of time between the exposure of defect and triggering of protective devices.

Conclusion. Offered model of control system by development of defect of knots of turbogenerator due to strengthening of informative and functional connections between the control of operating parameters, relay defence and management work of turbogenerator systems which allows to promote efficiency of the use of these systems.

Introduction

To develop and execute the complete list of recommendations in relation to the endlessly protracted service of the absolutely in good condition state of technical object, is basically impossible [1, 2]. In this regard, for the ensure the operation difficult technical objects are used by the control system operating parameters, diagnosis technical condition, management of the object [3] and relay protection.

Materials and methods

By case-technologies the operating model of connections (fig.1) is analysed between CASS of control of parameters of work of defence and management work of turbogenerator. Investigational principles of work and informing connection between the checking of operating parameters and relay defence system, between CASS of diagnostics and management work of turbogenerator, relay defence and control system by work of turbogenerator.
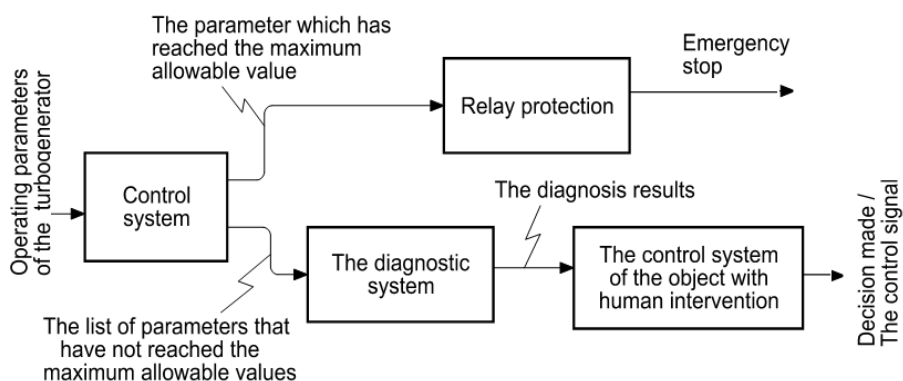
Fig.1. Existing model connections between automated systems of turbogenerator

Results and discussion

The main task of the control system of any technical object and turbogenerator is gathering and processing of information for finding a particular event in the object. As a result of defect formation and changing the value a particular technological (working) parameter turbogenerator can move from the good state in another state, for example to the limiting state [4], and the system controls the operating parameters should reflect this event.

After reportedly about moving from the good state to the limiting state of turbogenerator from control system should work turbogenerator protection system - relay protection, and automatically, without human intervention, is executed algorithm of control result of which is an emergency stop of the turbogenerator [5, 6, 7]. On the informative level, these two systems are closely related (fig. 2) and without them exploitation of the modern turbogenerator is impossible

From the above it follows that whatever type of defect type, its appearance became an event, which connects the states of object operability [8]. Hence, there is reason to believe that the system control parameters of the conditional object, which is able to endlessly maintain the good state, would have been much easier from existingsince in such circumstances it actually became part of the control modes of operation.

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┌──────────────────┐   ┌──────────────────┐      ┌──────────────────┐
│Getting information│──▶│  Operating       │─────▶│  Comparing the   │
│from the sensors   │   │ parameters of the│      │operating parameters│
└──────────────────┘   │  turbogenerator  │      │with allowable values│
                       └──────────────────┘      └──────────────────┘

┌──────────────────┐   ┌────────┐  ┌────────────┐  ┌──────────┐  ┌────────────┐
│Information about passport│ │Fixing  │ │Determination│ │ Starting │ │ Automatic  │
│ / experimental limit     │─│deviations│─│   node    │─│  relay   │─│ emergency  │
│   parameters             │ │        │ │            │ │protection│ │stop turbines│
└──────────────────┘   └────────┘  └────────────┘  └──────────┘  │and auxiliary│
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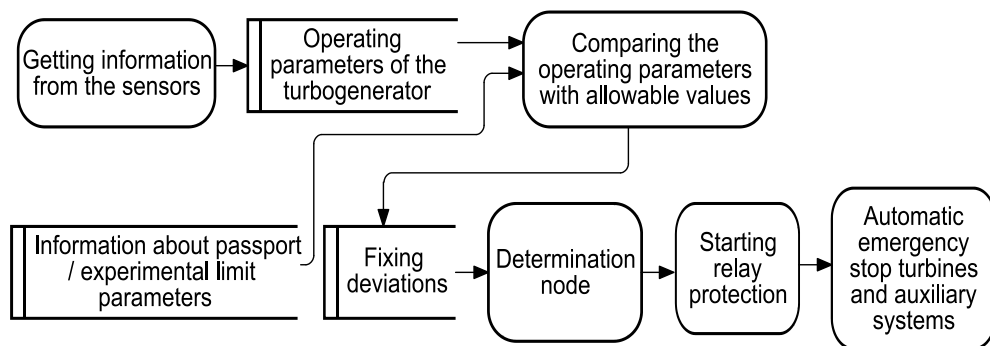
Fig.2. Model of the informative connection between the control system operating parameters and relay protection

Of course, it is impossible to carry out effective management of the turbogenerator having accurate information regarding his states, which provides diagnostic system [9, 10], the main task of which is to identify the defect as a result of which the turbogenerator can move to the limiting state and fixing intermediate functional and inoperable turbogenerator. It should distinguish between automatic control system operating modes of the object, which is not yet used to control turbogenerator, and automated control system of human intervention, which decides on the terms of future work or stops turbogenerator. Informative communication between automated systems for diagnosis and management of turbogenerator shown in Fig. 3.

What has been said about control system is fair and for the system of management of the object able to endlessly remain in good state. And the systems of the diagnosis and the protection of this object does not need. This means that the probability of the defect and, consequently, reduce the efficiency of the object, determine its difficulty of controlling the operating parameters, diagnosis, and management of protection

For warning of refuses, as a result of origin of defect, and diminishing of influence of human factor on the capacity of turbogenerator, it is necessary to have as the completest and most reliable information from the control of parameters and diagnostics of turbogenerator systems. The value of such information is substantially increased from the moment of origin of defect. It follows that the occurrence of the defect is an event that enhances (intensify) the information and functional conections between the control parameters and diagnostics and closely links them together.

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┌─────────────────┐                              ┌─────────────────┐
│ Fixing          │                              │ Informing staff │
│ reaction to     │ ◄───────────────────────────│ about their     │
│ the             │                              │ further actions │
│ appearance      │                              └────────┬────────┘
│ of the defect   │                                       ▲
└─────────────────┘                                       │
         ┌─────────────┐                          ┌────────────────────┐
         │ Fixing type │                          │ Responsible officials│
         │ of defect   │──────────┐               │ make solutions      │
         └──────┬──────┘          │               │ about further work  │
                ▼                 │               │ of the turbogenerator│
┌──────────────┐  ┌──────────────┐│               └──────────┬──────────┘
│ D5           │  │ Determining  ││                          ▲
│ Manual for   │  │ the location ││               ┌──────────────────────┐
│ staff of     │─►│ of the defect││               │ Informing decision   │
│ theirs actions│ │ and his type ││               │ makers about         │
│ if defect    │  └──────▲───────┘│               │ the type of defect   │
│ appearances  │         │        └──────────────►│ and state of the     │
└──────────────┘  ┌──────┴───────┐                │ turbohneratora       │
                  │ Informative  │───────────────►│ for decision making  │
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                  │ information   │
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                  │ D4 Fixing    │
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│ D1           │  │ Comparison   │   │ D3                     │
│ Operating    │  │ of diagnostic│   │ Information about      │
│ parameters   │─►│ system        │◄──│ passport /             │
│ turbogenerator│ │ operating     │   │ experimental parameters│
└──────────────┘  │ parameters    │   │ of the turbogenerator  │
                  │ with passport/│   └────────────────────────┘
                  │ experimental  │
                  │ data          │
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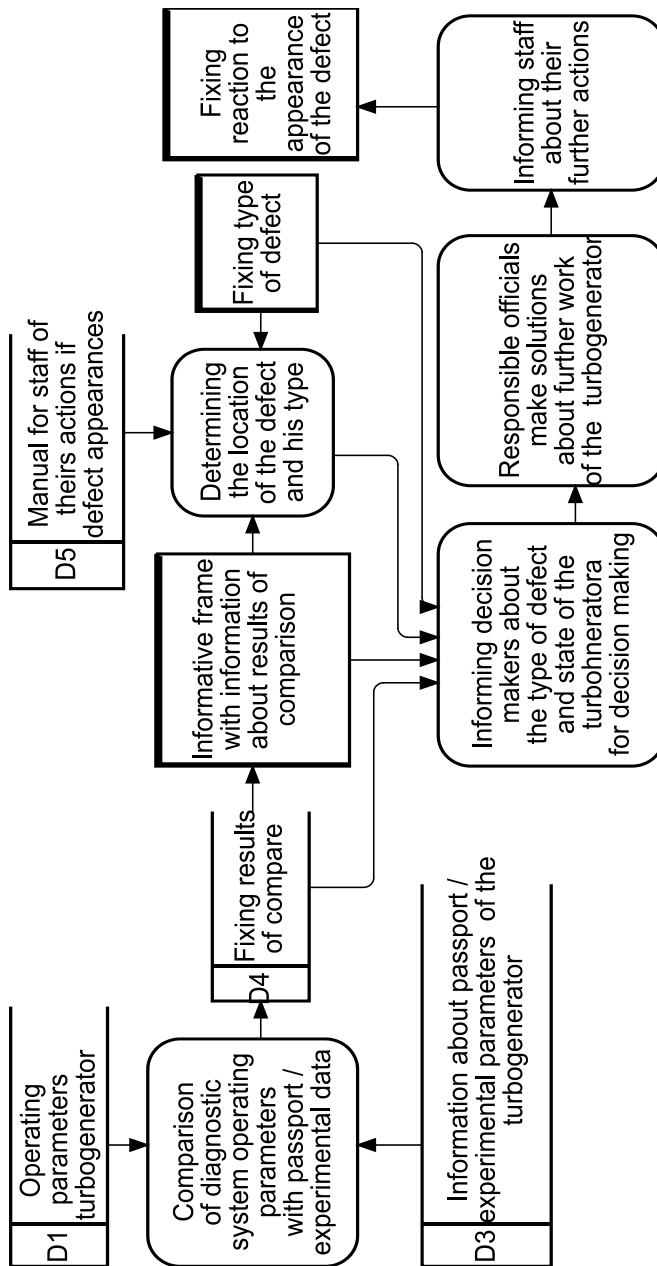
Fig. 3. A model of informing connection is between automated systems of diagnostics and management work of turbogenerator

In case of formation of defect a near-term, general task for the checking of parameters, diagnostics and management work of turbogenerator systems becomes as the quickest exposure of defect and realization of events, for example, of establishment of the modes works of turbogenerator, at that negative influence of defect on his technical state will be minimum or removed quite. In the case when the automatic system of defence and control system with intervention from a man are informing unconnected inter se (rice. 1), in case of occurring of defect and not possibility of man right to react on his appearance, the technical state of turbogenerator in any case will attain a maximum level and the consequences of development of defect will be maximally negative.

Thus, as a result of combination of work of four higher adopted systems have formation of control system by development of defect. If to stop development of defect it is not succeeded and the technical state of ТГ continues to get worse, in an eventual account, defence of turbogenerator. must work. But if to cut on the certain stage development short of defect and it negative influence on the technical state of turbogenerator, control system by work of object with intervention from a man and defence actually will carry out a management development of defect.

As an interruption in the receipt of electric energy to the consumers can cause the stop of their work [11], then implementation protecting and disconnecting of turbogenerator from a network essentially shows a soba an accident. Thus, the task of control system by development of defect must also be warning of emergency implementation of defence and providing, in a certain measure in good time pre-arranged and accordingly concerted, stop of turbogenerator for implementation of repair works.

From the above it follows, development management system defect (Fig. 4) combining together the work of the control system operating parameters, diagnosis technical condition, management of the object [6] and relay protection of the turbogenerator. In case of origin of defect of functioning of these systems separately one from the second not expedient, as a common task decides with their use. Besides, combination of possibilities of the systems assists the increase of them technical and economic efficiency.

Maximal duration of "passive" existence of control system by development of defect, it is determined by the interval of time between the exposure of defect and actuation of protective devices. It means that in case of origin of defect information technology of diagnostics, in particular, thermal state of статора of turbogenerator becomes the constituent of information technology of control system by development of defect.

From the above it follows, that one of the most perspective directions of perfection of IT of diagnostics of the thermal state of turbogenerator and, in particular статора of turbogenerator, there is strengthening of her lines and feed-backs on informative, functional and vehicle levels with information technologies of control of parameters and management work of turbogenerator.

Conclusion

Offered model of control system by development of defect of knots of turbogenerator due to strengthening of informative and functional connections between the control of operating parameters, relay defence and management work of turbogenerator systems which allows to promote efficiency of the use of these systems.
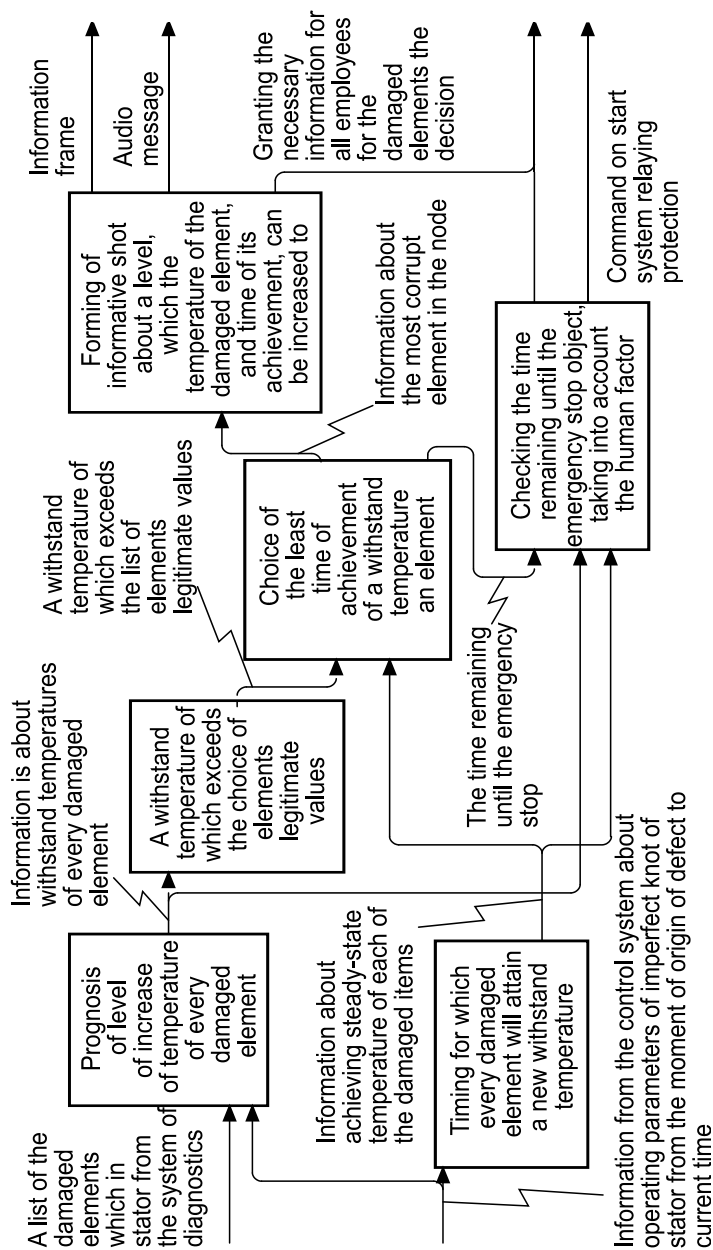
Fig. 4. Model of control system by development of defect of статора of turbogenerator

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Cause of the fire at the food industry enterprises

Olga Slobodyan, Vira Zaets,
Larysa Neshchadym, Svitlana Avdienko

National University of Food Technologies, Kyiv, Ukraine

Corresponding author:

Svitlana Avdienko
E-mail:
Sv_avdienko@mail.ru

Abstract

Introduction. Research the causes of fires at the food industry enterprises of Ukraine will allow develop effective measures to reduce the likelihood of their occurrence.

Material and methods. We used theoretical methods of research in the above privacy of data analysis of scientific literature on the subject , methods of synthesis , comparison and generalization of data relating the factors that contribute to the raising of fire risk on industrial objects of Ukraine.

Results and discussions. Analysis of fires in different areas of the food industry indicates that most likely their causes are violation of rules for the arrangement and maintenance of electrical installations, careless handling of fire, violation of process regimes (especially during baking, roasting, drying or other processing method), fault or outdated equipment, poor treatment with flammable liquids, violation of terms cleaning of combustible dust. These factors are compounded by the fact that these companies saved, transported or used a substance which under certain conditions can burn or explode, e.g. alcohol, ether, essences, organic acids, gasoline, acetone, hydrogen, etc.; the dust of many food products (flour, sugar, tobacco, tea, starch, cocoa, powdered milk and other); ammonia which used as refrigerant. Also, the food industry uses a large amount of combustible materials and packaging, which increases the fire risk of object.

According to these causes of fire reasonable measures to avoid: compliance the general requirements of fire safety, prevention of combustible environment and the occurrence of ignition sources in it, enhancing monitoring of process equipment and control devices.

Conclusions. The research results can be used in the development and improvement of effective measures to ensure fire safety at the food industry enterprises.

Introduction

Fires are a serious problem for many industrial enterprises, resulting in increased economic, environmental and social damages. Human casualties are the most important of them.

Every year over 6,000,000 fires take place on Earth, including about 60,000 fires in Ukraine.

The fire risks on industrial enterprises of Ukraine increase considerably due to such factors as increased power supply, increased density of transport communications, heightened temperature and pressure in the process equipment, using of new polymers with higher flammable properties. While the modern production processes attain lowered probability of fire, they at the same time get more serious aftermaths and greater damaged areas in case of fire. Statistics show that a fire reaches the maximum tolerable level of hazard within 5-10 minutes. The loss of the metal building structure bearing capacity is reached within another 10-15 minutes. Whereas the effective actions of fire brigade start only within 20-25 minutes after the fire start.

Increased concentration of combustible substances and material assets per unit area of the buildings leads to increasing level of fire hazard.

The main causes of fire are:

- Malfunction of the production equipment — 0.3%;
- Arson — 1.6%;
- Violation of rules for the arrangement and maintenance of ovens — 7.3%;
- Violation of rules for the arrangement and maintenance of electrical installations — 19.7%;
- Careless handling of fire — 59.8%;
- Other reasons — 11.3% [1].

Material and methods

During the investigation of the causes of fires at the food industry enterprises we used theoretical methods of research in the above privacy of data analysis of scientific literature on the subject , methods of synthesis , comparison and generalization of data relating the factors that contribute to the raising of fire risk on industrial objects of Ukraine.

The research was conducted by analyzing explosive and flammable substances and materials, factors available in the baking, confectionery, fermentation, sugar, alcohol, alcoholic beverages, oil extraction, and others food enterprises of Ukraine, that can cause fire and explosions, according to scientific papers in the field of fire safety.

Results and discussions

Combustion is a physical-chemical process of quick interaction between combustion agent and an oxidant accompanied by the production of heat and light. Oxidants may include not only oxygen and air, but also chlorine, fluorine, sulfur, nitric acid and other substances. Start of the combustion process requires three factors: the combustible substance, oxidant and the ignition source. The combustible substance and oxidant create the combustible system (material, mixture, construction). The ignition source starts the combustion process, which does not stop even after ignition source is removed.

Combustion is divided into several types, including blaze, ignition, flame and spontaneous combustion.

Spontaneous combustion is a condition that leads to a rapid temperature rising followed by combustion of a substance without source of ignition. Spontaneous combustion can be thermal, microbiological or chemical. Timber and woodwork, vegetable oil are exposed to thermal spontaneous combustion. Microbiological spontaneous combustion occurs during storage of grain, hay, peat and other vegetable materials [2]. Chemical spontaneous combustion occurs because of chemical interaction of substances as well as due to air and water influence on them. The chemical spontaneous combustion is typical for vegetable oils and animal fats. The ability of oil or fat to combust spontaneously characterized by iodine number. The higher the number is, the more these substances are prone to combust. For example, flaxseed oil has the iodine number of 175-205 and the spontaneous combustion temperature of 343°C, and hemp oil has the iodine number 150-172 and the spontaneous combustion temperature of 410°C. Spontaneous combustion greatly increases the fire hazard if the store rules of sunflower cake, oilcloth, etc. are violated.

Liquids prone to fire are divided into two categories: highly flammable and combustible. In manufacturing environments these liquids can form a steam-air mixture, but it will not ignite if the vapor concentration is too low or too high [3]. There are a lower and an upper flammability temperature. It is the lowest and the highest temperature of combustible liquid that can cause fire from the source of ignition.

Baking industry, confectioneries, pasta industry, fermentation plants and sugar refineries have many fire-hazardous and dangerously explosive places and operations, allocated all over the production chain – beginning from the feedstock storehouses and ending with the finished products warehouses. This is due to the fact that most raw materials, substances and materials utilized in manufacturing of semi-finished or finished products are solid or liquid combustible substances. Substantial part of these substances is also highly explosive.

Such enterprises of food industry as distillery, alcoholic beverage industry, perfumery, fat-and-oil industry utilize and produce fire-hazardous and dangerously explosive substances, e.g. alcohol, ether, essences, organic acids, oils, fats, benzine, acetone, hydrogen, etc.

Table 1

List some of the highly flammable and combustible liquids, gases and their fire-hazardous properties

Liquid	Limit of inflammability				Spontaneous combustion temperature, °C
	Lower		Upper		
	t, °C	Concentration, %	t, °C	Concentration, %	
Ammonia	-	17	-	27	700
Acetone	-10	2,91	-6	13	465
Acetylene	-	2,5	-	82	335
Dichloroethane	8	6,2	31	16	525
Acetic acid	35	3,3	76	22	454
Methanol	7	6,7	39	38,5	464
Ethanol	11	3,61	41	19	404
Hydrocarbon oxide	-	12,5	-	80	610
Toluene	0	1,95	30	7	536
Gasoline	-28	1,9	-9	5,1	260

The dust of many substances also has fire-hazardous and dangerously explosive properties [4,5,6]. Release of the combustible and explosive dust takes place during production of sugar, tobacco, tea, starch, flour, beverages, meat processing, backing.

Table 2

List explosive and fire-hazardous properties of dust

Substance	Minimal concentration for explosion, g/m^3	Spontaneous combustion temperature, °C	Substance	Minimal concentration for explosion, g/m^3	Flash point, °C
Class I (highly explosive)					
Glucose crystal	15,0	250	Dust: fodder	10	-
Forage maize	12,6	-	sugar	8,9	525
Dried milk:			sunflower meal	7,6	525
whole	7,6	875			
non-fat	8,9	825			
Meal: blood	7,6	-			
meat-and-bone	10,1	-			
Class II (explosive)					
Sunflower cake	22,7	825	Dust:		
Beet pulp	27,7	750	grain screenings	25,5	-
Cocoa powder	45,7	420	flour	17,6	800
Starch: potato	40,3	-	wheat grey	40	-
corn	50	625	coal	32,8	-
Meal: wheat	20	395	Pectin: beet	60	-
barley	32,8	750	apple	27,5	-
Wheat bran	22,7	-	Ground wheat	45,4	-
Class III (highly fire-hazardous)					
Dust: tobacco	68	205			
grain elevator	227	250			
Class IV (fire-hazardous)					
Timber dust	above 65	275			

Many food enterprises are equipped with refrigerators.

Ammonia — the most commonly used refrigerant — is an explosive and toxic gas. Thus, for the most of food industry enterprises the areas with high risk of fire includes ammoniac compressor station and refrigerator compartment with direct cooling [7,8].

Large amounts of combustible containers are utilized and manufactured at the food industry facilities: wood, plywood and cardboard boxes; cloth and paper bags; paper packets; labels, polyethylene and cellophane packaging, etc. The presence of combustible containers increases the fire risk at the enterprise.

Storage facilities and stockrooms to store grain, flour, cereals, vegetables, fruits, tobacco, etc. require disinfestation to combat pests. If carbon bisulfide, dichloroethane or sulfur is used for disinfestation, the fire hazard and explosion threat increase.

Heating, drying, roasting, boiling and baking at the food industry facility requires utilization of ovens working on solid, liquid and gaseous fuel.

The fire threat appears because of violation of technological requirements and fire safety requirements.

At such enterprises of food industry as distillery, alcoholic beverage facilities, fat-and-oil facilities, oil-extraction plants alcohol and fuel — which are highly flammable liquids — can form combustible mixtures with air in case of the equipment and pipeline seal failure due to violation of working and repair instructions. Flammable and combustible liquids leaks because of loose flange connection of pipelines, leaky sealing rings of pumps and shutoff valves, the alcohol in refrigerators is cooled insufficiently.

Leaky manufacturing equipment and communication fixtures cause high leakage of the benzene vapor or other solvents at oil-extraction plants. The highest leakage of explosive substances occurs due to technological requirements violation leading to an accident. The highly explosive mixture of benzene vapor and air occurs due to level drop in the bunker of meal (sunflower, etc.) processing.

There are different cases of the explosive and flammable substances combustion. The most frequent causes of ignition are spark formation of mechanical origin due to collision of the metal parts (ventilator, etc.); metal objects getting into granulators and other processing equipment; a tool falling onto metal surface or concrete floor; open fire of processing equipment, incineration sites, electric welding, matches and unquenched cigarette [9]; heat development of the electric current, short circuit arc or spark; static and atmosphere discharges [10]; ball bearings overheating due to lubricant misapplication, malfunction, wear or clogging.

Main reasons of fire in food industry may be divided into disciplinary reasons, processing reasons, reasons caused by electricity, reasons caused by lack of the inspection or its tardiness.

Disciplinary reasons includes violation of requirements for design of industrial and auxiliary buildings and facilities [11], for the building materials and constructions [12-16], for the facilities planning, for the processing equipment placement; departure from the operation and maintenance rules of the equipment, power consumers and power supply networks; violation of job instruction for fire safety; violation of the safety regulations during fire works; casual handling of open fire sources, smoking at the workshops and storehouses; mishandling of high combustible fluids; incorrect storing of oiled materials and cotton working clothes; violation of the combustible dust cleaning rules and terms [17].

Processing reasons of fire includes work on faulty processing equipment or with the workflow routine violation, especially during baking, roasting, drying or other processing method; use of combustible substances that do not conform to specification of processing stoves, violation of the stove lighting mode, of operation mode, of cutoff mode; incorrect filling of vessels and utility lines with high combustible liquids and gases, use of tools that produce sparks when hitting the solid surface.

List of indicators for fire explosion hazard substances and materials

№	Indicators	Using indicators of fire explosion hazard			
		Gas	Liquids	Solid materials	Dust
1	Group of combustibility	+	+	+	+
2	Temperature of flash	-	+	+	-
3	Temperature of flashing	-	+	+	+
4	Temperature of self-ignition	+	+	+	+
5	Concentration limits of spreading fire (flashing)	+	+	-	+
6	Temperature limits of spreading fire (flashing)	+	+	-	-
7	Temperature of self-heating	-	-	+	+
8	Smoldering temperature	-	-	+	+
9	Conditions of the thermal self-ignition	-	-	+	+
10	Minimal energy of flashing	+	+	-	+
11	Index of oxygen	-	-	+	-
12	Ability to explode and burn during interaction with water, air oxygen and other substances	+	+	+	+
13	Normal speed of fire spreading	+	+	-	-
14	Speed of burn up	-	+	-	-
15	Rate of smoke production	-	-	+	-
16	Index of fire spreading	-	-	+	-
17	Toxicity indicators of combustion products	-	-	+	-
18	The minimum explosive level of oxygen	+	+	-	+
19	Minimal retarding concentration of retarder	+	+	-	+
20	Maximum explosion pressure	+	+	-	+
21	Rate of pressure rising during the explosion	+	+	-	+

Note. «+» means applicable, «-» - means non applicable indicator

Reasons of fire related to electricity includes use of electrical equipment that do not correspond to fire and explosion hazard category of the production; overload of the processing transport mains operated from electric drive, overload of other electric equipment and networks; poor electric contact at a wiring point; insulation failure, other faults and damages to power supply consumers or networks; lack of safety devices from the static electricity on the processing equipment and workers, lack or crippling of the lightning rods and protective devices from the secondary effects of atmospheric electric linear discharges[18].

The main drawbacks of control measures leading to fire are lack or tardiness of technical inspection, lack of routine preventive repairs of the processing equipment, automation, control instrumentation and safety devices; insufficient control for temperature

conditions of the processing equipment that use open fire or of the equipment acting through the operating temperature rise (compressors).

Fire safety measures are very diverse but according to its target purpose they can be divided into four groups:

1. Measures in production process, providing fire safety during work of processing system and during storage of end products. Such measures are executed during design process, when in view of the fire safety the most safety temperatures and pressures, reliable control and preventive equipment are chosen and special rules of fire safety, rules of joint storage of materials and substances are set.

2. Construction measures aimed to eliminate the causes of fire breakout and creation of stable protective structure and building as the whole during the fire and limitation of fire spreading and explosion. Such measures are executed during design and construction process; they are connected with choosing buildings according to their level of fire resistance and number of floors according to the fire hazard of production process, choose of heater system, ventilation, construction of fire barriers.

3. Administrative and fire safety mass agitation measures, providing organization of object fire protection in whole and training of all staff measures for preventing fire and use of fire equipment, are executed during the process of exploitation.

4. Measures ensuring conditions and means of fast and successful fire suppression performed during construction and operation; they provide the choose of most effective ways and means of fighting fire, the units for fire water supply, fire alarm, creation of storage with means for fighting fire.

The studies are important to food companies not only in Ukraine but also the world.

Conclusions

The most important task of all fire safety systems is to protect people from the hazards that accompany combustion, and to rescue people in case of fire.

The essential task in the operation process of any facility is to ensure the full evacuation of all personnel in case of fire emergency before reaching the critical values of fire hazard [19].

It is strictly prohibited:

- To set up thresholds, turnstiles, sliding or roll shutter doors, etc. on the escape routes;
- To make clutter on the escape routes with furniture, equipment, materials or finished products even if they do not decrease the regulatory width of the passage ;
- To block, weld up, lock with a padlock the outward facility escape doors ;
- To use combustible materials in facings of walls, ceilings and stairs of the escape routes.

Finally, the one responsible for fire safety should always proceed from the fact that to prevent fire is always better than to fight its aftermath, especially when a human life is at stake.

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Mathematical model of decision-making with account the risk of injuries

Olga Evtushenko, Alina Siryc, Petro Porodko

National University of Food Technologies, Kyiv, Ukraine

Corresponding author:

Alina Siryc
E-mail:
alsok3030@gmail.com

Abstract

Introduction. In order to improve the mathematical models of decision making in company's safety management system was found that in the development of methodical maintenance decision support systems it is necessary to create a process of adaptation of decision-making tools.

Materials and methods. The research was conducted based on general system approach, grounded on interconnection of elements; the methods of logical simulation modeling and "fault tree" were used in the research.

Results and discussion. Risky alternative is an occupational safety measure, related to equipment modernization and is assessed in such a way: benefit (income) in the amount of a with the probability q; damage in the amount of b with the probability 1 – q. a and b can be chosen random, but their order shall meet the means, operated by an occupational safety specialist in the process of making a decision. For this purpose b is the benefit, which equals zero, and a equals 1. But alongside with it, at the disposal of an employer, making decisions in OSM at the enterprise there is another alternative – a strategy, not connected with risk, ensuring the profit in the amount of x. Mathematic profit expectation, the suggested occupational safety measure realized, is related to an increase in labor productivity, production quality, a decrease in pay-off expenditures, the injury risk will drop, depending on the figure q, while a and b are fixed. Risk inclination can be identified in such a way – an employee, making an OSM decision, is risk inclined, if he/she wants to make decisions in any alternative instead of obtaining a guaranteed profit for the enterprise in the amount of the expected one for the alternative. Benefit function peculiarities for an employee, making OSM risky decisions, are based on the following: an employee is inclined to risk, if the graph has a swept-up benefit function; with the rising benefit function an employee is risk inclined when its deterministic equivalent for any alternative exceeds the expected benefit, $x° > M [X]$; with the rising benefit function an employee is risk inclined when risk bonus will be negative at all alternatives, $\Delta R(X) < 0$.

Conclusion. Risk reluctance function has the following characteristics: two benefit functions are strategically equivalent only when they lead to one and the same risk reluctance function and the most probable benefit from the made OSM decision with $k \to 0$ approaches the mathematic expectation of the benefit from actions of the employee, neutral to risk, with $k \to -\infty$ the mathematic expectation of the benefit approaches the maximum possible one.

Introduction

The occupational safety analysis and industrial accidents rate prediction [1-3] point at three main constituents of the OSM functioning inefficiency, particularly insufficient methodological provision of the risk-oriented approach during: threatening danger analysis and accidents investigation; planning work at the stage of the task functional analysis while making managerial decisions in OSM; OSM computer informational constituent functioning for the purpose of decision making maintenance.

Thus, there is no enough methodologically reasoned «etalon», applying which any employee, ranging from an operator to a manager at any stage of the production cycle development or occurring a dangerous, crucial or emergency situation, taking into consideration a systemic risk-oriented approach and own psycho-physiological peculiarities, shall make concrete decisions from the certain list, where it is possible, and contribute to their fulfillment.

So it is necessary to develop and embody to the enterprise management system such a scheme, which would show the impact of occupational safety on the final objectives of the enterprise. With the scheme employers and engineers, organizing the production cycle in a certain way, should be provided with accident analysis methods, being a means of identifying threatening dangers. To solve mutually related tasks and functions of occupational safety concerning accountancy, analysis and prediction, and on their basis – to develop preventive measures, it is necessary to improve the management system, which should unite separate means into a single complex at all levels and stages of management.

The aim of the work is to improve decision making mathematic model within the system of occupational safety management of an enterprise.

The research object is the phenomenon of production accident rate at the enterprise.

For the purpose of analyzing decisions, made in OSM, under conditions of the increased risk of getting injured at the enterprise, one can employ such methods as the decision tree method, the probability tree method.

While making decisions, one should estimate their consequences and structure the task for the purpose of identifying a better (or essential, if it is necessary to achieve certain results at a certain stage) sequence of decisions [4–6].

Materials and methods

The decision tree analysis as an instrument of supporting decisions under conditions of OSM functioning at the enterprise enables to take into consideration employers' reluctance to make risky decisions, but the alternative choice criterion does not always coincide with minimization of the level of accident danger at certain work places or production sites.

Quantitative assessment of alternative action priority shall be relative, it depends on personal features of employees and it is called differently: the extent of benefit (advantage), usefulness, etc. We accept "benefit" as the basic term, so taking risky decisions with the help of decision and probability trees corresponds to Neimann-Morgenstern concept, according to which probability is probability of some events [7]. The term «usefulness» can be applied in a principally different assessment methods and ways of alternative choice – the method of multi-attributive usefulness.

The benefit concept in OSM functioning at the enterprise, taking into account [8], shall be based on contrasting two alternatives by each employee: a risky one, the assessment of which is mathematic expectation of loss as a result of injury, and a guaranteed one, bringing

a stable, though not huge, profit or damage under conditions of the acceptable risk theory application.

Meanwhile one should take into account possible alternatives of the decision, being made, the related factors of ambiguity, their potential result, and determine the choice criteria. If we structure the issues in a form of a decision tree, the choice dynamics can be assessed directly by the analogy with the net diagram or through correction of the appropriate characters. For it is necessary to formalize the method, restricting it with the conditions: a, b, c, d, e, f.

Results and discussions

a. The decision making process in OSM is iterative with an arbitrary number of branches, non-structured number of hierarchy levels, each of them combining binary pairs «action-event», the initial level having the code of I;

b. The known list of alternatives (d_i, where i is a serial number of action) is considered to be necessary for consideration at a certain stage of making a decision in OSM, and the condition of the optimal alternative choice at the initial level consists in solving the task of mathematic programming

$$\sum_{i=1}^{m_I} x_i a_i \to \max ,$$

(1)

$$\sum_{i=1}^{m_I} x_i = 1 ,$$

(2)

where a_i is i-action identifier, determined as a mathematic expectation of the possible result of accepting such an alternative; $x_i=1$ if i-action is accepted; $x_i = 0$ – otherwise;

c. Any alternative action is connected with the impact on its consequences of occasional factors, comprising a group of inconsistent occasional events, each of them characterized by the alternative usefulness criterion with the appropriate a priori possibility, the vector as the characteristics of i-action of the initial level being

$$(C_{ij}, P_{i,j}),$$

where C_i and $P_{i,j}$ are usefulness and possibility of j-event of i-action; $i = 1, m_I$; $j = 1, n_i$; m_i is the number of alternatives of the initial level; n_i is the number of occasional actions, causing i-action, that having been taken into account, can be represented like this

$$\sum_{j=1}^{n_i} P_{ij} = 1 ,$$

(3)

$$a_i = \sum_{j=1}^{n_i} C_{ij} P_{ij} ,$$

(4)

And the target function of the decision choice being:

$$P = (v = k) = (\frac{\alpha}{\alpha + \lambda})^\alpha \cdot \frac{\alpha(\alpha+1)...(\alpha+k-1)}{k!} \cdot (\frac{\lambda}{\alpha + \lambda})^k, \text{ (k} = 0, 1, 2, ...; \lambda > 0, \alpha \geq 0).$$

$$\sum_{i=1}^{m_i} \sum_{j=1}^{n_i} x_i c_{ij} p_{ij} \rightarrow \max; \qquad\qquad (5)$$

d. any event and its consequence of the higher level cause alternative actions of the next level, the identification of which is carried out due to the first condition with an increase in the indices number by one point, if it is not necessary to continue the process of the certain event detailing, the appropriate bond at the decision tree has no branches;

e. all variants of alternative decisions and their consequences are chosen in OSM non-officially by an employee, making the decision, supported by the informational system, such a procedure of identifying alternatives and their consequences eliminating uncertainty, being adjusted with the sufficient decision quality by intuition and being a rational way of achieving the system objectives;

f. all assessments, including assessments of event realization possibility with its usefulness, shall meet the transitivity conditions, and the alternative ranging condition, if alternative d_i is of a higher priority level, than alternative d_j, which, in its turn, higher than d_k, alternative d_i is of higher priority than d_k, can be identified in such a way

$$(d_i \succ d_j) \cap (d_j \succ d_k) \Rightarrow (d_i \succ d_k).$$

Risk is known to be a quantitative danger assessment or situational characteristics of any production structure activity, reflecting uncertainty of initial system position and possible negative consequences in case of coincidence of unfavorable circumstances. But it is necessary to remember that risk is expressed through the financial expenditures probability. So, risk rate in OSM at the enterprise shall be minimized and it is necessary to choose from several alternative decisions only the one, accompanied with the minimum risk. On the other hand – a real situation and the suggested in the developed countries theory of the acceptable risk causes the necessity of the optimal ratio of the risk level and occupational safety expenditures. Thus, it is also necessary to take into account a certain employee's wishes or inclinations whether to make a risky decision or not to do it.

Let's assume, that a risky alternative is an occupational safety measure, related to equipment modernization and is assessed in such a way: benefit (income) in the amount of a with the probability q; damage in the amount of b with the probability 1 – q.

Figures a and b can be chosen random, but their order shall meet the means, operated by an occupational safety specialist in the process of making a decision. For this purpose b is the benefit, which equals zero, and a equals 1. In the contracted form the alternative (lottery) can be represented like this: <a, q, b>. But alongside with it, at the disposal of an employer, making decisions in OSM at the enterprise there is another alternative – a strategy, not connected with risk, ensuring the profit in the amount of x.

Mathematic profit expectation, the suggested occupational safety measure realized, is related to an increase in labor productivity, production quality, a decrease in pay-off expenditures, the injury risk will drop, depending on the figure q, while a and b are fixed. It is calculated according to the formula M (q) = aq – b (1 – q).

In those cases, when the choice between two strategies becomes a similar ratio between x and expected result M (q) defines the equivalent basic measure with probability $\tilde{q}$. Three variants of event development are possible, depending on the employer, making occupational safety decisions:

1. He/she is not inclined to risk and chooses such $\tilde{q}$, with which M($\tilde{q}$) > x;
2. He/she is indifferent for whether the investment to the suggested occupational safety measure is risky and chooses $\tilde{q}$ from the condition M($\tilde{q}$) = x;
3. He/she is inclined to risk and chooses $\tilde{q}$ under the condition M($\tilde{q}$) < x.

   If benefit U(x) satisfies one of the variants, the alternative actions choice problem is restricted to assessment of each of them and at its highest value optimal alternative is determined. Alternative D benefit is determined from

$$U(Д) = \sum_{j=1}^{n_i} p_{ij} U_{ij}(c_{ij}) . \tag{6}$$

   The rule of applying the benefit function is demonstrated in picture 1. In the situation K_0, for which the choice of decision at the final stage is the assessment of four alternatives (K_1, ..., K_4) and the choice of the «best» of them.
   Chart 1. describes alternative decisions c_{ij} (in hryvnas) with the benefit function U(x), plotted in chart 2.
   With the help of the graphic representation of the function (Fig. 2) one can identify the profitability of making a decision in OSM at the enterprise for the conditions, set in chart 1.

Chart 1

Alternative decisions description in the situation K_0

Alternative actions	$p_1 = 0{,}4$	$p_2 = 0{,}4$	$p_3 = 0{,}4$
d_1 – to modernize equipment	150	-180	250
d_2 – to do nothing	0	0	0
d_3 – to apply for the permission	0	0	60
d_4 – to address an expert	-70	90	210

Chart 2

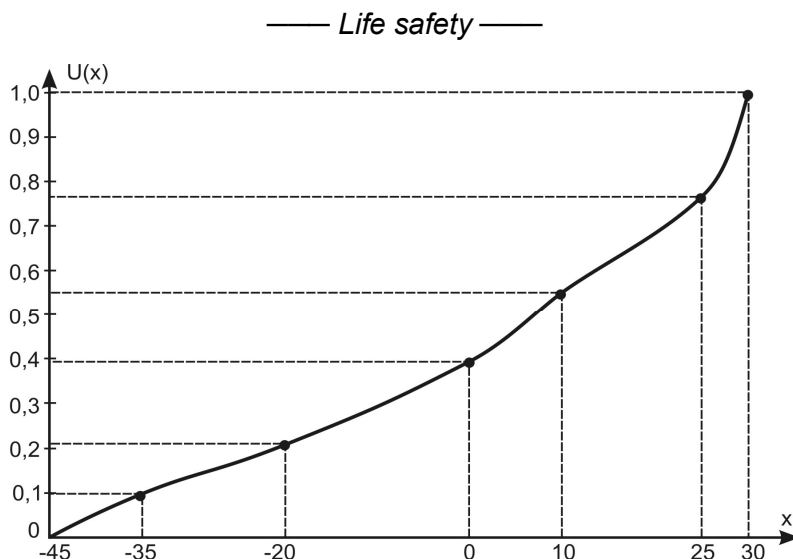**Distribution of the alternative decision profit function in OSM at the enterprise**

γ	1	2	3	4	5	6	7
α_j	-45	-35	-20	0	10	25	30
$U(x_j)$	0	0,1	0,21	0,39	0,55	0,77	1,00
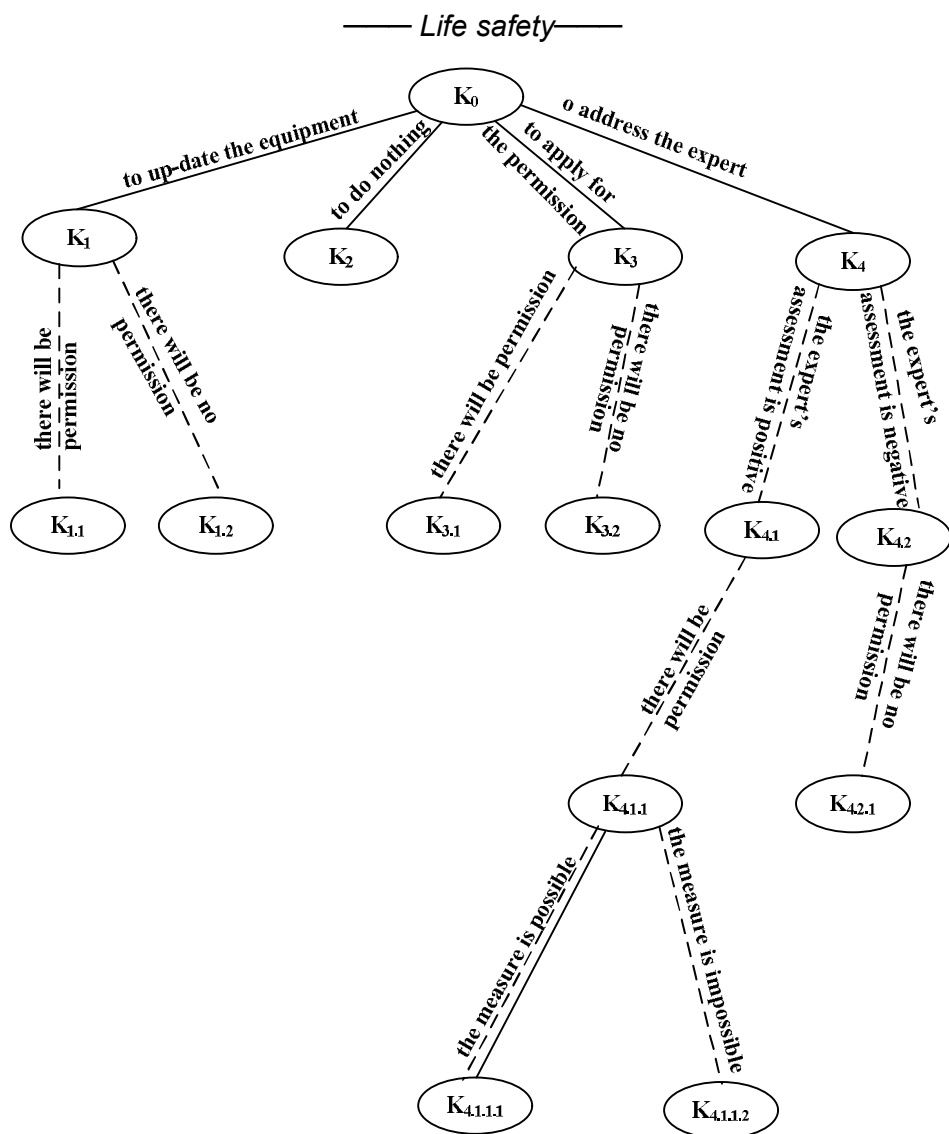
Fig. 1. Decision tree of the situation K_0:
----- – event branches are switched off;
——— – event branches are available.

For it formula (6) is applied

$$U\{d_1\} = p_1U(-150) + p_2U(-180) + p_3U(250) = 0,6;$$
$$U\{d_2\} = 0,45; \qquad U\{d_3\} = 0,475; \qquad U\{d_4\} = 0,71.$$

Fig. 2. Benefit function graph U(x) for matrix elements according to chart 1

The obtained results are shown in chart 3. Their analysis demonstrates that the fourth alternative is optimal according to the benefit criterion, which is proven by the curve U(x) (picture 2).

Alternatives benefit description

Alternatives	$p_1 = 0,4$	$p_2 = 0,2$	$p_3 = 0,5$	General alternative benefit
d_1	0,5	0,3	1	0,6
d_2	0,45	0,45	0,45	0,45
d_3	0	0	0,95	0,475
d_4	0,23	0,9	1	0,71

The second alternative K_2 (to do nothing) is the least probable and cannot bring profit to the enterprise.

If a < x <b, then U(a) = 0, U(b) = 1 and for higher amounts of dimension x high amounts of function U(x) will be responsible, thus there is the condition of monotony: if x_1 > x_2, then U (x_1) > U(x_2). Function U(x) of the actual variable x is strictly monotonous at some interval $x \in I$, if it is determined at it and if for any two points x_1 and x_2 at the interval if x_1 > x_2, resulting in inequality U (x_1) > U(x_2). That means that the benefit function, while making risky decisions in OSM at the enterprise, is monotonously increasing and has a derivative $U'_x = d(x)/dx$.

If there are no grounds for introducing to the benefit function non-regularities of «abruption», «break-up», for an employee, making decisions in OSM at the enterprise the benefit function can be the priorities expression. A concrete image of the benefit function can be chosen visually with the help of points at the coordinate plane or it can be approximated by the known function, due to the procedure of the least quadrates method.

If L–consequences probability tree x_1, x_2, ..., x_n of the OSM made decisions with the appropriate probabilities p_1, p_2, ..., p_n, with $\sum_{i=1}^{n} p_i = 1$, then it is referred to discretely distributed accidental value X, the mathematic expectation of which m_x can be calculated according to the formula

$$m_x = M[X] = \sum_{i=1}^{n} p_i x_i \; ,$$

(7)

And the expected benefit according to the formula

$$M[U(X)] = \sum_{i=1}^{n} p_i U(x_i) \; .$$

(8)

The determined equivalent of the probability tree L is the value x°, when the employee, making OSM decisions, is indifferent for the choice from L variants, that is participation in the «lottery», or receiving guaranteed income x°, the benefit is the same

$$U(x°) = M[U(x)] \qquad \text{or} \qquad x° = U^1\{M[U(x)]\}.$$

(9)

The benefit function being monotonous, deterministic equivalent is defined according to formula (9). Benefit functions $U_1(x)$ and $U_2(x)$ are strategically equivalent ($U_1(x) <=> U_2(x)$), if they similarly locate two random alternatives due to their priority, for any x from $U_1(x) <=> U_2(x)$ it is correct:

$$U_1^{-1}(M[U_1(x)]) = U_2^{-1}(M[U_2(x)]) \; .$$

(10)

If for some constants a and b the ratio is correct

$$U_1(x) = a + b \, U_2(x),$$

(11)

Then functions $U_1(x)$ and $U_2(x)$ are strategically equivalent, i.e. $U_1(x) <=> U_2(x)$.

If with the help of benefit function U_2 one chooses more convenient alternative x_A from x_A i x_B

$$U_1(x_A) > U_2(x_B),$$

(12)

Then opposing formulas (9) and (11) one can get
$U_1(x_A) = M[U_1(x_A)] = M[a + b U_2(x_A)]$, $U_1(x_A) = a + b(U_2(x_A))$

And similarly $U_1(x_B) = a + b_2(x_B)$. As b > 0, then from (12) it flows that $U_1(x_A) > U_2(x_B)$, benefit function $U_1(x)$ locates alternatives x_A and x_B due to their priority in the same order as function $U_2(x)$. The opposite statement is also correct – if $U_1(x) <=> U_2(x)$, constants a and b > 0, then there will be a linear dependence between them $U_1(x) = a + b U_2(x)$.

If U(x) = a + b(x), b > 0, and X is the alternative with mathematic expectation M_X, one can find deterministic equivalent for benefit function U(x) according to formula (9)

$$U(x°) = M[U(x)] = M[a + bx] = a + bM_X.$$

And according to formula (11) one can get $U(x°) = a + bx°$.

$x° = m_x$, and if the benefit function is linear, deterministic equivalent of the random alternative equals the expected victory at its realization. It confirms the fact that at the linear benefit function the optimal alternative choice should be made under the condition of maximizing the expected profit from the made occupational safety decision. To assess an employee's attitude to risk one can apply a special parameter – a risk bonus $\Delta R(X)$ concerning alternative X, which is a difference between the mathematic victory expectation m_x and deterministic equivalent $x°$

$$\Delta R(X) = M[X] – U^{-1}(M[U(x)]). \tag{13}$$

If an employee, making a decision, assesses the alternative with unfavorable consequences, the status qua is more profitable for him/her than the alternative with criterion X. But the employee can be risk neutral or not inclined to risk. The employee's peculiarities influence the type of benefit function. To identify the employee's risk reluctance one can consider alternatives with the minimum victory – B and with the maximum one – A, the probability of which is similar and equals 0,5 ($q_A = q_B = 0,5$). Mathematic benefit expectation <A, 1/2, B> is $m_x = 0,5(A + B)$. At it, as it was shown above, one can expect victory m_x or have a guaranteed profit m_x. If the employee prefers the second way, it testifies to his/her risk reluctance. Being risk neutral or reluctant is defined in such a way: from the point of view of the employee, making an OSM decision at the enterprise, both alternatives are equivalent. His/her risk reluctance can be identified in such a way: an employee, making a decision, is risk reluctant if he/she wants to obtain a surely expected benefit in any alternative instead of participating in making a decision due to it. Such an alternative is deprived of benefit, which can be obtained with the probability that equals 1. The main thing at it is that:

a) an employee, making a decision, is risk reluctant only if the benefit function is swept-up (by the analogy of picture 2), and for the alternative x_1 with probability p, x_2 – with probability $(1 – p)$, at it $0 < p < 1$, and benefit function $U(x)$ meets such a condition

$$U(px_1 + (1 – p)x_2) > pU(x_1) + (1 – p)U(x_2); \tag{14}$$

b) if the benefit function rises, an employee, making a decision, is not inclined to risk only when the deterministic benefit money equivalent for any alternative is less than the expected one, i.e. from $U(M[X]) > U(x°)$ derives $M[X] > x°$;

c) if the benefit function rises, an employee, making a decision, is not risk inclined only if the risk bonus is enough for him/her, i.e. $\Delta(R) > 0$.

Picture 3 graphically represents the mentioned peculiarities of benefit function ($\overline{u} = pU(x_1) + (1 – p)U(x_2)$ for the alternative $< x_1, 1/2, x_2 >$, $x° = \tilde{x}$, $M_x = \overline{x}$), which is rising, monotonous and swept-down for the employee, making a decision and not risk inclined. Directly from the function graph we obtain: $U(\overline{x}) > \overline{u}$ (statement a)); $\overline{x} > \tilde{x}$ (statement b)); $\Delta R(x) > 0$ (statement c)).

While developing the methodic provision system for supporting OSM decision-making at the enterprise it is necessary to create the procedure of adapting decision-making means, taking into consideration risk reluctance or the employee's attitude change, when the situation is changed. The measure of risk reluctance at point x is identified with the help of function r(x) in the form

$$r(x) = -\frac{U''(x)}{U'(x)}, \qquad \text{or} \qquad r(x) = -\frac{d[\ln U'(x)]}{dx}$$

$$(15)$$
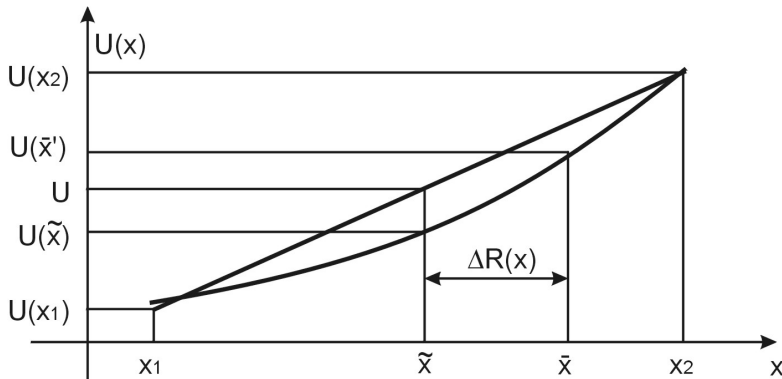
Fig. 3. Benefit function graph for an employee, making an OSM decision and risk reluctant

At it, risk reluctance function has such peculiarities:

– two benefit functions are strategically equivalent only when they lead to one and the same risk reluctance function, the necessity and sufficiency of which is easy to show through direct differentiating and integrating, taking into account that there is a linear dependence (11) between strategically equivalent benefit functions;

– if $r(x)$ is common for all x, then U(x) is swept–down and the employee is risk reluctant, and if his/her ability is constant, $r(x) = c > 0$.

Risk inclination can be identified in such a way – an employee, making an OSM decision, is risk inclined, if he/she wants to make decisions in any alternative instead of obtaining a guaranteed profit for the enterprise in the amount of the expected one for the alternative.

Benefit function peculiarities for an employee, making OSM risky decisions, are based on the following:

– an employee is inclined to risk, if the graph has a swept-up benefit function;

– with the rising benefit function an employee is risk inclined when its deterministic equivalent for any alternative exceeds the expected benefit, $x° > M[X]$;

– with the rising benefit function an employee is risk inclined when risk bonus will be negative at all alternatives, $\Delta R(X) < 0$.

Let us assume that risk reluctance measure is constant and distinct from zero $r(x) = k \neq 0$ at some interval [a, b], we shall count for it the benefit function U(x), the construction of which is nothing but solving such a final task

$$\frac{U''(x)}{U'(x)} = -k, \qquad U(a) = 0, \qquad U(b) = 1. \qquad (16)$$

To solve a differential equation it is necessary to decrease its order through substituting $U'(x) = U_1(x)$, we obtain the equation of the first order

$$U'_1(x) = -k\, U_1(x), \qquad (17)$$

The solution of which will be $U_1(x)$ – the benefit consistence function, and the common equation solution $U_1'(x) = -k\,U_1(x)$ will be like this

$$U_1(x) = C_1\,e^{-kx}.$$

(18)

As a result we obtain

$$\frac{dU_1(x)}{dx} = -kU_1(x)\,, \qquad \frac{dU_1(x)}{U_1(x)} = -kdx\,, \qquad \int \frac{dU_1}{U_1} = -\int kdx\,,$$

$$\ln U_1 = -kx + \ln C_1, \qquad U_1 = C_1\,e^{-kx},$$

(19)

and the general kind of the benefit function will be found through function $U_1(x)$ integration

$$U(x) = \int C_1 e^{-kx}\,dx = -\frac{C_1}{k}e^{-kx} + C_2\,.$$

(20)

Derivative constants C_1 and C_2 shall be found from *conditions U(a) = 0 and U(d) = 1,* we obtain

$$\begin{cases} -\dfrac{C_1}{k}e^{-ka} + C_2 = 0, \\ -\dfrac{C_1}{k}e^{-kb} + C_2 = 1. \end{cases}$$

(21)

In the first system equation constant $C_2 = \dfrac{C_1}{k}e^{-ka}$, we substitute it to the second equation and obtain the equation to find C_1.

$$C_1 = \frac{1}{1 - e^{k(a-b)}}$$

(22)

Having constants C_1 and C_2 we obtain the benefit function

$$U(x) = -\frac{k}{k(e^{-ka} - e^{-kb})}e^{-kx} + \frac{1}{1 - e^{k(a-b)}} = \frac{1}{1 - e^{k(a-b)}} - \frac{e^{-x}}{e^{-ka} - e^{-kb}} =$$

$$= \frac{1}{1 - e^{k(a-b)}} - \frac{e^{-x}}{e^{-ka} - e^{-kb}} = \frac{1}{(1 - e^{k(a-b)})} - \frac{e^{-k(x-a)}}{1 - e^{k(a-b)}} = \frac{1 - e^{-k(x-a)}}{1 - e^{-k(a-b)}}$$

(23)

Correspondingly the benefit consistency function looks like this

$$U_1(x) = U'(x) = \frac{ke^{-k(x-a)}}{1 - e^{-k(b-a)}}\,.$$

(24)

With the help of $U_1(x)$ one can find mathematic expectation, the most expected profit (or damage)

$$Mx = \int_a^b xk \frac{e^{-k(x-a)}}{1-e^{-k(b-a)}}dx \frac{k}{1-e^{-k(b-a)}} \int_a^d xe^{-k(x-a)}dx \qquad (25)$$

The latter integral is identified through integrating parts

$$Mx = \frac{1}{k} - \frac{b-ae^{k(b-a)}}{e^{k(b-a)}-1} . \qquad (26)$$

Investigating dependence of the mathematic expectation on k, particularly, if $k\to +\infty$, we obtain

$$\lim_{k\to +\infty} Mx = \lim_{k\to +\infty}\left(\frac{1}{k} - \frac{b-ae^{k(b-a)}-a}{e^{k(b-a)}-1}\right) = \lim_{k\to +\infty}\frac{1}{k} - \lim_{k\to +\infty}\frac{b-ae^{k(b-a)}-a}{e^{k(b-a)}-1} = 0 - \frac{b\cdot 0 - a}{1-0} = a.$$
$$(27)$$

The obtained dependence testifies to the fact that, when an employee, making an OSM decision, has a great inclination for risk at the enterprise, the enterprise mostly suffers damages, and if $k \to 0$, we obtain

$$\lim_{k\to 0} Mx = \lim_{k\to 0}\left(\frac{1}{k} - \frac{b-ae^{k(b-a)}}{e^{k(b-a)}-1}\right) = \left(\frac{e^{k(b-a)}-1}{k(e^{k(b-a)}-1)} - \frac{k(b-ae^{k(b-a)})}{k(e^{k(b-a)}-1)}\right) = \lim_{k\to 0}\frac{\frac{e^{k(b-a)}-1}{k} - b + ae^{k(b-a)}}{e^{k(b-a)}-1}$$
$$(28)$$

The edge can be found according to L'Hôpital's rule [9], differentiating a numerator and denominator

$$\lim_{k\to 0} Mx = \frac{a(b-a)e^{k(b-a)} + \frac{(b-a)ke^{k(b-a)} - (e^{k(b-a)}-1)}{k^2}}{(b-a)e^{k(b-a)}} = a + \frac{b-a}{2} = \frac{b+a}{2}. \qquad (29)$$

The most probable benefit from the made OSM decision with $k\to 0$ approaches the mathematic expectation of benefit from the employee's actions, risk neutral, with $k\to -\infty$

$$\lim_{k\to -\infty} Mx = \lim_{k\to -\infty}\left(\frac{1}{k} - \frac{b-ae^{k(b-a)}}{e^{k(b-a)}-1}\right) = \lim_{k\to -\infty}\left(\frac{1}{k}\right) - \lim_{k\to -\infty}\frac{b-ae^{k(b-a)}}{e^{k(b-a)}-1} = 0 - \frac{b-0}{0-1} = b, \qquad (30)$$

i.e. in this case mathematic benefit expectation approaches the maximum possible one.

Mode Mo_x is benefit x, at which its consistency function obtains its maximum value and equals

$$U_1(x) = \frac{ke^{-k(x-a)}}{1-e^{-k(x-a)}}.$$

(31)

With positive k→ +∞ function $U_1(x)$ is monotonously decreasing, reaches its maximum at $x = a$, $Mo_x = a$, and with negative k→ −∞ the function monotonously rises and reaches its maximum at $x = b$, $Mo_x = b$. The characteristics of the location, at which the benefit function obtains the value of 1/2 is the median, that can be found, if the equation is solved

$$U(x) = \frac{1-e^{-k(x-a)}}{1--e^{-k(b-a)}} = \frac{1}{2}, \quad \text{we obtain} \quad x = a - \frac{1}{k}\ln\left(\frac{1+e^{-k(b-a)}}{2}\right);$$

(32)

$$\text{Median } Me_x = a - \frac{1}{k}\ln\left(\frac{1+e^{-k(b-a)}}{2}\right).$$

At k→+∞ the median of benefit, as well as the mathematic expectation, targets to its maximum value

$$\lim_{k\to+\infty}\left(a - \frac{1}{k}\ln\left(\frac{1+e^{-k(b-a)}}{2}\right)\right) = a.$$

(33)

At k→ −∞ we obtain

$$\lim_{k\to+\infty}\left(a - \frac{1}{k}\ln\left(\frac{1+e^{-k(b-a)}}{2}\right)\right) = a - \lim_{k\to+\infty}\frac{-b+a}{\frac{1}{e^{-k(b-a)}}+1} = a-(a-b) = b.$$

(34)

At $k \to 0$ we obtain

$$\lim_{k\to+\infty}\left(a - \frac{1}{k}\ln\left(\frac{1+e^{-k(b-a)}}{2}\right)\right) = a - \frac{a-b}{2} = \frac{a+b}{2}.$$

(35)

Practically, the obtained benefit does not always coincide with the expected one, and, as a rule, it will be different from it, so, alongside with the characteristics of the mathematic expectation, it is necessary to assess diffusion characteristics as well. Dispersion D(x) is calculated according to the formula

$$D(x) = \int_a^b \left(x - M(x)\right)^2 U_1(x)dx,$$

(36)

Having received after transformations

$$D(x) = \frac{2}{k^2} + \frac{1}{e^{k(b-a)}-1}\left(a^2 e^{k(b-a)} - b^2 + \frac{2}{k}\left(ae^{k(b-a)} - b\right)\right) - \left(\frac{1}{k} - \frac{b-ae^{k(b-a)}}{e^{k(b-a)}-1}\right)^2$$

(37)

The obtained expression has quadratic values, thus, is not very user-estimation of the benefits of OSM management decisions in the company. Therefore, in addition to the

variance should use another characteristic of dispersion - standard deviation σ_x, which is defined by the formula

$$\sigma_x = \sqrt{DX} = \left(\frac{2}{k^2} + \frac{1}{e^{k(b-a)}-1} \left(a^2 e^{k(b-a)} - b^2 + \left| \frac{2}{k}\left(ae^{k(b-a)}-b\right) \right| \right) - \left(\frac{1}{k} - \frac{b-ae^{k(b-a)}}{e^{k(b-a)}-1} \right)^2 \right)^{1/2}$$

.

(38)

The obtained value satisfies its practical application.

The behavior of function dispersion characteristics while approaching non-inclination k to infinity, particularly with $k \to +\infty$, we investigate

$$\lim_{k \to +\infty} DX = \lim_{k \to +\infty} \left(\frac{2}{k^2} + \frac{1}{e^{k(b-a)}-1} \left(a^2 e^{k(b-a)} - b^2 + \right. \right.$$

$$\left. \left. + \left| \frac{2}{k}\left(ae^{k(b-a)}-b\right) \right| \right) - \left(\frac{1}{k} - \frac{b-ae^{k(b-a)}}{e^{k(b-a)}-1} \right)^2 \right) =$$

$$= \lim_{k \to +\infty} \frac{2}{k^2} + \lim_{k \to +\infty} \frac{a^2 e^{k(b-a)} - b^2}{e^{k(b-a)}-1} + \lim_{k \to +\infty} \frac{2\left(ae^{k(b-a)}-b\right)}{k\left(e^{k(b-a)}-1\right)} -$$

$$- \lim_{k \to +\infty} \left(\frac{1}{k} - \frac{b-ae^{k(b-a)}}{e^{k(b-a)}-1} \right)^2 = 0 + a^2 + 0 - a^2 = 0 ;$$

(39)

with $k \to -\infty$, $\lim_{k \to -\infty} \sigma_x = 0$, then

$$\lim_{k \to -\infty} D_x = \lim_{k \to -\infty} \left(\frac{2}{k^2} + \frac{a^2 - b^2 e^{-k(b-a)}}{1-e^{-k(b-a)}} + \right.$$

$$\left. + \frac{2\left(ae^{-k(b-a)}-b^2\right)}{e^{-k(b-a)}-1} - \left(\frac{1}{k} - \frac{b-ae^{-k(b-a)}}{e^{-k(b-a)}-1} \right) \right) = 0 + b^2 + 0 - b^2 = 0$$

$$\lim_{k \to -\infty} \sigma_x = \lim_{k \to -\infty} \sqrt{D_x} = 0 .$$

(40)

$$\lim_{k \to 0} D_x = \lim_{k \to 0} \left(\frac{2}{k^2} + \frac{1}{e^{k(b-a)}-1} \left(a^2 e^{k(b-a)} - b^2 + \frac{2}{k}\left(ae^{k(b-a)}-b\right) \right) - \left(\frac{1}{k} - \frac{b-ae^{k(b-a)}-1}{e^{k(b-a)}-1} \right) \right) =$$

$$= \frac{1}{12}\left(b^2 - 2ab + a^2\right) = \frac{1}{12}\left(b-a\right)^2 .$$

(41)

From (41) it is obvious that the diffusion dispersion coincides with the benefit function dispersion with $k \to 0$. Accordingly

$$\lim_{k \to 0} \sigma_x = \lim_{k \to 0} \sqrt{D_x} = \frac{b-a}{2\sqrt{3}} .$$

(42)

Conclusions

The developed mathematic model is limited by the following: the process of making an OSM decision is iterational with a random quantity of branches, non-regulated quantity of hierarchy levels, each of them combining a host of binary pairs «action-event», and the initial level having code I; the known list of alternatives (d_i, where i is the order number of the action), which is necessary for consideration at the certain stage of making an OSM decision, and the condition of the optimal alternative choice at the initial level consists in performing the task of mathematic programming; any action alternative is related to accidental factors consequences impact on it, creating a group of incompatible random events, each of them being characterized by the criterion of alternative usefulness with the appropriate antecedent probability; each event and its consequence of the high level causes alternative actions of the next level, identification of which is done according to the first condition, the index quantity is increasing by 1, and if the process of an event detailing continuation is not necessary, the appropriate bond at the decision tree does not have any branches; all variants of alternative decisions and their consequences are chose in OSM by an employee, making a decision, assisted by the information system, such a procedure of identifying alternatives and their consequences removes uncertainty, is agreed with the intuitive sufficient decision quality and is a rational way of achieving the system objectives; all assessments, including the assessment of the event realization probability with its usefulness, must satisfy the transitivity conditions.

It is discovered that while developing the methodic provision to support the system of making decisions in OSM at the enterprise, it is necessary to establish the procedure of adapting decision making means, taking into consideration the extent of risk reluctance or the employee's attitude change, when the situation changes. Risk reluctance function has the following characteristics: two benefit functions are strategically equivalent only when they lead to one and the same risk reluctance function and the most probable benefit from the made OSM decision with $k \to 0$ approaches the mathematic expectation of the benefit from actions of the employee, neutral to risk, with $k \to -\infty$ the mathematic expectation of the benefit approaches the maximum possible one.

It is discovered that the obtained benefit from the made OSM decision does not always coincide with the expected one, and, as a rule, will differ from it, so, besides the mathematic expectation characteristics, it is necessary to assess characteristics of diffusion as well – dispersion and average quadratic deviation, the first of which is the employee's risk reluctance, coincide (with $k \to 0$) with dispersion of the benefit function.

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Methodical approaches to the determination of intraproductive prices on enterprises of meat processing industry

Iryna Fedulova, Alina Dragan

National University of Food Technologies, Kyiv, Ukraine

Abstract

Introduction. The questions of application new approaches at determination of intraproductive prices on meat products.

Materials and research methods. The following methods are used in the research: system analysis in the questions of the transfer pricing and its usage in practical activity of the enterprise; analysis and synthesis − the calculation of transfer price on meat; analogies and comparisons − determination of intraproductive prices on byproducts on the basis of cost conception association and power value conception.

Results and discussions. Taking into account the specific of meat goods production and increase of responsibility for the financial indexes of every productive subdivision of the enterprise, there is a problem about the determination of intraproductive prices on products that is made and passed, as raw material, in other subdivisions. Abattoir block produces prepared products: meat (beef, pork), that is passed in sausage, canning workshops of meat-packing plants.

Three variants of methods of intraproductive prices determination on the basis of the transfer pricing depending on the productive structure of enterprise: at abattoir block to the productive structure - on a productive unit cost; at a workshop - on a productive prime price plus income (on the level of profitability); at a plant - on total expenses plus income (on the level of profitability) are offered in the article.

Open question is remained by determination of productive prime price on concomitant products (byproducts). It is offered for determination the productive prime price to apply methodology of combination of two conceptions of cost for a calculation productive prime price of beef and power value of beef byproducts in correlation with the power value of beef. Determination of productive prime price on byproducts is possible to count on basis: power value (calorie content) or consumer value (level of maintenance of albumen, fat, carbohydrates in a product).

Conclusions. Offered methodical approaches to the determination of intraproductive prices on enterprises is counted on the decline of wholesale prices on meat products that will assist forming of effective price politics and of products realization improvement.

Introduction

Passing to the managing in the conditions of Euro integration is a difficult process for the enterprises of meat processing industry. Economic terms in a modern period, where the enterprises of meat processing industry are: insufficiency of raw material in connection with the crisis state of stock-raising; permanent increasing price on raw material, power medium that results to price increase on meat products; strengthening of competition on internal and external markets. At the same time, substantial loosening of economic work is marked on enterprises, namely pricing take place by out-of-date methods without application of modern approaches.

Last publications of home and foreign authors the separate aspects of determination of intraproductive prices are examined on the basis of the transfer pricing, in particular in researches: Feinschreiber [1], M. Kent 2], U. King [3], Eccles [4], O. Desyatnyuk, O. Cherevko [5], P. Dzyuba [6], D. Korepanov [7], Makarenko, T. Savchenko [8], M. Seniv [9], V. Kostyuk and I. Shelamova [10] and other.

The methodical approaches to the determination of intraproductive prices on products on the enterprises of meat processing industry is not decided problem nowadays.

The aim of the article is to research the transfer pricing on determination of intraproductive prices on meat products.

Materials and methods

The following methods are used in the research: system analysis in the questions of the transfer pricing and its usage in practical activity of the enterprise; analysis and synthesis − the calculation of transfer price on meat; analogies and comparisons − determination of intraproductive prices on byproducts on the basis of cost conception association and power value conception.

Results and discussions

The enterprises of meat processing industry apply centralized control system as legal entity that carries out three types of activity operating, financial, investment. Separate productions, that is formed after the types of prepared products are ready-to-cook foods, belong to the complement of enterprises. Thus, actual for the enterprises of meat processing industry is deepening of intraproductive self-supporting basis, valuable market management mechanism, with the aim of providing the complex and rational use of material, labour and financial resources. Introduction of intraproductive calculation on the large enterprises of meat processing industry envisages creation of profitability centers. The centers of profitability are structural productive subdivisions that produce the eventual products of the enterprise and gain profit. For each center the responsibility is on the leader of productive subdivision. Guidance of the enterprise sets the plan of net profit (profit yields) from products realization and income plan to every structural productive subdivision. The increase of responsibility for financial indexes resulted in the origin of products problem estimation that is produced by productive subdivision and passed as raw material in other productive subdivisions.

The widespread organizational form of the enterprise of meat processing industry is a meat-packing plant. Abattoir block is a workshop that produces the basic type of meat products, and other byproducts of the first and second category, that will be realized at the

internal market of Ukraine. At the same time this products are raw material for sausage, canning and ready-to-cook foods workshops.

The cost of this raw material, to our opinion, must be estimated on principles of establishment of transfer cost of commodities or results of work.

The transfer pricing is the system of determination of ordinary cost of commodities or results of work (services), in operations confessed in accordance with the article 39 of Internal Revenue Code are controlled. By law the determination of wholesale price with the aim of taxation of profits (income, profit yield) of taxpayers, that are parties of the controlled operation, take place in one of the marked methods: comparative out-of-control price (analogues of sale); costs of resale; "charges plus"; net income; profit distribution.

A transfer price is a domestic production price on products, or service, operation that is paid by one productive subdivision to other productive subdivision by one legal entity of the enterprise.

To our opinion, there can be three variants of methods of transfer prices calculation on meat of beef and pork for a transmission in sausage, canning workshops and workshops of ready-to-cook foods for the enterprises of meat-packing plants:
- on the basis of productive unit cost;
- productive prime price plus profit (after the level of profitability);
- complete charges and profit (after the level of profitability).

It follows to define that in economic science the methodical approach is absent according to the choice of calculation method of transfer prices for the enterprises of meat processing industry.

To our opinion, choice of calculation method of transfer prices follows to carry out enterprises because of productive structure. On the enterprises of meat processing industry apply next productive structures: out of workshop, workshop and plant. Over 30% of meat processing industry enterprises can be attributed to small ones that have average quantity working to 100 persons, profits (profit yield) from realization of products to 500 thousand euro accordance with the article 35 of Economic Code of Ukraine, produce one type of products assortment: sausage products or ready-to-cook foods. Exactly the small enterprises have out of workshop productive structure.

As a rule, the abattoir block of small enterprise produces meat, and passing products as byproducts of the first and second category, that will be realized at the internal market. The prepared products (meat, byproducts) are within the limits of 60-80% are used, as raw material, for the production of sausage products and ready-to-cook foods. To our opinion, it is expediently for small enterprises to accept a transfer price the productive prime price of meat, as raw material that is determined by formula:

$$T = I_P \tag{1}$$

where T − is transfer unit costs;

I_P − is productive prime price for unit of products.

The large enterprises of meat processing industry in accordance with the article 35 of Economic Code of Ukraine have average quantity working over 1000 persons and profits (profit yield) from realization of products that exceeds 5 million euro and apply a plant productive structure.

The plant of the primary processing of cattle (PPC) has administrative charges - charges on labour remuneration and maintenance of administrative personnel of plant (director of plant, engineer-technologist, economist, veterinary doctors, engineer-mechanic, accountant) and other.

To our view, the calculation of domestic production prices is expedient to carry out the method of transfer prices "complete charges + income". Thus, charges can be expected by formula:

$$C_C = I_P + A_C \qquad (2)$$

where C_C − are complete charges on unit of products;

I_P− productive unit cost on 1 kg

A_C − permanent charges, that are administrative charges of plant, that fold to 2% to the productive prime price.

For example, according to the data of Public joint-stock company "Koziatynskyi meat-packing plant": the productive prime price of beef of II category makes USD 1.55. for a kg, administrative charges for slaughtering plant is 1,63% from a productive prime price, profitability of plant is in the limits of 5%.

$$B = 1,55 \cdot (1+1,63/100) = \text{USD } 1,58 \text{ for } 1 \text{ kg}$$

Thus, formula of transfer price determination is:

$$T = C_C + P \qquad (3)$$

where P − is the profit for the level of plan profitability;

R − plan level of profitability.

$$T = C_c \cdot (1 + R) = 1,58 \cdot (1 + \frac{5}{100}) = USD\, 1,66 \; for\, 1\, kg$$

The most widespread productive structure for enterprises is the workshop that is applied by not huge enterprises of meat processing industry. These enterprises of meat processing industry have average quantity of people approximately 900 persons, after profits (profit yields) from realization of products to 5 million euro accordance with the article 35 of Economic Code of Ukraine.

As practice testifies large and middle enterprises, a abattoir block production produces and realize the prepared products: on export − 15%; to the internal market of Ukraine − 20%; 65% of meat and byproducts of the first and second category that are used on the intraproductive industrial processing − on sausage products, can food, ready-to-cook foods.

For increasing the efficiency of intraproductive calculation, it is expedient to apply transfer prices on the prepared products of abattoir block production that is passed, as raw material, to productive subdivisions (sausage workshop and workshop of ready-to-cook foods) on the basis of "productive prime price plus profit" or certain share profit:

$$T = I_P + P \qquad (4)$$

where P − is the profit for the level of plan profitability.

$$T = 1,55 \cdot (1 + 5/100) = \text{USD } 1,63 \text{ for } 1 \text{ kg}$$

Intraptoductive prices on meat that is based on the method of the transfer pricing products are below from wholesale prices for what they are sold. Realization charges reduction, economy on permanent charges, decline of natural losses at transporting and exception of additional freezing processes cause it. Positive aspect in application of "expense + profit" method in comparing to the "productive prime price" is guarantee of income by abattoir block production. Intercommunication between structural productive subdivisions of enterprise of meat processing industry is close enough in connection with centralized control system and large volume of inside factory turnover of the prepared products of abattoir block production.

It is applied in abattoir block the normative method of calculation of wholesale prices on a production and realization of beef and pork meat, id est cost conception of pricing is used. The calculation of transfer prices depending on the productive structure of enterprise is given in the table 1.

Table 1

Transfer prices depending on the productive structure of enterprise are

Production	Production structure	Input cost 1 kg, USD*	Administrative cost, USD (1,63%)	Production profitability level, %	Profit 1 kg, USD	Transfer price 1 kg, USD*
Beef II category	*out of workshop*	1,55	–	–	–	1,55
Beef II category	*workshop*	1,55	–	5,0	0,08	1,63
Beef II category	*plant*	1,55	0,03	5,0	0,08	1,66
Pork II category	*out of workshop*	1,49	–	–	–	1,49
Pork II category	*workshop*	1,49	–	5,0	0,08	1,57
Pork II category	*plant*	1,49	0,03	5,0	0,08	1,60

* Dollar by the National Bank of Ukraine 12.02.2016.   USD 1 = 26,08 UAH.

At processing of cattle the production of meat folds 75-80%, other part is side foods, byproducts of the first and second category and wastes. Byproducts use for production of social meat foods, for example liver sausages, souse loaf and other like that.

Enterprises productive prime price on passing products, namely byproducts of the first and second, because of market wholesale prices expect on deduction of value-added (20%) tax and income, because of level of profitability in size of 10-20%. Thus, artificially calculate productive prime price, taking into account market wholesale prices on byproducts of the first and second category that does not represent actual charges on production and results to increasing prices on byproducts.

The question is not decided yet about the determination of productive prime price on byproducts. Researching open market and liberalization in a cost price concept the accent is done only on charges. Charges are taken to the individual ones and inflationary basis of price dynamics will prove to be the same.

To our opinion, for the calculation of productive passing unit (byproducts) cost it is necessary to apply methodology of combination of productive prime price determination of basic type products: beef on categories in obedience to cost conception and conception of byproducts power value in correlation with the power value of beef.

Conception that is related to the reflection in the cost of consumer properties of products is used. It is marked that prices on meat products are very flexible, as very wide possibilities of change of consumer properties of products at the production of goods from different raw material in the conditions of limit resources of stock raising.

Correlation of intraproductive prices according to the conception of consumer property of products on its interchangeable kinds, to our opinion, it is necessary to set with the orientation on:
- power value: calorie content of meat foods;
- nourishing value: a level of content of albumen, fat and carbohydrates.

According to the conception of consumer property of products, we count a productive prime price on beef byproducts on the basis of power value of byproducts in correlation with the power value of meat-beef and its productive prime price. Data calculation of productive transfer cost of byproducts that is passed in sausage (byproducts) workshops are given in the table 2.

The second variant of productive transfer price determination on beef byproducts on nourishing value is given in the table 3.

Table 2

Calculation of productive transfer price on beef byproducts to power value

№	Name of byproduct	Energy content 100 g, calorie	Ratio according to meat	Input cost 1 kg, USD
1	Beef II category	168	1,0	1,55
2	Brain	124	0,74	1,15
3	Liver	140	0,84	1,31
4	Kidney	66	0,40	0,62
5	Heart	96	0,58	0,90
6	Tongue	173	1,03	1,60
7	Lights	92	0,55	0,86

Authors' calculations on the basis of data [11, p.95, 107-108]

Table 3

Calculation of productive transfer price on beef byproducts of the first category on nourishing value

№	Name of byproducts	Power value, %	Ratio according to meat	Input cost 1 kg, USD
1	Beef II category	29,8	1,0	1,55
2	Brain	21,5	0,73	1,14
3	Liver	28,7	0,97	1,51
4	Kidney	21,4	0,72	1,12
5	Heart	24,6	0,83	1,29
6	Tongue	34,9	1,18	1,83
7	Lights	20,3	0,69	1,07

Authors' calculations on the basis of data [11, p.107-108]

Comparison of productive prime price calculations on beef byproducts in two variants testifies that productive prime price is calculated to nourishing value more expensive, than calculated to power value, as "nourishing value" takes into account more useful qualities of byproducts than "power value". These calculations of productive prime price can be applied, as low-limit (to power value), and maximal size of productive prime price (to nourishing value) at determining and calculation of wholesale prices on byproducts.

The calculation of transfer prices on byproducts combines two conceptions: cost conception and conception of power value. Thus, it is possible to summarise, that efficiency of products, at the same time, combines efficiency of goods production with efficiency of customers' consumption.

Conclusions

1. The application of methodical approaches to the determination of intraproductive prices on the basis of transfer pricing on the enterprises of meat processing industry will assist creation of transparent competition environment and determination of justified prices.
2. The offered methodical approaches to the determination of intraproductive prices on byproducts by combination of cost conception and conception of power (or nourishing) value is counted on the decline of wholesale prices on meat products that will assist forming of effective price politics of the enterprise and products realization improvement.

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World experience in managing alcohol industry of Ukraine

Liudmyla Shevchenko

National University of Food Technologies, Kiev, Ukraine

Corresponding author:

 Liudmyla
Shevchenko
E-mail:
milana1801@i.ua

Abstract

Introduction. Present research is dedicated solving the problem of the limited market for ethyl alcohol. European integration has a positive effect on the Ukrainian ethyl alcohol market and by implementing aspects and regulations of European standardization there is the possibility of entering foreign markets. Ukrainian ethyl alcohol market will have an opportunity to diversify its methods of making a profit.

Materials and methods. To investigate this problem, we used a theoretical method for the analysis of the conceptual base. Using the method of statistical analysis of the picture of foreign trade partners of Ukraine in 2015, we analyzed the ratio of export operations by regions of Ukraine. Using the methods of forecasting and modeling, we can predict a positive effect from the diversification of markets.

Results and discussion. Following the European integration Ukraine receives preferential access to the largest market in the world with 500 million customers and a GDP of 14 trillion euros and greater opportunities to export to global markets. This can help Ukraine to take a position of an exporter of ethyl alcohol and agricultural products, and to be a player fully integrated into EU and global value chains: a substantial leap in terms of added value of its production. To do this, a complete reform in the industry must be done. In the process of studying the needs of the European market the need for production of ethyl alcohol concentration of less than 80% was determined. Also SE «Ukrspirt» have the possibility to receive tariff rate quotas, which operate on a "first come, first received" for export. In 2016 alcohol companies can export 27 thousand tonnes of spirits, liqueurs and other spirituous beverages by 2207 and 2208 codes. The most essential aspect is to receive a license for shipment of alcohol by the code 2208 to European countries. To achieve the goals it is necessary to determine the number of factories that are closer to the western border of Ukraine in order to reduce logistics costs. Thereafter, these factories need to be reconstructed to provide the competitive production. It is necessary to implement energy efficient technologies and equipment that reduce fuel consumption by 30%. These measures will cover the needs of the European market in alcohol and will provide an opportunity to diversify the production of alcohol factories in Ukraine and increase the volume of planned and real profits.

Conclusion. Applying experience it is possible to use 20-30% of the capacity of Ukrainian alcohol factories of and getting currency earnings of around 15 mln. USD. It is an opportunity to renew the Ukrainian alcohol production and to provide wide range of possibilities to diversificate markets.

Introduction

Ukraine is a priority country within the European Neighbourhood Policy and the Eastern Partnership. The European Union is committed to a policy of sequenced engagement with Ukraine and to a close relationship that encompasses political association and economic integration. It is a huge opportunity for the enterprises of alcohol industry to enter new markets to sell alcohol.

The European Union is currently focusing on support to the comprehensive reform process underway in Ukraine, notably through the implementation of an unprecedented support package of €11bn. Against the background of the crisis in eastern Ukraine, the European Union supports all efforts for a lasting peaceful solution respecting the unity, sovereignty and territorial integrity of the country and which ensures a stable, prosperous and democratic future for all Ukrainian alcohol companies and industry at all.

The European Union and Ukraine signed the Deep and Comprehensive Free Trade Area (DCFTA) on 27 June 2014 as part of their broader Association Agreement (AA). In April 2014, in response to the security, political and economic challenges faced by Ukraine the EU unilaterally granted Ukraine preferential access to the European Union market until 31 December 2015.

To avoid further destabilisation of the country and in particular to guarantee Ukraine's access to the CIS market under the Ukraine-Russia bilateral preferential regime, in September 2014 the European Union postponed implementing the DCFTA until January 2016.

The European Union is Ukraine's largest trading partner, accounting for more than a third of its trade. It is also its main source of Foreign Direct Investment (FDI).

Main Ukraine exports to the European Union: raw materials (iron, steel, mining products, agricultural products), chemical products and machinery. Main European Union exports to Ukraine: machinery and transport equipment, chemicals, and manufactured goods.

Ukrainian alcohol market is in crisis and it is necessary to take measures to improve the situation on the market as quickly as possible. To do this, a complete reform in the industry must be done. Ukrainian alcohol market is represented by the State Enterpriese «Ukrspirt», which consists of 41 alcohol plants, all over territory of Ukraine. Unfortunatelly, only 20 % of the plants operate today. It is important to find ways to increase the sales of alcohol to start the the work of all plants. One such method is to export alcohol to other country.

Our main objective is to achieve a competitive level of Ukrainian alcohol and entering the European market.

Given Ukraine's industrial potential, the DCFTA provides an opportunity to make the country more competitive and diversify its alcohol exports.

The DCFTA aims at boosting bilateral trade in goods and services between the European Union and Ukraine by progressively cutting tariffs and by aligning Ukraine's rules with the European Union 's in selected industrial sectors and for agricultural products.

In the DCFTA Ukraine has committed itself to harmonising a large number of rules, norms and standards in a number of trade-related areas with those of the European Union. These areas are competition, public procurement, trade facilitation, protection of intellectual property rights and trade-related energy aspects, including on investment, transit and transport.

Since 1993 Ukraine has also benefitted from the European Union 's Generalised System of Preferences (GSP). In 2013, more than 70% of Ukrainian exports to the European Union of machinery and mechanical appliances, plants, oils, base metals, chemicals and textiles benefitted from GSP preferential tariffs.

When exporting to the European Union, it is a benefit from a big European market of 28 countries with around 500 million consumers.

The principle of free movement of goods, allowing goods to be transported and sold anywhere in the European Union, is a cornerstone of the European Union market. To a certain extent, complex and varied national laws have been replaced by a single set of European rules, cutting down on costs and inconvenience for businesses wanting to trade in other European Union countries.

The European Union market for goods is already highly integrated and harmonised along the 28 countries. However, to make the European Union market work efficiently, Ukrainean enterprises of alcohol industry have to respect a number of rules and compete fairly. Anticompetitive behaviours, such as the abuse of a dominant market position, price-fixing agreements and unwarranted public support, are prohibited.

Materials and methods

Using the theoretical method concepts such as European standardization was explored and identified the ways to implement these concepts in the alcohol industry is to achieve the maximum effect from enterprise management. Using the theoretical analysis the methods of renewing of alcohol industry of Ukraine were discovered.

Using the method of statistical analysis of the picture of foreign trade partners of Ukraine in 2015, we can conclude that Western Ukraine in its structure exports to the EU countries mostly, about 90% (Zakarpatye region) from the total volume of export operations. In other regions, export to the EU countries waries from 11% to 49%.

Using the methods of forecasting and modeling, we have identified a systematic approach considering the alcohol industry enterprises as objects of implementation of standardization European standards of doing business.

Results and discussions

The free trade area came into effect on 1 January 2016. From this date on, the European Union and Ukraine offer each other privileged access to their respective markets. The DCFTA is much more than a classic free trade agreement.

It contains three major pillars:

I. It opens markets through the progressive removal of customs duties and restrictions on services and public procurement.

II. It ensures fair competition between European Union and Ukrainian firms by safeguarding the respect of

- intellectual property rights;
- basic workers' protection or environmental standards;
- disciplines on use of subsidies and anti-competitive behaviour.

III. It lays the ground for gradual alignment of norms and standards, including on food safety and technical regulations.

The European Union provides Ukraine with significant support not only to bring its legislation in line with the European Union 's but also through macro-financial and technical assistance.

An improved regulatory framework and easier access to the European Union market is expected to increase trade and make Ukraine more attractive to European investors.

The EU is also the principal source of investment in Ukraine. More than 50% of Foreign Direct Investment (FDI) in Ukraine comes from the EU.

Ukraine is also an economic bridge to other countries of the EU's Eastern Neighbourhood.

In the longer term, this should support Ukraine's economic development and generate more demand for European products and services - a win-win situation.

Table 1

Indicators of production by alcohol industry and SE "Ukrspirt" 2014-2015

Index	Production (alcohol industry)		SE "Ukrspirt"	
	2014 (11 m.)	2015 (11 m.)	2014 (11 m.)	2015 (11 m.)
Ethyl alcohol, thousand decaliters	12 391	9 397	11 070	8 374
Commercial products, mln grn	1 898	1 844	1 637	1 579
Index	Production		Capacity, %	
Component of motor fuel alternative, K tons	20	25	22	35
Bioethanol, K tons	12	6	20	12
Alcoholic beverages, thousand decaliters	211	204	3	

As we can see from the Table 1 the output of ethanol in the industry for 11 months 2015 decreased by 24%.

The share of ethanol in the total production of ethyl alcohol was 89% in SE "Ukrspirt".

Capacity utilization ratio declined as in the industry in general and in the SE "Ukrspirt".

Commercial products production in current prices for 11 months in 2015 decreased in SE "Ukrspirt" (-4%) and the industry in general (-3%).

The share of commercial production (in current prices) amounted to 86% in SE "Ukrspirt".

It was produced 25 thousand tones of Component of motor fuel alternative during 11 months in 2015, which is on 30% more than in 2014. Capacity utilization ratio was 35%.

It was produced produced 6.4 thousand tons of bioethanol during 11 months in 2015, which is on 30% more than in 2014, that is 30% less than the corresponding period of 2014. Capacity utilization ratio was 12%.

The production of alcoholic beverages decreased by 3%. The only two companies from the 16 produce alcoholic beverages in alcohol industry. Capacity utilization ratio was only 3%.

The DCFTA offers EU suppliers and service providers full access to Ukrainian public procurement markets. They can participate in public tenders related to infrastructure, transport, medical care and education on an equal footing with Ukrainian companies. These benefits EU companies, but also the Ukrainian taxpayer.

As the world's leading exporter, the European Union is sometimes the subject of trade defence investigations initiated in non- European Union countries.

The European Union 's trade policy aims to help the European Union to compete better on international markets. Unwarranted trade defence measures unfairly block European

Union exporters' free access to the world's markets, and their negative impact should be minimised whenever possible.

Any exporting industry subject to a trade defence action initiated by a non- European Union country is responsible for defending its rights throughout the proceedings and for cooperating with the investigating authorities to favour a positive outcome.

The European Commission monitors and assists affected European Union industries when non- European Union countries take trade defence measures against European Union exporters. The Commission also plays a more direct role in anti-subsidy and safeguard investigations when European Union subsidies are involved and the European Union as a whole is targeted.

The beverage alcohol industry contributed over $21 billion directly to state and local revenues during 2010. Of that amount, distilled spirits accounted for over $8.8 billion or 41% of this direct revenue.

In 2010, beverage alcohol's total contribution to state and local revenues was over $41 billion. Of that amount, $20.1 billion came from indirect revenues such as corporate, personal income, property and other taxes generated by the beverage alcohol industry.

Total revenues from distilled spirits (direct and indirect) were $15.5 billion in 2010, or 37% of total beverage alcohol revenue.

For a detailed analysis of the latest started threads we need to consider the principles of the sale of alcohol in the world.

Distilled spirits are one of the higest taxed consumer products in the United States.

Standardizing for alcohol content, the distilled spirits federal excise tax burden (per proof gallon) is more than double that of beer and almost triple that of wine. The federal excise tax burden per proof gallon for distilled spirits is $13.50. In comparison, the tax burden per proof gallon for beer and wine is $6.18 and $4.86, respectively.

Federal, state and local taxes accounted for $7.83, or 54%, of the average $14.42 price for a typical 750ml bottle of 80 proof distilled spirits in the United States in 2012.

While rejecting suggestions of a causal link between advertising for alcoholic drinks and alcohol-related social problems, the alcoholic beverage industry recognises the need for social responsibility in the sphere of commercial communications.

The Brewers of Europe have partnered with EASA to evaluate the effectiveness of self-regulation of the beer sector of the alcohol industry. The report, "Responsible beer advertising through self-regulation", was published in 2010 and reflects the progress made in the implementation of the commitment to the European Alcohol and Health forum in relation to the advertising self-regulation.

Alcohol carries the potential for abuse and, if misused, can lead to health and social problems. Defining an ethical position for the industry and its members must, therefore, acknowledge these adverse consequences. While rejecting suggestions of a direct causal link between alcohol advertising and alcohol-related social problems, the alcohol industry recognises the need for responsibility in the sphere of commercial communications.

As with all advertising, regardless of sector, commercial communications by the alcoholic beverage industry should be legal, decent, honest and truthful and conform to accepted principles of fair competition and good business practice, prepared with a due sense of social responsibility and based on principles of fairness and good faith. They should not, under any circumstances, be unethical or otherwise impugn human dignity and integrity.

Advertisements for alcoholic drinks should not encourage excessive or irresponsible consumption, present abstinence or moderation in a negative way, or suggest any link with violent, aggressive, dangerous or antisocial behaviour.

Whereas the majority of alcohol advertising codes of practice deal primarily with brand advertising, it is now increasingly common for codes to cover all aspects of marketing communications (such as brand naming and packaging, internet promotional activities and point-of-sale promotions at retailer level). This is a good way of ensuring that all commercial communications are covered by self-regulatory rules. Nevertheless, practices such as labelling, packaging or pointof-sale promotion (below-the-line advertising) fall outside the remit of the general advertising SRO and are in most countries regulated by an alcohol industry funded social aspects organisation (SAO). SAOs are also responsible for the social responsibility campaigns run by the alcohol sector at national level, such as for example "anti-drink-drive" campaigns4 , responsible serving programmes, consumer information and awareness campaigns. Both SAOs and SROs work for responsible consumption through the promotion of responsible drinking patterns.

While each of the branches that together constitute the alcohol sector (spirits, beer and wine) has traditionally written codes applicable only to its own products, national SROs adjudicate on all branches indiscriminately. In some countries, all codes have been merged into a single "alcohol section" under the general advertising code administered by the national SRO. Various sectoral codes can also co-exist in a country as long as there is a degree of convergence, and as long as the codes and their enforcement are equally credible.

The commitment and consensus among the key players in the sector to ensure that advertising meets high standards of responsibility is a fundamental requirement for all self-regulatory systems. This commitment to responsibility needs to be reflected in the Code of Practice, written by the alcohol industry, which sets out the principles that will govern the content of advertisements. The scope of the code will depend on the extent to which advertising is already regulated by law, as there is no point in a code that simply duplicates existing regulations. The code must be reviewed and updated when necessary, to reflect changing circumstances in society or technology. It must be widely publicised among the industry and communicated to the general public. Among the industry codes adopted throughout the world, the general standards include the following.

These principles come from the ICC Consolidated Code of Advertising and Marketing Communication Practice applicable to all marketing communications, and therefore also to alcohol marketing communications.

- Advertisements for alcoholic drinks should be legal, decent, honest and truthful. They should conform to accepted principles of fair competition and good business practice. All aspects of the law have to be respected, from commercial aspects to copyright and data protection. Ads should not be misleading, whether by omission or exaggeration, and competitors should be respected.

- Advertisements for alcoholic drinks should be prepared with a due sense of social responsibility and based on principles of fairness and good faith, including when using testimonials. Advertisements should not show anti-social behaviour (e.g., street violence, hooliganism) or portray dangerous or distressing situations (e.g., suicide, inappropriate use of guns or knives.

- Under no circumstances should alcohol advertisements be unethical, offend against generally prevailing standards of taste and decency or otherwise offend human dignity and integrity in the country where they are appearing. National sensitivities around specific issues, be it due to societal or religious reasons, should be respected (e.g., use of religious references or personalities). Issues around the portrayal of gender should be handled with care in all marketing communications but even more specifically in alcohol advertisements.

- Advertisements for alcoholic drinks should not encourage, condone nor portray excessive or irresponsible consumption, present abstinence or moderation in a negative way,

or suggest any link with violent, aggressive, dangerous or anti-social behaviour. If a group of people is shown consuming the product, the person who is not consuming should not be ridiculed. Likewise, advertisements should not suggest that drinking is an essential part of life or a necessary routine.

- Advertisements should not associate drinking with dangerous or daring activities (e.g., driving a motor vehicle of any kind or operating of potentially dangerous machinery). Driving any type of vehicle under the influence of alcohol is dangerous; it is illegal in most countries. Any type of motor-operated vehicle falls under this rule (e.g., motorbikes, cars, trucks, boats, planes). Operating machinery under the influence of alcohol can be dangerous and increases risks of getting harmed. Advertisements should not portray, for example, people operating a forming press in a factory or handling melting metals.

- Advertisements should avoid any confusion about the nature and strength of alcoholic drinks. They may present information for consumers on alcoholic strength but should not emphasise high alcoholic strength in itself as a positive quality. Reversely, messages may not imply that consuming beverages of low alcohol content will avoid alcohol misuse. High alcohol content in a given drink should not be presented in itself as a positive quality in order to avoid misuse or incitation to abuse.

- Advertisements should not create the impression that consumption of alcohol is a requirement for sexual success and should not imply that the successful outcome of a social occasion is dependent on the consumption of alcohol. Such references are often common in advertisements for other product categories but are not to be used in relation to alcohol advertising. Alcohol should not be presented as a means to seduce the opposite sex or as enhancing someone's seduction power or attractiveness.

In Europe, two entities work together on issues of responsible marketing communications for spirits:

- EFRD—The European Forum for Responsible Drinking The European Forum for Responsible Drinking is an alliance of leading European spirits producers supporting targeted initiatives to promote responsible drinking. These initiatives focus on attitudinal and awareness programmes, responsible marketing and self-regulation, as well as the promotion of a better understanding of the evidence base. In 2008, EFRD became a member of the European Spirits Organisation—CEPS to support the overall spirits industry in meeting the expectations of stakeholders towards responsible commercial communications and a reduction of alcohol-related harm.

- CEPS—The European Spirits Organisation The European Spirits Organisation—CEPS acts as the European representative body for producers of spirit drinks. With members from across Europe, CEPS ensures that no form of commercial communication about their products encourages or condones excessive consumption or misuse of spirits, or specifically targets underage drinkers. All members adhere to the principles enshrined in the EFRD Common Standards for Commercial Communications effective and credible alternative to the consumption control approach.

In North America, the regulation of alcohol production is as follows.

- DISCUS—The Distilled Spirits Council of the United States The Distilled Spirits Council is the national trade association representing America's leading distillers and nearly 80% of all distilled spirits brands sold in the United States. The DISCUS Code of Responsible Practices for Beverage Alcohol Advertising and Marketing provides for a Code Review Board comprised of senior member company representatives charged with reviewing complaints about advertising and marketing materials in the marketplace. Additionally, the Code has an Advisory Board made up of outside independent experts from academia, government and broadcasting. The distilled spirits industry's approach to self-

regulation, pointed to as a model for other industries by the Federal Trade Commission, has been commended on numerous occasions by regulators, industry watchdogs and the media.

- ACD—Association of Canadian Distillers The Association of Canadian Distillers is the national trade association representing Canada's major distillers. The ACD feels a special obligation to encourage moderate consumption of alcoholic beverages and to promote a sense of responsibility. Toward this end, the Association supports and develops educational projects focusing on responsible consumption and help consumers make informed decisions.

In Asia-Pacific, the regulation of alcohol production is as follows

- DSICA—Distilled Spirits Industry Council of Australia The Distilled Spirits Industry Council of Australia is the national organisation representing and advancing the interests of manufacturers and importers of distilled spirits and liqueurs in Australia. DSICA's mission is to create an informed political and social environment that recognises the benefits from moderate alcohol consumption and encourages responsible community attitudes towards alcohol.

- Distilled Spirits Association of New Zealand The Association is the national organisation representing the views of New Zealand's leading producers and marketers of premium spirits and liqueurs. The Association is committed to working with all stakeholders to promote responsibility in the consumption and sale of alcohol. The code approved by the sector is administered by the Advertising Standards Authority.

A comparison of the comprehensiveness and strictness of the alcohol policy in different countries was made according to a new scale developed by Karlsson, Lindeman and Österberg (2013). This scale is a further development of the previous scale developed by Karlsson and Österberg (2001), because more aspects of the policies are considered and it includes an assessment of how the formal rules are enforced in the different countries. The scale is a sum score of six different categories of alcohol policy measures. The two main categories are a) control of production, retail sale and distribution, and b) alcohol taxation and price, which weigh 25 per cent each in the total score. The other categories are: c) age limits and personal control, d) control of drunk driving and e) control of advertising, marketing and sponsorship of alcoholic beverages, which weigh 15 per cent each, and f) public policy, which weighs 5 per cent. The six categories are divided into several subcategories, presented in a questionnaire, which was filled out by experts in each country. The countries were given points for each subcategory of restrictions that were in place.

The maximum number of points a country could have is 160. The scores for the seven actual countries are presented here by permission of the constructors of the scale. An interesting aspect of this study is the comparison between the formal and informal rules that are assumed to regulate alcohol consumption, and the drinking patterns themselves. This is a difficult task, because we lack relevant data on drinking patterns that are comparable between countries.

The only relatively credible data source is recorded alcohol consumption in the different countries. But, in addition, we have consumption from unrecorded sources. These sources are not very reliable for comparative purposes due to different estimation methods in different countries. Nevertheless, mean consumption is not the most interesting feature of drinking habits in relation to formal and informal rules. It is not drinking itself that is important to other people and to legal authorities, but the problems it generates. Therefore, what is needed is comparable data on different types of alcohol-related behaviour that could be seen as problematic or worrying and cause reactions, either from the general public (normative response) or from the authorities (formal rules and laws), or from both. This type of data is scarce, and not very reliable for comparisons. The most comprehensive meta-study

on these topics is probably the report of Anderson and Baumberg, and their conclusions are used here.

The policy indices are contrary to the normative indices; when the normative index is low, the policy index is high, and vice versa. If we compare the Nordic countries with Germany, Spain and Tuscany/Italy, this is very obvious. The policy indices in Poland and Slovenia lie in-between the policy indices in the Nordic countries and the three other countries. Although the normative indices are relatively high in Poland and Slovenia, the policy indices are also relatively high, though not as high as in the Nordic countries.

In their report, Anderson and Baumberg summarize European drinking patterns in four points:

• People in southern countries prefer wine, while people in central and northern countries prefer beer.

• People in southern countries do more of their drinking with meals than people in other countries.

• People in southern countries drink alcohol more often than people in northern countries.

• Binge drinking and drunkenness are more common in northern countries than in southern countries. In other words, and even though there are exceptions to this main conclusion, their study supports the common impression of a north-south gradient in drinking habits: drinking on more occasions, especially of wine and with meals, but less drunkenness in the south, and vice versa in the north of Europe.

The results seem to support the complementary hypothesis: While the Nordic countries have strict alcohol policy measures, the "normative climate" seems to be quite tolerant for drunkenness. In Germany, Spain and Tuscany/Italy it is the other way round: The norms for drinking behaviour are rather strict, corresponding to a more decent behaviour, while the formal rules are more liberal. The norms in Poland and Slovenia come in a middle position: While the informal norms are rather strict, and quite similar to those in the neighbouring countries, the formal rules are stricter than in the neighbouring countries. This might be seen as a remnant from the quite recent communist period of these two countries. In this period, many areas were controlled by more formal rules, including the area of alcohol. Probably the authorities in these countries do not see it as rational to abandon these rules, especially since all other European countries are either continuously introducing stricter rules (Karlsson & Österberg 2001), or stricter rules already apply (the Nordic countries).

Systems at country and European levels should be established to provide sustainable monitoring and surveillance of alcohol marketing including:

a) documenting and tracking all existing regulations on alcohol marketing practices
b) monitoring media use and exposure to young people
c) monitoring young people's perceptions to alcohol marketing practices
d) monitoring new technologies and types of media
e) monitoring cross border marketing
f) documenting violations of existing regulations

Conclusion

Ukrainian alcohol companies should consider Europe-wide and country-based policy on alcohol marketing and should address the advertising and promotion of alcohol products through all media and the sponsorship of arts, cultural, musical and sporting events.

Policy on alcohol marketing should be based on the scientific evidence of what works, and on public health principles that protect vulnerable populations. In order to protect young

people and other vulnerable groups, alcohol marketing restrictions at European and country levels should be strengthened.

Ukrainian regulations on alcohol marketing should be aimed at:
1. restricting the placement of alcohol marketing to reduce exposure to young people;
2. limiting alcohol marketing that is misleading about the characteristics or effects of alcohol;
3. prohibiting alcohol marketing that appeals to minors and other vulnerable groups;
4. including information that alcohol is not a risk free product.

The European Union and countries should work together to:
1. Explore agreements and mechanisms to restrict the marketing of alcoholic beverages at the European level, ensuring a standard and equal system across Europe
2. Develop standards based on the best available evidence to reduce exposure and ensure that content does not influence the drinking expectancies and behaviour of young people
3. Develop technologies and other means necessary to regulate cross-border marketing, including the internet and mobile phone use
4. Recognise that countries which have a ban on certain forms of alcohol marketing have the sovereign right to maintain such a ban.

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Agricultural sector of Ukraine: overview of benefits and ways to improve negative aspects

Kseniia Omelchenko

National University of Food Technologies, Kyiv, Ukraine

Corresponding author:

Kseniia Omelchenko
E-mail:
kseniiya.omelchenko@
gmail.com

Abstract

Introduction. A research is objective to analyze the state of the agrarian sector of Ukraine, find out the weaknesses and strengths of the sector and to suggest ways to improve its efficiency.

Materials and methods. Such methods as: extrapolation, scientific abstraction, synthesis, analysis, comparison and deductive method were used in the article. Analysis were used for specification of the main gains and deficiencies of reform in the agro-industrial complex. Were defined the main directions of land reform implementation.

Results and discussion. More than two thirds (71,2%) of the total land area is agricultural land, compared to only 13,2% in Russia and 44,3% in the EU. Arable land at 32,5 million hectares has the largest area in Europe after Russia, accounting for 56,1% of the total land area – the highest percentage in Europe after Denmark. About 80 percent of the agricultural area is arable land, two-thirds of it the agriculturally rich black soil. The primary food harvest products in Ukraine are barley, maize, potatoes, rice, soybeans, sugar beets, and wheat. The main problems that we can identify in the sector are credit problems, problems of employment, drawbacks of state regulation mechanisms for agricultural sector development of Ukrainian economy, investment climate, property rights, corruption, obsolete machinery and inadequate on-farm storage, shrinking of livestock inventories, forming and effective use of physical capital at agricultural enterprises under changeable market conditions, lack of full implementation of agrarian reforms, complicated, ever-changing schedule of charges in the tax system of the country.

Theoretically speaking, sensible Ukraine land reform could cause an agricultural boom in a country commonly known as the "breadbasket of Europe."

The Government of Ukraine has set the goals of agrarian reform. Five directions have been defined: land reform and reform of property relations in the agro-industrial complex; establishment of new business entities on the basis of collective agricultural enterprises, employing private property and land ownership; formation of market infrastructure in the agro-industrial complex; modernization of production, establishment of competitive agricultural enterprises; improvement of the mechanisms of state regulation in the agricultural sector. State support could be structured in four big blocks: VAT exemption for farming industry, direct subsidies, general services and fixed agricultural tax.

Conclusions. Further progress aimed to improve efficiency in Ukrainian agriculture requires continued restructuring of farm enterprises into smaller autonomous units based on private ownership of land and assets, clear formulation of procedures that allow individuals and small groups with shares of land and assets to exist, development of land markets, and establishment of functioning market infrastructure for competitive input supply, marketing services and financial services.

Introduction

Ukraine is rich in farming and forestry resources. Agriculture has traditionally been one of the most important sectors of the Ukrainian economy, which produces high quality products. More than two thirds (71,2%) of the total land area is agricultural land, compared to only 13,2% in Russia and 44,3% in the EU. Arable land at 32,5 million hectares has the largest area in Europe after Russia, accounting for 56,1% of the total land area – the highest percentage in Europe after Denmark.

So, about 80 percent of the agricultural area is arable land, two-thirds of it are rich black soil. The main food harvest products in Ukraine are barley, maize, potatoes, rice, soybeans, sugar beets, and wheat.

Research objective. To reflect the importance of the chosen topic, as it is considered to be one of the major economic and food safety problem of the country.

In Ukraine, land reform has been mostly limited to transforming state ownership into collective ownership. The weak reforms have failed due to radically change of the traditional organization of collective Ukrainian farms. Break-up and internal restructuring of large farms has been very limited. Hence it should not be a surprise that the transition process is not delivered in the terms of increased profitability and efficiency.

Materials and methods

Such methods as: extrapolation, scientific abstraction, synthesis, analysis, comparison and deductive method were used in the article. Analysis were used for specification of the main gains and deficiencies of reform in the agro-industrial complex. Were defined the main directions of land reform implementation.

Analysis of recent research and publications. Recently, much attention was paid to the study of the topic. Results of the research can be found on the Internet, where it is possible to find not only political articles on the subject, but the results of the scientific research.

Results and discussion

In recent years, agricultural production has declined drastically because of a decrease in the number of tractors and combine harvesters in working conditions and to the lack of fertilizers and pesticides. These shortfalls in agricultural inputs reflect the decline of investment in agriculture and decline of production.

In 2014 Ukraine total grain crop was estimated to be record 64 million metric tons, however as several regions claimed their independence due to the War in Donbass and the Crimea Crisis the actual available crop yield dropped down to 60,5 million metric tons [3].

But Ukrainian economy is on his knees after 20 years of neglect and robbery. There is one sector that is already flourishing and could be an engine of recovery [4].

As farming is a low-margin, labour-intensive business, the sector was largely ignored by the incumbent oligarchs, who preferred to pick off the easy-to-steal metal plants and simple-to-run banks.

Living closer to the EU is obviously a good thing for Ukrainians farmers. However as it is reported that under the terms of free trade and association deal, signed this year with the EU access for Ukraine's agricultural products to EU markets is actually limited, in order to protect the EU's own agricultural production. About 40% of the EU budget goes on farm

subsidies, whereas only 1,8% of Ukraine's budget is spent on this way. But we need to understand, if we move to the EU, we will not only change the market, we will change the way they work fundamentally.

While the task of reforming the country's agriculture sector looks daunting, there is actually a lot of money about the pressure on the global food supply caused by the population rise.

Agriculture could provide the impetus for investment and economic reforms.

Investments into leading agricultural companies is pointless unless it is accompanied by associated investment into supporting infrastructure.

One key change for the agricultural sector is to implement land reform. Ukraine has some 20mn hectares of arable land, of which 10mn hectares belong to the government, and it could be sold off.

However, no one is expecting this to happen quickly; the privatisation of land remains one of the most politically charged issues that any country has to deal with.

All agricultural markets will be negatively affected by the poor macroeconomic fundamentals in Ukraine. There will be limited investment into the country over the coming quarters giving the instability, which will affect agricultural production over forecast period. Russia's ban on imports from Ukraine will impact production for dairy and livestock industries, because Russia is one of largest agricultural export markets. Furthermore, significant currency depreciation will limit imports, hitting input usage and domestic investment of Ukraine [5].

The agricultural sector is experiencing serious internal difficulties, due to the transitional nature of the economy. A new policy and direction for Ukrainian agricultural sector are necessary. Agriculture poses the greatest challenge to the survival of Ukraine's political leaders, because almost half of all Ukrainian population live in rural areas [6].

In general, Ukraine has tremendous agricultural potential but this potential has not been fully exploited due to depressed farm incomes and a lack of modernization within the sector. Insecure land ownership and an inefficient registration system have also held back Ukrainian farming sector, but it has been improved in recent years.

Ukraine should become attractive for foreign investors, get complex tax codes, laws and regulations, decause poor corporate governance and weak enforcement of contract law make doing business within the country difficult.

The World Bank ranked Ukraine 137 out of 183 economies in its Doing Business Report in 2015. Many foreign financial institutions have left the Ukrainian market, according to a February U.S. State Department report [7].

So, the main problems that we can identify in the sector are the following:

-   Credit Problems. Most farms are able to receive credit, but interest rates and collateral demands are high. Since many farms are already heavily in debt to banks or suppliers of fertilizer and plant-protection chemicals, and since agricultural loans are not guaranteed by the government, banks are largely unwilling to give long-term loans. Most credits are seasonal loans (six to ten months) used almost exclusively for the purchase of fertilizer and plant protection chemicals.

-   Problems of employment. The decline of employment in agriculture has taken place as a result of negative factors caused by both demand and supply. Formation of labor supply determines the unfavorable demographic situation and the lack of proper motivation and incentives work.

-   Drawback of state regulation mechanisms for agricultural sector development in Ukrainian economy. The main problem is that the implementation of state agricultural policy through appropriate mechanisms of state regulation for agricultural sector must

decide triple task, aimed to ensure food security and create an efficient economy, provide an integrated socio-economic development of rural areas.

- Investment climate. Doing Business 2013 data for Ukraine shows attractiveness of Ukraine for investors. Ukraine is currently ranked 134th (out of 185 economies), which shows a 4,6% increase compared to the previous year of 2012, when it was ranked 152. The aim of the current government is to be between the top - 100 countries by the end of the 2016.

- Property rights. In Ukraine the property rights are not clearly defined yet.

- Corruption. As it was mentioned before, Ukraine scores extremely low on the freedom from corruption index. Ukraine ranks 144 from 174 countries in the Corruption Perception Index with 26 points out of 100 in 2014 (one of the most corrupted countries in Eastern European and Central Asia).

- Obsolete Machinery and Inadequate On-Farm Storage. A chronic lack of modern harvesting equipment is one of the main obstacles to increasing grain output and quality.

- Shrinking Livestock Inventories.

- Forming and effective use of physical capital at agricultural enterprises under changeable market conditions.

- Lack of full implementation of agrarian reforms.

- Complicated, ever-changing schedule of charges in the tax system of the country.

Theoretically speaking, a sensible Ukraine land reform could cause an agricultural boom in the country commonly known as the "breadbasket of Europe."

The efficiency of agrarian reform largely determines the overall course and results of market transformation, since the agrarian sector accounts for 32% of Ukraine's population, almost a quarter of production assets and about 14% of the annual output of goods and services. The documents that determine the strategy of reform in Ukraine point out that agricultural policy should be the "key element, stimulating factor" of accelerated market transformation of economy.

The necessity for deep reform of the agrarian sector is caused not only by the systemic nature of socio-economic transformation that Ukraine is presently undergoing, but also by the critical state of agriculture.

The documents that determine the strategy of the state policy define the goal of transformation in the agrarian sector of Ukraine's economy as the following: "The strategic goal of the agrarian policy is to create a true owner and master of land, social and economic progress of the countryside, solve the food problem, and raise the agricultural sector of Ukraine's economy to the world level. Agrarian reform encompasses all basic elements of the agricultural sector:

- production or property relations (economic aspect);
- social structure (social aspect);
- production technology (techno-economic aspect);
- management (organisational-economic aspect);
- legislative support for all processes and results of reform (legal aspect).

Therefore, agrarian reform has a comprehensive, systemic character and should be implemented according to the requirements of co-ordination and balance of the changes in each of the above aspects.

The Government of Ukraine has to set goals of agrarian reform in five directions:

land reform and reform of property relations in the agro-industrial complex. Under legislation adopted in 1992, Ukrainian law recognizes private ownership of agricultural land, as well as collective and state ownership. Also, a program to transfer land from state ownership to collective and individual ownership was initiated on a large scale, with

procedures to restructure collective and state farms. The transfer of land ownership and restructuring of traditional farms creates opportunities to develop for private farming in Ukraine after decades of collective management of agriculture;

establishment of new business entities on the basis of collective agricultural enterprises, employment of private property and land ownership, relying on leasing;

formation of market infrastructure in the agro-industrial complex;

modernisation of production, and establishment of competitive agricultural enterprises (domestic and international);

improvement of the mechanisms of state regulation in the agricultural sector.

Next, all state support to agriculture could be structured in four big blocks [9]:

- VAT exemption for farming industry. An agricultural producer is eligible to retain the difference between the VAT paid on inputs (i.e. fertilizer, fuel, plant protection, grain drying, etc) and the VAT received when selling outputs (i.e. crops grown).

- Direct subsidies; These are cash disbursements from the state budget under various government support programs, including schemes widely adopted globally, such as interest expense reimbursement, capex refunds for new animal farms, etc. While most of these programs have not been working, the amounts of available under these programs are budgeted every year and vary widely. Moreover, the distribution of these subsidies is believed to be corrupted. The below numbers show the dynamics of the budgeted amounts of the subsidies (while actual numbers are likely to be lower):

Table 1

Direct state subsidies, USD mln

Index / years	2010	2011	2012	2013	2014	2015
Livestock sector	169	254	92	81	74	0
Perennial crops	60	70	135	13	8	0
Other	31	35	139	15	0	15
Total	**259**	**359**	**365**	**109**	**83**	**15**

Source: Ukrainian Agrarian Association

- General services; The Organisation for Economic Cooperation and Development (OECD) is an international economic organisation of 34 countries, founded in 1961 to stimulate economic progress and world trade. It is a forum of countries describing themselves as committed to democracy and the market economy, providing a platform to compare policy experiences, seeking answers to common problems, identify good practices and coordinate domestic and international policies of its members. Under OECD methodology, the government expenditures on bureaucracy, research and regulatory agencies are considered to be a part of the state support. While business benefits from certain internationally required certification, majority of these money is spent on soviet-style barely benefits from this so-called research, excessive and excessive certification and bureaucracy.

- Fixed agricultural tax. An agricultural producer is eligible to pay fixed agricultural tax (~USD 0.8/ha per year until 2015, ~USD 6/ha since 2015) instead of corporate income tax (now 18%). This was considered to be a material subsidy prior to 2015; levels established from 1 January 2015 are comparable to the ones which should pay under general corporate profit tax of 18%. The absence of reliable data on dynamics of farmers'

average profitability and high doubts of whether any of income tax would be collected under general regime, this subsidy is omitted from these calculations.

The negative actions come through two ways: absence of VAT refunds and export quotas and duties. Of course, there are many small positives and negatives affects from the state policy but they are relatively immaterial.

Excessive taxation of agriculture exports:

1. Absence of VAT refunds on grain exports. Value added tax is one paid in the country of consumption. The tax is gradually collected from the value created, each participant in the chain pays its share of the tax. To avoid double taxation and unintended non-taxation during international trade, the common approach is used by all countries which adopted the VAT is that imported goods are subject to a VAT rate based on import price, while exported goods are eligible for refunds of VAT paid on inputs. To put things simple, if iron ore producer in Ukraine pays USD 10 per ton of VAT during the production process, the same amount would be refunded when this iron ore is exported. The importer in the country of consumption would pay the applicable VAT amount (based on tax rate in his country).

2. Export quotas and duties. In addition to cancelation the refunds of VAT, the government also introduced grain export duties in 2011/12. Though they lasted for several months only, they had negative affect on the agriculture industry earnings.

One year earlier, in 2010/11, Ukrainian government restricted grain exports through introduction of quotas on grain export. Because amounts stipulated in quotas were materially lower than available grain export surplus (production minus domestic consumption), the spread between domestic and international prices increased sharply, and farmers earned less than they could under free trade.

Conclusions

As you can see from the article, there are many problem areas in the agricultural sector of Ukraine. But there are also strengths, that when state aid can be strengthened to improve farms effective activity.

Further progress toward improved efficiency in Ukrainian agriculture requires continued restructuring of farm enterprises into smaller autonomous units based on private ownership of land and assets, clear formulation of procedures that allow exit of individuals and small groups with shares of land and assets, development of land markets, and establishment of functioning market infrastructure for competitive input supply, marketing services, and financial services.

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Paper drying process for corrugation (fluting) using radiant energy

Viktor Marchevsky, Oleg Novokhat, Oleksiy Tsepkalo

National Technical University of Ukraine "Kyiv Polytechnic Institute", Kyiv, Ukraine

Abstract

Introduction. The growing market demand in corrugated package products requires increase of fluting production, which is limited by the process of drying. Therefore, intensification of drying by the use of new sources of heat and reduction of air emissions is an urgent problem.

Materials and methods. The subject of the study is the process of fluting drying using infrared radiation. The object of the study is the kinetics of fluting drying process using infrared radiation. The experiments were carried out on fluting samples of grades B-0, B-1 and B-2 according to technical specifications Ukraine TS U 21.1-31812534-023:2009 (112, 125 and 140 g/m^2), and samples of irregular fluting with increased mass per square meter of 200 g/m^2. The mathematical modelling methods and experimental studies using a computerized test facility and statistical processing of findings were used.

Results and discussion. The experimental curves of drying and the process main parameters are approximated with sufficient accuracy by the proposed mathematical description. The root-to-mean deviations of the calculated and experimental values of the moisture content does not exceed 0,04 kg/kg, enabling the fluting drying calculation at heat flux density up to 35 kW/m^2.

With increase of radial heat flux density from 2 kW/m^2 to 35 kW/m^2 the total time of fluting drying is reduced more than 20 times.

The maximum value of the heat flux density is limited by fluting rising surface temperature of 150 °C in the first period. Therefore, at the heat flux density of 35 kW/m^2 the drying process of fluting should be carried out only at the end of the first period, the duration of which is increased referred to a heat flux density increase.

Conclusions. Kinetic patterns and basic parameters of fluting drying using infrared radiation which are received in the study, allows performing calculations needed to design industrial processes of fluting drying and equipment for their effective implementation.

Introduction

Every year, the turnover is increasing by accelerating the material production rate for packaging. There are many types of similar materials. Until recently, the most common packaging material was polyethylene. However, time of polyethylene decomposition is much longer than paper, consequently it can lead to environmental problems [1]. Because of this environmentally-friendly natural materials have increasingly been common in use.

One of the most common natural materials for packaging is paper. This is due to its naturalness and high consumer characteristics, large reserves of raw materials for its production and a number of production facilities.

For transportation a packaging material must feature distinguishably increased rigidity and durability. Corrugated cardboard possesses these properties [2]. With a relatively small mass and cost, corrugated cardboard features high physical performance. The feature of corrugated cardboard production is the possibility of using paper and paperboard which are made of waste paper [3]. This can reduce the cost of its production and save natural resources.

Corrugated cardboard is made of three main components: cardboard for surface layers (liner), paper for corrugating (fluting) and glue that binds them. Due to high loads during corrugation and exploitation especially strict requirements for fluting characteristics are specified.

In production liner and fluting pass the following main stages: forming, pressing and drying [4]. The most energy intensive of these stages is drying.

The most common type of paper drying is contact drying method of paper web on drying cylinders surface [5]. Despite of relatively high performance, this method has several disadvantages [6]. First of all, it is cumbersome equipment and use of steam as a coolant for drying. In steam production it is necessary to burn natural gas, which increases the amount of carbon emissions into the environment. Carbon dioxide increases the greenhouse effect leading to global warming [7].

The drawback of the contact drying method is that the heating rate of wet paper is limited by its low thermal conductivity and it decreases by heat consumption on water evaporation during heating.

These factors stipulate the search for alternative methods of drying paper and cardboard. One of such promising methods is paper drying using infrared radiation [8]. This type of radiation is known to have a deep penetrating ability into material. Consequently, heating of material is not limited by its thermal conductivity. In addition, the use of infrared radiation does not need to burn natural gas. This will enable to reduce carbon dioxide emissions in the atmosphere.

To develop a highly effective device for fluting drying using infrared kinetic patterns it is necessary to be familiar with the process and its basic parameters. In literature survey of scientific publications the information on fluting drying by infrared radiation was not found. Therefore, the definition of kinetic patterns and basic parameters of fluting drying using infrared radiation needed to develop a high-performance drying unit is relevant.

Materials and methods

In the studies there were used fluting samples of grades B-0, B-1 and B-2 according to technical specifications Ukraine TS U 21.1-31812534-023:2009 (112, 125 and 140 g/m^2) and irregular samples with fluting with increased mass per square meter of 200 g/m^2. The

samples diameter was 80 mm. The fluting for various experiments was pre-soaked to the original moisture content within 1,4-1,8 kg/kg.

To calculate the moisture content the test prototypes were labeled, dried in a drying chamber until the constant mass and weighed on the scales with an accuracy of 3 mg. Then the dried samples were pre-soaked for some time and were kept in the desiccator within 24 hours to even moisture distribution inside.

After the desiccator the soaked fluting samples were placed on electronic scales of the experimental facility, which transferred the initial and current values of the mass on the personal computer. On the computer, these values are converted to the appropriate mass moisture values used for drying curve in the software environment of Excel.

The method of drying paper is radiation. An electric ceramic transducer with a rated electrical output of 1 kW is applied as the radiation source. The working emitter surface has the form with the sides of 0,122×0,122 m and an average temperature of working surface is about 600 °C. The wavelength from the infrared emitter is 2,9–5 microns. The actual electric power consumed by radiator, was measured with a wattmeter. To reduce heat loss the radiator is equipped with a reflector.

The schematic of the experimental facility for determination of the drying process kinetic patterns is shown in Figure 1.
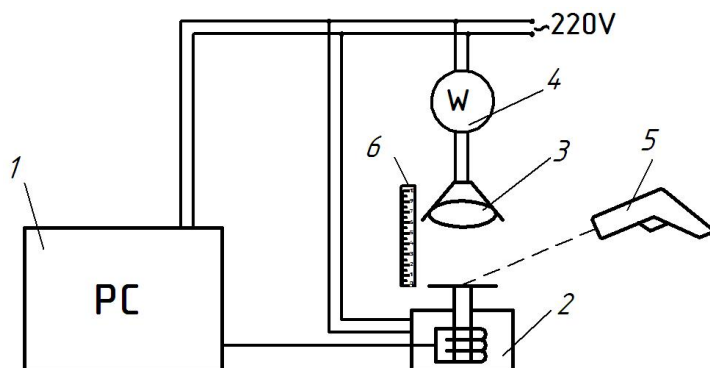
Fig. 1. The experimental facility for determination of drying process kinetics
1 – personal computer; 2 – electronic scales; 3 – infrared radiator reflector;
4 – wattmeter; 5 – pyrometer; 6 – ruler

The radiant flux density from the emitter working surface to the paper surface was adjusted by distance change between them.

During the experiment the sample fluting was placed on the platform with a mesh surface. The platform was installed on electronic scales. The scales dial resolution constitutes 1 mg, measurement error is 3 mg. The scales with a frequency of 3 times per second transmitted the current value of the wet mass of paper to the personal computer.

The surface temperature of the paper was measured with a pyrometer.

For experimental confirmation of the value of heat flux density from the infrared emitter a conventional heat flux sensor PTP-04t was used.

Physical features of fluting drying process using infrared radiation and its mathematical description are given in [9].

The developed mathematical model was also tested in the study of sanitary paper drying using infrared radiation [10].

The radiation type drying other kinds of paper and board are in the works of other authors [11, 12, 13].

Results and discussion

The results of calculations of the mathematical description and experimental data are presented in the form of moisture content and temperature–drying time characteristic curves. According to the calculations drying rate–moisture content characteristic curves were obtained as well.

These important kinetic dependences and parameters and process features were used for creation of fluting drying technology.

Dependences of moisture on drying time ("drying curves") for fluting of mass per square meter of 125 g/m^2 at different densities of heat flux are shown in Figure 2.
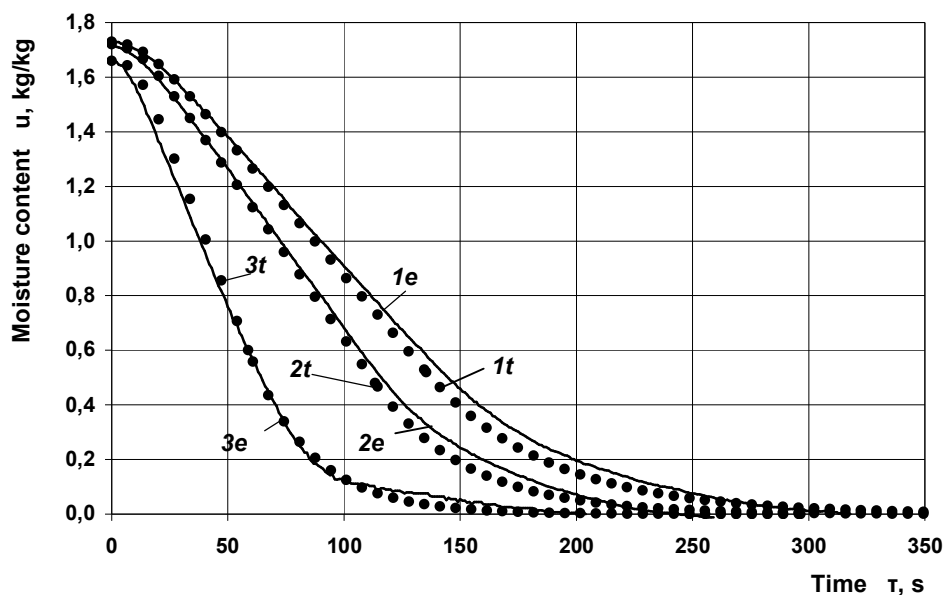
Fig. 2. Dependence of moisture content on drying time when g=125 g/m^2:
e – experimental data, t – estimated data
1 – q = 3665 W/m^2, 2 – q = 4300 W/m^2, 1 – q = 6835 W/m^2

For fluting per square meter mass of 125 g/m^2 with increasing heat flux density of 3665 W/m^2 to 4300 W/m^2 and 6835 W/m^2 fluting total drying time is reduced from 318 s to 244 s and 203 s, respectively. The duration of the first period of fluting drying at these densities of heat flux is 144 s at drying rates 0,009 kg/kg•s, constitutes 116 s at rate of 0,012 kg/kg•s and constitutes 64 s at rate of 0,020 kg/kg•s, respectively.

Thus, with increasing heat flux density on 635 W/m^2 the drying time reduces from 350 s to 250 s (final moisture content $u_{2k} = 0$).

The drying rate dependence of these fluting samples according to drying periods is shown in Figure 3.
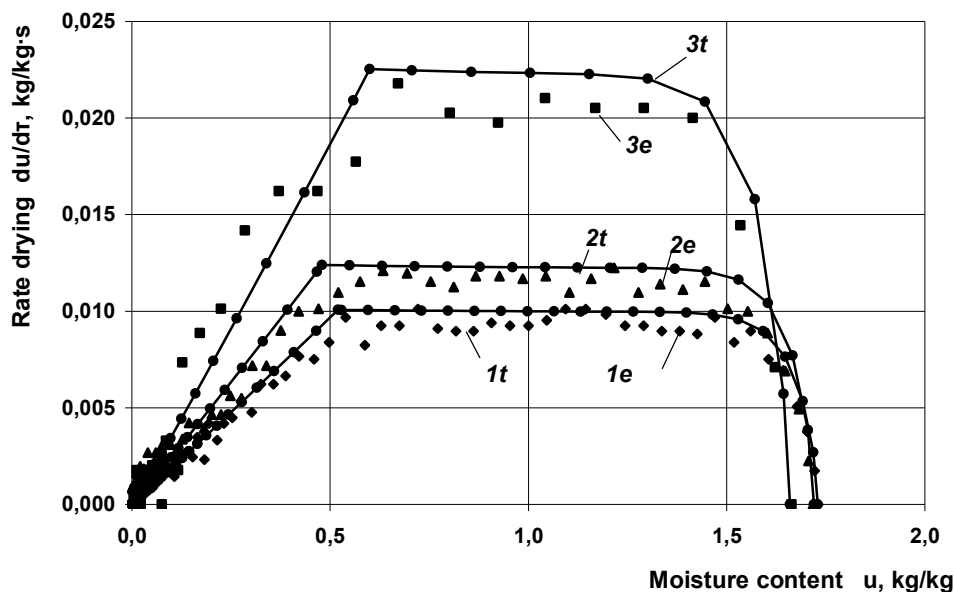
Fig. 3. Dependence of drying rate on moisture when g = 125 g/m^2:
e – experimental data, t – estimated data,
1 – q = 3665 W/m^2, 2 – q = 4300 W/m^2, 1 – q = 6835 W/m^2

As shown in Fig. 3, the intensity of drying in the first period increases with radiant heat flux density.   This is due to the fact that infrared radiation is internal heat source for thin materials [14]. This critical moisture content does not change and remains at u_{1k}=0,4 kg/kg. The increase of radiant heat flux density from 3685 W/m^2 to 4300 W/m^2 leads to increase of drying intensity from 0,01 1/s to 0,0125 1/s, while the increase of radiant heat flux density from 3685 W/m^2 to 6835 W/m^2, the intensity of drying increases from 0,01 1/s to 0,0225 1/s.

Analysis of the results shows that the small radial heat flux densities up to 7000 W/m^2 and a constant relative humidity of drying intensity in the first period are proportional to the radiant heat flux density. This dependence indicates that the intensity in the first period of drying is limited by radiant heat flux density. During drying by constant radiant flux density with moisture content change of fluting the surface temperature, on which heat flux is directed and, accordingly, the temperature on fluting thickness, changes.

The change in surface temperature of fluting according to drying time is shown in Figure 4.
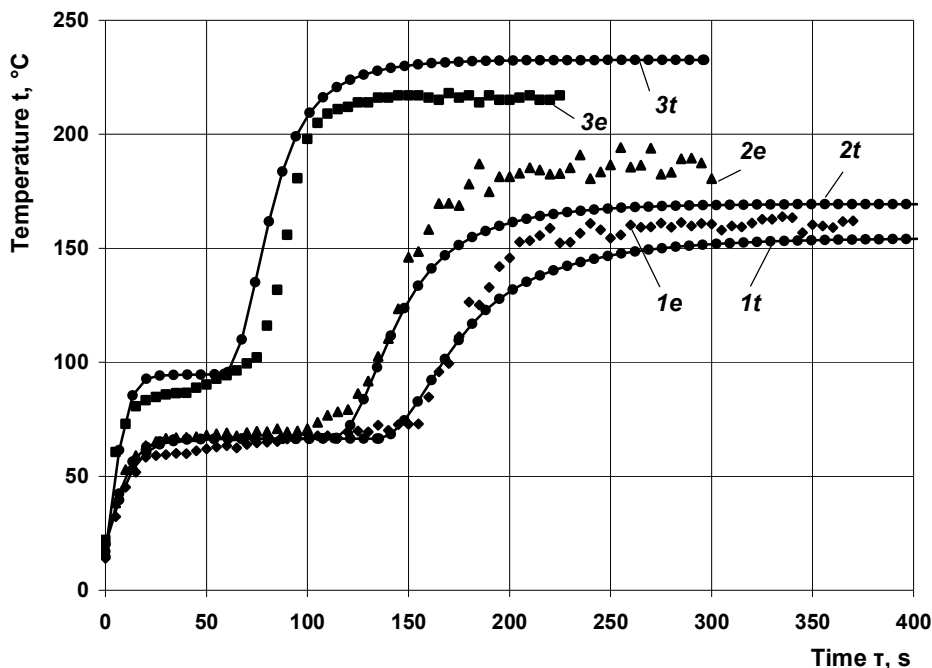
Fig. 4. Temperature-drying time characteristic curves when g = 125 g/m²:
e – experimental data, t – estimated data,
1 - q = 3665 W/m², 2 - q = 4300 W/m², 1 - q = 6835 W/m²

The average temperature of fluting surface with a specific mass of 125 g/m² at heat flux density of 3665 W/m² in the constant rate period is 66 °C, at 4300 W/m² it constitutes 69 °C and 87 °C at 6835 W/m² respectively.

The equilibrium temperature of fluting surface at the end of drying at heat flux densities of 3665 W/m², 4300 W/m² and 6835 W/m² constitutes 161 °C, 187 °C and 217 °C respectively.

As shown in Fig. 4, the process of fluting heating to the first period temperature is carried out for a short time, which is only 4-5% of the total drying time.

The temperature of fluting wet surface in the first period at low density of radiant heat flux of 3685 W/m² and a constant relative humidity is kept constant and close to temperature of the wet thermometer (curve 1). The temperature constancy in the first period is maintained constant by radiant heat flux density which is spent on evaporation of the moisture surface.

With increase in radiant heat flux density (curve 2) the fluting temperature in the first period gradually increases, which is obviously due to the heat increase in the fluting inner layers, the temperature of which is higher than the fluting surface temperature, which loses heat to the environment.

With a substantial increase in the radiant heat flux density (curve 3) the fluting temperature increases dramatically. Its value increases gradually throughout the first period and depends obviously on saturation pressure and temperature does not meet the wet thermometer.

At the beginning of the second period, starting after the first critical moisture content, there are straight sections of temperature curves in Fig. 4. These curves state points to constant rate of increase in temperature, which apparently can be explained by moisture evaporation from microcapillaries, the mass of which is reduced at a constant speed.

A transition straight section of temperature curves to curved sections is obviously determined by evaporation of absorption moisture. The rate of temperature increase tends to zero when reaching the

moisture content equilibrium. If the fluting surface temperature reaches the oxidation temperature at the end of drying, the rate of temperature increase will accelerate, and the process will end with fluting ignition.

Increase of theoretical values of temperature deviations from experimental at the end of drying process (curve 3) can be explained by increase in energy to overcome the adsorption forces of water molecules that are not taken into account in the equations of the mathematical model.

Moisture content-drying time characteristic curves for fluting with different masses per square meter at heat flux density of 6835 W/m^2 are shown in Figure 5.
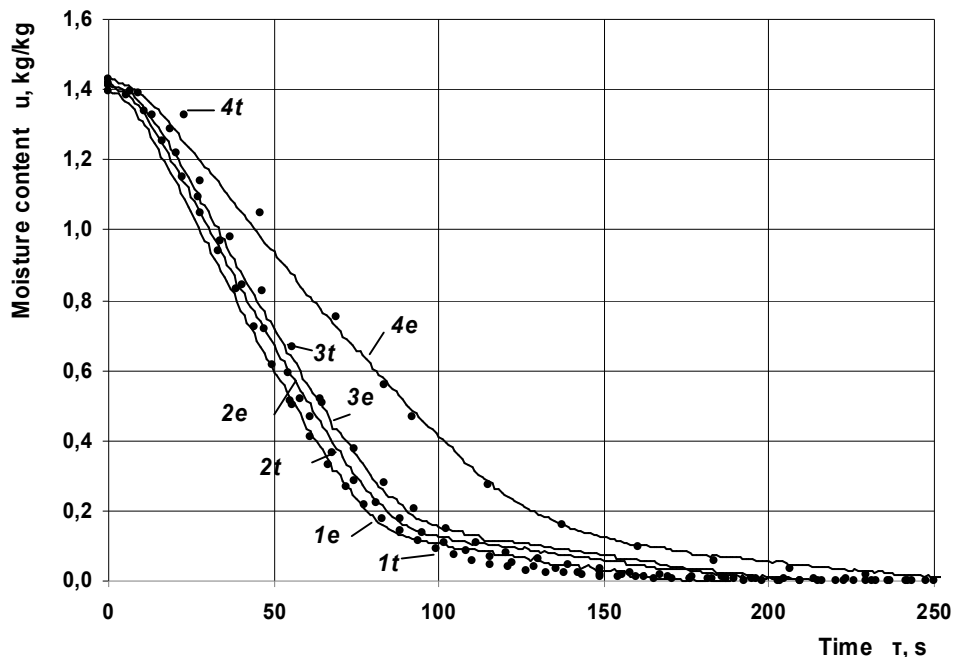
Fig. 5. Dependence of moisture content on drying time when q = 6835 W/m^2:
e – experimental data, t – estimated data,
1 - g = 112 g/m^2, 2 – g = 125 g/m^2, 3 - g = 140 g/m^2, 4 - g = 200 g/m^2

With the heat flux density at 6835 W/m^2 for fluting of masses per square meter of 112 g/m^2, 125 g/m^2, 140 g/m^2 and 200 g/m^2 the total drying time is 189 s, 207 s, 212 s and 252 s, respectively. The duration of the first drying period at mass of dry fluting square meter of 112 g/m^2 is 56 s, and the drying rate constitutes 0,0192 kg/kg•s; at 125 g/m^2 in the first drying period is 61 s, and the speed of 0,0174 kg/kg• s; at 140 g/m^2 duration of the first drying period is 65 s and the speed of 0,0166 kg/kg•s and at mass square meter of 200 g/m^2 duration of the first drying period is 90 seconds, and the drying rate constitutes 0,0112 kg/kg•s.

The drying curves analysis shows that with increase in mass per square meter of fluting the drying time increases and drying intensity (rate) decreases. The reason for such dependences is samples thickness increase referred to their masses increase per square meter [15]. With increase of fluting thickness heat, diffusion and hydraulic resistance referred to samples mass are increased. Therefore, samples with less thickness and mass

with the same radiant heat flux density warm and dry much faster compared with samples of greater thickness, which contain more water and require more energy to dry it.

The change in temperature of fluting surface at drying time is shown in Figure 6.
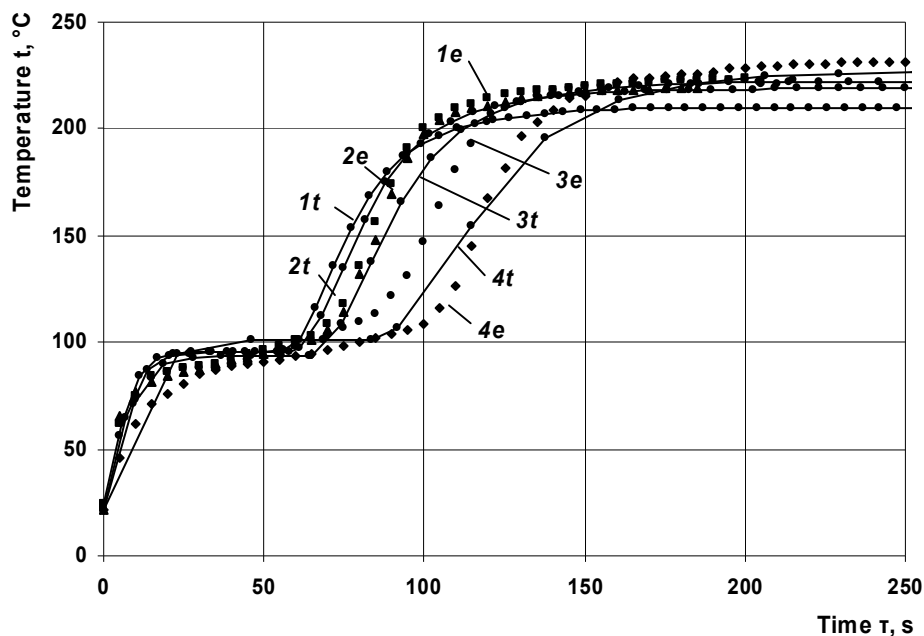

Fig. 6. Dependence of drying rate on moisture content when q = 6835 W/m^2:
e – experimental data, t – estimated data,
1 - g = 112 g/m^2, 2 - g = 125 g/m^2, 3 - g = 140 g/m^2, 4 - g = 200 g/m^2

The average temperature of fluting surface at heat flux density of 6835 W/m^2 for fluting mass per square meter of 112 g/m^2 in a period of constant speed of 90 °C, 125 g/m^2 it constitutes 92 °C, at 140 g/m^2 it is 94 °C, and at 200 g/m^2 it amounts 98 °C

The equilibrium temperature of fluting surface at the end of drying at heat flux density of 6835 W/m^2 for fluting of mass per square meter of 112 g/m^2 amounts 223 °C, at 125 g/m^2 it is 223 °C, 140 g/m^2 it is 221 °C and it constitutes 231 °C at 200 g/m^2.

The analysis of samples masses influence on their heating surface temperature shows that in the first period the surface temperature is close to the boiling point at atmospheric pressure. A higher surface temperature of thicker samples is determined by significant release of thermal energy in their volume and a higher thermal resistance.

After the first critical moisture content the samples surface temperature increases in the transition period according to the power law, followed by a rapid temperature rise linearly, due to the moisture evaporation from microcapillaries. After linear temperature increasing its growth begins due to the power law from the second critical to the ultimate equilibrium, which is due to the evaporation of absorption moisture to the equilibrium.

Graphical dependences of moisture content on drying time for samples with different masses at different initial moisture contents and heat flux density of 6835 W/m^2 are shown in Figure 7.
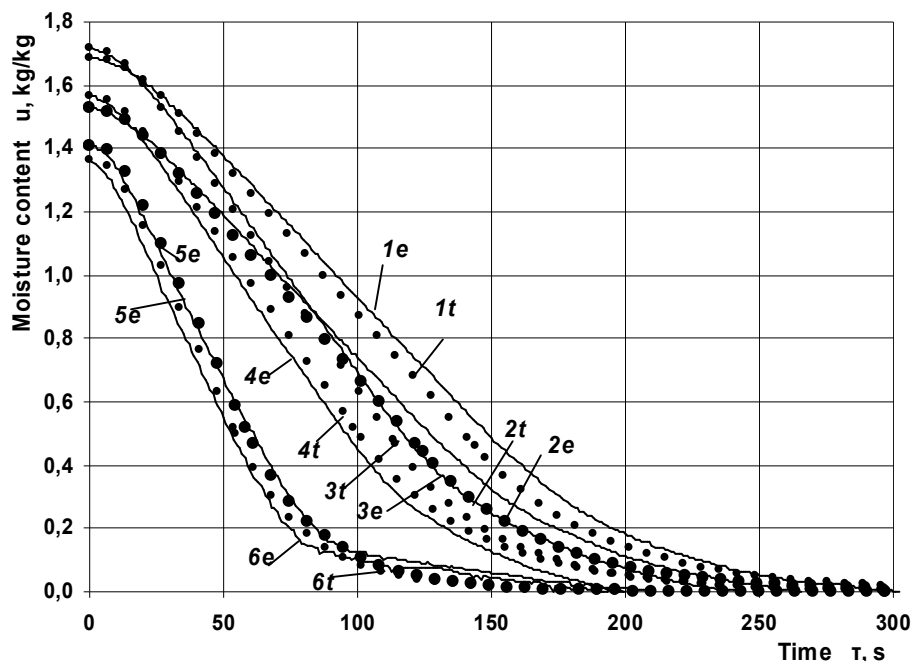
Fig. 7 – Dependence of moisture content on drying time when g=125 g/m²:
e – experimental data, t – estimated data,
1 - q = 3665 W/m², u_0 = 1,71 kg/kg, 2 - q = 3665 W/m², u_0 = 1,53 kg/kg,
3 - q = 4300 W/m², u_0 = 1,72 kg/kg, 4 - q = 4300 W/m², u_0 = 1,57 kg/kg,
5 - q = 6835 W/m², u_0 = 1,41 kg/kg, 6 - q = 6835 W/m², u_0 = 1,36 kg/kg

The change in fluting surface temperature referred to drying time is shown in Figure 8.

For fluting of mass per square meter of 125 g/m² and heat flux density of 3665 W/m² at the initial moisture content of 1,71 kg/kg and 1.53 kg/kg of drying rate of the first period is the same and it constitutes 0,0091 kg/kg•s. Also, there are the same values of average temperature of the first period of drying (64 °C) and equilibrium fluting surface temperature at the end of drying (162 °C) (Fig. 8). The first period of drying for fluting with initial moisture content of 1,71 kg/kg is 148 s, and the total drying time to the final moisture content is 302 s. When the moisture content is 1,53 kg/kg, duration of the first drying period and at the end of the second period are 127 s and 264 s respectively.

For fluting of mass per square meter of 125 g/m² heat flux density of 4300 W/m² the rate of the first period of drying is 0,0122 kg/kg•s. The first period drying temperature is 70 °C and the equilibrium fluting surface temperature at the end of drying constitutes 186 °C (Fig. 8). The first period of drying for fluting with initial moisture content of 1,72 kg/kg is 115 s, total drying time to final moisture content is 238 s. When moisture content is 1,57 kg/kg, duration of the first drying period and at the end of the second period are 95 s and 200 s respectively.

For fluting of mass per square meter of 130 g/m² and heat flux density 6835 W/m² the first period drying rate is 0,0172 kg/kg•s. The first period drying temperature is 90 °C and the equilibrium fluting surface temperature at the end of drying constitutes 218 °C. The first period of drying for fluting with initial moisture content of 1,41 kg/kg is 61 s, the drying

end time is 206 s. When moisture content is 1,36 kg/kg, duration of the first drying period and the total drying time are 53 s and 189 s respectively.
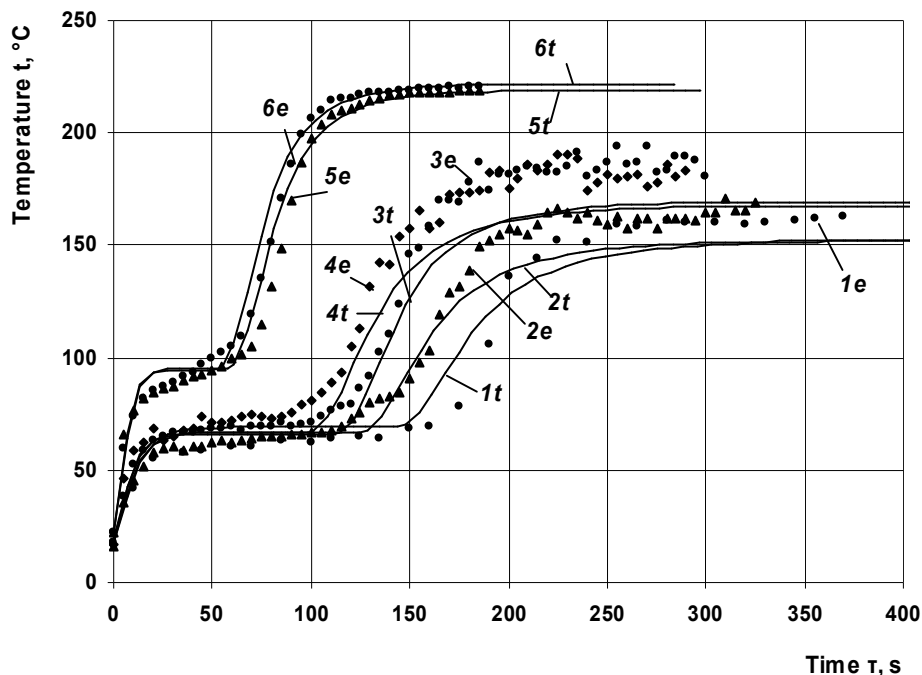

Fig. 8. Dependence of surface temperature on drying time when
$$g = 125 \text{ g/m}^2:$$
e – experimental data, t – estimated data,
1 - q = 3665 W/m², u₀ = 1,71 kg/kg, 2 - q = 3665 W/m², u₀ = 1,53 kg/kg,
3 - q = 4300 W/m², u₀ = 1,72 kg/kg, 4 - q = 4300 W/m², u₀ = 1,57 kg/kg,
5 - q = 6835 W/m², u₀ = 1,41 kg/kg, 6 - q = 6835 W/m², u₀ = 1,36 kg/kg

Analyzing the influence of the initial moisture content value on the drying process it can be noted that the initial moisture content does not affect the drying rate. However, with increase of the initial moisture content the drying time increases as a result of presence of more moisture in the material inside. This trend continues by changing the heat flux density.

Significant influence of the initial moisture content on fluting temperature during drying was not found.

Graphic dependences of the estimated moisture content values on the fluting drying time with masses per square meter of 112 g/m², 125 g/m², 140 g/m² and 200 g/m² with initial moisture content of 1,72 kg/kg and heat flux density of 35 kW/m² are shown in Figure 9.
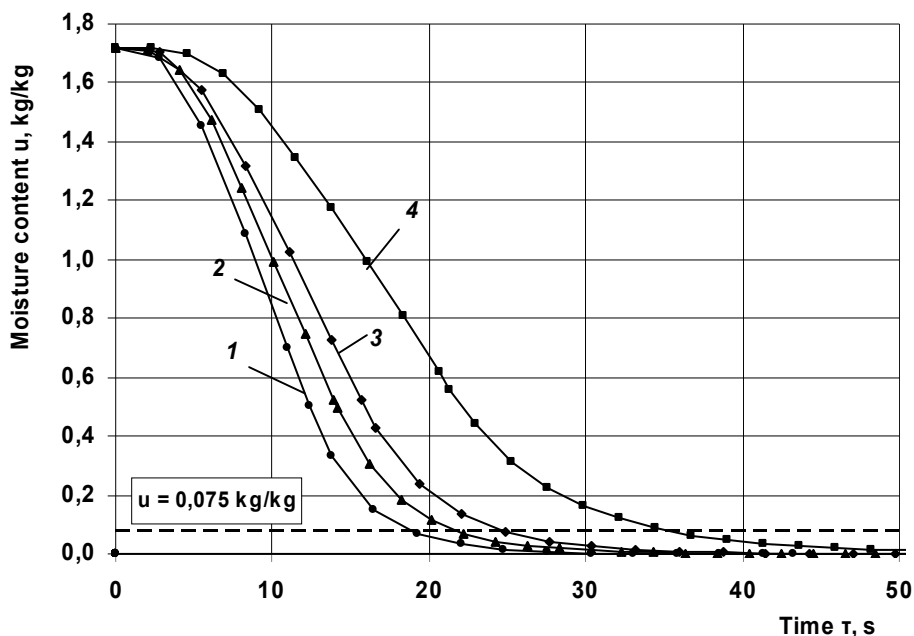
Fig. 9. Moisture-time characteristic curves when q = 35 kW/m²:
e – experimental data, t – estimated data,
1 - g = 112 g/m², 2 – g = 125 g/m², 3 - g = 140 g/m², 4 - g = 200 g/m²

With heat flux density of 35 kW/m², the fluting drying duration of mass per square meter of 112 g/m², 125 g/m², 140 g/m² and 200 g/m² with the regulatory dryness of 93% (0,075 kg/kg) are 19 s, 22 s 25 s and 36 s, respectively. The fluting drying time from the process beginning to the first period end for these masses per square meter is 12,4 s, 13,9 s, 15,7 s and 21,3 s, respectively.

Thus, the increase in heat flux density is the most appropriate for heating and the first period of drying.

To determine whether the experimental data refer to estimated data mean-square deviations of the moisture content were defined. The maximum standard deviation constituted 0,04 kg/kg.

The analysis of the theoretical and experimental results confirms the sufficient adequacy of the obtained kinetic patterns (probability 95% by Fischer), which allows to calculate the kinetic parameters of industrial processes of fluting drying using powerful radiant heat flux.

Conclusions

Kinetic patterns and basic parameters of fluting drying using infrared radiation which are received in the study, allows performing calculations needed to design industrial processes of fluting drying and equipment for their effective implementation.

The use of infrared for fluting drying will reduce the gas costs for the steam production resulting in replacement of contact drying method on radiation method, the decrease in natural gas combustion will reduce emissions of carbon dioxide in the atmosphere.

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Simultaneous unsteady calculation of temperature distribution in the «larger sugar crystal–larger sugar crystal sucrose solution–less sugar crystal sucrose solution–smaller sugar crystal–massecuite» system cells and sucrose solutions cells concentrations in the same system depending on the boiling sugar massecuite time

Taras Pogorilyy

National University of Food Technologies, Kyiv, Ukraine

Abstract

Introduction. In this paper we realized one of the following steps to create a mathematical model of the sucrose crystallization process.

Materials and methods. For simultaneous solution of a system of 7 unsteady heat conduction problems in each separate area with constant and with variable thermophysical coefficients, and also three separate unsteady diffusion mass transfer problems for the four sucrose solution regions with constant and variable diffusion mass transfer coefficients applied numerical methods (controlling volume method).

Results and discussion. Temperature distribution in each considered system cells area found from the non-stationary parabolic type differential equations in partial derivatives systems solution for ten cases relative time boiling sugar massecuite τ/τ_c ($\tau/\tau_c = 0,15$; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9; 1,0).

At the relative boiling sugar massecuite time $\tau/\tau_c = 0,15$ temperatures are equal: 99,547°C for the left larger crystal sucrose solution area with constant coefficients and 99,479°C for all variables coefficients; 94,799°C for larger sugar crystal with constant coefficients and 94,409°C for all variables coefficients; 90,234°C for the right larger crystal sucrose solution area with constant coefficients and 89,640°C for all variables coefficients; 89,485°C for the left smaller crystal sucrose solution area with constant coefficients and 88,820°C for all variables coefficients; 87,325°C for smaller sugar crystal with constant coefficients and 86,630°C for all variables coefficients; 85,285°C for the right smaller crystal sucrose solution area with constant coefficients and 84,590°C for all variables coefficients; 75,107°C for massecuite with constant coefficients and 75,098°C for all variable coefficients

At the same time concentrations distribution found in each sucrose solution region considered system cells. At the relative boiling sugar massecuite time $\tau/\tau_c = 0,15$ concentrations are equal: 82.710% for the left larger crystal sucrose solution area with constant coefficients and 82.274% for all variables coefficients; 80.400%for right larger crystal sucrose solution area with constant coefficients and 79.893% for all variables coefficients; 80.269% for the left smaller crystal sucrose solution area with constant coefficients and 79.765% for all variables coefficients; 79.418% for the right smaller crystal sucrose solution area with constant coefficients and 79.026% for all variable coefficients.

Conclusions. Found temperature distribution in the system cells that is presented in the form of seven one-dimensional areas and, accordingly, found the concentrations distribution in four sucrose solutions areas system cells.

Introduction

The process of obtaining crystalline sucrose is the most energy intensive in sugar production. For its control in this paper realized one of the following steps to create a mathematical model of the sucrose crystallization process

The performed literature review indicates that the issue of sucrose crystallization process and related processes that directly affect the process were engaged Tetiana Vasylenko and Sergii Vasylenko [1], Hugot E. [2, 6], Jenkins G.H. [3], Jiahui Chen [4], Baikow V.E. [5], Lauret P. [7], Alewijn W.F. [8], Semlali Aouragh Hassani [9] and Thomas R. Gillett [10].

From the literature review it can be concluded that describe the sucrose crystallization extremely difficult. Moreover, today there is no single universally accepted approach on this issue.

Therefore, in this paper the author realized one of the following steps to create as the most complete mathematical model of the sucrose crystallization process.
This model should fully describe the heat and mass transfer process, which takes place between the multiphase system components such as sugar massecuite.

Note that to described the above process with all the technological, thermal and hydrodynamic characteristics that affect the mass sucrose crystallization process, almost extremely difficult. Therefore adopted a number of simplifications. Thus, the mass crystallization mathematical model is idealized nature.

Continuing studies [11, 12], in this case sugar massecuite also represented as a cellular model [13, 14, 15].

Considered that each sugar crystal cell [14] surrounded by a corresponding sucrose solution cell [15] for the whole sugar massecuite boiling time.

Further, hydrodynamic interactions occur only between cells. But the heat and mass transfer processes occurring both within the cells, and between them.

Simulation of unsteady heat and mass transfer processes carried out in several stages.

The first stage it is necessary to find the temperature distribution in all cell system that has been done and detailed for a single crystal sugar in [11] and for the two sugar crystals in [12].

The second stage it is necessary to find the value in each cell sucrose solution concentration, sucrose value transferred between the cells and the amount of crystalline sugar that will crystallize (or dissolve) in a crystal sugar cell.

This issue of the simultaneous of temperatures values distribution in the cells system and concentrations values distribution in each sucrose solution cell is devoted this work. Note that in this paper the distribution concentration in the initial time in each sucrose solution cell adopted for saturated sucrose solution adopted in accordance with the initial temperature.

It is understandable that this unsteady diffusion mass transfer problem between cells, from which the massecuite is completely based on getting unsteady temperature field distribution in the system cells. Therefore, the unsteady heat transfer problem for seven area of whole system cells and three individual unsteady diffusion mass transfer problem to four areas sucrose solutions were solved simultaneously.

In this work, to continue [11, 12] demonstrate the simultaneous modeling of the unsteady heat process and unsteady diffusion mass transfer processes simultaneously for the two sugar crystals, which are surrounded by respective cells sucrose solution and simultaneously interact with massecuite.

Based on unsteady heat conduction problem solution is determined by temperature distribution in each component of cells that are inside the heating tube. Based on the solutions of three unsteady diffusion mass transfer problems is determined by the concentration distribution in each cell sucrose solution considered above system cells.

Accepted the initial time $\tau_{c,0} = 0$, when the whole cells system adjudged (included) to the bottom of a vertically oriented heating tube. Final $\tau_{c,end}$ is the one time when the whole system comes out simultaneously with heating tubes in its upper part. It is understandable that $\tau_{\kappa,1}$ value will depend on the relative time of boiling sugar massecuite, i.e., $\tau_{c,end} = \tau_{c,end}(\tau/\tau_c)$.

Note also that the crystal's, sucrose solution's and massecuite's cell thermal characteristics and diffusion mass transfer coefficient of sucrose solutions cells are based on the value of $\tau_{c,0}$, will depend on the relative boiling sugar massecuite time τ/τ_c.

Materials and methods

In this paper, the search concentration distribution between the components sucrose solution cells fully based on the resulting temperature distribution in the components of the whole system cells. Note that, in turn, in this paper the temperature distribution in the whole system cells also calculated as having depending on the resulting concentrations distribution in the sucrose solution areas. Thus, in this paper the problem of interference between simultaneous unsteady temperature distribution in all areas of the whole one-dimensional cell system and unsteady concentrations distributions only one-dimensional sucrose solution areas was considered.

Methods of obtaining only temperature distribution in the system cells, without interference with the concentration distribution in sucrose solution areas was considered in detail in [12].

Similarly in [12], first consider the volumetric case system of cells: «larger sugar crystal–larger sugar crystal sucrose solution–less sugar crystal sucrose solution–smaller sugar crystal–massecuite». By a similar method [12] made the transition from the volume cell model to equivalent one-dimensional model.

Thus, for non-stationary heat and mass transfer problems considered next 7 dimensional regions (Fig. 1), simultaneously pairs in contact with each other:

1 - left area larger crystal sucrose solution;
2 - larger crystal sugar;
3 - rights area larger crystal sucrose solution;
4 - sucrose solution left area smaller crystal;
5 - smaller crystal sugar;
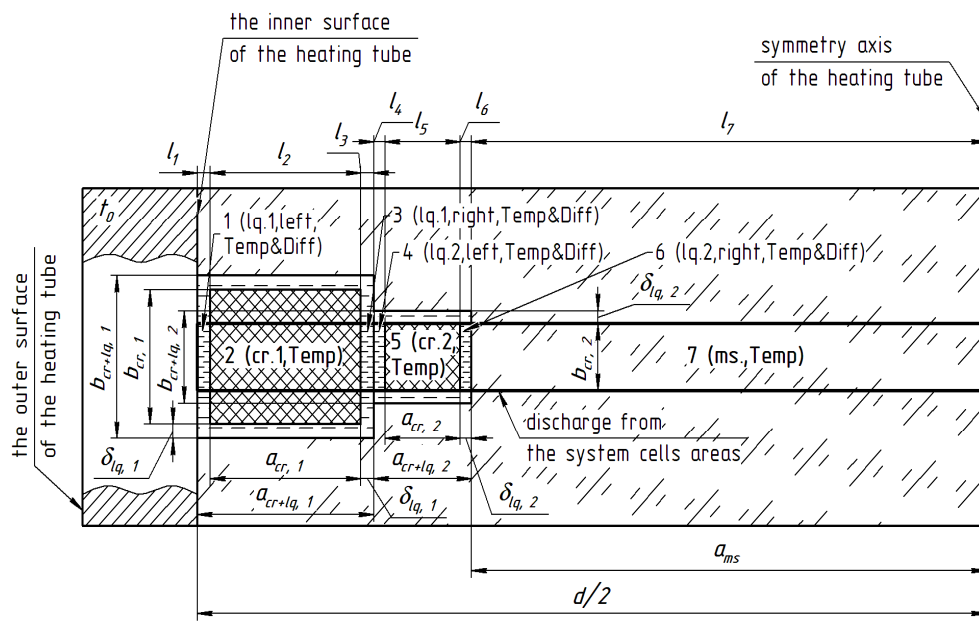6 - rights area smaller crystal sucrose solution
7 - massecuite.

For three individual unsteady mass transfer problems considered one-dimensional four areas (Fig. 1): 1, 3, 4, and 6, where 3 and 4 area pairs simultaneously in contact with each other.

The first unsteady diffusion mass transfer problem involved the first area, representing the left larger crystal sucrose solution region (Fig. 1).

The second unsteady diffusion mass transfer problem involved the simultaneous contact areas 3 and 4 of the ideal mass transfer between them (Fig. 1).

The third unsteady diffusion mass transfer problem was about the sixth area, representing the right smaller crystal sucrose solution region (Fig. 1).

Note that in Fig. 1 shows a one-dimensional area as two-dimensional region with the same height for all, equal to the average side $b_{cr+lq,2}$ smaller crystal.

Fig. 1. The one-dimensional case systems of cells "the left side larger crystal sucrose solution cell–larger sugar crystal cell–right side larger crystal sucrose solution cell–left side smaller crystal sucrose solution cell–smaller sugar crystal cell–right side smaller crystal sucrose solution cell–massecuite" simultaneously taking participate in the non-stationary heat exchange and diffusion mass transfer processes.
Designation of areas for:
Temp — considered only unsteady heat conduction problems;
Temp&Diff — considered simultaneously unsteady heat problem and nonstationary mass diffusion transfer problem**.**

Formulation (and solution) non-stationary heat and mass transfer problems considered for the following cases thermal characteristics and diffusion mass transfer coefficient:

I) all thermal characteristics and diffusion mass transfer coefficient is constant in all sucrose solution areas.

In this case, the calculation of the diffusion coefficient, which depends on the sucrose concentration content in the cell was calculated on the basis of sucrose sustainable value content in massecuite at a current relative time τ/τ_c.

II) All thermal characteristics and diffusion mass transfer coefficient is variable in all sucrose solution regions.

Because of the complexity of the problem, the second case (II) considered three different options of variable thermal characteristics and diffusion mass transfer coefficient:

II, a) at every calculating time step all variable thermal characteristics (density ρ_i, (i=1,...,7), the thermal conductivity λ_i, (i=1,...,7), and the heat capacity c_i, (i=1...,7)) in all regions and diffusion mass transfer coefficient D_i, (i=1,3,4,6), in sucrose solution areas depend only on the current temperature of the corresponding cell. All other changes are dependent on ρ_i, (i=1,...,7), λ_i, (i=1,...,7), c_i, (i=1,...,7) and D_i, (i=1,3,4,6) — were fixed on each respective region at this time relative τ/τ_c.

Note that in this case the diffusion mass transfer coefficient in each sucrose solution region depended on the fixed sucrose concentration content in massecuite at a given time relative τ/τ_c.

II, b) at every calculating time step variable thermal characteristics (density ρ_i, (i=1,...,7), the thermal conductivity λ_i, (i=1,...,7), and the heat capacity c_i, (i=1,...,7)) in all regions are dependent on the current temperature of the corresponding cell. All other changes are dependent on ρ_i, (i=1,...,7), λ_i, (i=1,...,7), and c_i, (i=1,...,7) — were fixed for each respective region at this relative time τ/τ_c.

At every calculating time step variable diffusion mass transfer coefficient D_i, (i=1,3,4,6), in sucrose solution areas dependent on the current temperature and the current sucrose content in each respective region.

II, c) at every calculating time step variable thermal characteristics (density ρ_i, (i=1,...,7), and the heat capacity c_i, (i=1,...,7)) in all regions are dependent on the current temperature of the corresponding cell. All other changes are dependent on ρ_i, (i=1,...,7), and c_i, (i=1,...,7) — were fixed on each respective region at this relative time τ/τ_c.

At every calculating time step variable thermal conductivity λ_i, (i=2,5,7), in the crystals and massecuite areas depended only on the current temperature and current solids content in the cell massecuite was fixed at a given time relative τ/τ_c.

At every calculating time step variable thermal conductivity λ_i, (i=1,3,4,6) in the sucrose solution areas depended on the current temperature and the current dry matter content in each respective sucrose solution area.

At every calculating time step variable diffusion mass transfer coefficient D_i, (i=1,3,4,6), in the sucrose solution areas depends on the current temperature and the current sucrose content in each respective area cell sucrose solution.

Note that the unsteady heat conduction problem for variants (II, a) and (II, b) without consideration of unsteady mass transfer problems completely identical with each other.

Production of non-stationary heat conduction problems for the constant thermal characteristics case (I) and variable thermal characteristics case (IIa), (IIb) and methods of solving such problems by numerical methods was discussed in detail in [12].

Production of non-stationary heat conduction problems for the variable thermal characteristics case (II, c) and methods of solving such problems by numerical methods will be similar to the method discussed in [12].

Along with solving unsteady heat conduction problems for all 7 regions were simultaneously solved the unsteady three separate diffusion mass transfer problem for 4 areas sucrose solution.

Exactly for them in this work and will consider setting unsteady diffusion mass transfer problems. To reduce further records only consider the case (II, c) of the variable thermal characteristics and mass transfer diffusion coefficient.

Thus, the first non-stationary diffusion mass transfer problem for one-dimensional sucrose solution area 1 (Fig. 1) needs to find a solution unsteady parabolic type differential equation (1) in the partial derivatives with mixed boundary conditions (2)–(3) and the initial condition (4):

$$\rho_1(t_1, P_1, \mathrm{DS}_1)\frac{\partial C_1}{\partial \tau} = \frac{\partial}{\partial x}\left(\rho_1(t_1, P_1, \mathrm{DS}_1)\cdot D_1(t_1, Sg_1)\frac{\partial C_1}{\partial x}\right), \tag{1}$$

$$\left.\frac{\partial C_1}{\partial x}\right|_{X=0} = 0, \tag{2}$$

$$C_1(l_1, \tau) = C_{sat}(t_{12}(\tau)), \tag{3}$$

$$C_1(x, 0) = C_{1,0}, \tag{4}$$

(where C — sucrose concentration in the sucrose solution area,%; t — temperature, °C; C_{sat} — sucrose saturation concentration at current temperatures t, %; $t_{12}(\tau)$ — the boundary temperature of the contact areas 1 and 2 at time τ, °C; ρ — density, kg/m³; D — sucrose solution diffusion coefficient m²/s, l_1 — length of region 1 (Fig. 1), m; P — purity of sucrose solution area, %; DS — dry substance content in the sucrose solution area, %; Sg — content amount of sucrose in sucrose solution area, %).

Next, the second unsteady diffusion mass transfer problem applies to both areas 3 and 4 sucrose solution (Fig. 1).

For it is necessary to find a simultaneously system solution for two non-stationary parabolic type differential equations (5) in partial derivatives with mixed boundary conditions (6)–(9) and the initial conditions (10):

$$\rho_i(t_i, P_i, \mathrm{DS}_i)\frac{\partial C_i}{\partial \tau} = \frac{\partial}{\partial x}\left(\rho_i(t_i, P_i, \mathrm{DS}_i)\cdot D_i(t, Sg_i)\frac{\partial C_i}{\partial x}\right), (i = \overline{3,4}), \tag{5}$$

$$C_3(l_1 + l_2, \tau) = C_{sat}(t_{23}(\tau)), \tag{6}$$

$$C_4(l_1 + l_2 + l_3 + l_4, \tau) = C_{sat}(t_{45}(\tau)), \tag{7}$$

$$-\rho_3(t_3, P_3, \mathrm{DS}_3)\cdot D_3(t_3, Sg_3)\left.\frac{\partial C_3}{\partial x}\right|_{x=l_1+l_2+l_3} = -\rho_4(t_4, P_4, \mathrm{DS}_4)\cdot D_4(t_4, Sg_4)\left.\frac{\partial C_4}{\partial x}\right|_{x=l_1+l_2+l_3}, \tag{8}$$

$$C_3\big|_{x=l_1+l_2+l_3} = C_4\big|_{x=l_1+l_2+l_3}, \tag{9}$$

$$C_i(x, 0) = C_{i,0}, (i = \overline{3,4}), \tag{10}$$

(where $t_{23}(\tau)$ — the temperature on the boundary of the contact areas 2 and 3 at time ,τ °C; $t_{45}(\tau)$ — the temperature on the boundary of the contact areas 4 and 5 at time ,τ °C; l_i — length field i, ($i = \overline{1,4}$), (Fig. 1), m).

Conditions (8)–(9) — the so-called "crosslinking"conditions.

For the third unsteady diffusion mass transfer problem for one-dimensional region 6 (Fig. 1) sucrose solution needs to find a solution unsteady parabolic type differential equation (11) in partial derivatives with mixed boundary conditions (12)–(13) and the initial condition (14):

$$\rho_6(t_6, P_6, \mathrm{DS}_6)\frac{\partial C_6}{\partial \tau} = \frac{\partial}{\partial x}\left(\rho_6(t_6, P_6, \mathrm{DS}_6)\cdot D_6(t_6, Sg_6)\frac{\partial C_6}{\partial x}\right), \tag{11}$$

$$C_6(l_1 + l_2 + l_3 + l_4 + l_5, \tau) = C_{sat}(t_{56}(\tau)), \tag{12}$$

$$\left.\frac{\partial C_6}{\partial x}\right|_{x=\sum_{k=1}^{6} l_k} = 0, \tag{13}$$

$$C_6(x,0) = C_{6,0}, \tag{14}$$

(where $t_{56}(\tau)$ — the temperature at the contact boundary areas 5 and 6 at time τ, °C; l_i — length field i, ($i = \overline{1,6}$), (Fig. 1)).

As in [12], the initial temperature of the system cells (Fig. 1) assumed equally to all areas simultaneously and equal $t_{i,0} = 75$°C, ($i = \overline{1,7}$).

The initial concentration for each area between the crystal sucrose solution (areas 1, 3, 4 and 6 in Fig. 1) calculated with a coefficient supersaturation $S = 1$. Thus, it shall be taken as in the saturation concentration state under already accepted the initial temperature and equal to $C_{i,0} = C_{i,0}(t_{i,0}) = 77,594\%$.

The temperature of the heating tube's inner wall assumed constant over the tube entire height and equal to 100 °C.

It was this temperature has been taken as a first region's left boundary condition (Fig. 2).

Boundary conditions (8)–(9) for the second unsteady diffusion mass transfer problem expressing the ideal mass transfer laws between the neighboring 3 and 4 regions of the system cells.

Boundary condition (2) for the first unsteady mass transfer problem derived from the physical sense, as in the first region (Fig. 1) is present wall heating tubes on the left, which is not leading mass.

Boundary conditions (12) for the third unsteady mass transfer problem derived from the assumption that the diffusion mass transfer between sucrose solution area 6 and massecuite region 7 is not happening, or so small that it can be neglected.

To solve the non-stationary heat conduction problem [16] along with three non-stationary diffusion mass transfer tasks (1)–(4), (5)–(10) and (11)–(14) using analytical methods is impossible.

Therefore, in this case, as the case [12], were used numerical methods using well-known controlling volume methods [17, 18].

Discretization in time was $\Delta\tau_c = 0,01$ s.

When conducting sampling the coordinate assumed irregular grid. For each separate area 1–6 step sampling was evenly. For massecuite region 7 (Fig. 1) step sample was not uniform.

Each region separately (Fig. 1) smashed on the corresponding control volumes number: $n_1 = n_3 = n_4 = n_6 = 10$, $n_2 = n_5 = 20$, $n_7 = 100$.

The cells values are accepted the following sizes: $a_{cr, 1} = 5,0 \cdot 10^{-4}$ m, $\delta_{lq, 1} = 4,29 \cdot 10^{-5}$ m, $a_{cr, 2} = 2,5 \cdot 10^{-4}$ m, $\delta_{lq, 2} = 3,73 \cdot 10^{-5}$ m, $a_{ms} = 4,83896 \cdot 10^{-2}$ m.

Based on the calculations, the end contact time of the cell system with the heating tubes wall for boiling relative time $\tau/\tau_c = 0,15$ is $\tau_{c,end} = 3,95$ sec, and with $\tau/\tau_c = 1,0$ is $\tau_{c,end} = 67,93$ sec.

Results and discussion

The calculations for the above-mentioned non-stationary heat conduction problems and three non-stationary diffusion mass transfer problems (1)–(4), (5)–(10) and (11)–(14) were conducted for all areas of system cells the following values relative sugar massecuite boiling time τ/τ_c = 0,15; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9; 1,0.

Because of limited volume in this paper are given only two cases relative boiling sugar massecuite time τ/τ_c : at the winding crystals time (τ/τ_c = 0,15) and complete the boiling sugar massecuite time (τ/τ_c = 1,0).

Also, due to the limited amount of paper we consider the temperature and concentration distribution only sucrose solution areas, that is, for areas 1, 3, 4 and 6 (Fig. 1).

Average temperatures at the heating tubes outlet will be considered in the 7 regions case simultaneously the whole system cells, as it was considered in [12].

Thus, in each case relative time boiling sugar massecuite results obtained numerical calculations were presented in the following three cases of temperature and concentrations distribution.

1) In the first case (denoted by T.1346.τ) is considered of the temperatures distribution average along the coordinate in the sucrose solutions regions (Fig. 1) depending on the entire system cells contact time with the heating tube inner surface.

2) In the second case (denoted by T.1-7.x) presented the final temperatures distribution along the coordinate x (x distance from the heating tube inner surface to its symmetry axis) in all one-dimensional areas (Fig. 1) the entire system cells that corresponds to the system cells output with heating tubes in its upper point.

3) In the third case (denoted by C.1346.τ) for each non-stationary diffusion mass transfer problem was considered of average along the coordinate concentration distribution in sucrose solutions areas (Fig. 1) depending on the entire system cells contact time with the heating tube inner surface.

So first graphics presented considered in three cases (T.1-7.x), (T.1346.τ) and (C.1346.τ) at sugar massecuite boiling relative time τ/τ_c = 0,15.

The temperature calculations distribution results in the sucrose solution region for the first case (T.1346.τ) at τ/τ_c = 0,15 is shown in Fig. 2, 3, 4 and 5.
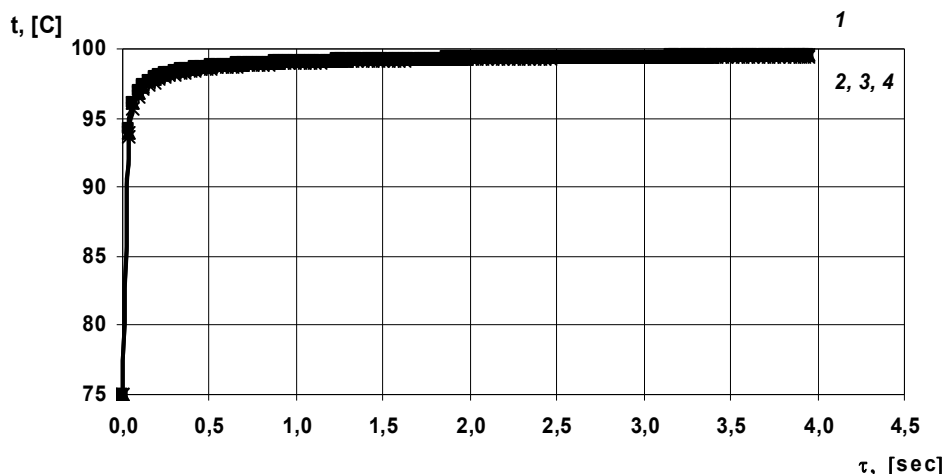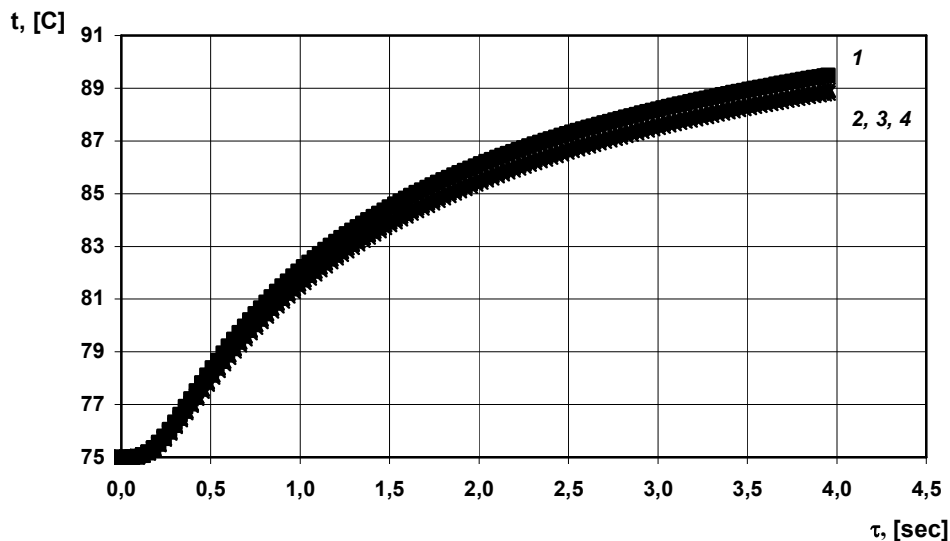
Fig. 2. The average values (along the area's coordinate) temperatures distribution in the sucrose solution region 1 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 0,15$:

1 - all thermal characteristics and diffusion mass transfer coefficient for region 1 is a constant (option I);
2 - thermal characteristics and diffusion mass transfer coefficient for region 1 is variables (variant II, a);
3 - thermal characteristics and diffusion mass transfer coefficient for region 1 is variables (variant II, b);
4 - thermal characteristics and diffusion mass transfer coefficient for region 1 is variables (variant II, c);
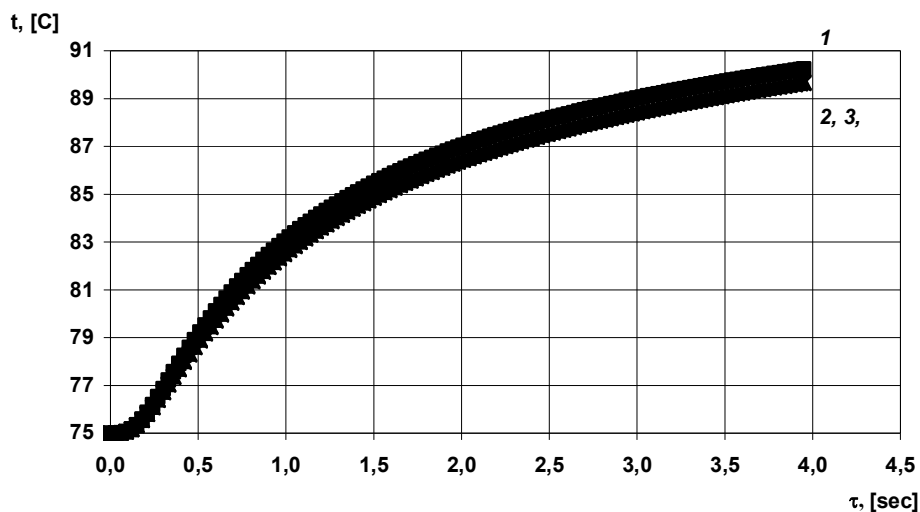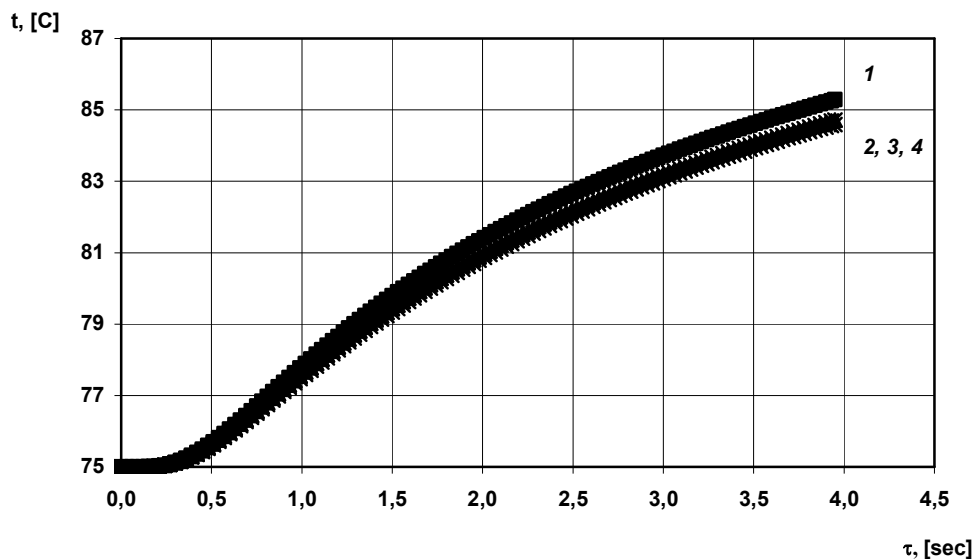

Fig. 3. The average values (along the area's coordinate) temperatures distribution in the sucrose solution region 3 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 0,15$.
* Designations the same as in Fig. 2.

Fig. 4. The average values (along the area's coordinate) temperatures distribution in the sucrose solution region 4 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time τ/τ$_c$ = 0,15.
* Designations the same as in Fig. 2.

Fig. 5. The average values (along the area's coordinate) temperatures distribution in the sucrose solution region 6 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time τ/τ$_c$ = 0,15.
* Designations the same as in Fig. 2.

The temperature distribution calculations results in all regions (Fig. 1) simultaneously the entire system cells to the second case (T.1-7.x) at sugar massecuite boiling relative time $\tau/\tau_c = 0{,}15$ shown in Fig. 6.
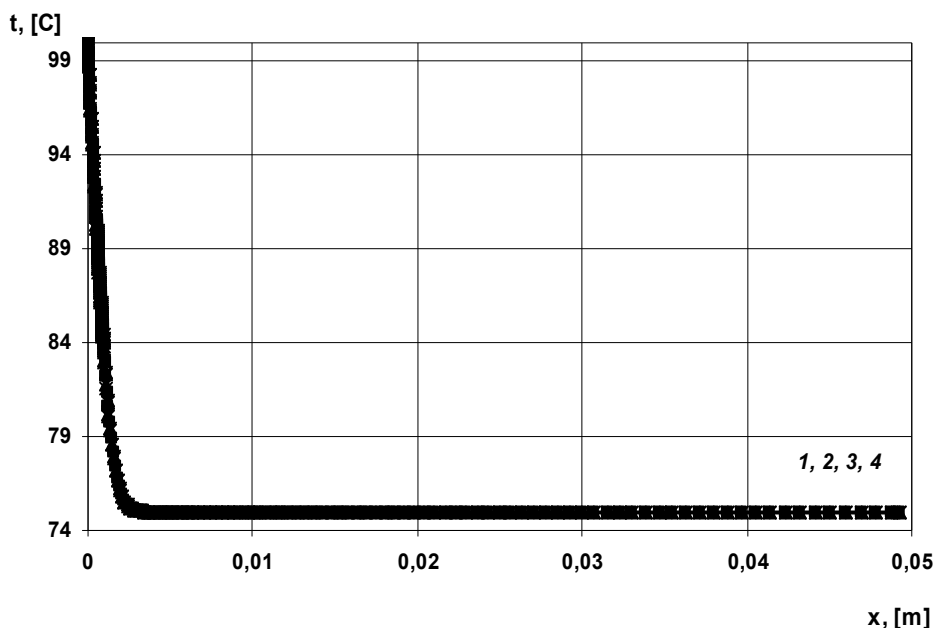

Fig. 6. The distribution temperatures in all system cells areas depending on the distance *x* from the heating tube inner surface to its symmetry axis at boiling massecuite relative time
$\tau/\tau_c = 0{,}15$.
* Designations the same as in Fig. 2.

The concentration distribution calculation results in the sucrose solutions areas for the third case (C.1346.τ) at sugar massecuite boiling relative time $\tau/\tau_c = 0{,}15$ shown in Fig. 7, 8, 9 and 10.
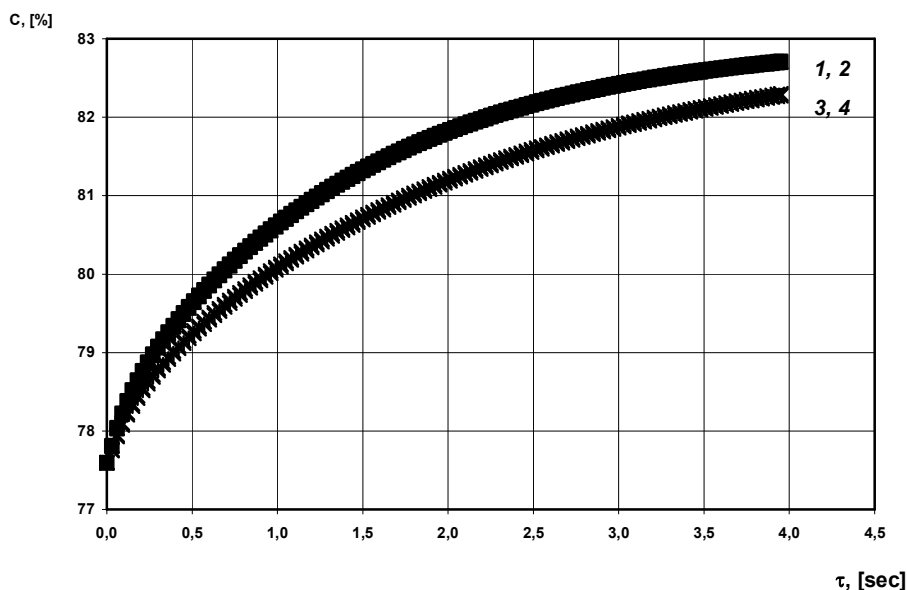
Fig. 7. The average values (along the area's coordinate) concentrations distribution in the sucrose solution region 1 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 0,15$.
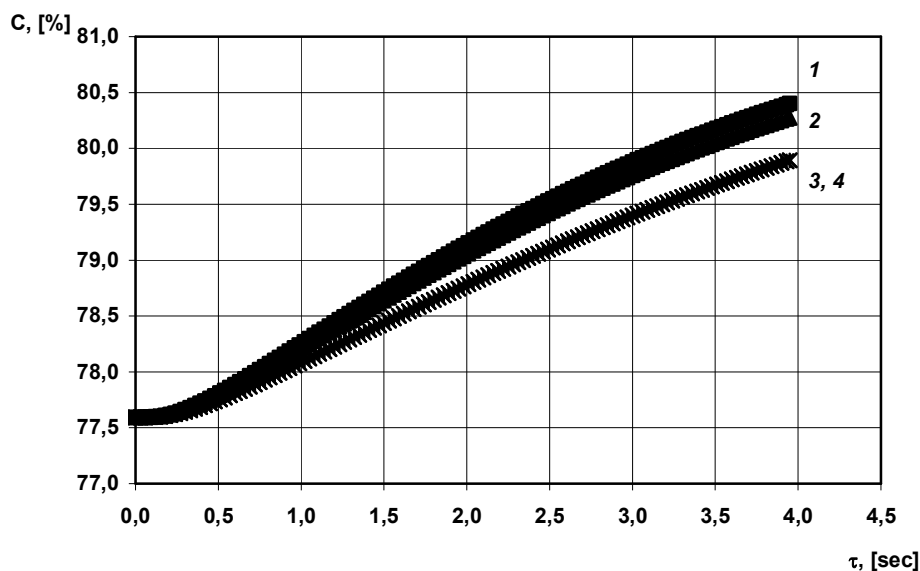*** Designations the same as in Fig. 2.**

Fig. 8. The average values (along the area's coordinate) concentrations distribution in the sucrose solution region 3 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 0,15$.
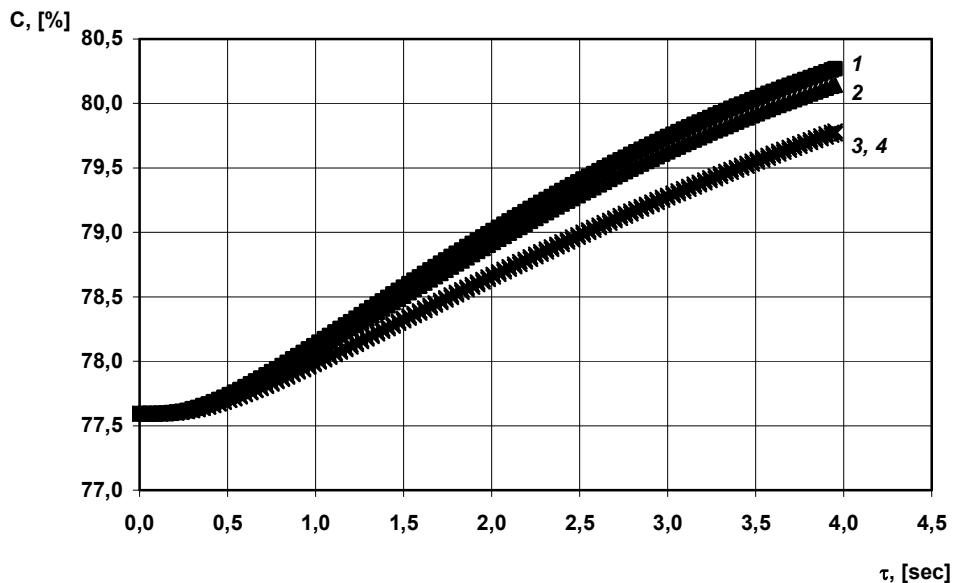*** Designations the same as in Fig. 2.**

Fig. 9. The average values (along the area's coordinate) concentrations distribution in the sucrose solution region 4 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 0,15$. Designations the same as in Fig. 2.
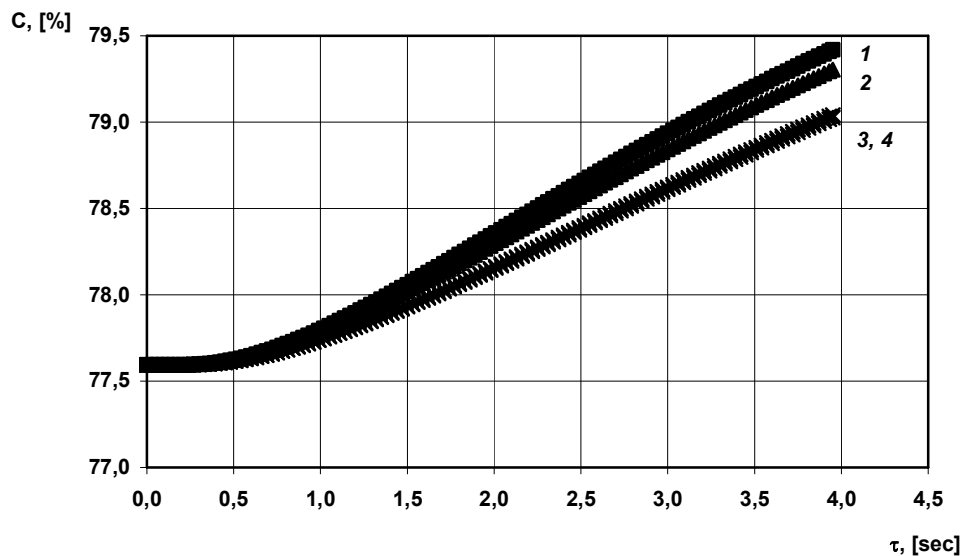

Fig. 10. The average values (along the area's coordinate) concentrations distribution in the sucrose solution region 6 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 0,15$. * Designations the same as in Fig. 2.

At the relative boiling sugar massecuite time $\tau/\tau_c = 0{,}15$ temperatures are equal: 99,547°C for the left larger crystal sucrose solution area with constant coefficients and 99,479°C for all variables coefficients; 94,799°C for larger sugar crystal with constant coefficients and 94,409°C for all variables coefficients; 90,234°C for the right larger crystal sucrose solution area with constant coefficients and 89,640°C for all variables coefficients; 89,485°C for the left smaller crystal sucrose solution area with constant coefficients and 88,820°C for all variables coefficients; 87,325°C for smaller sugar crystal with constant coefficients and 86,630°C for all variables coefficients; 85,285°C for the right smaller crystal sucrose solution area with constant coefficients and 84,590°C for all variables coefficients; 75,107°C for massecuite with constant coefficients and 75,098°C for all variable coefficients

At the same time concentrations distribution found in each sucrose solution region considered system cells. At the relative boiling sugar massecuite time $\tau/\tau_c = 0{,}15$ concentrations are equal: 82.710% for the left larger crystal sucrose solution area with constant coefficients and 82.274% for all variables coefficients; 80.400%for right larger crystal sucrose solution area with constant coefficients and 79.893% for all variables coefficients; 80.269% for the left smaller crystal sucrose solution area with constant coefficients and 79.765% for all variables coefficients; 79.418% for the right smaller crystal sucrose solution area with constant coefficients and 79.026% for all variable coefficients.

Finally, the graphics presented considered in three cases (T.1-7.x), (T.1346.τ) and (C.1346.τ) at sugar massecuite boiling relative time $\tau/\tau_c = 1{,}0$.

The temperature calculations distribution results in the sucrose solution region for the first case (T.1346.τ) at $\tau/\tau_c = 1{,}0$ is shown in Fig. 11, 12, 13, and 14.
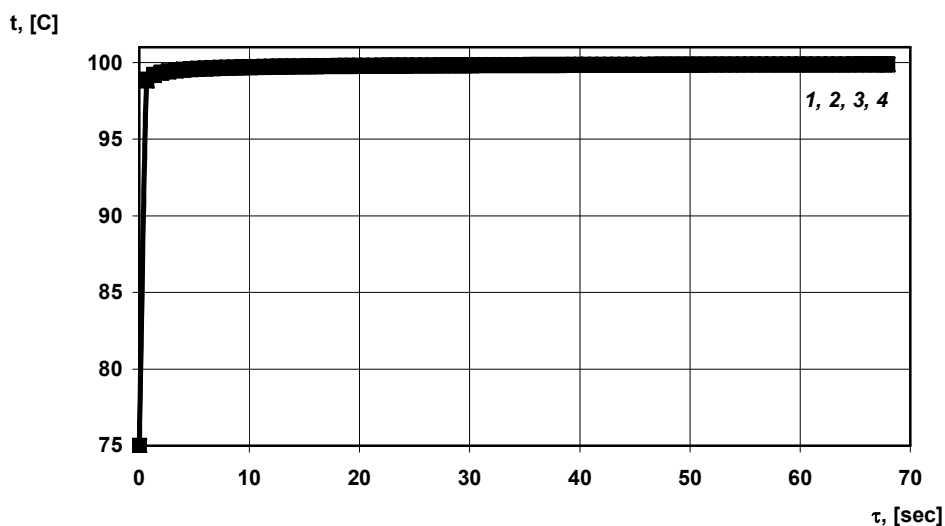
Fig. 11. The average values (along the area's coordinate) temperatures distribution in the sucrose solution region 1 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 1{,}0$.
* Designations the same as in Fig. 2.

Fig. 12. The average values (along the area's coordinate) temperatures distribution in the sucrose solution region 3 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 1,0$.
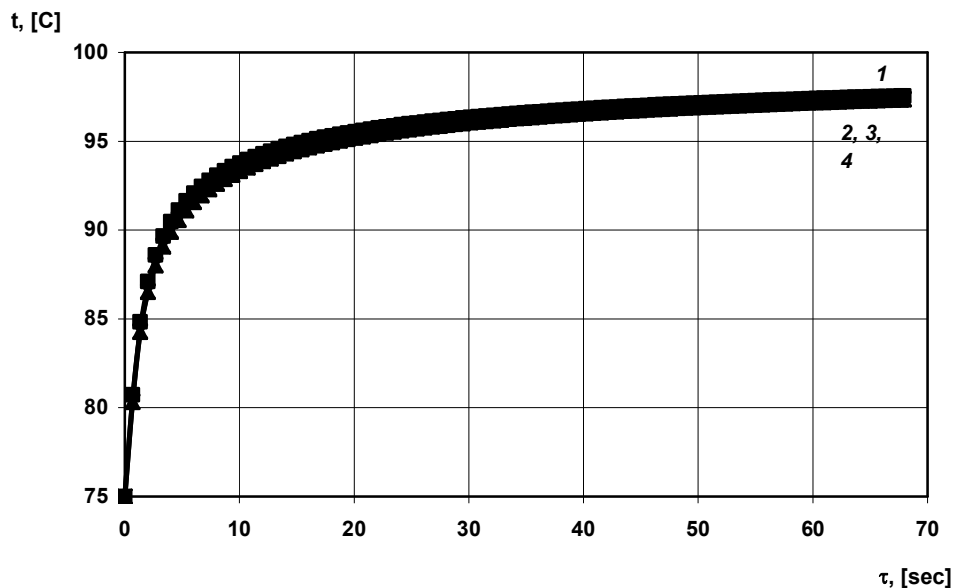*** Designations the same as in Fig. 2.**

Fig. 13. The average values (along the area's coordinate) temperatures distribution in the sucrose solution region 4 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 1,0$.
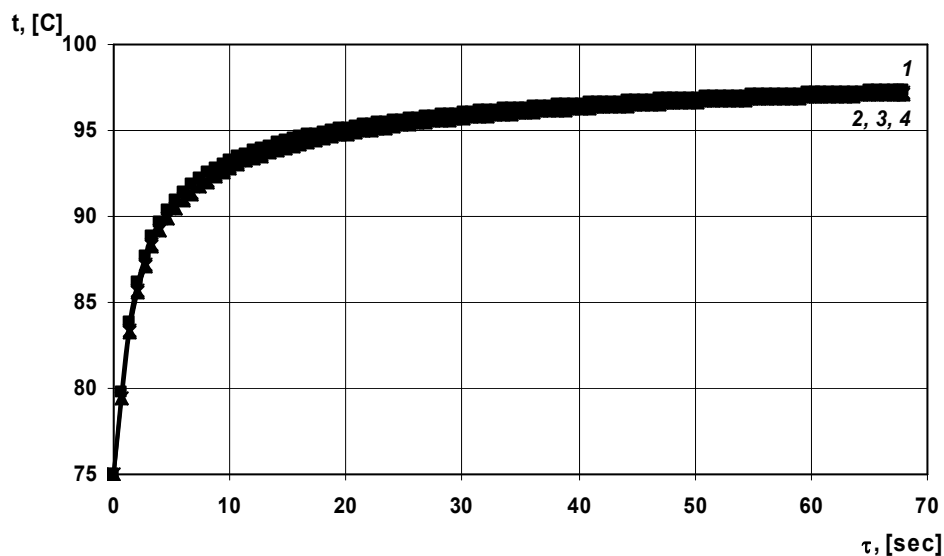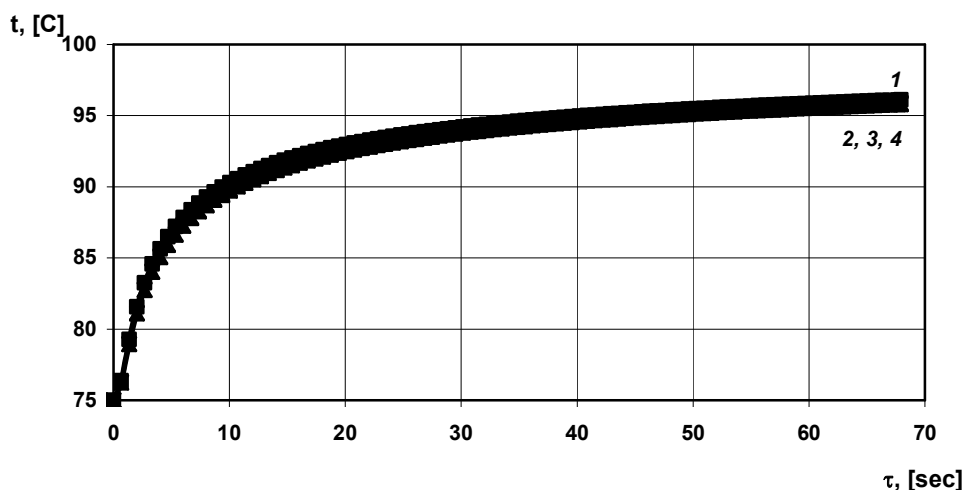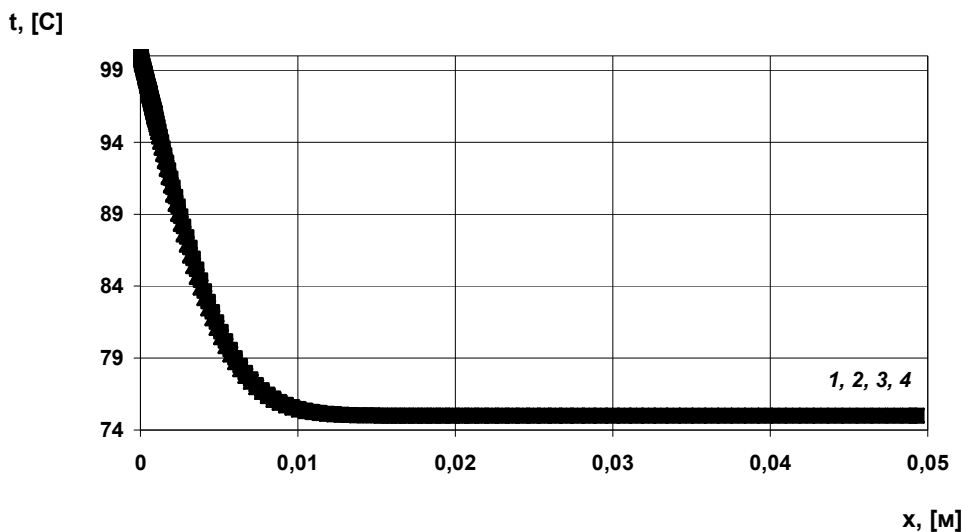*** Designations the same as in Fig. 2.**

Fig. 14. The average values (along the area's coordinate) temperatures distribution in the sucrose solution region 6 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 1,0$.
* Designations the same as in Fig. 2.

The temperature distribution calculations results in all regions (Fig. 1) simultaneously the entire system cells to the second case (T.1-7.x) at sugar massecuite boiling relative time $\tau/\tau_c = 1,0$ shown in Fig. 15.

Fig. 15. The distribution temperatures in all system cells areas depending on the distance x from the heating tube inner surface to its symmetry axis at boiling massecuite relative time $\tau/\tau_c = 1,0$.
* Designations the same as in Fig. 2.

The concentration distribution calculation results in the sucrose solutions areas for the third case (C.1346.τ) at sugar massecuite boiling relative time $\tau/\tau_c = 1,0$ shown in Fig. 16, 17, 18, and 19.

Fig. 16. The average values (along the area's coordinate) concentrations distribution in the sucrose solution region 1 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 1,0$.
* Designations the same as in Fig. 2.

Fig. 17. The average values (along the area's coordinate) concentrations distribution in the sucrose solution region 3 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 1,0$.
* Designations the same as in Fig. 2.

Fig. 18. The average values (along the area's coordinate) concentrations distribution in the sucrose solution region 4 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 1,0$.
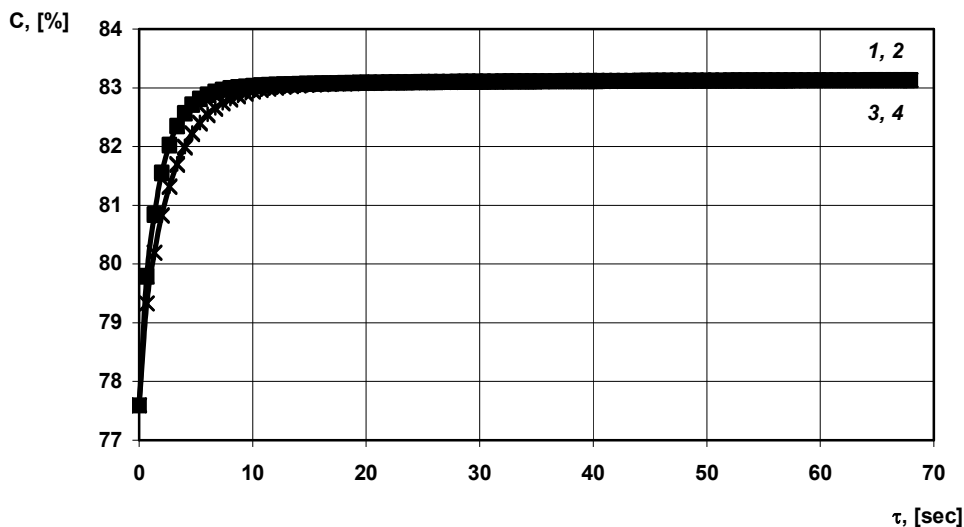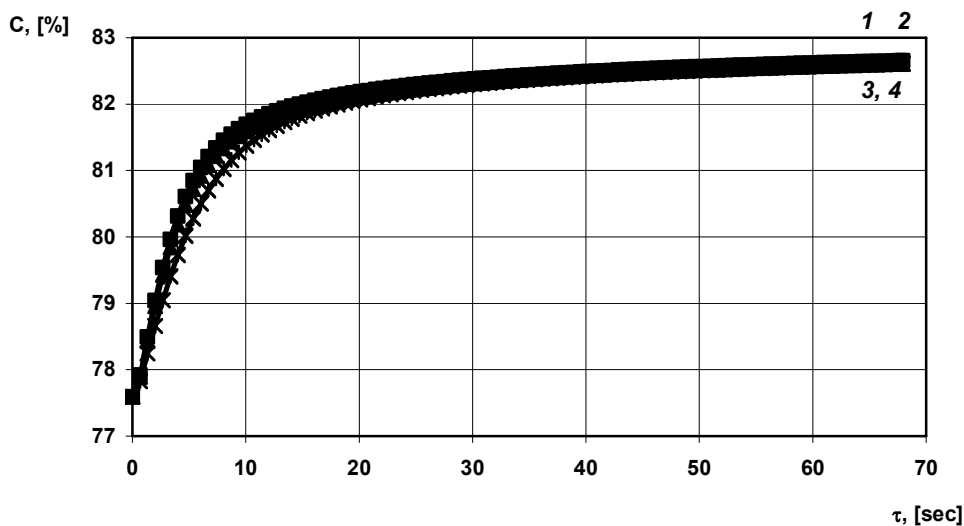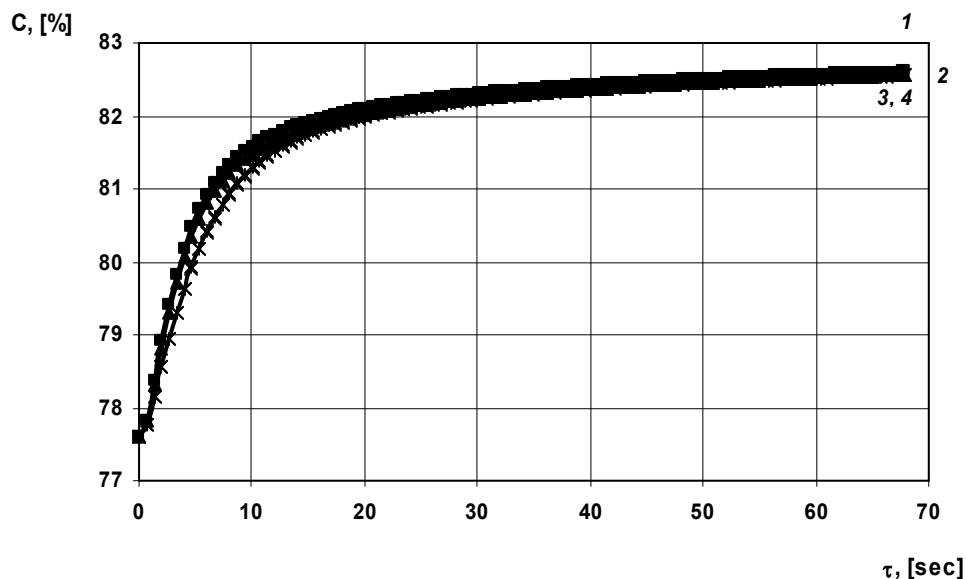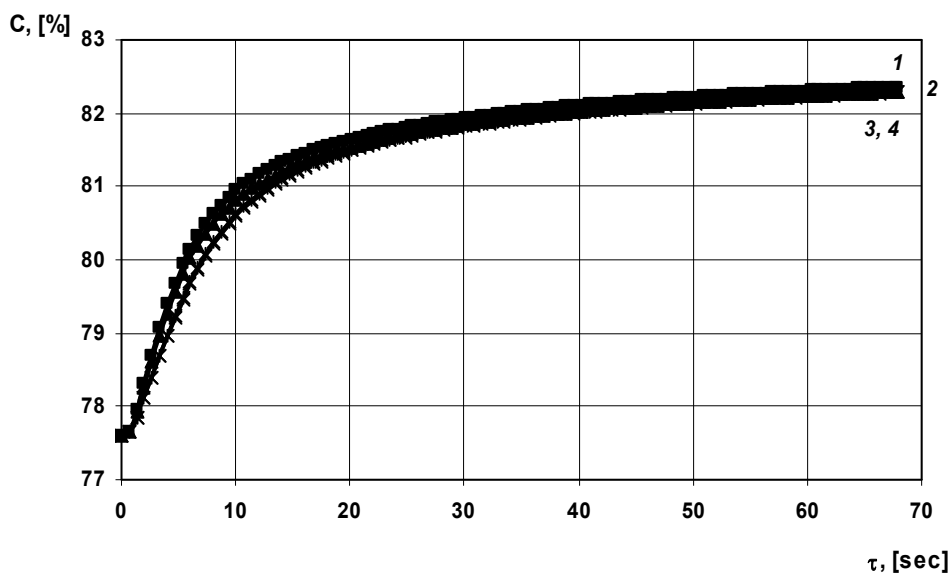*** Designations the same as in Fig. 2.**

Fig. 19. The average values (along the area's coordinate) concentrations distribution in the sucrose solution region 6 (Fig. 1), depending on the system cells contact time τ with the heating tubes inner surface at massecuite boiling relative time $\tau/\tau_c = 1,0$.
* Designations the same as in Fig. 2.

As shown in the temperature distribution graphs (Fig. 2–Fig. 6), (Fig. 11–Fig. 15) and the concentrations distribution graphs (Fig. 7–Fig. 10), (Fig. 16–Fig. 19), the calculations with constant thermophysical coefficients and mass transfer diffusion coefficient by the option (I) different from the calculations with variable thermophysical characteristics by the options (II, a), (II, b) and (II, c) cases.

Further, the calculations with variable thermophysical characteristics by the option (II, a) in the temperature distribution case (Fig. 2–Fig. 6 and Fig. 11–Fig. 15) is almost the same results with variable thermophysical characteristics by the options (II, b) and (II, c).

But in the concentrations distribution case (Fig. 7–Fig. 10 and Fig. 16–Fig. 19) the calculations with variable thermal characteristics by the option (II, a) differ from results obtained with variable thermophysical characteristics by the options (II, b) and (II, c).

And for almost all of the temperature distribution calculations with variable thermophysical characteristics (Fig. 2–Fig. 6), (Fig. 11–Fig. 15) and concentrations (Fig. 7–Fig. 10), (Fig. 16–Fig. 19) received the calculations results by the option (II, b) nearly coincide with the calculations results by the option (II, c).

It is clear that during the current thermal conductivity values calculation for each sucrose solution area taking into account the variable sucrose content for computing (i.e., option II, c) more consistent with the real physical mass sucrose crystallization process compared with the option, when considered fixed sugar sucrose content in massecuite for relative massecuite boiling time τ/τ_c (version II b). Note that in both variants (II, b and II, c) considered a variable diffusion coefficient from the sucrose content variable in each sucrose solution cell. And the results show that these two variants (II, b and II, c) almost coincide with each other. At the same time, research option (II, b) much easier to create an algorithm calculations program and reduces the computation time.

Thus, according to the author in further conducting research to create a mathematical model is to choose the formulation and solution of non-stationary heat conduction problems and mass transfer problems with variable thermophysical characteristics for variant (II b), which correspond the most real physical mass sucrose crystallization process of these options (I, II, a and II, b), although it will concede option calculations (II, c).

Conclusions

This paper was received temperature distribution results in the whole system cells that represented the seven one-dimensional regions (Fig. 1), and concentration distribution for sucrose solution areas of the same system cells. The results obtained from the simultaneous solution of unsteady heat conduction problems and three non-stationary diffusion mass transfer problems by numerical methods.

Calculations were made for relative boiling sugar massecuite time $\tau/\tau_c =$ 0.15; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 1.0.

This paper presents the results only for two cases relative boiling time: $\tau/\tau_c = 0,15$ and $\tau/\tau_c = 1,0$.

For each τ/τ_c of these options in this paper considered four different options for computing: with constant (option I) and three variants (II, a, II, b and II, c) with variable thermophysical characteristics and the mass transfer diffusion coefficient.

The results obtained of temperature and concentration distributions needed in the future for getting value amounts transferred sucrose between sucrose solution cells for one and second crystal sugar, and the number of crystal sugar will crystallize (or dissolve) in the each sugar crystal cell of the considered system cells.

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Machining meat deformation

Victor Goots, Olga Koval

National University of Food Technologies, Kyiv, Ukraine

Corresponding author:

Victor Goots
E-mail:
goots@ukr.net

Abstract

Introduction. Salting meat is an important stage in manufacturing technology of meat products. The uniform distribution accelerating process in thickness salt solution product is reached by using multi-needle extrusion and massaging meat with cyclic deformation.

Materials and methods. For the experimental studies we used pork with NOR's signs. Presents the results of research in salting meat by analyzing changes in its structure under external pathogen - the driving force of a mechanical nature, using simulation theory and computer symbolic mathematic.

Result and discussion. Mechanical meat processing affects the product quality. In the meat technology, promising is the use of mechanical meat pieces deformation which can be either with constant load or with changing load like impact. To optimize the massaging meat process it is important to know the mechanism of deformation, which depends on the equipment, on its operation modes and can vary widely. Here were mentioned the mathematical models which made it possible to calculate the energy performance of massaging process and to optimize it.

Thanks the results of experimental studies which we have got by the method of penetration needles we set the change degree in the meat consistency and obtained its curve of deformation by impact. In its analysis has been estimated that deformation process is short and lasts about $3.5 \cdot 10^{-3}$ seconds. This made it possible to optimize the manufacturing process of salting meat by using the special technological equipment in which mechanical effects of product impacting was implemented.

Conclusionи. Mathematical models were gotten that enable to optimize a process of meat salting and determination of massage modes method has been offered. Energy characteristics of deformation process lay in foundation of this method.

Introduction

This paper has been presented the mechanical processing of meat during salting. Improving the technology process, production of quality products, saving energy and raw materials are possible upon condition of comprehensive study of the phenomena occurring in the production of meat products and convenience food.

Salting meat is an important stage in manufacturing technology of meat products. It is a combination of different processes: the formations of primary areas which accumulate salting substances; equal distribution them in the volume of convenience food by filtration and diffusion through pores and capillaries through osmotic membranes and membrane fibres; passing the mass transfer processes in equalization concentrations to salt solutions.

In consequence of interaction proteins with salted substances the physical and chemical proteins properties of changes which leads to the proteins swelling, increasing of water-binding capacity, changes in the structural and mechanical properties, consistency, plasticity of meat, formation of adherent layer of water and salt-soluble proteins. The microstructure of the product changes as a result of developing enzymatic process and the presence of salted substances and physical impact assists it. There is the formation of taste and ham's aroma through the enzymatic or microbial processes and changes in composition of the microflora.

By wet pickling the products quality depends mainly on the concentration and composition salt solutions and on their distribution`s uniform in raw materials. It has been proved that the process length and the salting meat methods affect the quality of finished products, economic efficiency and, consequently, the cost of finished products, so it is reasonable to optimization and improvement. Taking into consideration the diversity of raw meat for determining the optimal salting meat mode it is necessary to have the experimental results. Before we begin the experiment, it is advisable to perform a theoretical justification of meat's machining processes and develop the mathematical model. Mathematical model will provide an opportunity to pick up technological equipment, to intensify its work, to optimize the machining process by massaging (softening and saturation solution) different type and structure of the meat.

In the meat promising technology we use the mechanical material deformation by the impact. To optimize the mechanical meat massaging by this way it is important to know the mechanism of its saturation solution. A meat is regarded as a rheological system with a different set of viscous and elastic properties which are malformed by driving force.

Materials and methods

We have used signs NOR pork with weight 0.7 kg. The piece we bag out with brine and later it was subjected to machining to massager drum. The drum's rotation speed massager - 24 turn / min., the load index - 0.6. Massaging cycle was performed so: 20 minutes for drum working and 10 minutes for rest. Meat was weighed after machining. Then gravitational penetrometer measured the degree of penetrations. This index gives an indication of the consistency or using technological term – softness of meat. The results of the study – dependence of stiffness «R» of meat to the duration «t» of massaging is presented graphically.

Result and discussion

Salted meat or ham's products are the most popular among population. Their technology is based on the complex processes in which the raw materials are impacted by the external factors of various natures. The salting meat process can be seen as a filtration and diffusive saturation of the salted brine piece. Salt gets into the meat slowly, that is why we need to speed up this process periodically deforming the piece by using different physical methods. One of the intensification methods is the mechanical impact and also the periodic deformation - massaging or tenderization. It is possible to optimize these processes by dosing the mechanical impact or by short compression or stretching. The modern structures of cylindrical masseurs in this regard are not so effective because they operate with large intervals between deformations and stand [2].

The uniform distribution accelerating process in thickness salt solution product is reached by using multi-needle extrusion and massaging meat with cyclic deformation. As a result, pores and capillaries periodically compress and expand, the fluid pressure changes in them thereby intensifies the filtering process. During the deformation also changes the internal structure of meat [3].

To optimize the massaging process is possible only with using of short intermittent mechanical meat compression. Promising is the impact using which can be performed by variety of ways. The most common is falling meat from a height in drums that rotates slowly or maybe short compression or stretching in other equipment.

The following basic modes of movement meat piece are possible in the drum-type massagers in the case of slow drum rotation:

- the piece moving by sliding on the inner surface (feed well);
- the partial it`s lifting from the following rolling or crawling to the drum bottom;
- the piece`s rise and fall to the drum`s bottom solution.

Depending on the technology regulations requirements in a case of machining various raw meat in drums is possible to implement different types of deformation. The deformation intensity depends on the product`s trajectory. It is associated with the turnover rate, availability, type and the activators shape (shelves) and also with the drum`s size. The objective characteristic that determines the efficiency of handling raw meat in the case of massaging is changing the product structure. It is directly related to the energy quantity that is absorbed by piece. A common way to determine the structural and mechanical product properties is a method of gravitational penetration [4].

Depending on the technology needs is necessary to use different massaging modes. Soft massaging causes small deformation in the product or changes in the structure. They appear like swellings in the muscle fibres, like increasing the number of cross-slot violations, like destructions of membrane structures, like loosening and swelling mayo-fibrils proteins or like initiating links between actin and myosin. Restructuring, softness and water-binding power of meat increase slowly at this stage of processing.

With increasing duration of mechanical processing or with conversion to the tighter regime by increasing deformation efforts, muscle fibres swell throughout the volume of the piece which causes formation of the protein mass that fills the inner pore space. It increases with subsequent disruption of the structure in fibres muscle. In this case, one part of the protein's mass crops up the surface of a piece. After such processing water-retaining capacity of meat increases but stiffness decreases. This stage is classified as a moderate massaging.

Moderate massaging borders can hold more moisture with the stage of optimal massaging, when there are areas of significant destruction of myofibrils, and takes place increasing in the number of free molecular bonds.

The disintegration of proto-fibril substance of mayo-fibrils throughout the piece ensues during the further processing and conversion to the hard mode, which leads to the release to the surface and then transition to solution. This way leads to the reduction of water-retaining meat capacity, to the organoleptic properties deterioration and also reduces the finished products output. The operating mode is classified as excessive massaging. The needle of penetrometer immerses into the product fully at determining meat texture.

As a rule, in existing massager's designs has been used one of mentioned above processing modes. It can be regulated by increasing or decreasing the processing time in a meat massager or sometimes by changing the speed of drum rotation.

The main reason of insufficient or excessive massaging meat is the lack of methods for determining the energy of mechanical product impact with different structural and mechanical properties. This makes it impossible to identify the optimal deformation mode and to regulate the massaging effectiveness.

Machining deformation meat has its special aspects in modern designs of massagers meat arises deformation from P (t) - driving force that is variable in time and stretches or compresses meat.

The nature of the changes in the structure of meat can be investigated by determining rheological indexes – characteristics of elastic «c» and viscous properties «μ» of visco-elastic body which is meat. Indexes vary under different deformation conditions, especially under driving force τ (t), and characterize the product's ability to resist external influence and energy that was spent on deformation.

To determine the structural and mechanical properties of meat it is possible to represent it as a rheological body with visco-elastic characteristics. Mechanical body model has the appearance of gradually connected viscous element «μ» with an elastic «c». Under the influence of the variable in time voltage τ (t), meat deforms by the law, which can be described by the differential equation:

$$\tau(t) + \frac{\mu}{c}\dot{\tau}(t) = \mu\dot{x}(t) , \qquad (1)$$

x - relative deformation (dimensionless number),

$\dot{x}(t) = \dfrac{dx}{dt}$ – the deformation rate (1/s),

$\dot{\tau}(t) = \dfrac{d\tau}{dt}$ – the voltage changes rate (Pa/s).

If massaging during some time (cycle) occurs periodically vacuum or pressure, then there is intermittent compression or stretching of meat and in this case τ (t) = const. Taking into account this, the initial conditions t = 0 => x (0) = x_0, and duration «t» of action of tension, solution of differential equation (1) will be:

$$x(t) = \frac{1}{\mu}\tau t + x_0 \qquad (2)$$

After completing the differentiation of equation (2), we will obtain the rate of deformation:

$$\frac{dx}{dt} = V = \frac{\tau}{\mu} \qquad (3)$$

The energy (work) «A» of deformation will be:

$$A = A_1 + A_2 = \frac{\tau^2 t}{\mu} + \tau x_0 \ ,$$
(4)

A1 – energy needed for elastic deformation;
A2 – energy required for viscous deformation.
Energy consumption N during deformation time «t» will be:

$$N = \frac{A}{t} = \frac{\tau^2}{\mu} + \frac{\tau x_0}{t_1}$$
(5)

When the duration «t» of piece of meat is known and meat is under constant stress τ, from equations (5) and (6) we can determine the parameters of massaging energy per cycle. If we multiply it on the number of treatment cycles then it is possible to calculate the general (total) energy's efficiency and also massaging efficiency, softening of raw materials and saturation of its brine [5].

In figure 2 has been shown a massager of low productivity, which operates in a mode of constant voltage action τ = const and variable in time τ = Asin (wt) [6].

In modern designs of massagers meat processing occurs under $\tau \neq$ const: for example when it falls from a height. In this case, the effectiveness of massaging - consistency (stiffness) of the product can be determined by examining its kinetic deformation curve under pulsed load (impact) [7]. It looks like (Figure 3)
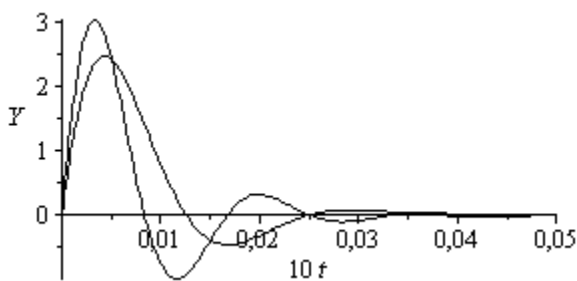
Figure 3. The kinetic deformation meat curve by impact

We can describe the deformation curve by this equation:

$$Y(t) = Pe^{kt} \sin(wt) \ ,$$
(6)

Y(t) - deformation; P - index of the curve's amplitude; k - characteristic, which determines the decline curve rate; w - frequency of oscillations. The indexes «w; P; k» make it possible to find out the fracture of patterns meat - its degree of softening, depending on a period massaging.

The curve deformation study (elastic deformation wave), that occurs in meat during rapid deformation, such as impact, shows that the deformation process lasts about $3.5 \cdot 10^{-3}$ seconds [8]. It is short. This makes it possible to conclude that during the period of impact the rapid pores compression and capillaries comes up with subsequent relaxation, during which we have the filtering saturation of piece of meat with brine. The liquid is sucked and

pushed through pores and capillaries. During the distribution it divides by diffusion due to concentration differences.

Most of modern designs of drum-type massagers have inside shelves, edges. In practice, to determine the rotation speed and the critical angle with increasing of which the piece of meat doesn't separate from the sidewall without shell is possible by using this equation:

$$n = \frac{30}{\pi} \sqrt{\frac{g \sin \alpha}{R}} \approx 30 \sqrt{\frac{\sin \alpha}{R}}, \qquad (7)$$

n - rotational drum speed (turn / min); R- drum's radius (m); α - angle that separates meat from the drum sidewall.

Modern designs of massagers have the radial shelves inside the drum. Determining the rotation drum speed in a case of tearing off a meat piece from the shelf and dropping it to the drum bottom from the maximum altitude requires special calculations.

Differential equations of meat motion along the shelf we will write down:

$$m \frac{d^2 s(t)}{dt^2} + F_{on} = mg \sin(\omega t), \qquad (7)$$

m – weight of the piece; s (t) - the shelf length; t - the duration of the meat piece movement with beginning from the horizontal position of the shelf; w- frequency of the massager drum turnover; Fon - resistance to piece movement.

Assume Fon = fmg, where «f» - index of resistance (average number considering friction, centrifugal force, angle of shelf slope). Suggested approach to determine Fon makes it possible don't take into account mass of the piece which greatly simplifies the calculations at making minor mistakes.

Solution of equation (7) in a case of initial conditions t = 0 => s (0) = 0; V (0) = 0:

$$s(t) = g \left(\frac{t}{w} - \frac{\sin(wt)}{w^2} - \frac{ft^2}{2} \right). \qquad (8)$$

Substituting values in equation g = 9.8 m / s2; f = 0,12; w = 0,4 turn / s; m = 0,7 kg, construct a graph of s (t).
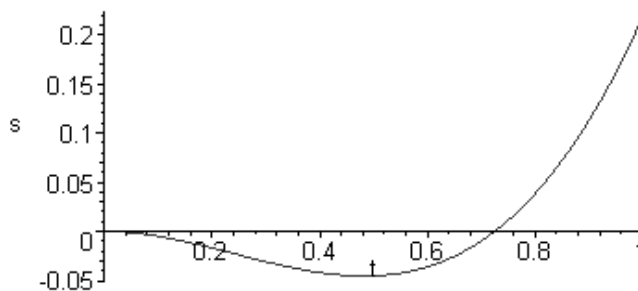
X-Y plot shown in Fig. 4.

Figure 4. Functional dependence s (t)

The dependence analysis s (t) shows that the piece movement along the drum shelf which rotates at a speed 24 turn / min begins in 0.75 seconds after the shelf will take horizontal position. It hits the shelf on the drum bottom at the point 0 (Figure 5). Initially, on the arc segment 0 - 1 the piece presses against the drum shell by the gravity and centrifugal force, on the segment arc 1 - 2 rests on the shelf, at point 2 begins to shift to the drum centre. For a short shelf it almost immediately breaks away and falls down, for longer - slips on it and then shifts to the distance «s», breaks and falls down of the drum. During this period of time drum will turn on the arc with length L. For the shelf with length 100 mm it will happen in 0.92 seconds (Figure 4).

From equation (8) we can found, knowing the length of the shelf and the drum rotation speed, the movement piece duration along the shelf and, accordingly, the arc with length L. In figure 5 it is shown various drum with shelves that are of different lengths which are divided into areas 0 - 1; 1 - 2; 2 - 3; 3 -4; 4 - 0.
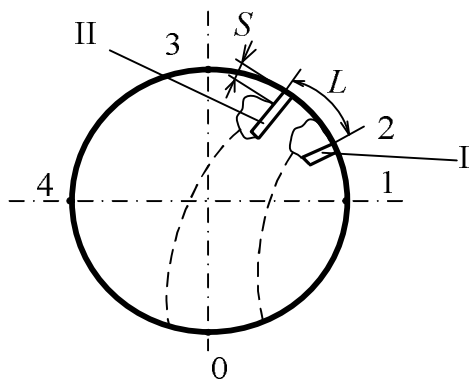

Fig. 5. Positions of the meat pieces in a drum with shelves that varies in length

The meat piece is on the short shelf 1; the meat piece is on the long shelf 2 with shift «s» before the shelf fall.

Basing on the results of theoretical developments in conditions of production we made an experimental research. We have used signs NOR pork with weight 0.7 kg. The piece we bag out with brine and later it was subjected to machining to massager drum with a diameter of 1 meter for 2 hours. The drum's rotation speed massager - 24 turn / min., the load index - 0.6. Massaging cycle was performed so: 20 minutes for drum working and 10 minutes for rest. Meat was weighed after machining. Its weight increased by 18%.

Then gravitational penetrometer measured the degree of penetrations. This index gives an indication of the consistency or using technological term – softness of meat. The results of the study – dependence of stiffness «R» of meat to the duration «t» of massaging is presented graphically in Figure 6.

Analysis of the curve R = f (t) gives opportunity to make a conclusion that during 120 minutes of staying meat in massager with a diameter of drum 1 m, the value «P» of meat decreased by 28%. For various periods of time it can be defined by using the equation of approximate function.

$$P = e^{-0,002t}. \qquad (9)$$

Visual examination under a microscope showed that the mechanical processing of meat is accompanied by profound changes in its rheological properties and affected the microstructure. In muscle's fibres increased the number of cross-chink violations, the places of punctures were subtle, the muscle fibres swelled. At the same time there was a partial mechanical damage of muscle fibres, which led to the intensification of the majority of mass transfer processes that occurred during the process of pickling meat. As a result of biochemical processes, of joint action of tissue enzymes and microorganisms and selective lactic acid bacteria in the presence of salt so-called flavour and aroma of ham appeared in the finished product.
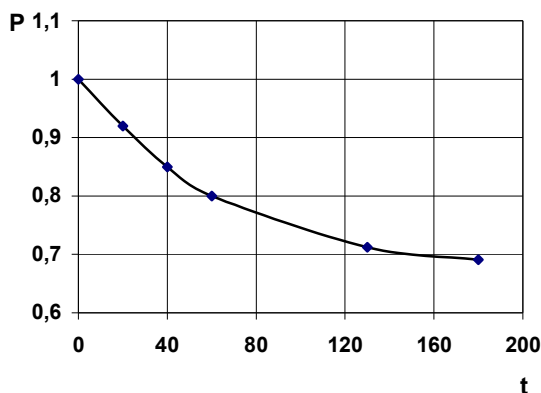
Fig. 6. Dependence of the stiffness «R» of meat to the duration «t» of massaging

Conclusion

Mechanical treatment of meat by salting is a complex manufacturing process. During this process the structure of meat changes, decreases its hardness, accelerates filters and diffusion processes, which leads to the penetration and uniform distribution of salt in the product and acceleration of biochemical transformations. Mechanical meat processing affects the product quality.

In the meat technology, promising is the use of mechanical meat pieces deformation which can be either with constant load or with changing load like impact. To optimize the massaging meat process it is important to know the mechanism of deformation, which depends on the equipment, on its operation modes and can vary widely. Here were mentioned the mathematical models which made it possible to calculate the energy performance of massaging process and to optimize it.

Thanks the results of experimental studies which we have got by the method of penetration needles we set the change degree in the meat consistency and obtained its curve of deformation by impact. In its analysis has been estimated that deformation process is short and lasts about $3.5 \cdot 10^{-3}$ seconds. This made it possible to optimize the manufacturing process of salting meat by using the special technological equipment in which mechanical effects of product impacting was implemented.

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Hydro cyclone unit design features influence in the clarification process of beer wort

Lesya Martsinkevich[1], Maksim Shpak[1], Sergiy Udodov[1], Dmytro Ryndyuk [1,2]

1 - National university of food technologies, Kyiv, Ukraine
2 - National Technical University of Ukraine "Kyiv Polytechnic Institute", Kyiv, Ukraine

Abstract

Introduction. The deposition process of suspended solids in the working volume of hydrocyclone apparatus (whirlpool) was researched to improve the quality of lighting beer wort and reduce the time of passage process.

Materials and methods. Investigation of the process of clarification of beer wort was made by the software package based on the finite volume method, designed for three-dimensional simulation of flows in technical and natural objects, as well as the visualization of these flows by computer graphics. Research was conducted on these models of hydrocyclone apparatus: with the classical form of the bottom (flat), the conical insert, the two cylindrical inserts and applying the wort to each of the inserts, with conical bottom and radial guide inserts.

Results and discussion. Analyzing the data it can be argued that the wort in the machine acquires the rotational movement, which is provided by tangentially mounted nozzle of product feed. The resulting vortex flow helps the particles to deposit in a form of a protein precipitation plate.

As already noted, an important role in the clarification process has feed speed of the wort into the machine, which is the speed at the input nozzle's output. If the speed exceeds 3.5 m/s, the product is subjected to considerable shearing stresses. As a result, low-sized particles are created and they aren't deposit in the hydrocyclone apparatus. It is clear from the foregoing that correctly chosen initial wort feed rate into the apparatus (with further reduce it during lightening) greatly affects the efficiency of hydrocyclone apparatus. Also were researched shear stresses (τ), which appears in the wort during its supply. When the value of τ exceeds 50 Pa, the destruction of protein precipitate particles begins.

Conclusions. The results justifying the appropriateness submission of recommendations for implementation in production hydrocyclone apparatus with radial guides inserts. It will reduce the time of the process and improve the quality of beer wort.

Introduction

Before fermentation of hot hopped wort a significant amount of suspended particles formed during boiling must be removed, because they negatively affect the further process of making beer, namely reducing the rate of fermentation, making filtration of beer complicated and worsen taste of the finished beverage.

Suspended substances of hot wort, called bruch, are predominantly coagulated proteins and hop bitter products. They are quite large, their size is 30 - 80 micrometers.

The amount of suspended substances after pumping hot wort is 6000 - 8000 mg per liter, and it must be reduced after the removal of substances for up to 100 mg per liter. However, the aim is the complete removal of suspended substances from the hot wort [1,2].

Insufficient removal of suspended substances due to a number of the technological parameters of the process and quality indicators of the product, namely, improper maintenance of the filtration of beer mash and adding hops, which doesn't contain or contain insufficient amount of tannins, the poor quality of malt and non-optimal composition of its grinding. But also imperfect equipment used to lighten significantly affects the quality of beer wort clarification.

Removal of suspended substances from hot wort is carried out today in the most of breweries primarily via hydrocyclone unit (whirlpool). Some of them make the wort clarification by a separator (centrifuge), but this method is not widely used because of its complication and high cost [3].

Materials and methods

Investigation of the process of clarification of beer wort was made by the software package based on the finite volume method, designed for three-dimensional simulation of flows in technical and natural objects, as well as the visualization of these flows by computer graphics.

The analytical model of the process of clarification of beer wort is based on the following equation:
- Navier-Stokes equation:

$$\frac{\partial V}{\partial t} + \nabla (V \otimes V) = -\frac{\nabla P}{\rho} + \frac{1}{\rho}(\mu + \mu_t)\left[\nabla V + (\nabla V)^T\right] + \left(1 - \frac{\rho_{hyd}}{\rho}\right)g \qquad (1)$$

- flow continuity equation:

$$\nabla V = 0, \qquad (2)$$

Where:
V - relative velocity vector, m/s;
t – time, s;
P - relative pressure, Pa;
ρ - density, kg / m^3;
μ, μ_t - respectively dynamic and turbulent viscosity, Pa·s ;
ρ_{hyd} - hydrostatic density, kg/m^3 ;
g - gravity vector m/s^2.

Also, using k-ε turbulence model of the first closing level to close the system is needed to get the formula for a coefficient of a turbulent viscosity μ_t. Currently in order to achieve this objective often used two-parameter model, called so because μ_t in this formula is determined by two parameters, which are solved using more differential equations in partial derivatives [2] :

$$\boldsymbol{\mu}_t = c_\mu \rho \frac{k^2}{\varepsilon} \tag{3}$$

In addition, the model includes equations for the turbulent energy k and the turbulent energy dissipation rate ε:

$$\frac{\partial(\rho k)}{\partial t} + \nabla(\rho V k) = \nabla\left[\left[\mu + \frac{\mu_t}{\sigma_k}\right]\nabla k\right] + \mu_t G - \rho\varepsilon , \tag{4}$$

$$\frac{\partial(\rho\varepsilon)}{\partial t} + \nabla(\rho V\varepsilon) = \nabla\left[\left[\mu + \frac{\mu_t}{\sigma_\varepsilon}\right]\nabla\varepsilon\right] + C_1\frac{\varepsilon}{k}\mu_t G - C_2\rho\frac{\varepsilon^2}{k} , \tag{5}$$

where G indicates such equation:

$$G = D_{ij}\frac{\partial V_i}{\partial x_j}, \tag{6}$$

$$D_{ij} = S_{ij} - \frac{2}{3}\left[\nabla \cdot V + \frac{\rho k}{\mu_t}\right]\delta_{ij} , \tag{7}$$

$$S_{ij} = \frac{\partial V_i}{\partial x_j} + \frac{\partial V_j}{\partial x_i} . \tag{8}$$

The values are [3]:

$$\sigma_k = 1;\ \sigma_\varepsilon = 1{,}3;\ \ C_\mu = 0.09;\ \ C_1 = 1{,}44;\ \ C_2 = 1{,}92.$$

Modeling of the movement of solid particles in the carrier phase is subject to the following equations:

$$\frac{dX_p}{dt} = V_p \tag{9}$$

$$\frac{dV_p}{dt} = \frac{\pi d^2}{8m}C_D\rho_g |V_r|V_r + g\left(1 - \frac{\rho_g}{\rho_p}\right), \tag{10}$$

where $V_r = V_g - V_p$ - velocity relative to the carrier phase.

It were excluded the effect of the associated mass, strength Basset, Sofmana and Magnus.

For the calculation of the resistance C_D formula was used:

$$C_D = \frac{21,12}{\mathrm{Re}} + 6{,}3\,\mathrm{Re}^{-0,5} + 0{,}25 \tag{11}$$

When heated particles assumed that the heat transfer within the particle is infinitely fast.

Saving weight:

$$\frac{dm}{dt} = \dot{m}\pi d^2 , \tag{12}$$

$$\dot{m} = \frac{Sh}{Sc} \frac{\mu_g}{d} \Phi, \tag{13}$$

where Sh - Sherwood number, Sc - Schmidt number.

Φ value was calculated as follows:

$$\Phi = \ln\left(1 + \frac{Y_{1,\text{sat}}(T_p) - Y_1}{1 - Y_{1,\text{sat}}(T_p)}\right). \tag{14}$$

The interaction of particles with the wall defining Weber number:

$$W = \frac{\rho_d d V_{dn}^2}{\sigma(T_d)}. \tag{15}$$

Mode particle adhesion slowly come on to the wall, sticks, and flows into the film.

Mode of attachment: $W_в < 5$.
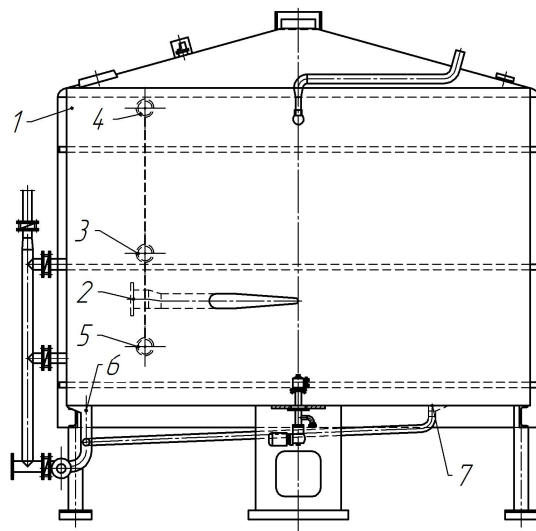
At larger speeds drop normal bounces off the wall.

Rebound mode: $5 < W_в < 10$.

Next regime - a regime similar to the regime infusion sticking.

Daily injections: $10 < W_в, S < 1$.

Hydrocyclone unit (Fig.1) is a cylindrical container 1 with a conical lid, flat bottom and nozzle 2, which is tangentially arranged at the bottom of the machine for feeding wort [6].

Principle of fast separation of coarse and fine weighted particles is: hot wort with a relatively high speed is pumped to a hydrocyclone unit tangentially. With the influence of centrifugal force mash particles of wort precipitate in the cone form at the bottom of the unit.

After some time the clarified wort is removed through the pipes for the descent of the clarified wort 3, 4 and 5, turbid wort - through the pipe 6 for lowering turbid wort, and the residue washes away with water and goes down through the pipe 7, located at the bottom of the unit.

Case studies and observation of the hydrocyclone apparatus allowed to determine that its optimum performance depends not only on the quality indicators of the hot wort, but also on the speed of its submission, the geometry of the container , as well as design parameters and location of pipes to supply and lowering of wort.

In order to determine the parameters of rational design of hydrocyclone apparatus it is appropriate to examine all of the major factors, which influence to the quality of the process of clarification.

Fig. 1. Hydrocyclone (whirlpool)

In the simulation of hydrocyclone apparatus were used these initial parameters:
- Input speed of unit - 3,5 m/s; [4, 5]
- density of wort – 1045 kg/m^3;
- the dynamic viscosity of the wort - 0,0006 Pa·s;
- size of the particles - 30 • 10^{-6} m; 42,5 • 10^{-6} m; 57,5 • 10^{-6} m; 80 • 10^{-6} m.

Research of the influence of the feed rate of the wort in the apparatus for clarification process carried out in the following models of hydrocyclone apparatus: with the classical form of the bottom (flat) (Fig. 2a), the conical insert (Fig. 2b), the two cylindrical inserts and applying the wort to each of the inserts (Fig. 2c), with conical bottom and radial guide inserts (Fig. 2d).
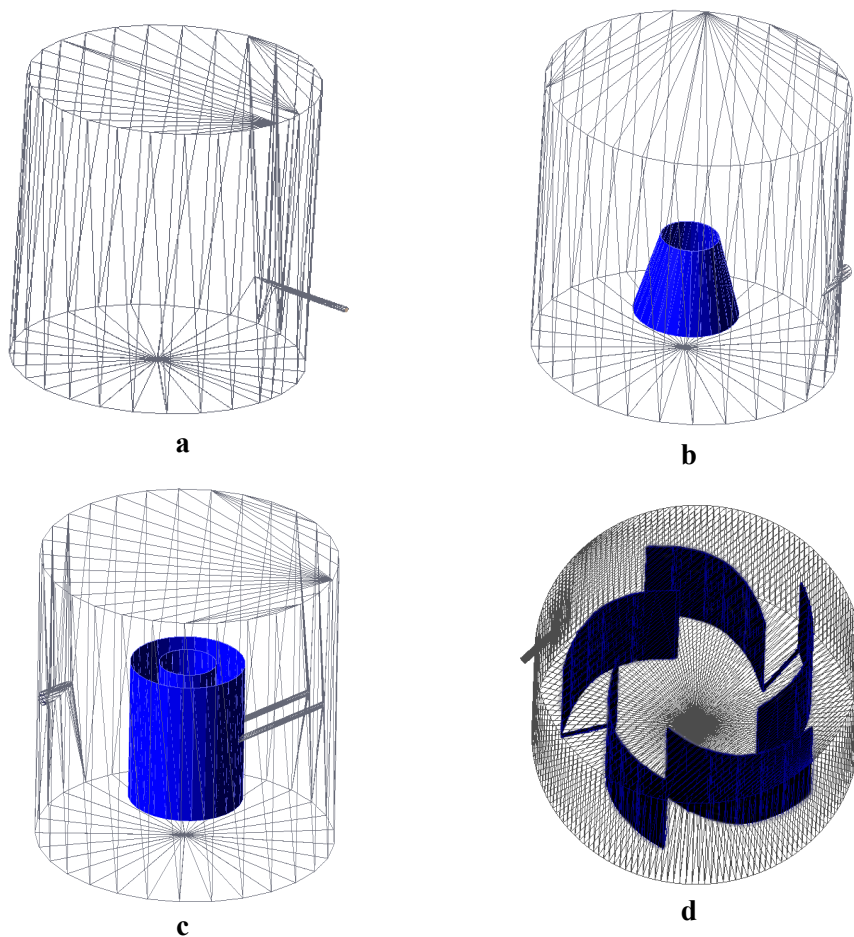
Fig. 2. Models of hydrocyclone unit (whirlpool)

Results and discussion

Visualization of wort's movement inside the hydrocyclone unit (whirlpool) is shown by the example of the apparatus with simple construction, which is the most used at the facility (Fig. 3). Analyzing the data it can be argued that the wort in the machine acquires the rotational movement, which is provided by tangentially mounted nozzle of product feed. The resulting vortex flow helps the particles to deposit in a form of a protein precipitation plate.

The biggest concentration of particles is located in the middle of the unit's bottom (fig. 3b).

a   *b*
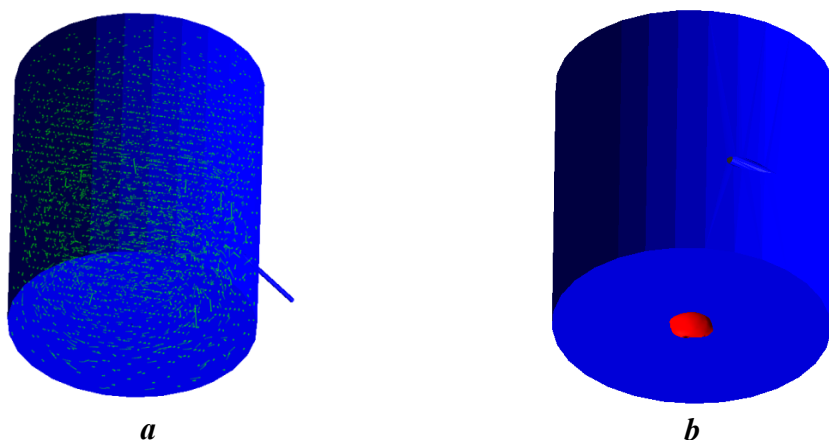
Fig. 2. Trajectories of move (a) and the particles' concentration distribution (b) in the unit

As already noted, an important role in the clarification process has feed speed of the wort into the machine, which is the speed at the input nozzle's output. If the speed exceeds 3.5 m/s [3], the product is subjected to considerable shearing stresses. As a result, low-sized particles are created and they aren't deposit in the hydrocyclone apparatus. If the value is less than the recommended rate [4, 5], there may be secondary vortex flows, which may interfere with the main flow and hence the separation of suspended solids.

It is clear from the foregoing that correctly chosen initial wort feed rate into the apparatus (with further reduce it during lightening) greatly affects the efficiency of hydrocyclone apparatus.

For the above options of structural performance of hydrocyclone apparatus (whirlpools), was analyzed the circulation zones, which are encountered in the device during tangential flow of wort [6, 7].

Analysis of the results showed the occurrence of undesired secondary circulating vortices in versions 1, 2 and 3, which prevents the effective deposition of the protein precipitate (Figure 4).

Moreover, in the first embodiment undesired secondary circulation vortices occur in the central and upper areas of the machine. In embodiments 2 and 3 circulating vortices arised in the lower zone of the machine that leads to the destruction of the cone and the mixing of the protein precipitate wort. In the fourth embodiment, the above drawbacks are much smaller.
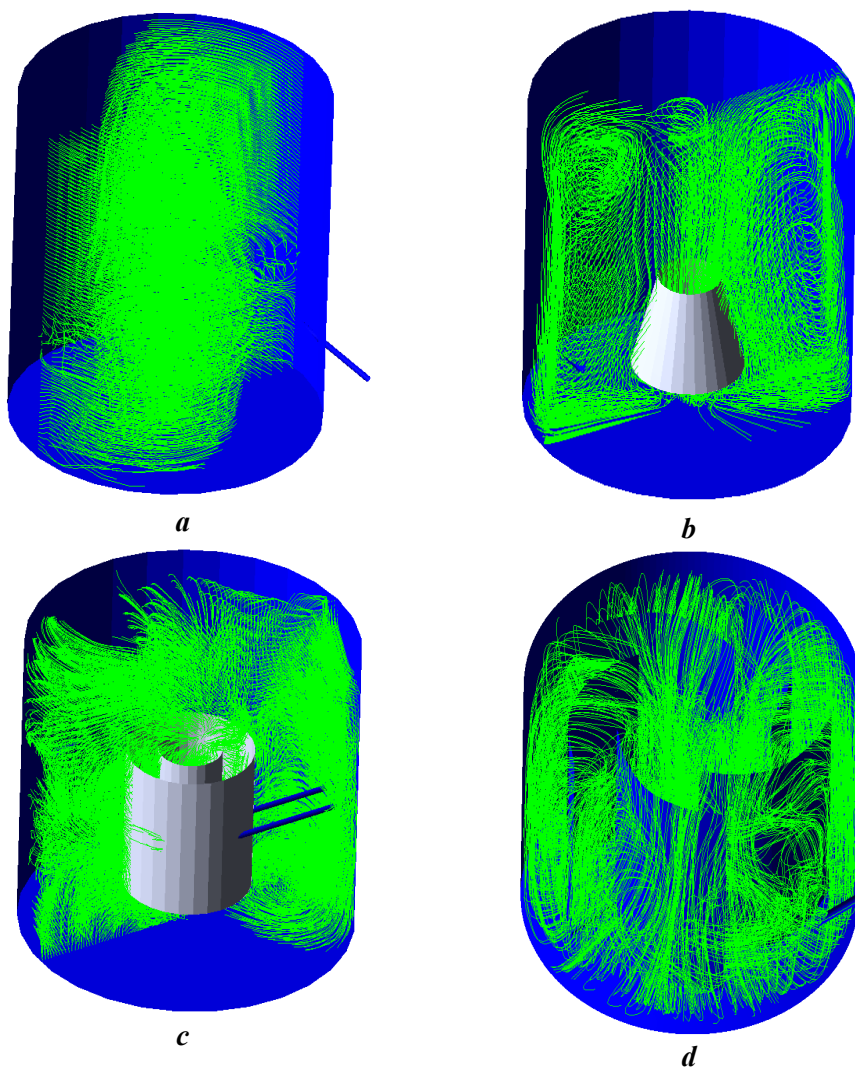
Fig. 4. The trajectories of the particles in the apparatus with the classical form of the bottom (flat) (a), the conical insert (b), two cylindrical inserts and applying the wort to each of the inserts (c), with a conical bottom and radial guiding inserts (d).

Also were researched shear stresses (τ), which appears in the wort during its supply. According to [4], when the value of τ exceeds 50 Pa, the destruction of protein precipitate particles begins.

During mathematical simulation were received result, which indicate that in the embodiments 1 and 4, the values of shear stresses do not exceed the permissible value

(respectively 26 and 47 Pa), and in embodiments 2 and 3, this value exceeds the allowable (respectively 176 and 440 Pa).

Analyzing the results for the 4th version inserts (Fig. 2, d) can be argued that the principal amount of the dispersed phase, gradually moves to the center of the device, which also settles, forming a cone pipe. Using inserts the above design has a positive effect on the process (20% compared with the base construction). Due to gravity and friction particles to insert and wall system, the bottom of the last sedymentuye increasing number of deposit (Fig. 5 a-c).

a

b

c
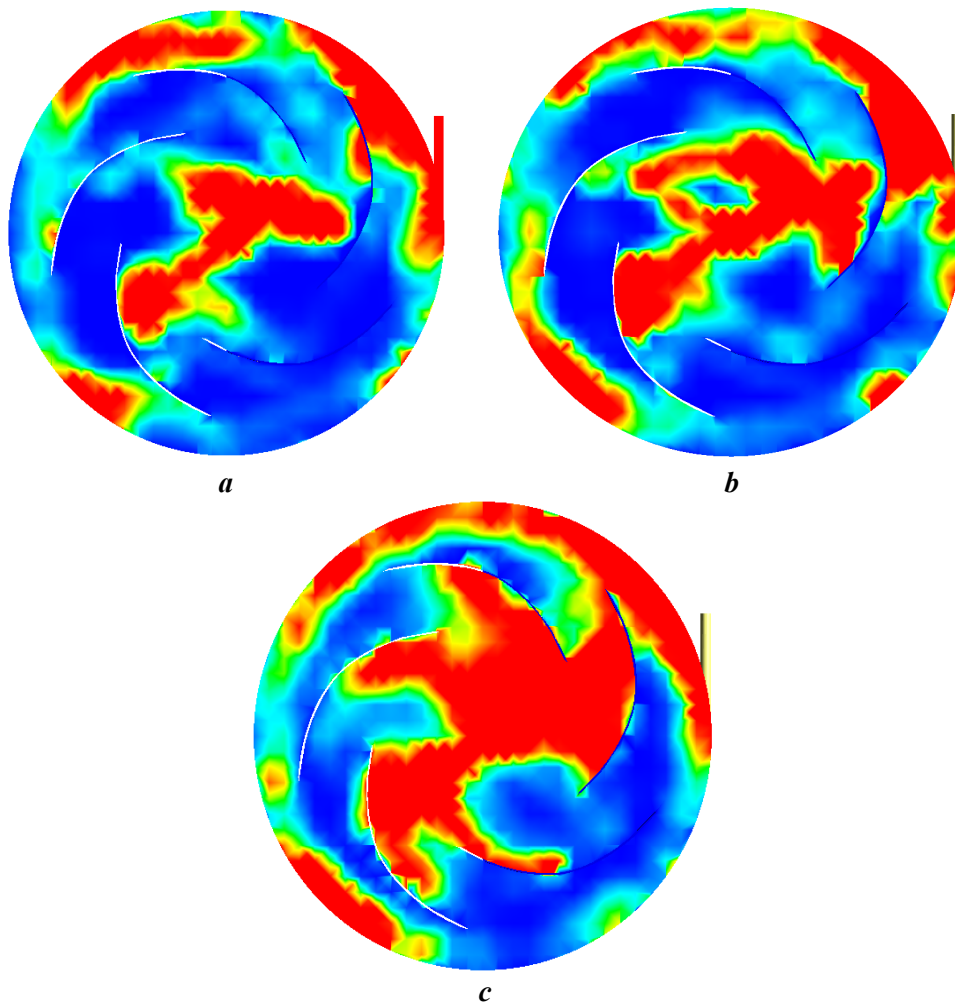
Fig. 5. Fields of concentration of particles in the horizontal cut apparatus at different levels from the bottom, m: a – 0,3; b – 0,15; c – 0,05

During the process of light beer wort solids sludge are complex trajectory of the incoming pipe to the bottom of the central apparatus. Due to the pressure difference between peripheral and central areas braking system and motion of particles near the walls of the apparatus and the insert, the latter is moving to the center of the cyclone. Distribution of changes in the concentration of particles precipitate height of the device shown in Fig. 6.
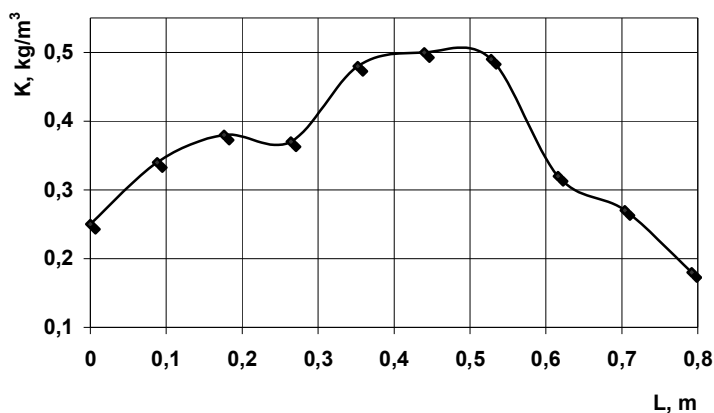
Fig. 6. Schedule changes in the concentration of particles in the vertical section of apparatus

Conclusions

So, the results of the analysis of the researched variants of hydrocyclone unit (whirlpool) proves the feasibility of feeding recommendations for implementation in the production embodiment 4 - hydrocyclone unit with conical bottom and radial guide inserts. Further research is planned to analyze the influence of the geometric dimensions of the radial guide insert on the beer wort clarification quality, the height above the bottom of the insert placement apparatus and the number of pipes supplying wort feed rate.

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Theoretical substantiation of intensification process possibilities of conductive frying meat natural products

Viacheslav Skrypnyk

Poltava University of Economics and Trade, Poltava, Ukraine

Abstract

Introduction. The process of conductive frying meat products is the most costly process concerning to natural energy and resources. The possibilities of intensification and resource conservation process have been theoretically discussed.

Results and discussion. The analytical method of published experimental and theoretical data was used.

Materials and methods. For improving energy efficiency and resource conservation of the process conductive frying meat natural products the possible intensification factors have been overviewed. The increasing of temperature level of the process more than 423 K is inappropriate due to the formation in the product surface layer of heterocyclic amines. The intensification process is possible in case of bilateral heat supply and the usage of physical and electro physical methods of influence on row.

The influence of compression or variable frequency electric current in the process of conductive meat frying leads to the formation the effective meat layer, which is less than the initial thickness of semi-finished product with terminal properties of a substance.

The usage of functionally closed capacities in the bilateral meat frying with a high content of connective tissue under compression conditions limiting meat allows saving native moisture amount which is enough for the hydrolysis of collagen in the required amount.

The process of bilateral frying meat under physical and electro physical methods of influence can be subdivided into three main stages according to the duration.

As for the energy the most costly is the second stage at which heat is transferred through the surface layer of meat because of constant evaporation that forms due to the removal of moisture in the surface layers of the product to frying surfaces. The analytical model of the process has been grounded.

Conclusions. Firstly the intensification factors, analytical model of conductive frying meat natural products, including and high content of connective tissue has been proved.

Introduction

The frying of meat products is the main method which is wide-spread among the heat processing characterized by losing significant weight (up to11…35%) and unit cost of heat (up to 1000…1300 kJ/kg) [1]. The energy efficient of this process mostly depends on the method of heat connection and on the peculiarities of the construction equipment and can't be too high as this process requires maintaining the high-temperature control (423…473 К), and the devices for its implementation are characterized by large thermal tension heating surfaces (up to 45 кW/m^2).

The analysis of the equipment development for the implementation conductive meat frying process, the scientific sources confirm that the energy efficiency of this process, devices implementation, the increase of product outcome and product safety weren't paid enough attention [2].

The process of conductive meat frying has the resource limits concerning to frying appropriateness of definite parts of trunk butchers. It means the sirloin, fore ribs and the front part, the rump contain no more then 10…20% [3, 4] in cattle. Definitely in this parts the connecting material presents think and softy net which mostly consists from cologne fibers. Other parts of butchers (neck, topside silverside, and chuck) contain more connected material, it means that they are not appropriate for conductive meat frying, and it has to be used for cooking cutting semi-finished product.

Annual population of horned-cattle and parks in Ukraine is getting less in average on 4,5% [5, 6], hence the resource base of frying meat products' process reduce, which negatively influences on the semi-finished product cost. For improving the situation the Ukrainian Council developed the import of meat row from different countries of the world (Brazil, Poland, Germany and others). As a rule, the cost of import row is lower than national, but the quality is not so high and it much influence on energy efficiency process of heat processing [7].

According to this issue the problem of low energy efficiency, a little product outcome and deficient resource basis of conductive meat frying process. The increasing energy efficiency, complete product outcome, the enlargement of resource base of conductive natural meat frying process is a contemporary scientific and practical mission.

Materials and methods

The object of the research is conductive meat frying process of natural products taking into account materials with a high content of connective tissue. The analytical research methods of published experimental and theoretical data have been used.

Results and discussion

It is well-known that technological process intensification of thermal processing of food raw materials are: increasing the temperature level of the process, increasing the heat exchange surface between the raw material and the heating medium (surface), increase the coefficient of heat transfer from the heating medium (surfaces) to materials and the modification of the thermal properties of the product.

The temperature increasing of the frying surface or fat on it above 423 K leads to significant process intensification conductive frying meat, but it has a considerable impact

on the quality of the end product because of overheating its surface layer and leads to the formation of fat in the crust of frying harmful substances - heterocyclic amines [8-12]. Taking into account these objectionable effects of the technological process of temperature increasing above 423 K is inappropriate.

The increasing of heat transfer surface during the process of the conductive frying meat is possible due to bilateral heat supply, which leads to a considerable decrease in duration of frying, the unit cost of energy and increasing the end product outcome [2].

The increasing of heat transfer coefficient from frying meat surfaces and modification of its thermal physic properties are possible by using some physical and electrical methods, such as pressure and electric current. In addition, the use of physical and electrical methods during conductive frying of meat natural products due to constant reducing in the surface layers of the product free moisture allow to prevent large overheating the product surface layers and, consequently, the formation of heterocyclic amines.

The influence of intensification factors aims to achieve the effective thickness δ_m of the meat layer thickness δ_{ef}, smaller than the meat thickness, i.e. $\delta_{ef} < \delta_m$, which has a heat-conducting properties of liquids (meat juice). To achieve an effective meat layer δ_{ef} for bilateral meat frying it is possible through its compression between the frying surfaces with efforts which provide the excess pressure of water vapor in the surface layers of meat on the level p_{ex}, and provide the capillaries and pores filled with meat substance (liquid), or due to the occurrence of flow substance.

$$J_s = V_s / (S_m \cdot \tau), \text{ m/s,}$$

where V_s - number of substances carried through the meat section S_m in unit time τ by an electric current of variable frequency.

According to sources [13-15] in capillary-porous bodies under a potential difference a flow substance appears, the value of which depends on the physicochemical properties of these bodies. The use of variable frequency electric current in the process of bilateral meat frying under condition of the formation the flow substance J_s inside the meat, consequently, the effective layer δ_{ef} allow significantly reduce the duration of the process and increase the finished product outcome.

Under such conditions, the vapor in each meat surface layer, which is formed as a result of influence of heat flow from the heater, starts to act as interim heat transfer: firstly water evaporation from the surface of the capillary meniscus and the formation of excess vapor pressure by the compression effort take place, and an effective layer forms in meat less than the meat thickness. The thermal conductivity of an effective layer is much higher than the thermal conductivity of meat and almost equal to the thermal conductivity of meat juice.

In terms of the combined effects of heat flow from the heater and electric current according meat the volume desiccated layer of the surface heating will increase in value V_s. It consists of cavities volumes filled with vapor in a sample of meat in each capillaries, i.e.

$$V_s = \sum_{i=1}^{i=n} \left(\frac{\pi \cdot d_i^2}{4} \cdot h_i + \frac{\pi \cdot d_i^3}{12} \right), \text{ m}^3;$$

where d_i - the diameter a single capillary, m;

h_i - height cavity filled vapor in a separate capillary, m;

n - the number of capillaries per unit area of a sample of meat items/m^2.

Using the law of separation capillaries and pores, the porosity of the body, and their portion it is possible to find out the height h_i

$$h_i = \frac{V_s - \sum\limits_{i=1}^{i=n} \dfrac{\pi \cdot d_i^3}{12}}{\sum\limits_{i=1}^{i=n} \dfrac{\pi \cdot d_i^2}{4}} \text{ , m.}$$

Hence the thickness of effective meat layer

$$\delta_{ef_i} = \delta_m - h_i \text{ , m.}$$

In bilateral meat frying with a high content of connective tissue the supplying heat occurs only to the product surface, which is directly contact with the heating surface. In this case the supplying heat is not provided to the side of meat surface and the heating is carried out only through the distribution of heat inside the product. Moreover, as a result the product loses its heat.

To solve the problem of more complete usage of supplying heating surfaces to thermal energy and providing the heating surfaces possible under the conditions of frying process, in which the vapor that previously was lost together with the heat of vaporization to the atmosphere, the maximum amount of it would remain in the contact with the side surfaces product. In this case, the contact the vapor with product side surfaces that has lower temperature throughout the process of frying than the temperature of vapor, the condensation will occur.

It is possible if to create functionally closed capacities and to start a frying process of meat products in it [16]. In addition, the extruded air by vapor from the working area functionally closed capacities will promote to a significant increase of heat transfer coefficient from the vapor to the side surface of the product.

The rational effort of product compression during frying can be considered a value that provides the formation of water vapor pressure in the roasting crust and removal of air (or contraction) out of the capillaries and pores of meat, but does not result in irreversible deformation. This will increase the coefficient of thermal conductivity to values close to the thermal conductivity of liquid (meat juice). Excessive compression efficiency efforts, resulted in the destruction of meat structure through the moisture extraction, will adversely affect the efficiency of frying and quality of the final product. In addition, in the process of the bilateral frying of meat high in connective tissue under excessive steam pressure at the threshold level there is virtually no flow of substances that leads to preservation of native moisture and, consequently, creates conditions for sufficient hydrolysis of collagen.

The limit of intensification of bilateral frying of meat high in connective tissue under compression in a functionally closed capacity is the value of thermal conductivity of the moisture in the meat at a given pressure.

Under the conditions of non-rigid fixation of the heating surface moisture removal from the product would be compensated by the compression of meat height (thickness). Thus, it can be stated that the vapor pressure in the contact zone is maintained constant, and consequently the temperature is equal to the temperature of saturated steam at pressure created.

The process of frying should be done by placing semi-finished products made from meat high in connective tissue, between two heating surfaces in functionally closed capacity and under a certain compression. Heating of the upper and lower surfaces of the product that contact with the heating surface is provided by two heat flows respectively. In addition, the heating of the lateral surface is provided by condensation of wet steam on it.

Thus, proposed method provides heating to the entire surface of the product. In addition, removal of air from functionally closed capacity with steam significantly increases steam heat transfer coefficient to the side surfaces of the product.

Since in the contact area of the product and heating surface, with the temperature of 423 K, phase transitions "liquid-vapor-liquid" occur, this will provide intensive supply of heat to the surface of the product. Given that the product is compressed between two heating surfaces, the phase transitions in the contact zone will occur at a pressure higher than atmospheric, and therefore at a temperature higher than 373 K. Moreover, the vapor from the lateral sides of the product will condensate at atmospheric pressure, while liquid evaporation from the surface of the product in contact with heating surface, will be a basis for filtration mass transfer. Along with it some amount of vapor produced during frying is lost into the environment due to leakage of functionally closed capacity.

The transfer of heat from the heating surfaces to the product is due to the continuous evaporation and condensation on surfaces in contact with functionally closed capacity, and its condensation on its lateral surface.

The whole process of bilateral frying under pressure at given conditions and under electric current can be divided into three stages.

The first stage, the stage of warming up a small part of the surface layers of semi-finished products to the water evaporation temperature, is short-termed and almost instantaneous. During the first stage there is a sharp decrease in temperature of frying surfaces above and below the semi-finished product.

The second stage is the basic frying process in terms of energy costs required at which the heat is transferred to the surface layers of the product through layers of steam, and ends in the center of semi-finished product at about 338...343 K when the meat loses its tough-elastic structure and acquires properties inherent in a solid body through the thermal changes of proteins it contains.

The third stage is the formation of roasting crusts on the surface of the product due to increased temperature. The duration of the third stage affects organoleptic properties of the finished product: by increasing the duration a greater degree of roasted surface layers is achieved; by reducing the duration of the third stage it is possible to obtain a high quality finished product, probably dietary, as this will form dehydrated or negligible crust.

Meat high in connective tissue is an extremely complex structure, consisting of muscle fibers joined in primary bundles, the primary combined into larger bundles, etc., and the space between them incorporates significant layers of connective tissue and is filled with fluid. Therefore, diameters of different capillaries may vary widely. Thus, the diameter of muscle fibers may be $(45…60) \cdot 10^{-6}$ m [17], which in turn depends on the type of muscles, age, sex of a animal, conditions of food and drinking, storage conditions, and so on. In addition, there are capillaries between fibers, primary bundles and others, and their diameters, in turn, depend on the way the capillaries are joined and placed, and on the aforementioned factors. In the capillaries and pores of the meat, including meat high in connective tissue, there is some space filled with gases (water vapor, air, etc.). Compressing with particular effort or applying electric current in meat processing leads to the formation of effective thickness of the product that is heated, reduces the loss of steam into the environment and, consequently, reduces the time of frying and increases the output of the finished product.

Under these conditions, the process of conductive frying of natural meat products can be considered as the heating of an infinite plate. The analytical model of this process under conditions of applying electric current and bilateral frying in terms of compression in

functionality closed capacity providing effective thickness of the meat layer is the formula proposed by the author [18]

$$\tau_0 = \frac{Fo \cdot \delta_{ef}^{\,2}}{a},$$

where a - a temperature conductivity of the product, m^2/s;

Fo - Fourier criterion.

Conclusions

The factors of intensification the convective meat frying process have been analyzed and justified, they include:

- increasing the heat transfer surface and the meat contact surface with the surfaces of frying with the bilateral supply of heat and associated with this increase of the coefficient of heat transfer from the surface of frying to the surface of meat;

- changing of the thermophysical properties of the meat, in particular, increase in thermal conductivity;

- reducing the thickness of the meat δ_m to the effective thickness of the liquid δ_{ef} by applying pressure or electric current to the conductive frying.

It has been proposed to divide the bilateral frying meat process, including meat high in connective tissue in functionality closed capacity and under the influence of electric current, into three main stages according to the duration, of which the most significant in terms of energy costs is the second at which the heat is transferred through the surface layer of meat as a result of phase transitions of water vapor formed due to the removal of moisture out of the product surface layers to the frying surfaces.

The analytical model of bilateral meat frying process under the influence of electrophysical methods based on the factors of intensification has been substantiated, in particular, reducing the thickness of the meat from δ_m to effective δ_{ef}, increasing the thermal conductivity of meat λ_m and increase the coefficient of heat transfer from frying surface to the surface of meat.

For practical substantiation of the analytical model it is necessary to study the processes of occurrence of meat weight conductivity under the influence of heat flow and combined effect of heat flow and the difference of potentials of variable frequency to determine the patterns of occurrence of substance flow aimed to establish rational parameters of bilateral meat frying, including meat high in connective tissue.

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Mathematical model of drying fruit particles

Dmytro Kolomiets, Tetiana Roman, Liliia Kharchenko, Mariia Rotai, Oleksandr Mazurenko

National university of food technologies, Kyiv, Ukraine

Corresponding author:

Dmytro Kolomiets
E-mail:
kdp1210@i.ua

Abstract

Introduction. For parameter optimization of drying and obtaining finished products which have high quality, it is important to have a real mathematical model of heat and mass transfer in the dried layer of the product.

Methods and materials. According to the analys of many known mathematical models which was presented by the researchers as regression equations of the experimental data,which was solved as simplified problem of internal water transfer for different instantiations.They combined this General theory with a simple and particle models of the drying process of wet materials.

Results and discussion. In the process of developing the model of drying fruit products in the soft regime, it was taken as a basis one of the most common assumptions about the kinetics of the drying process - liquid inside the porous structure moves almost free, evaporation of the liquid is only on the outer surface of the body, and the moisture is removed during the process drying, evaporation rises to the surface of the inner region of the material at low moisture gradient. It gives us opportunity to develop a mathematical model in the form of differential equations for retain the moisture, heat and changes in filtration transfer capacity , which describe, respectively, the transient field moisture content, temperature and total pressure capillary-porous body at constant transfer coefficients.

On the basis of known mathematical models drying wet materials in a thin layer of product, and use of the provisions of the modern theory of internal mass transfer based on the concept of a single potential transfer of moisture to the layer product in the form of unlimited plate decided the equation moving the interface damp body - space drying in the drying modes. Under these conditions, drying moisture transfer by the pressure gradient can be neglected. Therefore, the selected boundary conditions, solve the problem of Stephen for compatible transfer processes of heat and moisture in the wet material drying. The boundary problem for a system of two second order differential equations. The calculation results move the interface damp body - drying space on the proposed model satisfactorily consistent with experimental research.

Conclusions. The use of the model dry fruit particles improve the quality of regulation as the drying process and the finished product.

Introduction

Edible fruits and mushrooms are the main sources of essential nutrients of natural origin. They greatly enrich the diet of people. Most of fruits are well stored for a long time and can be consumed raw or processed. Almost all kinds of edible mushrooms have a short shelf life and require compulsory heat treatment. This is because as the presence of a significant amount of moisture (87-95% per 100 grams of edible part[1]) and active enzymatic and microbiological activity of fruits cells. Nutritional of mushrooms depending on their sort, vegetation and storage conditions.

Today the cultivated species of mushrooms considered promising and useful source of nutrition. It is highly profitable and of high household culture[2]. Proved their nutritional and medicinal value [3].

Development of Fungiculture in Ukraine it held within the framework of the program "Mushrooms of Ukraine." Production of cultivated mushrooms in Ukraine increased annually by 25-30%, it is the fastest pace in Europe. The most common among cultivated mushroom are heterotrophic saprophytic mushroom – twospores champignon (Agaricus bisporus (Lange) Sing). Today it is grown in almost all countries.

Freshly mushrooms are most helpful. But because of the high moisture content at ambient temperature over +18 ° C mushrooms can be stored for only 24 hours. Unrealised fruits should be processed in mushroom products in any way. The most commonly for this purpose used drying. It can not only extend shelf life of products, reduce the cost of transportation and storage, but also improve the nutritional value of the product [2, 4].

In tissues fruiting bodies of mushrooms moisture (inter- and intracellular fluid) is solvent, the other - kept biopolymers pulp. Both may have inherent properties or clean water (free moisture or freezing), or those acquired as a result of hydration - energetically favorable interactions with water soluble biopolymer pulp and substances of cell sap (bound or nonfreezing wet) [5] .

So the main purpose of drying foods - reducing humidity to a level that allows you to safely store products for an extended period. [6] . For drying mushrooms successfully use air, sublinear , microwave, osmotic and other drying. Each method has advantages and disadvantages, but the most widely known is the convective drying with hot air. [7]. Drying - the process of removing moisture conditions for simultaneous heat and mass transfer between the product and coolant. For most foods, it is the last (incident) during the drying speed and continues until equilibrium moisture, characterized by the least amount of moisture, which can remain in the product in the circumstances of the drying process. [8]. Usually before drying product is ground and formed from it optimal layer dry-through product [9].

An important role in shaping the economic and quality of dried product plays time and drying conditions. In order to optimize these parameters from experimental data to develop mathematical models that make it possible to generalize curves drying various fruits: apricots [9, 10], grapes [11, 12] mulberry [13], figs [14], apple [15, 16]. Effect modes of drying, the fungus particles, the size of the crushed particles forming layer product drying considered in mathematical models given in [1, 2, 3, 8, 17, 18, 19, 20, 21, 22].

Materials and methods

Analyzing the real processes of fruits drying – which are bodies with a complex structure, it is difficult to count an influence of the interior elementary types of heat and moisture transferring. That's why finding of analytical solution of the whole equations'

system of heat- and mass transferring interrelated processes inside of wet body is almost impossible. In the case when all necessary numerical coefficients are included in the differential equations and uniqueness conditions, we can solve the simplified problem of internal water transfer for different instantiations [29-31] by combining the General theory with a simpler and private models of the drying process of wet materials.

So, in the model proposed in [32], we can make the assumption that as the drying product is localized deepening of the front evaporation of moisture and, in this case, the heat to the front will be totaled due to the heat conductivity of the dried layer material.

To develop a mathematical model of the drying of fruit products in the soft modes we take as a basis one of the simplest assumptions about the kinetics of the drying process, which lies in the fact that the liquid inside of porous structure moves relatively freely, and the evaporation of a liquid is carried out only from the outer surface of the body, and the moisture is removed during the drying process is supplied to the surface of the evaporation from the inner zones of the material with a low gradient moisture [32].

Results and discussion

We use the statement of the modern theory of internal heat and mass transfer, based on the notion of a single potential migration of moisture Θ^*. The value of the potential Θ^* is proportional to the local moisture ω content in the material and inversely proportional to masons body c_m. During theconvective drying it unites potentials of all possible elementary transfer of moisture in capillary-porous body due to the gradients of moisture, temperature and pressure [32].

Given that the process of formation of steam inside of the wet material is a source of vapor phase and also contributes to the outflow of heat use in further reasoning the notion of the criterion of phase transformation $\varepsilon_f = \partial \omega_f / \partial \omega$ [32], which can be considered as an independent process parameter and to determine from the ratio of the mass of moisture $\partial \omega_f$ involved in a phase transition (power source), up to a total mass change of moisture in internal wet point of the material $\partial \omega$. Due to certain conditions, the criteria may be limit values: $\varepsilon_f = 0$ *or* $\varepsilon_f = 1$. In drying conditions, when phase transitions are absent, and the moisture in the middle of the dried-up body is moved only by movement of the liquid phase $\varepsilon_f = 0$. When the change of moisture content in the body occurs only through evaporation or condensation, $\varepsilon_f = 1$ it. Note that when intense protonen in the pores of the dried product may occur the excess pressure of water vapor, leading to the appearance of the pressure gradient intensifies the General suffered moisture in the body.

In most of cases the potentials of elementary processes of moisture transfer depends on the structure of the body, temperature Θ and moisture content ω.

We'll take that the layer dried the wet product, the thermal diffusivity which is α, potential conductivity α_m and the coefficient of filter transfer pressure , has the form of an unlimited plate α_p with an initial thickness of the H_o. Differential equation of conservation of moisture, of warmth and of changes in filtration capacity transfer, describing, respectively, the nonstationary fields of moisture, temperature and total pressure in the middle of the capillary-porous body with constant transport coefficients are of the form [32].

$$\frac{\partial \omega}{\partial \tau} = \alpha_m \frac{\partial^2 \omega}{\partial x^2} + \alpha_m \delta \frac{\partial^2 \Theta}{\partial x^2} \; ; \tag{1}$$

$$\frac{\partial \Theta}{\partial \tau} = \alpha \frac{\partial^2 \Theta}{\partial x^2} + \varepsilon_f \frac{r}{c} \cdot \frac{\partial \omega}{\partial \tau} \; ; \tag{2}$$

$$\frac{\partial P}{\partial \tau} = \alpha_p \frac{\partial^2 P}{\partial x^2} - \varepsilon_f \frac{c_m}{c} \cdot \frac{\partial \Theta^*}{\partial \tau} \; , \tag{3}$$

де $\delta = c_m (\partial \Theta^* / \partial \Theta)\big|_\omega$ - thermogradient coefficient of moisture transfer.

If we'll count (1-3) we can have a General differential equation describing the unsteady field of potentional Θ^*

$$\frac{\partial \Theta^*}{\partial \tau} = \alpha_m \frac{\partial^2 \Theta^*}{\partial x^2} + \alpha_m \frac{\delta}{c_m} \cdot \frac{\partial^2 \Theta}{\partial x^2} + \alpha_m \delta_{fil} \frac{\partial^2 P}{\partial x^2} \; , \tag{4}$$

Where $\delta_{fil} = K_{fil} / \lambda_m$ - the filtration coefficient of moisture transfer is proportional to the ratio of the filtration permeability of the porous material K_{fil} and inversely proportional to the coefficient of conductivity of the wet body λ_m.

We'll assume that a certain time reduce the volume of the dried body is carried out by reducing the volume of the liquid phase of the substance, that is $(\partial V / \partial t) = (\partial V / \partial t)_\omega$. In this case, to determine the moving boundary of evaporation, you can use the heat balance equation on the boundary of the wet body - environment, under which the total amount of heat ∂Q_τ supplied to the body, is spent on heating of the body (∂Q_t) and evaporating part of the moisture (∂Q_ω), that is

$$\partial Q_\tau = \partial Q_t + \partial Q_\omega \, ,$$

or

$$-\lambda \left(\partial \Theta / \partial x \right)\big|_{x=h} \cdot F_H \cdot \partial \tau - r \cdot \rho_\omega \cdot F_H \cdot \partial h = \alpha(t_{dr} - t_{sur}) F_H \cdot \partial \tau \, , \tag{5}$$

where $\partial \Theta / \partial x$ - the temperature gradient

While drying fruit products in the soft mode the transfer of moisture due to the pressure gradient can be neglected. In this case, the set of differential equations (1), (2) and (5) together with boundary conditions of type

$$\Theta(0, \tau) = \Theta_1(\tau); \; \omega(0, \tau) = \omega_1(\tau) \; ; \tag{6}$$

$$\Theta(h, \tau) = \Theta_2(\tau); \; \omega(h, \tau) = \omega_2(\tau) \, , \tag{7}$$

define the Stefan problem for the joint processes of moisture transfer and warmth inside the wet material during the drying process[32 - 35].

By simple transformations the expression (5) we'll find the equation of the moving boundary's wet body - drying space

$$\frac{\partial h}{\partial \tau} = -\frac{\lambda}{r\rho_\omega} \cdot \frac{\partial \Theta}{\partial x}\bigg|_{x=h} - \frac{\alpha}{r\rho_\omega}[t_{dr} - t_2(\tau)]; \tau = 0, h = H_o. \tag{8}$$

To solve the system of differential equations (1) and (2) that would satisfy boundary conditions (6), (7) and equation (8), we'll use a new variable [34 - 38] and get:

$$\begin{cases} \dfrac{\partial^2 \omega}{\partial U^2} + \dfrac{1}{2\alpha_m} U \dfrac{\partial \omega}{\partial U} + \delta \dfrac{\partial^2 \Theta}{\partial U^2} = 0; \\[2mm] \dfrac{\partial^2 \Theta}{\partial U^2} + \dfrac{1}{2\alpha} U \dfrac{\partial \Theta}{\partial U} - \dfrac{r}{2\alpha \cdot c} \varepsilon_f \cdot U \dfrac{\partial \omega}{\partial U} = 0; \\[2mm] \omega(0) = \omega_1(\tau); \omega(h) = \omega_2(\tau); \\[2mm] \Theta(0) = \Theta_1(\tau); \Theta(h) = \Theta_2(\tau), \end{cases} \tag{9}$$

that is, the boundary-value task for system of two differential equations of the second order [38].

Typing the replacement $\dfrac{\partial \Theta}{\partial U} = T, \dfrac{\partial \omega}{\partial U} = V$ i $\dfrac{U^2}{2} = Z,$ after a number of transformations and simplifications, we give the system (9) the form

$$\begin{cases} \dfrac{\partial T}{\partial Z} = \dfrac{r}{2\alpha \cdot c} \cdot \varepsilon_f \cdot V - \dfrac{1}{2\alpha} \cdot T; \\[2mm] \dfrac{\partial V}{\partial Z} = \dfrac{\delta}{2\alpha} \cdot T - (\delta \dfrac{r}{2\alpha \cdot c} \cdot \varepsilon_f + \dfrac{1}{2\alpha_m})V. \end{cases} \tag{10}$$

(10), has the form [38]:

$$\begin{vmatrix} -\dfrac{1}{2\alpha} - \Lambda & \dfrac{r}{2\alpha \cdot c} \cdot \varepsilon_f \\[3mm] \dfrac{\delta}{2\alpha} - \dfrac{r}{2\alpha \cdot c} \cdot \varepsilon_f & \dfrac{\delta}{2\alpha_m} - \Lambda \end{vmatrix} = \Lambda^2 + (\dfrac{1}{\alpha_m} + \dfrac{r}{2\alpha \cdot c} \cdot \varepsilon_f + \dfrac{1}{2\alpha})\Lambda + \dfrac{1}{4\alpha\alpha_m} = 0, \tag{11}$$

Where Λ - the root of the characteristic equation.

The value of the discriminant of the quadratic equation (11) is determined by the formula

$$D = \frac{1}{4}(\frac{1}{\alpha_m} + \frac{r\delta}{\alpha c} \cdot \varepsilon_f + \frac{1}{\alpha})^2 - \frac{1}{\alpha\alpha_m}.$$

In this case there can be three cases: $D = 0; D > 0; D < 0$. Depending on the value of D, Λ is:

$$1) \; D > 0; \; \Lambda_{1,2} = -\frac{1}{4}\left(\frac{1}{\alpha_m} + \frac{r\delta}{\alpha c} \cdot \varepsilon_f + \frac{1}{\alpha}\right) \pm \sqrt{D};$$

$$2) \; D < 0; \; \Lambda_{1,2} = \Lambda_o \pm \Lambda' \cdot \acute{i}; \; \Lambda_o = -\frac{1}{4}\left(\frac{1}{\alpha_m} + \frac{r\delta}{\alpha c} \cdot \varepsilon_f + \frac{1}{\alpha}\right); \; \Lambda'' = \frac{1}{2}\sqrt{-D};$$

$$3) \; D = 0; \; \Lambda_o = \Lambda_1 = \Lambda_2.$$

From the first equation of the system (9) we find

$$V(Z) = \frac{2\alpha c}{r\varepsilon_f} \cdot \frac{\partial T}{\partial Z} + \frac{c}{r\varepsilon_f} \cdot T(Z). \tag{12}$$

Then, having the general solution for $T(Z)$, having $D > 0$, we get

$$\begin{cases} T(Z) = C_1 e^{\Lambda_1 Z} + C_2 e^{\Lambda_2 Z}; \\ V(Z) = \dfrac{c}{r\varepsilon_f}(2\alpha\Lambda_1 + 1)C_1 e^{0,5\Lambda_1 U^2} + \dfrac{c}{r\varepsilon_f}(2\alpha\Lambda_2 + 1)C_2 e^{0,5\Lambda_2 U^2}; \end{cases}$$

or

$$\begin{cases} \dfrac{\partial\Theta}{\partial U} = C_1 e^{0,5\Lambda_1 U^2} + C_2 e^{0,5\Lambda_2 U^2}; \\ \dfrac{\partial\omega}{\partial U} = \dfrac{c}{r\varepsilon_f}(2\alpha\Lambda_1 + 1)C_1 e^{0,5\Lambda_1 U^2} + \dfrac{c}{r\varepsilon_f}(2\alpha\Lambda_2 + 1)C_2 e^{0,5\Lambda_2 U^2}; \end{cases}$$

From this

$$\begin{cases} \Theta(x,\tau) = C_1 erf\left(ix\sqrt{\dfrac{\Lambda_1}{\tau}}\right) + C_2 erf\left(ix\sqrt{\dfrac{\Lambda_2}{\tau}}\right) + C_3; \\ \omega(x,\tau) = \dfrac{c}{r\varepsilon_f}(2\alpha\Lambda_1 + 1)C_1 erf\left(ix\sqrt{\dfrac{\Lambda_1}{\tau}}\right) + \\ \qquad\qquad + \dfrac{c}{r\varepsilon_f}(2\alpha\Lambda_2 + 1)C_2 erf\left(ix\sqrt{\dfrac{\Lambda_2}{\tau}}\right) + C_4; \end{cases} \tag{13}$$

Taking into account the boundary conditions (6), we find

$$C_3 = \Theta_1(\tau); \; C_4 = \omega_1(\tau) \tag{14}$$

Using the boundary conditions (7) and the value (14), get a system of linear algebraic equations

$$\begin{cases} C_1 erf(ih\sqrt{\Lambda_1/\tau}) + C_2 erf(ih\sqrt{\Lambda_2/\tau}) = \Delta\Theta; \\ C_1(2\alpha\Lambda_1+1)erf(ih\sqrt{\Lambda_1/\tau}) + C_2(2\alpha\Lambda_2+1)erf(ih\sqrt{\Lambda_2/\tau}) = \Delta\omega\cdot\dfrac{r\varepsilon_f}{c}, \end{cases}$$

(15)

where

$$\Delta\Theta = \Theta_2(\tau) - \Theta_1(\tau); \quad \Delta\omega = \omega_2(\tau) - \omega_1(\tau).$$

(16)

Calculating from the system (15) C_1 і C_2 and taking into account (14), із (13) you can find the final dependence according to $\Theta(x,\tau)$ and $\omega(x,\tau)$ having $D > 0$.

Having $D < 0$, we get

$$\begin{cases} T(Z) = C_1 e^{\Lambda_o Z}\sin(\Lambda'Z) + C_2 e^{\Lambda_o Z}\cos(\Lambda'Z); \\ V(Z) = \dfrac{c}{r\varepsilon_f}[(2\alpha\Lambda_o+1)C_1 - 2\alpha\Lambda'C_2]e^{\Lambda_o Z}\sin(\Lambda'Z) + \\ \qquad\qquad + \dfrac{c}{r\varepsilon_f}[(2\alpha\Lambda_o+1)C_2 + 2\alpha\Lambda'C_1]e^{\Lambda_o Z}\cos(\Lambda'Z); \end{cases}$$

or

$$\begin{cases} \dfrac{\partial\Theta}{\partial U} = e^{\Lambda_o Z}[C_1\sin(\Lambda'\dfrac{U^2}{2}) + C_2\cos(\Lambda'\dfrac{U^2}{2})]; \\ \dfrac{\partial\omega}{\partial U} = \dfrac{c}{r\varepsilon_f}e^{\Lambda_o Z}\{[(2\alpha\Lambda_o+1)C_1 - 2\alpha\Lambda'C_2]\sin(\Lambda'\dfrac{U^2}{2}) + \\ \qquad\qquad + [(2\alpha\Lambda_o+1)C_2 + 2\alpha\Lambda'C_1]\cos(\Lambda'\dfrac{U^2}{2})\}; \end{cases}$$

From this

$$\begin{cases} \Theta(x,\tau) = \displaystyle\int_o^{x/\sqrt{\tau}} e^{\Lambda_o\frac{Z^2}{2\tau}}[C_1\sin(\Lambda'\dfrac{Z^2}{2\tau}) + C_2\cos(\Lambda'\dfrac{Z^2}{2\tau})]\dfrac{\partial Z}{\sqrt{\tau}} + C_3; \\ \omega(x,\tau) = \dfrac{c}{r\varepsilon_f}\displaystyle\int_o^{x/\sqrt{\tau}} e^{\Lambda_o\frac{Z^2}{2\tau}}([(2\alpha\Lambda_o+1)C_1 - 2\alpha C_2]\sin(\Lambda'\dfrac{Z^2}{2\tau}) + \\ \qquad\qquad + [(2\alpha\Lambda_o+1)C_2 + 2\alpha\Lambda'C_1]\cos(\Lambda'\dfrac{Z^2}{2\tau}))\dfrac{\partial Z}{\sqrt{\tau}} + C_4. \end{cases}$$

(17)

Having Solved (17), we get:

$$C_3 = \Theta_1(\tau), \ C_4 = \omega_1(\tau).$$

(18)

Having used (7) and having taken into account (16), get

$$\begin{cases} C_1 \int\limits_o^{h/\sqrt{\tau}} [e^{\Lambda_o \frac{Z^2}{2\tau}} \sin(\Lambda' \frac{Z^2}{2\tau})] \partial Z + C_2 \int\limits_o^{h/\sqrt{\tau}} [e^{\Lambda_o \frac{Z^2}{2\tau}} \cos(\Lambda' \frac{Z^2}{2\tau})] \partial Z = \Delta\Theta\sqrt{\tau}; \\ C_1 \int\limits_o^{h/\sqrt{\tau}} e^{\Lambda_o \frac{Z^2}{2\tau}} [(2\alpha\Lambda_o + 1)\sin(\Lambda' \frac{Z^2}{2\tau}) + 2\alpha\Lambda'\cos(\Lambda' \frac{Z^2}{2\tau})] \partial Z + \\ + C_2 \int\limits_o^{h/\sqrt{\tau}} e^{\Lambda_o \frac{Z^2}{2\tau}} [(2\alpha\Lambda_o + 1)?os(\Lambda' \frac{Z^2}{2\tau}) - 2\alpha\Lambda'\sin(\Lambda' \frac{Z^2}{2\tau})] \partial Z = \Delta\omega\varepsilon_f r \frac{\sqrt{\tau}}{c}; \end{cases}$$

(19)

From (19) C_1 and C_2 and having taken into account (18), fron (17), it is possible to obtain analytical dependence for the determination $\Theta(x,\tau)$ and $\omega(x,\tau)$ at $D < 0$.

If $D = 0$, then

$$\begin{cases} T(Z) = (C_1 + C_2 Z)e^{\Lambda_o Z}; \\ V(Z) = \frac{c}{r\varepsilon_f}[2\alpha C_2 + (2\alpha\Lambda_o + 1)C_1 + (2\alpha\Lambda_o + 1)C_2 Z]e^{0,5\Lambda_o U^2}; \end{cases}$$

Or

$$\begin{cases} \frac{\partial\Theta}{\partial U} = (C_1 + 0,5C_2 U^2)e^{0,5\Lambda_o U^2}; \\ \frac{\partial\omega}{\partial U} = \frac{c}{r\varepsilon_f}[(2\alpha\Lambda_o + 1)C_1 + C_2(2\alpha + (\alpha\Lambda_o + 0,5U^2))]e^{0,5\Lambda_o U^2}; \end{cases}$$

From this

$$\begin{cases} \Theta(x,\tau) = C_1 erf(ix\sqrt{\Lambda_o/\tau}) + \frac{C_2}{2\tau\sqrt{\tau}} \int\limits_o^{x/\sqrt{\tau}} (Z^2 e^{\Lambda_o \frac{Z^2}{2\tau}}) \partial Z + C_3; \\ \omega(x,\tau) = \frac{c}{r\varepsilon_f}([2\alpha C_2 + (2\alpha\Lambda_o + 1)C_1]erf(ix\sqrt{\Lambda_o/\tau}) + \\ \quad + (2\alpha\Lambda_o + 1)\frac{C_2}{2\tau\sqrt{\tau}} \int\limits_o^{x/\sqrt{\tau}} (Z^2 e^{\Lambda_o \frac{Z^2}{2\tau}}) \partial Z) + C_4, \end{cases}$$

(20)

where

$$C_3 = \Theta_1(\tau), C_4 = \omega_1(\tau).$$

(21)

Having used (7) and (21), we get з (20) a system of linear equations

$$
\begin{cases}
C_1 erf(ih\sqrt{\Lambda_o/\tau}) + \dfrac{C_2}{2\tau\sqrt{\tau}} \int\limits_o^{h/\sqrt{\tau}} (Z^2 e^{\Lambda_o \frac{Z^2}{2\tau}})\partial Z = \Delta\Theta; \\
C_1(2\alpha\Lambda_o + 1)erf(ih\sqrt{\Lambda_o/\tau}) + C_2[2\alpha \cdot erf(ih\sqrt{\Lambda_o/\tau}) + \\
\qquad + \dfrac{(2\alpha\Lambda_o + 1)}{2\tau\sqrt{\tau}} \int\limits_o^{h/\sqrt{\tau}} (Z^2 e^{\Lambda_o \frac{Z^2}{2\tau}})\partial Z] = \dfrac{\varepsilon_f r}{c} \Delta\Theta.
\end{cases}
\tag{22}
$$

Having solved (22), we get C_1 and C_2 and, taking into account (21), from (20) it is possible to find analytical expressions for $\Theta(x,\tau)$ and $\omega(x,\tau)$ at $D = 0$.

To determine the equation of the moving boundary environments, wet material drying space, find $\left.\dfrac{\partial\Theta}{\partial x}\right|_{x=h}$ at different value of the discriminant.

At $D > 0$ we find

$$
\left.\frac{\partial\Theta}{\partial x}\right|_{x=h} = C_1 e^{\Lambda_1 \frac{h^2}{2\tau}} + C_2 e^{\Lambda_2 \frac{h^2}{2\tau}},
\tag{23}
$$

Having put (23) into (8), get

$$
\frac{\partial h}{\partial\tau} = -\frac{\lambda}{r\rho_\omega}(C_1 e^{\Lambda_1 \frac{h^2}{2\tau}} + C_2 e^{\Lambda_2 \frac{h^2}{2\tau}}) - \frac{\alpha}{r\rho_\omega}(t_{dr} - t_2(\tau)); \tau \to 0; h \to H_o,
\tag{24}
$$

where C_1 and C_2 - constants, determined from the system of equations (15).

When $D < 0$,

$$
\left.\frac{\partial\Theta}{\partial x}\right|_{x=h} = e^{\Lambda_1 \frac{h^2}{2\tau}}[C_1 \sin(\frac{\Lambda' h^2}{2\tau}) + C_2 \cos(\frac{\Lambda' h^2}{2\tau})].
\tag{25}
$$

Having put (25) into (8), get

$$
\frac{\partial h}{\partial\tau} = -\frac{\lambda}{r\rho_\omega} \cdot e^{\Lambda_o \frac{h^2}{2\tau}}[C_1 \sin(\frac{\Lambda' h^2}{2\tau}) + C_2 \cos(\frac{\Lambda' h^2}{2\tau})] - \frac{\alpha}{r\rho_\omega}(t_c - t_2(\tau));
\tag{26}
$$

$$
\tau \to 0; h \to H_o,
$$

where C_1 and C_2 - constants, which are solved from (19).

If $D = 0$, then

$$\left.\frac{\partial \Theta}{\partial x}\right|_{x=h} = e^{\Lambda_1 \frac{h^2}{2\tau}}[C_1 + C_2 \frac{h^2}{2\tau}]. \tag{27}$$

Having put (27) into (8), find

$$\frac{\partial h}{\partial \tau} = -\frac{\lambda}{r\rho_\omega} \cdot e^{\Lambda_o \frac{h^2}{2\tau}}[C_1 + C_2 \frac{h^2}{2\tau}] - \frac{\alpha}{r\rho_\omega}(t_c - t_2(\tau)); \tau \to 0; h \to H_o, \tag{28}$$

where C_1 and C_2 - constants, which are solved from (20).

Consider the moving boundary of evaporation when drying in conditions, when $\varepsilon_f = 0$. In this case, the system composed of differential equations (1) i (2) and boundary conditions (6) i (7), is

$$\begin{cases} \dfrac{\partial \Theta}{\partial \tau} = \alpha \dfrac{\partial^2 \Theta}{\partial x^2}; \\[2mm] \dfrac{\partial \omega}{\partial \tau} = \alpha_m \dfrac{\partial^2 \omega}{\partial x^2} + \alpha_m \delta \dfrac{\partial^2 \Theta}{\partial x^2}; \\[2mm] \Theta(0,\tau) = \Theta_1(\tau); \omega(0,\tau) = \omega_1(\tau); \\[2mm] \Theta(h,\tau) = \Theta_2(\tau); \omega(h,\tau) = \omega_2(\tau); \end{cases} \tag{29}$$

Having used a new variable $U = x\sqrt{\tau}$,get

$$\begin{cases} \dfrac{\partial^2 \omega}{\partial U^2} + \dfrac{1}{2\alpha_m} U \dfrac{\partial \omega}{\partial U} = -\delta \dfrac{\partial^2 \Theta}{\partial U^2}; \\[2mm] \dfrac{\partial^2 \Theta}{\partial U^2} + \dfrac{1}{2\alpha} U \dfrac{\partial \Theta}{\partial U} = 0; \\[2mm] \omega(0) = \omega_1; \omega(h) = \omega_2; \\[2mm] \Theta(0) = \Theta_1; \Theta(h) = \Theta_2, \end{cases} \tag{30}$$

Having made a replacement $\dfrac{\partial \Theta}{\partial U} = T$ and $\dfrac{\partial \omega}{\partial U} = V$, get a system

$$\begin{cases} \dfrac{\partial T}{\partial U} + \dfrac{1}{2\alpha} \cdot UT = 0, \\[2mm] \dfrac{\partial V}{\partial U} + \dfrac{1}{2\alpha} \cdot UV = -\delta \dfrac{\partial T}{\partial U}, \end{cases}$$

the solution of which is of the form

$$
\begin{cases}
T(U) = C_1 e^{-\frac{U^2}{4\alpha}}; \\
V(U) = A_1 e^{-\frac{U^2}{4\alpha}} + \frac{\delta \cdot C_1 \cdot \alpha_m}{\alpha - 2\alpha_m} e^{-\frac{U^2}{4\alpha}};
\end{cases}
\tag{31}
$$

or

$$
\begin{cases}
\Theta = C_2 + C_1 \int_0^u (e^{-\frac{Z^2}{4\alpha}}) \partial Z = C_2 + C_1 erf(x/\sqrt{2\alpha\tau}); \\
\omega = A_2 + A_1 erf(x/\sqrt{2\alpha\tau}) + \frac{\delta \cdot C_1 \cdot \alpha_m}{\alpha - 2\alpha_m} erf(x/\sqrt{2\alpha\tau}),
\end{cases}
\tag{32}
$$

where $C_2 = \Theta_1(\tau)$, $A_2 = \omega_1(\tau)$.

Having determined from the boundary conditions (7) constants C_1, A_1, get

$$
\begin{cases}
\Theta(x,\tau) = \Theta_1(\tau) + [\Theta_2(\tau) - \Theta_1(\tau)] \dfrac{erf(x/\sqrt{2\alpha\tau})}{erf(h/\sqrt{2\alpha\tau})}, \\
\omega(x,\tau) = \omega_1(\tau) + [\omega_2(\tau) - \omega_1(\tau)] - \dfrac{\delta[\Theta_2(\tau) - \Theta_1(\tau)]}{\alpha - 2\alpha_m} \alpha_m + \\
\qquad + [\Theta_2(\tau) - \Theta_1(\tau)] \dfrac{erf(x/\sqrt{2\alpha\tau})}{erf(h/\sqrt{2\alpha\tau})}.
\end{cases}
\tag{33}
$$

Taking into account that

$$
\left. \frac{\partial \Theta}{\partial x} \right|_{x=h} = \frac{\Theta_2(\tau) - \Theta_1(\tau)}{erf(h/\sqrt{2\alpha\tau})\sqrt{2\pi}} \exp(-\frac{h^2}{2\alpha\tau}),
\tag{34}
$$

equation (8) can be reduced to the form:

$$
\frac{\partial h}{\partial \tau} = -\frac{\lambda}{r\rho_\omega} \cdot \frac{\Theta_2(\tau) - \Theta_1(\tau)}{erf(h/\sqrt{2\alpha\tau})\sqrt{2\pi}} \exp(-\frac{h^2}{2\alpha\tau}) - \frac{\alpha}{r\rho_\omega}(t_c - t_2(\tau)); \tau \to 0; h \to H_o,
\tag{35}
$$

At the beginning of drying the body, when $\tau \to 0$, have $\exp(-\frac{h^2}{2\alpha\tau}) \to 0$, a $erf(h/\sqrt{2\alpha\tau}) \to 1$. Substituting these values in (35), get

$$\frac{\partial h}{\partial \tau} = -\frac{\alpha}{r\rho_\omega}(t_{dr} - t_2(\tau)); \tau \to 0; h \to H_o, \tag{36}$$

Finally, from (36) find

$$h(\tau) = H_o - \frac{\alpha}{r\rho_\omega}\int_0^\tau [t_{dr} - t_2(\tau)]\partial\tau. \tag{37}$$

Conclusion

Most mathematical models proposed in [9-22] represent a regression of experimental data, so the extent is limited to a certain extent is terms of drying specific fruit particles.

Using the internal regulations of the modern theory of mass transfer, which is based on the notion of a single potential transfer of moisture, for layer product in the form of unlimited plates for only a soft dry mode allows you to get moving equation the interface wet body - drying space. In this case, when the transfer of moisture due to the pressure gradient can be neglected, thene the appropriate boundary conditions compatible processes heat of and moisture transfer in the wet material can solve as the Stephen problem.

Using the developed mathematical model of drying fruit particles improve the quality of regulation as the drying process, so the finished product.

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Анотації

Харчові технології

Вплив модифікованого крохмалю на стан вологи в бісквітах

Ірина Стрілець

Національний університет харчових технологій

Вступ. В даній роботі вивчено вплив модифікованого крохмалю холодного набухання на перерозподіл вологи в бісквітах. З метою прогнозування процесу зберігання виробів досліджували їх сорбційні властивості.

Матеріали та методи. Кількість вільної та зв'язаної вологи розраховували за дериватографічним аналізом з урахуванням виникнення пошарового прогріву виробів. Сорбційно-десорбційні властивості виробів досліджували за традиційною методикою у вакуумному приладі Мак-Бена за температури 20 ℃. В якості адсорбтиву використовували водяну пару.

Результати і обговорення. Вивчено вплив зшитих видів модифікованого крохмалю холодного набухання: гідроксипропил дикрохмальфосфату (Microlys FH 02), ацетильованого дикрохмальфосфату (Swely Gel Soft), ацетильованого крохмалю адипату (Cold Swell 5771) на перерозподіл вологи в бісквітах.

Дослідження показали, що завдяки своїй розгалуженій просторовій будові, модифікований крохмаль холодного набухання здатний швидко зв'язувати та утримувати воду. Додавання 1 % крохмалю до борошна сприяє збільшенню кількості зв'язаної води в продукті на 7.17...13,23%.

Сорбційні властивості бісквітів з додаванням модифікованого крохмалю значно покращилися. Завдяки взаємодії крохмалю з компонентами борошна і утворенню більш міцних зв'язків з водою, загальна кількість сорбованої води для виробів з модифікованим крохмалем збільшилась на 3,14 см^3 / 100г для «Cold Swell 5771», на 5,67 см^3/100 г для «Swely Gel Soft» и на 18, 97 см^3/100 г для «Microlys FH02».

Висновки. Модифікований крохмаль холодного набухання позитивно впливає на перерозподіл вологи в бісквітах, що поліпшить термін збереження свіжості виробів.

Ключові слова: *бісквіт, крохмаль, волога, сорбція, свіжість.*

Визначення антиоксидантної активності сухих речовин екстрактів із соняшникової макухи

Дмитро Добрунов, Леонід Перевалов, Олена Півень

Національний технічний університет «Харківський політехнічний інститут»

Вступ. Дана робота має на меті визначення антиоксидантних властивостей екстрактів із соняшникової макухи (із безлушпинного ядра), отриманих із використанням кавітаційної установки.

Матеріали та методи. Насіння соняшника (сорту НК-Бріо) охолоджували рідким азотом та обрушували. Безлушпинне ядро відпресовували на екструдері. Макуху обробляли у кавітаційній установці (з використанням розчинників – гексану

та етилового спирту). Після відгонки розчинника отримали 4 зразки «Сухих речовин екстрактів із соняшникової макухи» (СРЕСМ).

Результати та обговорення. Із-за невідомої природи антиоксидантів, присутніх у СРЕСМ, автори могли тільки припустити склад СРЕСМ. Найвірогідніше, це токофероли, хлорогенова кислота, фосфоліпіди і т.п. Виходячи з цього всі розрахунки концентрації інгібітору у дослідних зразках СРЕСМ ([InH]) проводили у перерахунку на α-токоферол, як найбільш очікуваний антиоксидант.

Для визначення антиоксидантних властивостей отриманих зразків СРЕСМ було проведено серію дослідів з ініційованого окиснення модельного вуглеводню (кумолу) з додавання СРЕСМ та без них. Отримані експериментальні дані підтверджують наявність у СРЕСМ речовин з антиоксидантними властивостями таких, як: токофероли, стероли, хлорогенову кислота та фосфоліпіди. Наявність фосфоліпідів у отриманих СРЕСМ обумовлена тим, що вміст олії у шроті (після кавітаційної обробки) склала 0,9%, а кількість фосфоліпідів в олії склала 0,05%. Ці дані свідчать, що більша частина фосфоліпідів перейшла до СРЕСМ. Склад СРЕСМ досліджували за допомогою ВЕРХ (високоефективної рідинної хроматографії). Константи обриву ланцюгів (k_7) 4 дослідних зразків СРЕСМ змінювались у межах $1.0 \cdot 10^5 - 1.6 \cdot 10^5$ л/моль·с. Для найбільш відомого природного антиоксиданту – токоферолу (k_7) змінюється у межах $0.7 \cdot 10^5 - 3 \cdot 10^5$ л/моль·с.

Значення констант швидкості обриву ланцюгів (k_7) показують, що всі дослідні зразки СРЕНС є не менш ефективними інгібіторами, ніж токоферол. Це означає, що всі отримані зразки СРЕСМ є інгібіторами окиснення та уповільнюють реакцію продовження ланцюгів.

Висновки. СРЕСМ можуть бути використані для запобігання окиснювального псування жировмісних виробів та збільшення терміну їх придатності.

Ключові слова: *антиоксиданти, соняшник, кавітація, гексан, етанол*

Підвищення ефективності сухих білкових препаратів гідратованих електроактивованою водою

Людмила Вінникова, Ксенія Пронькіна, Андрій Кишеня

Одеська національна академія харчових технологій, Одеса, Україна

Вступ. В умовах сучасного виробництва м'ясних продуктів існує проблема якості сировини. Розробка технологій виробництва м'ясних продуктів з використанням білкових добавок є перспективним та економічно вигідним напрямком.

Матеріали та методи. Досліджено сухі білкові препарати різного походження: білок зі свинячої шкіри Progel C-95, Supro 500E – соєвий білок. Визначали основні функціонально-технологічні властивості білкових препаратів при їх гідратації фракціями електроактивованої води.

Результати і обговорення. Зміна pH середовища гідратації сухих білкових препаратів у лужну сторону за допомогою католіту дозволила підвищити в'язкість зразків добавок, але найефективніше це відбулося у білкового препарату рослинного походження Supro 500E . В'язкість цього препарату була на 35% більша ніж у контрольного зразка.

Визначення вологоутримуючої та жироутримоючої здатності добавок показало найбільшу ефективність використання католіту у добавці тваринного походження Progel C-95, які становили відповідно 95% і 42%.

—— *Abstracts* ——

Використання католіту для гідратації дозволило підвищити емульсійну здатність та стабільність емульсії найбільш ефективно у зразках білкової добавки тваринного походження Progel С-95. У порівнянні з контрольним зразком стабільність емульсії підвищилась на 8%.

Одним з показників економічної ефективності використання сухих білкових препаратів є критична концентрація гелеутворення. Ефективності використання добавок зворотньопропорційна показнику критичної концентрації гелеутворення. Загалом, використання католіту знизило цей показник у всіх препаратах, але у зразка добавки із свинячої шкірки Progel С-95 цей показник досяг мінімального значення і становив 5%.

Висновки. Запропонований спосіб підвищення функціонально-технологічних властивостей сухих білкових препаратів за допомогою лужної фракції електроактивованої води доводить свою ефективність. Найкращі результати поліпшення ефективності добавок відзначено за низкою показників у препараті тваринного походження Progel С-95.

Ключові слова: *добавка, електроактивована вода, католіт, аноліт, м'ясо.*

Вплив способу консервування фруктів і овочів на їх структурно-механічні властивості

Наталія Орлова, Ігор Кузьменко, Роман Романенко

Київський національний торговельно-економічний університет, Україна

Вступ. Мета дослідження полягає у встановленні найбільш ефективного способу консервування плодів і овочів, шляхом порівняння значення твердості тканинної структури досліджуваних зразків плодів і овочів консервованих різними способами.

Матеріали і методи. Аналізували плоди гарбуза, айви, кабачка і аличі консервовані в різний спосіб. Визначали постійне зусилля пенетрації структури тканини дослідних зразків циліндричним голчастим індентором з діаметром голки (d) 1,4 мм, що проникає в досліджуваний зразок зі швидкістю 3,45 мм/с на глибину 7 мм.

Результати і обговорення. Цифрове значення межі міцності тканин консервованого гарбуза дослідного зразка становило 1300–1500 мН/мм^2, що втричі вище значення контрольного, а айви – майже у 2 рази вище контрольного зразка. Величина межі міцності консервованих кабачків і аличі для дослідних зразків в середньому у 1,8-2 рази перевищувала показники для контрольних. Такі розбіжності у величині межі міцності структури плодів і овочів контрольних зразків консервів відносно дослідних спричинені більш високою і тривалою термічною обробкою контрольних зразків, що передбачає класична технологічна інструкція.

Результати експериментальних досліджень структурно-механічних властивостей співставлено із баловою оцінкою органолептичних показників, в т.ч. оцінки консистенції. Дослідні зразки кабачково-аличевих і гарбузово-айвових консервів отримали 4,81 і 4,79 балів відповідно; контрольні 3,25 і 3,48 відповідно. Також консистенцію дослідних і контрольних зразків порівняли описовим (дескриптивним) методом. Дослідні зразки характеризувались гарно збереженою формою, пружною нерозвареною консистенцією шматочків порівняно із контролем. Консистенцію контрольних зразків характеризували дескриптори "Рихла, плодова шкірка відстає від м'якоті", "М'яка, розварена". Тобто оцтова кислота, додана до

контрольних зразків консервів, не забезпечила очікуваного ефекту щодо стабілізації пружності структури тканин плодів і овочів.

Висновки. Результати дослідження підтвердили, що удосконалений спосіб консервування має позитивний ефект на збереження зовнішнього вигляду, форми шматочків продукту і формуванню більш пружної його консистенції.

Ключові слова: *консерва, термообробка, пенетрація, твердість, міцність, консистенція.*

Автоматизація технологічних процесів

Визначення глибини гнучкості технологічної системи

Іващук В'ячеслав, Ладанюк Анатолій

Національний університет харчових технологій, Київ, Україна

Вступ. При зміні асортименту продуктів виробничої лінії фахівці намагаються максимально використовувати потужності та ресурси підприємства, для збільшення сукупного прибутку.

Матеріали та методи. Досліджується рекурсія характеристик типових технологічних процесів, що розраховані на багатоасортиментне виробництво, у технологічні параметри та режими роботи обладнання. Для отримання проекцій характеристик споживача в необхідну глибину варіацій технічних характеристик використаємо методику структуризації розгортання функції якостей споживача. Для оцінки необхідних варіацій, змінних за цільової зміни обраної характеристики, скористаємось діаграмою Парето. Для оцінки можливих реалізації керування застосуємо функціональний аналіз. Локалізацію необхідних керувальних дій використаємо метод багаторазової послідовної класифікації. Для оцінки необхідної глибини технологічної гнучкості використовуємо матричний аналіз.

Результати та обговорення. Критерієм ефективної глибини асортименту визначається чистий прибуток від втрат на зміну налаштування. Прибуток від інвестицій ефективно оцінюється для кількості замовлень, які рахуються на визначений «час життя» продукту. Ініціалізація гнучкості класифікується за експлуатаційними вимогами, відповідно до термінальних планів, аварійних ситуацій, характеристик сировини.

Ефективність запровадження гнучкості ставиться у відповідність до результатами аналізу кумулятивної діаграми Парето, що відповідає за варіацію першопричин зміни цільових характеристик продукту. На прикладі розпилювальної сушарки вказано, що розв'язання проблем по трьом координатам процесу може відповідати за 70% загальної ефективності виробництва. Попередньо отримані альтернативні конфігурації гнучких систем кількісно оцінюються необхідною продуктивністю. Гнучкість технологічного процесу обмежується ступенем свободи – кількістю координат технологічного процесу та межами, що визначають відповідні зміни характеристик продуктів. Ліміти гнучкості технологічних процесів обмежуються потужностями обладнання та об'ємами ресурсів, що переробляються.

Висновки. Отримані оцінки гнучкості процесу дозволяють здійснити впровадження перспективної програми виробництва, оптимізацію технологічних маршрутів та мінімізацію проектних затрат при створенні продуктового асортименту.

Ключові слова: *гнучкість, процес, асортимент, ефективність.*

Фрактальний аналіз часових рядів функціонування брагоректифікаційної установки в задачах прогнозування та керування

Наталія Новаковська, Василь Кишенько

Національний університет харчових технологій, Київ, Україна

Вступ. Поведінка брагоректифікаційної установки як об'єкта керування характеризується наявністю проявів стохасичності і хаотичності, що вимагає їх ідентифікації методами нелінійної динаміки для організації специфічних відповідних стратегій керування.

Матеріали та методи. Для розв'язання задач прогнозування та керування брагоректифікаційною установкою як об'єктом управління були використані методи синергетики та теорії детермінованого хаосу. Аналіз часових рядів проводився за допомогою алгоритму нормованого розмаху Херста, методу покриття та кореляційних методів. Часові ряди обробляються за допомогою програмного пакету FRACTAN.

Результати та обговорення. Дослідження часових рядів брагоректифікаційної установки показало, що процеси брагоректифікації характеризуються наявністю як стохастичних, так і хаотичних режимів, розмірність атракторів яких лежить в межах від 3 до 8. Більшість з таких рядів є фракталали, тобто, незважаючи на значну нестабільність процесу, їх поведінка залишається незмінною, що дає можливість прогнозувати зміну їх стану у майбутньому. Показник кореляційної ентропії вказав на час, на який можна спрогнозувати поведінку нашої системи. Змінювання режимів роботи брагоректифікаційної установки проходить з різною періодичністю, що досягає 4-10 годин. Для аналізу хаотичності процесу в поведінці об'єкта ми використали показник кореляційної розмірності, який показав, що для даного об'єкта властива значна трендостійкість (персистентність), що характеризується високим значенням показника Херста в межах від 0,7 до 0,96. Передбачуваність поведінки процесів брагоректифікації висока, особливо для температури, і зростає при збільшенні фрактальної розмірності атракторів, досягаючи десятків хвилин.

При фрактальній розмірності менше 1.4, на систему впливає одна або кілька сил, що рухають систему в одному напрямку. Якщо розмірність близько 1.5, то сили, що діють на систему, різнонаправлені, але більш-менш компенсують одна одну. Якщо ж фрактальна розмірність значно більше 1.6, система стає нестійкою і готова перейти в новий стан. Аналіз фрактальної розмірності часового ряду тиску низу бражної колони показав, що фрактальна розмірність лежить у межах від 1.0 до 1.4, що в свою чергу вказує на те, що на систему впливає декілька сил, які рухають її в одному напрямку, тобто система стійка.

Висновки. Виявлені особливості функціонування брагоректифікаційної установки як складного нелінійного об'єкта керування дають можливість реалізації ресурсоощадних стратегій управління на основі діагностики його поведінки методами фрактального аналізу.

Ключові слова: *фрактал, брагоректифікація, керування, прогнозування, часовий ряд.*

Модель системи управління розвитком дефекту статора турбогенератора

Ольга Мазуренко, Самсонов Валерій, Загоровська Лариса

Національний університет харчових технологій, Київ, Україна

Вступ. Виконати повний перелік рекомендацій щодо нескінченно тривалого збереження абсолютно справного стану технічного об'єкта, в тому числі і

——— *Abstract* ———

турбогенератора, є неможливим в принципі в зв'язку з його складністю. Тому для забезпечення роботи складних технічних об'єктів доцільно використовувати системи контролю робочих параметрів, діагностики технічного стану, управління роботою та захисту.

Матеріали та методи. За допомогою CASE-технологій проаналізована діюча модель зв'язків між автоматизованими системами контролю параметрів роботи захисту та керування роботою турбогенератора. Досліджені принципи роботи та інформативний зв'язок між системою контролю робочих параметрів і релейного захисту, між автоматизованими системами діагностики і управління роботою турбогенератора, релейним захистом і системою управління роботою турбогенератора.

Результати і обговорення. На інформаційному рівні системи контролю параметрів роботи і релейного захисту турбогенератора тісно пов'язані між собою. У випадку, коли системи захисту, діагностики та управління інформативно не пов'язані між собою, у разі виникнення дефекту і не здатності людини вірно реагувати на його появу, технічний стан турбогенератора може сягнути граничного рівня. У цьому випадку наслідки розвитку дефекту будуть максимально негативні. У разі утворення дефекту першочерговий, спільним завданням для систем контролю параметрів, діагностики та управління роботою турбогенератора стає якомога швидке виявлення дефекту і здійснення необхідних заходів. Тому функціонування цих систем окремо один від одного не доцільно, оскільки з їх використанням вирішується спільне завдання. З викладеного випливає, що система управління розвитком дефекту поєднує між собою роботу систем контролю параметрів, діагностики, управління роботою і захисту турбогенератора. Максимальна тривалість «пасивного» існування системи управління розвитком дефекту, визначається проміжком часу між виявленням дефекту і спрацюванням захисних пристроїв.

Висновок. Запропонована модель системи управління розвитком дефекту вузлів турбогенератора за рахунок підсилення інформаційних та функціональних зв'язків між системами контролю робочих параметрів, захисту та управління роботою турбогенератора яка дозволяє підвищити ефективність використання цих систем.

Ключові слова: *турбогенератор, дефект, контроль, діагностика, реле, захист.*

Безпека життєдіяльності

Причини виникнення пожеж на підприємствах харчової промисловості

Ольга Слободян, Віра Заєць, Лариса Нещадим, Світлана Авдієнко

Національний університет харчових технологій, Київ, Україна

Вступ. Дослідження причин виникнення пожеж на підприємствах харчової промисловості України дозволить розробити ефективні заходи щодо зниження ймовірності їх виникнення.

Матеріали і методи. В роботі застосовувались теоретичні методи дослідження, зокрема аналіз наукових літературних даних з означеної проблеми, методи синтезу, порівняння та узагальнення отриманих даних щодо факторів, що сприяють підвищенню рівня пожежної небезпеки промислових об'єктів України.

Результати і обговорення. Аналіз пожеж в різних галузях харчової промисловості свідчить про те, що найбільш ймовірними їх причинами є: порушення

правил улаштування і експлуатації електроустановок, необережне поводження з вогнем, порушення режимів технологічних процесів (особливо при випічці, обжарюванні, сушінні), несправність або застаріле устаткування, неправильне поводження з легкозаймистими рідинами та порушення правил і термінів прибирання горючого пилу. Ці фактори посилюються тим, що на даних підприємствах зберігаються, транспортуються або використовуються речовини, які за певних умов здатні горіти та вибухати. Серед таких речовин – спирти, ефіри, есенції, органічні кислоти, бензин, ацетон та ін.; пил багатьох харчових продуктів (борошняний, цукровий, тютюновий, чайний, крохмальний, какао, сухе молоко та інші); аміак, який використовується в якості холодоагента. Також на підприємствах харчової промисловості використовується велика кількість горючої тари та матеріалів, що посилює пожежну небезпеку об'єкта.

Відповідно до зазначених причин пожеж обгрунтовано основні заходи щодо їх уникнення: дотримання загальних вимог пожежної безпеки, запобігання утворенню горючого середовища та виникненню в ньому джерел запалювання, посилення контролю за станом технологічного устаткування та контрольно-вимірювальної апаратури.

Висновки. Результати досліджень можуть бути використані при розробці та удосконаленні ефективних заходів щодо забезпечення пожежної безпеки підприємств харчової промисловості.

Ключові слова: *пожежа, горіння, самозаймання, пожежонебезпека, вибухонебезпека.*

Математична модель прийняття рішень з урахуванням ризиків травмування

Ольга Євтушенко, Алина Сірик, Петро Породько
Національний університет харчових технологій

Вступ. З метою удосконалення математичної моделі прийняття рішень в системі управління охороною праці підприємства було встановлено, що при розробці методичного забезпечення системи підтримки прийняття рішень необхідно створити процедуру адаптації засобів прийняття рішень.

Матеріали і методи. Дослідження проведене на основі загального системного підходу, що грунтується на взаємозв'язку елементів; використано метод логіко-імітаційного моделювання та метод «дерева відмов».

Результати та обговорення. Ризикована альтернатива – захід з охорони праці пов'язаний з модернізацією обладнання і оцінюється розподілом: вигода (дохід) розміром а з імовірністю q; збиток розміром b з імовірністю 1 – q. Величини а і b можуть бути обрані довільними, але їх порядок повинен відповідати засобам, якими оперує спеціаліст з охорони праці в процесі прийняття рішень. При цьому b відповідає значенню вигідності, яка дорівнює нулю, а а – одиниці. Але крім неї в розпорядженні у працівника, що приймає рішення в СУОП на підприємстві, є й інша альтернатива – стратегія, яка не пов'язана з ризиком і дає гарантований дохід розміром х.

Математичне очікування доходу при реалізації запропонованого заходу з охорони праці пов'язане з підвищенням продуктивності праці, якості продукції, зменшенням витрат на виплати, ризик травмування знизиться, і залежить від величини q при фіксованих значеннях а і b. Властивості функції вигоди для працівника, що приймає ризиковані рішення в СУОП, грунтуються на наступному:

—— *Abstract* ——

працівник схильний до ризику у випадку, якщо графік має вигнуту вгору функцію вигоди; при зростанні функцій вигоди працівник схильний до ризику тоді, коли його детермінований еквівалент для будь-якої альтернативи більше очікуваної вигоди, x° > M [X]; при зростанні функцій вигоди працівник схильний до ризику, коли надбавка за нього буде негативною при всіх альтернативах, $\Delta R(X) < 0$.

Висновки. Функція несхильності до ризику, має наступні властивості: дві функції вигоди стратегічно еквівалентні тільки тоді, коли вони ведуть до однієї і тієї ж функції несхильності до ризику, а найбільш ймовірна вигода від прийнятого рішення з охорони праці при $k \rightarrow 0$ наближається до математичного очікування вигоди від дій працівника, нейтрального до ризику, при $k \rightarrow -\infty$ математичне очікування вигоди наближається до максимально можливого.

Ключові слова: *безпека, праця, травматизм, ризик.*

Вплив конструктивних особливостей гідроциклонного апарату на процесс освітлення пивного сусла

Леся Марцинкевич[1], Максим Шпак[1], Сергій Удодов[1], Дмитро Риндюк[1,2]

1 - Національний університет харчових технологій, Київ, Україна
2 - Національний технічний університет України «Київський політехнічний інститут», Київ, Україна

Вступ. З метою підвищення якості освітлення пивного сусла та скорочення часу проходження процесу проведено дослідження процесу осадження завислих речових у робочому об'ємі гідроциклонного апарату (вірпула).

Матеріали та методи. Дослідження процеса освітлення пивного сусла здійснювалося за допомогою програмного комплексу, заснований на методі кінцевих об'ємів та призначений для моделювання тримірних течій рідин та газу у технічних та природніх об'єктах, а також візуалізації цих течій методами комп'ютерної графіки. Дослідження проводилося на наступних моделях гидроциклоного апарата: с класичною формою днища (плоске), конічною вставкою, двома циліндричними вставками та подачею сусла на кожні із вставок, з конічним днищем та радіальними направляючими вставками.

Результати і обговорення. Сусло у гідроциклонному апараті набуває обертального руху, яке забезпечується тангенційно встановленим патрубком подачі продукта. Утворений вихревий потік сприяє тому, що частинки осідають, утворюючи тарілку білкового осаду. Важливу роль в процесі освітлення відіграє швидкість подачі сусла у апарат, тобто швидкість на виході з сопла вхідного патрубка. Якщо швидкість перевищує 3,5 м/с, то продукт зазнає значних дотичних напружень, що призводить до утворення дрібнодисперсних частинок, які у гідроциклонному апараті не осідають. Також було досліджено дотичні напруження τ, які утворюються у суслі під час його подачі. При перевищенні значення $\tau \geq 50$ Па починається руйнування частинок білкового осаду.

Висновки. Результати досліджень обгрунтовують доцільність подання рекомендацій для впровадження у виробництво гідроциклонного апарату з радіальними направляючими вставками. Це дасть можливість скоротити час проходження процесу та покращити якість пивного сусла.

Ключові слова: *гідроциклон, вірпул, пивне сусло, освітлення.*

Економіка і управління

Методичні підходи до визначення внутрішньовиробничих цін на підприємствах м'ясопереробної галузі

Ірина Федулова, Аліна Драган

Національний університет харчових технологій, Київ, Україна

Вступ. Розглядаються питання застосування нових підходів при визначенні внутрішньовиробничих цін на м'ясну продукцію.

Матеріали і методи дослідження. У роботі застосовуються методи: системного аналізу в питаннях трансфертного ціноутворення та використання його в практичній діяльності підприємства; аналізу і синтезу − для розрахунку трансфертної ціни на м'ясо; аналогії і зіставлення − для визначення внутрішньовиробничих цін на субпродукти на підставі об'єднання вартісної концепції і концепції енергетичної цінності.

Результати та обговорення. З огляду на специфіку виробництва м'ясної продукції і підвищення відповідальності за фінансово-економічні показники кожного виробничого підрозділу підприємства, виникає проблема щодо визначення внутрішньовиробничих цін на продукцію, яка виготовляється і передається, як сировина, в інші підрозділи. Мясожіровой цех виробляє готову продукцію − м'ясо (яловичину, свинину), які передаються в ковбасний, консервний цехи м'ясокомбінатів.

Запропоновано три варіанти методів визначення внутрішньовиробничих цін на основі трансфертного ціноутворення в залежності від виробничої структури підприємства: при безцеховій виробничій структурі − за виробничою собівартістю продукції; при цеховій − за виробничою собівартістю плюс прибуток (за рівнем рентабельності); при заводській − по загальних витратах плюс прибуток (за рівнем рентабельності).

Невирішеним питанням залишається визначення виробничої собівартості на супутню продукцію (субпродукти). Пропонується для визначення виробничої собівартості застосувати методику поєднання двох концепцій вартісної для розрахунку виробничої собівартості яловичини і енергетичної цінності яловичих субпродуктів у співвідношенні з енергетичною цінністю яловичини. Визначення виробничої собівартості на субпродукти можна розрахувати на основі: енергетичної цінності (калорійності) або споживчої цінності (рівень вмісту білка, жиру, вуглеводів у продукті).

Висновки. Запропоновані методичні підходи до визначення внутрішньовиробничих цін на підприємствах розраховані на зниження оптових цін на м'ясну продукцію, що сприятиме формуванню ефективної цінової політики і поліпшенню реалізації продукції.

Ключові слова: *ціна, ціноутворення, продукція, підприємство.*

Використання досвіду в управлінні спиртовою промисловістю України

Людмила Шевченко

Національний університет харчових технологій, Київ, Україна

—— *Abstract* ——

Вступ. Дане дослідження присвячено вирішенню проблеми обмеженості ринку для українського етилового спирту. Євроінтеграція та застосування зарубіжного досвіду та впровадження окремих аспектів і положень Європейської стандартизації може мати позитивний вплив, а саме можливість виходу на нові ринки збуту та можливість диверсифікувати методи отримання прибутку.

Матеріали та методи. Для дослідження проблеми, ми використовували теоретичний метод для аналізу понятійної бази. Використовуючи метод статистичного аналізу іноземних торгових партнерів України в 2015 році, ми проаналізували співвідношення експортних операцій по регіонах України. Використовуючи методи прогнозування і моделювання, ми можемо передбачити позитивний ефект від диверсифікації ринків збуту.

Результати. Європейська інтеграція надає Україні отримати преференційний доступ на найбільший ринок у світі з 500 млн. клієнтів та із ВВП на рівні 14 трлн євро. Це може допомогти Україні посісти стабільну позицію експортера етилового спирту і спиртовмісних рідин.

Для цього необхідна повна реформа галузі. Під час вивчення потреб європейського ринку визначилась необхідність виробництва спирту з концентрацією менш як 80 об.,%. ДП «Укрспирт» має можливість отримати тарифні квоти, які діють за принципом "перший прийшов, перший отримав" на експорт. У 2016 році ДП «Укрспирт» зможе експортувати 27 тис тонн спирту та інших спиртовмісних рідин по коду 2207 та 2208. Найбільш важливим аспектом для ДП «Укрспирт» є отримання ліцензії по коду 2208 на постачання спирту з концентрацією менш як 80 об.,% в європейські країни. Наступним кроком необхідно визначити кількість заводів, які знаходяться ближче до західного кордону України з метою скорочення витрат на логістику. Таким чином, ці заводи повинні бути реконструйовані, для забезпечення конкурентоспроможності продукції. Необхідно впровадити енергоефективні технології та обладнання, які знизять споживання палива на 30%. Ці заходи охоплять потреби європейського ринку в спирті і нададуть можливість диверсифікувати виробництво ДП «Укрспирт» і збільшити обсяг запланованих і реальних прибутків.

Висновок. Застосовуючи іноземний досвід можливо додатково залучити 20-30% потужностей українських спиртових заводів і як наслідок збільшити надходження валютних коштів в розмірі близько 15 млн. доларів США. Таким чином, можливо відродження спиртової галузі через диверсифікацію ринків збуту.

Ключові слова: *ринок, спирт, управління.*

Аграрний сектор України: огляд переваг і способів поліпшення негативних сторін

Омельченко Ксенія

Національний університет харчових технологій, Київ, Україна

Вступ. Дослідження є об'єктивним, щоб проаналізувати стан аграрного сектора України, з'ясувати слабкі і сильні сторони галузі і запропонувати шляхи підвищення ефективності його роботи.

Матеріали та методи. Такі методи, як: екстраполяції, наукової абстракції, синтезу, аналізу, порівняння та дедуктивного методу були використані в статті. Для аналізу були використані уточнення основних переваг і недоліків реформ в агропромисловому комплексі. Були визначені основні напрямки реалізації земельної реформи.

Результати та обговорення. Понад дві третини (71,2%) від загальної площі земель України є землями сільськогосподарського призначення, в порівнянні з лише 13,2% в Росії і 44,3% в ЄС. Орні землі в Україні складають 32,5 мільйона гектарів, що складає найбільшу площу в Європі після Росії і становить 56,1% від загальної площі земель. Це найвищий відсоток у Європі після Данії. Близько 80 відсотків сільськогосподарських площ України є землями сільськогосподарського призначення, дві третини яких багаті чорноземом. Первинні харчові продукти врожаю в Україні ячмінь, кукурудза, картопля, соєві боби, цукровий буряк, і пшениця.

Основні проблеми, які ми можемо визначити в секторі є кредитні проблеми, проблеми зайнятості, недоліки механізмів державного регулювання розвитку аграрного сектора економіки України, інвестиційного клімату, майнових прав, корупції, застарілої техніки і недостатньої технічної бази на фермах для зберігання продукції, усадки поголів'я худоби, формування і ефективне використання фізичного капіталу в сільськогосподарських підприємствах у ринкових умовах, відсутність повної реалізації аграрних реформ, складна, постійно змінювана сітка оподаткування в країні. Теоретично кажучи, розумна земельна реформа в Україні може призвести до сільськогосподарського буму в країні і держава може стати «житницею Європи».

Уряд України встановив цілі аграрної реформи. Так, були визначені п'ять основних напрямків: Земельна реформа і реформа відносин власності в АПК; створення нових господарюючих суб'єктів на основі колективних сільськогосподарських підприємств, що використовують приватну власність і власність на землю; формування ринкової інфраструктури в АПК; модернізація виробництва, створення конкурентоспроможних сільськогосподарських підприємств; удосконалення механізмів державного регулювання в сільськогосподарському секторі. Державна підтримка може бути структурована в чотирьох великих блоках: звільнення від ПДВ для сільськогосподарського виробництва, прямих субсидій, загальних послугах і фіксованого сільськогосподарського податку.

Висновки. Подальший прогрес, який спрямований на підвищення ефективності сільського господарства України, вимагає постійної поступової реструктуризації сільськогосподарських підприємств на більш дрібні автономні одиниці, які будуть засновані на приватній власності на землю і майно, з чіткого сформульованими процедурами, які дозволяють особам і невеликим групам людей з часткою землі і активів існувати. Так само важливо освоєння земель і ринків збуту з метою створення функціонуючої ринкової інфраструктури для надання конкурентних маркетингових і фінансових послуг в цій сфері.

Клочові слова: *АПК, реформування, ринок, земля.*

Процеси та обладнання харчових виробництв

Процес сушіння паперу для гофрування (флютинга) із застосуванням енергії випромінювання

Віктор Марчевський, Олег Новохат, Олексій Цепкало

Національний технічний університет України
«Київський політехнічний інститут», Київ, Україна

Вступ. Зростаючий попит ринку в гофротарі вимагає збільшення виробництва флютинга, що лімітується процесом сушіння. Тому інтенсифікація сушіння шляхом використання нових джерел тепла та зменшення викидів в атмосферу є актуальною проблемою.

Матеріали та методи. Предметом дослідження є процес сушіння флютингу із застосуванням інфрачервоного випромінювання. Об'єктом дослідження є кінетика процесу сушіння флютингу із застосуванням інфрачервоного випромінювання. Експерименти проведені на зразках флютингу марок Б-0, Б-1 та Б-2 згідно технічних умов України ТУ У 21.1-31812534-023:2009 (112, 125 та 140 г/м^2), а також на зразках з нестандартного флютингу зі збільшеною масою квадратного метру 200 г/м^2. Використані методи математичного моделювання та експериментальні дослідження на комп'ютеризованій дослідній установці, використана статистична обробка отриманих результатів.

Результати та обговорення. Експериментальні криві сушіння та основні параметри процесу з достатньою точністю апроксимуються запропонованим математичним описанням. Середньоквадратичні відхилення розрахункових та експериментальних значень вологовмісту не перевищу 0,04 кг/кг, що дозволяє здійснювати розрахунки сушіння флютинга при густині теплового потоку до 35 кВт/м^2.

Із збільшенням густини променевих теплових потоків від 2 кВт/м^2 до 35 кВт/м^2 загальний час сушіння флютинга зменшується більше, ніж в 20 разів.

Максимальна величина густини теплового потоку обмежена зростанням температури поверхні флютинга 150 °C в першому періоді. Тому при густині теплового потоку більше 35 кВт/м^2 процес сушіння флютинга слід здійснювати лише до кінця першого періоду, тривалість якого збільшується зі збільшення густини теплового потоку.

Висновки. Кінетичні закономірності і основні параметри процесу сушіння флютинга із застосуванням інфрачервоного випромінювання, що отримані в роботі, дозволять виконувати розрахунки, необхідні для проектування промислових процесів сушіння флютингу та ефективного обладнання для їх здійснення.

Ключові слова: *інфрачервоне випромінювання, сушіння, флютинг, вологовміст.*

Одночасний розрахунок нестаціонарного розподілу температур в системі комірок: «більший кристал цукру–розчин сахарози більшого кристалу–менший кристал цукру–розчин сахарози меншого кристалу–утфель» та концентрацій сахарози в комірках міжкристальних розчинів цієї ж системи в залежності від часу уварювання цукрового утфелю

Тарас Погорілий
Національний університет харчових технологій, Київ, Україна

Вступ. В даній роботі реалізовано один із наступних етапів створення математичної моделі процесу кристалізації сахарози.

Матеріали та методи. Для одночасного розв'язання системи із 7 нестаціонарних задач теплопровідності по кожній окремій області зі сталими та зі змінними теплофізичними коефіцієнтами, а також трьох окремих нестаціонарних задач дифузійного масообміну для чотирьох областей міжкристального розчину сахарози зі сталими та зі змінними коефіцієнтами дифузійного масообміну застосовано чисельні методи (метод контрольного об'єму).

Результати і обговорення. Для десяти випадків відносного часу уварювання цукрового утфелю τ/τ_ц (τ/τ_ц = 0,15; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9; 1,0) на основі розв'язку системи нестаціонарних диференціальних рівнянь в частинних похідних параболічного типу знайдено розподіл температур в кожній області системи комірок. При відносному часі уварювання цукрового утфеля τ/τ_ц = 0,15 температури дорівнюють: для лівої області міжкристального розчину сахарози більшого кристалу 99,547 °C при сталих коефіцієнтах та 99,479 °C при всіх змінних коефіцієнтах; для більшого кристалу цукру 94,799 °C при сталих коефіцієнтах та 94,409 °C при всіх змінних коефіцієнтах; для правої області міжкристального розчину сахарози більшого кристалу 90,234 °C при сталих коефіцієнтах та 89,640 °C при всіх змінних коефіцієнтах; для лівої області міжкристального розчину сахарози меншого кристалу 89,485 °C при сталих коефіцієнтах та 88,820 °C при всіх змінних коефіцієнтах; для меншого кристалу цукру 87,325 °C при сталих коефіцієнтах та 86,630 °C при всіх змінних коефіцієнтах; для правої області міжкристального розчину сахарози меншого кристалу 85,285 °C при сталих коефіцієнтах та 84,590 °C при всіх змінних коефіцієнтах; для утфелю 75,107 °C при сталих коефіцієнтах та 75,098 °C при всіх змінних коефіцієнтах. Одночасно з цим знайдено розподіл концентрацій в кожній області міжкристального розчину сахарози розглядуваної системи комірок. При відносному часі уварювання цукрового утфелюτ/τ_ц = 0,15 концентрації дорівнюють: для лівої області міжкристального розчину сахарози більшого кристалу 82,710% при сталих коефіцієнтах та 82,274% при всіх змінних коефіцієнтах; для правої області міжкристального розчину сахарози більшого кристалу 80,400% при сталих коефіцієнтах та 79,893% при всіх змінних коефіцієнтах; для лівої області міжкристального розчину сахарози меншого кристалу 80,269% при сталих коефіцієнтах та 79,765% при всіх змінних коефіцієнтах; для правої області міжкристального розчину сахарози меншого кристалу кристалу 79,418% при сталих коефіцієнтах та 79,026% при всіх змінних коефіцієнтах.

Висновки. Отримано одночасний нестаціонарний розподіл температур в семи одновимірних областях, що представляють об'ємну систему комірок «більший кристал цукру–розчин сахарози більшого кристалу–менший кристал цукру–розчин сахарози меншого кристалу–утфель» та нестаціонарний розподіл концентрацій в чотирьох областях міжкристальних розчинів сахарози цієї системи комірок.

Ключові слова: *температура, концентрація, комірка, розчин, кристал, утфіль.*

Теоретичне обґрунтування можливості інтенсифікації і ресурсозбереження процесу кондуктивного жарення м'ясних натуральних виробів

Вячеслав Скрипник

Полтавський університет економіки і торгівлі, Полтава, Україна

Вступ. Процес кондуктивного жарення м'ясних натуральних виробів є енерго- і ресурсовитратним. Теоретично розглянуті можливості інтенсифікації і ресурсозбереження процесу.

Матеріали та методи. Використовувався аналітичний метод дослідження опублікованих експериментальних і теоретичних даних.

Результати і обговорення. Для підвищення енергетичної ефективності і ресурсозбереження процесу кондуктивного жарення м'ясних натуральних виробів

──── *Abstract* ────

розглянуто можливі фактори інтенсифікації. Підвищення температурного рівню процесу понад 423 К не бажане через утворення в поверхневому шарі виробу гетероциклічних амінів. Інтенсифікація процесу стає можливою у разі двостороннього підведення теплоти і використання фізичних і електрофізичних методів впливу на сировину.

Дія тиску або електричного струму змінної частоти в процесі кондуктивного жарення призводить до утворення в м'ясі ефективного шару, меншого за початкову товщину напівфабрикату, з теплопровідними властивостями рідини.

Використання функціонально замкненого об'єму в процесі двостороннього жарення м'яса з високим вмістом сполучної тканини під тиском на рівні граничного для цього м'яса дозволяє зберегти нативну вологу, кількості якої достатньо для гідролізу колагену в необхідній мірі. Процес двостороннього жарення м'яса під дією фізичних і електрофізичних методів за тривалістю запропоновано поділити на три основні стадії.

Найбільш значимою в загальних енергетичних витратах є друга, при якій теплота передається через поверхневий шар м'яса внаслідок фазових перетворень водяної пари, що утворюється завдяки виведенню вологи в поверхневі шари продукту до поверхонь жарення. Обґрунтовано аналітичну модель процесу.

Висновки. Вперше обґрунтовано фактори інтенсифікації, аналітичну модель процесу кондуктивного жарення м'ясних натуральних виробів, в т.ч. і з високим вмістом сполучної тканини.

Ключові слова: *жарення, кондукція, м'ясо, тиск, електричний струм.*

Математична модель процесу сушіння плодових часток

Дмитро Коломієць, Тетяна Роман, Лілія Харченко,
Марія Ротай, Олександр Мазуренко
Національний університет харчових технологій, Київ, Україна

Вступ. Для оптимізації параметрів сушіння й отримання готової продукції високої якості важливо мати достовірну математичну модель тепломасообміну в шарі висушуваного продукту.

Матеріали і методи. На основі аналізу відомих багаточисельних математичних моделей, представлених дослідниками у вигляді рівнянь регресії експериментальних даних, вирішували спрощену задачу внутрішнього вологопереносу для різних окремих випадків, поєднуючи при цьому загальну теорію з більш простими, частинними моделями процесів сушіння вологих матеріалів.

Результати і обговорення. При розробці моделі сушіння плодових продуктів у м'яких режимах за основу було прийнято одне з найбільш простих припущень про кінетику процесу сушіння - рідина всередині пористої структури переміщується відносно вільно, випаровування рідини здійснюється тільки з зовнішньої поверхні тіла, а волога, що вилучається протягом процесу сушіння, підводиться до поверхні випаровування з внутрішніх зон матеріалу при малому градієнті вологовмісту. Це надало можливість розробити математичну модель у вигляді диференційних рівнянь збереження вологи, теплоти та зміни фільтраційного потенціалу переносу, які описують, відповідно, нестаціонарні поля вологовмісту, температури та загального тиску капілярно-пористого тіла при сталих коефіцієнтах переносу.

На основі відомих математичних моделей сушіння вологих матеріалів у тонкому шарі продукту та використання положень сучасної теорії внутрішнього

масопереносу, що базується на понятті єдиного потенціалу переносу вологи, для шару продукту у формі необмеженої пластини було вирішено рівняння переміщення границі розділу вологе тіло – простір сушіння у м'ягких режимах сушіння. За таких умов сушіння переносом вологи за рахунок градієнта тиску можна знехтувати, тому за вибраних граничних умов, вирішували задачу Стефана для сумісних процесів переносу вологи і теплоти всередині вологого матеріалу при сушінні, тобто крайову задачу для системи двох диференціальних рівнянь другого порядку. Результати розрахунку переміщення границі розділу вологе тіло – простір сушіння за запропонованою моделлю задовільно узгоджуються з результатами експериментального дослідження.

Висновки. Використання розробленої моделі сушіння плодових часток покращить якість як регулювання процесу сушіння, так і готового продукту.

Ключові слова: *сушіння, плід, тепломасоперенос, модель.*

—— *Abstract* ——

Аннотации

Пищевые технологии

Влияние модифицированных крахмалов на состояние воды в бисквита

Ирина Стрилец

Национальный университет пищевых технологий

Введение. В данной работе изучено влияние модифицированных крахмалов холодного набухания на перераспределение влаги в бисквитах. С целью прогнозирования процесса хранения изделий исследовали их сорбционные свойства.

Материалы и методы. Количество свободной и связанной влаги рассчитывали при помощи дериватографического анализа с учетом возникновения послойного прогрева изделий. Сорбционно-десорбционные свойства изделий исследовали по традиционной методике в вакуумном приборе Мак-Бена при 20 ℃. В качестве адсорбтива использовали водяной пар.

Результаты и обсуждение. Изучено влияние сшитых видов модифицированного крахмала холодного набухания: гидроксипропил дикрохмальфосфата (Microlys FH 02), ацетилированного дикрохмальфосфата (Swely Gel Soft), ацетилированного крахмала адипата (Cold Swell 5771) на перераспределение влаги в бисквитах.

Исследования показали, что благодаря своему разветвленному пространственному строению, модифицированный крахмал холодного набухания способен быстро связывать и удерживать воду. Добавление 1% крахмала к муке способствует увеличению количества связанной воды в продукте на 7.17...13,23%.

Сорбционные свойства бисквитов с добавлением модифицированного крахмала значительно улучшились. Благодаря взаимодействию крахмала с компонентами муки и образованию более прочных связей с водой, общее количество сорбированной воды для изделий с модифицированным крахмалом увеличилась на 3,14 см^3 / 100г для «Cold Swell 5771», на 5,67 см^3 / 100 г для «Swely Gel Soft» и на 18, 97 см^3 / 100 г для «Microlys FH02».

Выводы. Модифицированный крахмал холодного набухания положительно влияет на перераспределение влаги в бисквитах, что улучшит срок сохранения свежести изделий.

Ключевые слова: *бисквит, крахмал, влага, сорбция, свежесть.*

Определение антиоксидантной активности сухих веществ экстрактов из подсолнечного жмыха

Дмитрий Добрунов, Леонид Перевалов, Елена Пивень

1 − Национальный технический университет «Харьковский политехнический институт»

Введение. Данная работа посвящена определению антиоксидантной эффективности сухих веществ экстрактов подсолнечного жмыха (из безлузгового ядра), полученных с использованием кавитационной установки.

Материалы и методы. Семена подсолнечника (сорта НК-Брио) охлаждались жидким азотом и обрушивались. Безлузговое ядро отпрессовывалось на экструдере.

Жмых обрабатывался в кавитационной установке (с использованием растворителей − гексана и этилового спирта). После отгонки растворителя, получили 4 образца «Сухих веществ экстрактов из подсолнечного жмыха» (СВЭПЖ).

Результаты и обсуждение. Так как природа антиоксидантов в СВЭПЖ была неизвестна, авторы могли только предположить состав СВЭПЖ. Вероятнее всего, это токоферолы, хлорогеновая кислота, фосфолипиды и т.д.. Исходя из этого все расчеты концентрации ингибитора в исследуемых образцах СВЭПЖ ([InH]) проводились в перерасчете на α-токоферол (как наиболее ожидаемый антиоксидант).

Для определения антиоксидантных свойств полученных образцов СВЭПЖ была проведена серия опытов по инициированному окислению модельного углеводорода (кумола) с добавлением СВЭПЖ и без них. Полученные экспериментальные данные подтверждают наличие в СВЭПЖ веществ с антиоксидантными свойствами таких как: токоферолы, стеролы, хлорогеновая кислота и фосфолипиды. Присутствие фосфолипидов в полученных СВЭПЖ обусловлено тем, что масличность шрота (после кавитационной обработки жмыха) составила 0,9%, а количество фосфолипидов в масле составило 0,05%. Эти данные свидетельствуют о переходе большей части фосфолипидов в СВЭПЖ. Состав полученных СВЭПЖ исследовали с помощью метода ВЭЖХ.

Константы обрыва цепей (k_7) 4 исследуемых образцов СВЭПЖ варьировались в пределах $1.0 \cdot 10^5 − 1.6 \cdot 10^5$ л/моль·с. Для наиболее известного природного антиоксиданта – токоферола (k_7) варьируется в пределах $0.7 \cdot 10^5 − 3 \cdot 10^5$ л/моль·с.

Значения констант скорости обрыва цепей (k_7) показывают, что все исследуемые образцы СВЭПЖ не менее эффективные ингибиторы, чем токоферол.

Это значит, что все полученные образцы СВЭПЖ являются ингибиторами окисления и тормозят реакцию продолжения цепей.

Выводы. СВЭПЖ могут быть использованы для торможения окислительной порчи жиросодержащих изделий и увеличения срока их хранения.

Ключевые слова: *антиоксиданты, подсолнечник, кавитация, гексан, этанол.*

Повышение эффективности сухих белковых препаратов гидратированных электроактивованою водой

Людмила Винникова, Ксения Пронькина, Андрей Кишеня

Одесская национальная академия пищевых технологий, Одесса, Украина

Введение. В условиях современного производства мясных продуктов существует проблема качества сырья. Разработка технологий производства мясных продуктов с использованием белковых добавок является перспективным и экономически выгодным направлением.

Материалы и методы. Исследованы сухие белковые препараты различного происхождения: белок из свиной кожи Progel C-95, Supro 500E – соевый белок. Определяли основные функционально-технологические свойства белковых препаратов при их гидратации фракциями электроактированной воды.

Результаты и обсуждение. Изменение pH среды гидратации сухих белковых препаратов в щелочную сторону при помощи католита позволила повысить вязкость образцов добавок, но наиболее эффективно это произошло у белкового препарата растительного происхождения Supro 500E . Вязкость этого препарата была на 35% больше чем у контрольного образца.

——— *Abstract* ———

Определение влагоудерживающей и жироудерживающей способности добавок показало наибольшую эффективность использования католита в добавке животного происхождения Progel C-95, которые составляли соответственно 95% и 42%.

Использование католита для гидратации позволило повысить эмульсионную способность и стабильность эмульсии наиболее эффективно в образцах белковой добавки животного происхождения Progel C-95. В сравнении с контрольным образцом стабильность эмульсии повысилась на 8%.

Одним из показателей экономической эффективности использования сухих белковых препаратов является критическая концентрация гелеобразования. Эффективности использования добавок обратнопропорциональна показателю критической концентрации гелеобразования. В общем, использование католита снизило этот показатель во всех препаратах, но у образца добавки из свиной шкурки Progel C-95 этот показатель достиг минимального значения и составил 5%.

Выводы. Предложенный способ повышения функционально-технологических свойств сухих белковых препаратов с помощью щелочной фракции электроактированной воды доказывает свою эффективность. Лучшие результаты повышения эффективности добавок отмечено по ряду показателей в препарате животного происхождения Progel C-95.

Ключевые слова: *добавка, электроактированной вода, католит, анолит, мясо.*

Влияние способа консервирования фруктов и овощей на их структурно-механические свойства

Наталия Орлова, Игорь Кузьменко, Роман Романенко

Киевский национальный университет экономики и торговли, Украина

Введение. Для плодоовощных консервов важна сохраненная форма и упругая консистенция компонентов. Задача исследования состоит в установлении наиболее эффективного способа консервирования плодов и овощей, путем сопоставления значение твердости тканевой структуры исследуемых образцов плодов и овощей консервированных разными способами.

Материалы и методы. Анализировали плоды тыквы, айвы, кабачка и алычи консервированные разными способами. Определяли постоянное усилие пенетрации тканевой структуры цилиндрическим игольчатым индентором с диаметром иглы (d) 1,4 мм, что проникает в исследуемый образец со скоростью 3,45 мм/с на глубину 7 мм.

Результаты и обсуждение. Цифровое значение предела прочности тканей консервированной тыквы опытного образца составило 1300-1500 Мн/мм^2, что втрое превысило значение контрольного, а айвы - почти в 2 раза выше контрольного образца. Величина предела прочности консервированных кабачков и алычи для опытных образцов в среднем в 1,8-2 раза превысила эти же показатели для контрольных образцов. Различия в значении предела прочности структуры плодов и овощей контрольных образцов консервов относительно опытных вызванные более высокой и длительной термической обработкой контрольных образцов, что предусматривает классическая технологическая инструкция.

Результаты экспериментальных исследований прочности тканей сопоставлены с балловой оценкой органолептических показателей, в частности и оценки консистенции. Опытные образцы кабачково-алычевых и тыквенно-айвовых консервов получили 4,81 и 4,79 баллов соответственно, контрольные образцы 3,25 и 3,48

соответственно. Консистенцию исследовательских и контрольных образцов сравнили также описательным (дескриптивным) методом. Опытные образцы отличались хорошо сохранившейся формой, упругой неразваренной консистенцией кусочков по сравнению с контролем. Консистенцию контрольных образцов характеризировали дескрипторы "Рыхлая, плодовая кожура отстает от мякоти", "Мягкая, разваренная". То есть уксусная кислота, добавлена в контрольные образцы, не дала ожидаемого эффекта по поводу упругости тканей плодов и овощей и сохранения их формы.

Выводы. Установлено, что применение усовершенствованного способа консервирования имеет положительный эффект и способствует сохранению внешнего вида, формы кусочков продукта и формирование более упругой его консистенции.

Ключевые слова: *консерва, термообработка, пенетрация, твердость, прочность, консистенция.*

Автоматизация технологических процессов

Определение глубины гибкости технологической системы

Иващук Вячеслав, Ладанюк Анатолий
Национальный университет пищевых технологий, Киев, Украина

Введение. При изменении ассортимента продуктов производственной линии специалисты стараются максимально использовать мощности и ресурсы предприятия, для увеличения совокупного дохода.

Материалы и методы. Исследуется рекурсия характеристик типовых технологических процессов, которые рассчитаны на многоассортиментное производство, в технологические параметры и режимы работы оборудования. Для получения проекций характеристик потребителя в необходимую глубину вариаций технических характеристик используем методику структуризации развертывания функции качества потребителя. Для оценки необходимых вариаций переменных при целевом изменении выбранной характеристики воспользуемся диаграммой Парето. Для оценки возможных реализаций управления используем функциональный анализ. Для локализации необходимых управляющих действий используем метод многократной последовательной классификации. Для оценки необходимой глубины технологической гибкости используем матричный анализ.

Результаты и обсуждение. Критерием эффективной глубины ассортимента определяется чистая прибыль от потерь для изменения параметров процесса. Прибыль от инвестиций эффективно оценивается по количеству заказов, которые рассчитываются на определенное «время жизни» продукта. Инициализация гибкости классифицируется по эксплуатационным требованиям, в соответствии с терминальными планами, аварийными ситуациями, характеристиками сырья.

Эффективность введения гибкости ставится в соответствие с результатами анализа кумулятивной диаграммы Парето, отвечающий за вариацию первопричин изменения целевых характеристик продукта. На примере распылительной сушилки указано, что решение проблем по трем координатам процесса может отвечать за 70% общей эффективности производства. Предварительно полученные альтернативные конфигурации гибких систем количественно оцениваются необходимой производительностью. Гибкость технологического процесса ограничивается степенью

свободы - количеством координат технологического процесса и пределами, определяющих соответствующие изменения характеристик продуктов. Лимиты гибкости технологических процессов ограничиваются мощностями оборудования и объемами ресурсов перерабатываемых материалов.

Выводы. Полученные оценки гибкости процесса позволяют осуществить внедрение перспективной программы производства, оптимизацию технологических маршрутов и минимизацию проектных затрат при создании ассортимента продуктов.

Ключевые слова: *гибкость, процесс, ассортимент, эффективность.*

Фрактальный анализ временных рядов функционирования брагоректификационной установки в задачах прогнозирования и управления

Наталия Новаковская, Василий Кишенько

Национальный университет пищевых технологий, Киев, Украина

Введение. Поведение брагоректификационной установки как объекта управления характеризуется наличием проявлений стохасичности и хаотичности, что требует их идентификации методами нелинейной динамики для организации специфических соответствующих стратегий управления.

Материалы и методы. Для решения задач прогнозирования и управления брагоректификационной установкой были использованы методы синергетики и теории детерминированного хаоса. Анализ временных рядов проводился с помощью алгоритма нормированного размаха Херста, метода покрытия и корреляционных методов. Временные ряды обрабатываются с помощью программного пакета FRACTAN.

Результаты и обсуждение. Исследование временных рядов брагоректификационной установки показало, что процессы брагоректификации характеризуются наличием как стохастических, так и хаотических режимов, размерность аттракторов которых лежит в пределах от 3 до 8. Большинство из таких рядов является фракталами, то есть, несмотря на значительную нестабильность процесса, их поведение остается неизменным, что позволяет прогнозировать изменение их состояния в будущем. Показатель корреляционной энтропии указал на время, на которое можно спрогнозировать поведение нашей системы. Изменение режимов работы брагоректификационной установки проходит с разной периодичностью, достигая 4-10 часов.

Для анализа хаотичности процесса в поведении объекта мы использовали показатель корреляционной размерности, который показал, что для данного объекта свойственна значительная трендоустойчивость (персистентность), характеризующаяся высоким значением показателя Херста в пределах от 0,7 до 0,96. Предсказуемость поведения процессов брагоректификации высока, особенно для температуры, и возрастает при увеличении фрактальной размерности аттракторов, достигая десятков минут.

При фрактальной размерности менее 1.4, на систему влияет одна или несколько сил, которые движут систему в одном направлении. Если размерность около 1.5, то силы, действующие на систему, разнонаправленные, но более или менее компенсируют друг друга. Если же фрактальная размерность значительно больше 1.6, система становится неустойчивой и готова перейти в новое состояние. Анализ фрактальной размерности временного ряда давления низа бражной колонны показал, что фрактальная размерность лежит в пределах от 1.0 до 1.4, что в свою очередь указывает

на то, что на систему влияет несколько сил, которые двигают ее в одном направлении, то есть система устойчива.

Выводы. Выявленные особенности функционирования брагоректификационной установки как сложного нелинейного объекта управления дают возможность реализации ресурсосберегающих стратегий управления на основе диагностики его поведения методами фрактального анализа.

Ключевые слова: *фрактал, брагоректификация, управление, прогнозирование, временной ряд.*

Модель системы управления развитием дефекта статора турбогенератора

Ольга Мазуренко, Самсонов Валерий, Загоровская Лариса
Национальный университет пищевых технологий, Киев, Украина

Введение. Выполнить полный перечень рекомендаций по бесконечно длительному сохранению абсолютно исправного состояния технического объекта, в том числе и турбогенератора, невозможно в принципе в связи с его сложностью. Поэтому для обеспечения работы сложных технических объектов целесообразно использовать системы контроля рабочих параметров, диагностики технического состояния, управления работой и защиты.

Материалы и методы. С помощью CASE-технологий проанализирована действующая модель связей между автоматизированными системами контроля параметров работы защиты и управления работой турбогенератора. Исследованы принципы работы и информативные связи между системой контроля рабочих параметров и релейной защиты, между автоматизированными системами диагностики и управления работой турбогенератора, релейной защитой и системой управления работой турбогенератора.

Результаты и обсуждение. На информационном уровне системы контроля параметров работы и релейной защиты турбогенератора тесно связаны между собой. В случае, когда системы защиты, диагностики и управления информативно не связаны между собой, в случае возникновения дефекта и не способности человека верно отреагировать на его появление, техническое состояние турбогенератора может достичь предельного уровня. В этом случае последствия развития дефекта будут максимально негативные. В случае образования дефекта первоочередной, общей задачей для систем контроля параметров, диагностики и управления работой турбогенератора становится как можно быстрое обнаружение дефекта и осуществления необходимых мер. Поэтому функционирование этих систем в отдельности друг от друга не целесообразно, так как с их использованием решается общая задача. Из изложенного следует, что система управления развитием дефекта сочетает между собой работу систем контроля параметров, диагностики, управления работой и защиты турбогенератора. Максимальная продолжительность «пассивного» существования системы управления развитием дефекта, определяется промежутком времени между обнаружением дефекта и износом защитных устройств.

Вывод. Предложенная модель системы управления развитием дефекта узлов турбогенератора за счет усиления информационных и функциональных связей между системами контроля рабочих параметров, защиты и управления работой турбогенератора которая позволяет повысить эффективность использования этих систем.

Ключевые слова: турбогенератор, дефект, контроль, диагностика, реле, защита.

—— *Abstract* ——

Безопасность жизнедеятельности

Причины возникновения пожаров на предприятиях пищевой промышленности

Ольга Слободян, Вера Заец, Лариса Нещадим, Светлана Авдиенко

Национальный университет пищевых технологий, Киев, Украина

Введение. Исследование причин возникновения пожаров на предприятиях пищевой промышленности Украины позволит разработать эффективные меры по снижению вероятности их возникновения.

Материалы и методы: В работе использовались теоретические методы исследования, в частности анализ научных литературных данных по данной проблеме, методы синтеза, сравнения и обобщения полученной информации относительно факторов, которые способствуют повышению уровня пожарной опасности промышленных объектов Украины.

Результаты и обсуждения. Анализ пожаров в различных отраслях пищевой промышленности свидетельствует о том, что наиболее вероятными их причинами являются: нарушение правил устройства и эксплуатации электроустановок, неосторожное обращение с огнем, нарушение режимов технологических процессов (особенно при выпечке, обжаривании, сушении), неисправность или устаревшее оборудование, неправильное обращение с легковоспламеняющимися жидкостями и нарушение правил и сроков уборки горючей пыли. Эти факторы усиливаются тем, что на данных предприятиях хранятся, транспортируются или используются вещества, которые при определенных условиях способны гореть и взрываться. Среди таких веществ – спирты, эфиры, эссенции, органические кислоты, бензин, ацетон и др.; пыль многих пищевых продуктов (мучная, сахарная, табачная, чайная, крахмальная, какао, сухого молока и др.); аммиак, который используется в качестве хладоагента. Также на предприятиях пищевой промышленности используется большое количество горючей тары и материалов, что усиливает пожарную опасность объекта.

В соответствии с указанными причинами пожаров обоснованы основные меры по их предотвращению: соблюдение общих требований пожарной безопасности, предотвращение образования горючей среды и возникновения в ней источника возгорания, усиление контроля за состоянием технологического оборудования и контрольно-измерительной аппаратуры.

Выводы. Результаты исследований могут быть использованы при разработке и усовершенствовании эффективных мероприятий по обеспечению пожарной безопасности объектов пищевой промышленности.

Ключевые слова: *пожар, горение, самовозгорание, пожароопасность, взрывоопасность.*

Математическая модель принятия решений с учетом рисков травмирования

Ольга Евтушенко, Алина Сирик, Петр Породько

Национальный университет пищевых технологий

Введение. С целью усовершенствования математической модели принятия решений в системе управления охраной труда предприятия было установлено, что при

разработке методического обеспечения системы поддержки принятия решений необходимо создать процедуру адаптации средств принятия решений.

Материалы и методы. Исследование проведено на основе общего системного подхода, основанного на взаимосвязи элементов; использован метод логико-имитационного моделирования и метод «дерева отказов».

Результаты и обсуждение. Рискованная альтернатива - мероприятие по охране труда связан с модернизацией оборудования и оценивается распределением: выгода (доход) размером a с вероятностью q; убыток в размере b с вероятностью 1 - q. Величины a и b могут быть выбраны произвольными, но их порядок должен соответствовать средствам, которыми оперирует специалист по охране труда в процессе принятия решений. При этом b соответствует значению выгодности, равной нулю, а a - единицы. Но кроме нее в распоряжении у работника, принимающего решения в СУОТ на предприятии, есть и другая альтернатива - стратегия, которая не связана с риском и дает гарантированный доход размером x.

Математическое ожидание дохода при реализации предложенного мероприятия по охране труда связано с повышением производительности труда, качества продукции, сокращением расходов на выплаты, риск травмирования снизится, и зависит от величины q при фиксированных значениях a и b. Свойства функции выгоды для работника, принимающего рискованные решения в СУОТ, основываются на следующем: работник подвержен риску в случае, если график имеет изогнутую вверх функцию выгоды; при росте функций выгоды работник подвержен риску тогда, когда его детерминированный эквивалент для любой альтернативы больше ожидаемой выгоды, $x ° > M [X]$; при росте функций выгоды работник подвержен риску, когда надбавка за него будет отрицательным при всех альтернативах, $\Delta R (X) < 0$.

Выводы. Функция несклонности к риску, обладает следующими свойствами: две функции выгоды стратегически эквивалентны только тогда, когда они ведут к одной и той же функции несклонности к риску, а наиболее вероятная выгода от принятого решения по охране труда при $k \to 0$ приближается к математическому ожиданию выгоды от действий работника, нейтрального к риску, при $k \to -\infty$ математическое ожидание выгоды приближается к максимально возможному.

Ключевые слова: *безопасность, труд, травматизм, риск.*

Экономика и управление

Методические подходы к определению внутрипроизводственых цен на предприятиях мясоперерабатывающей отрасли

Ирина Федулова, Алина Драган

Национальный университет пищевых технологий, Киев, Украина

Введение. Рассматриваются вопросы применения новых подходов при определении внутрипроизводственных цен на мясную продукцию.

Материалы и методы исследования. В работе применяются методы: системного анализа в вопросах трансфертного ценообразования и использования его в практической деятельности предприятия; анализа и синтеза − для расчёта трансфертной цены на мясо; аналогии и сопоставления − для определения

внутрипроизводственных цен на субпродукты на основании объединения стоимостной концепции и концепции энергетической ценности.

Результаты и обсуждения. Учитывая специфику производства мясной продукции и повышение ответственности за финансово-экономические показатели каждого производственного подразделения предприятия, возникает проблема об определении внутрипроизводственных цен на продукцию, что изготовляется и передаётся, как сырьё, в другие подразделения. Мясожировой цех производит готовую продукцию – мясо (говядину, свинину), которые передаются в колбасный, консервный цеха мясокомбинатов.

Предложены три варианта методов определения внутрипро-изводственных цен на основе трансфертного ценообразования в зависимости от производственной структуры предприятия: при бесцеховой производственной структуре – по производственной себестоимости продукции; при цеховой – по производственной себестоимости плюс прибыль (по уровню рентабельности); при заводской – по общим затратам плюс прибыль (по уровню рентабельности).

Нерешённым вопросом остаётся определение производственной себестоимости на сопутствующую продукцию (субпродукты). Предлагается для определения производственной себестоимости применить методику сочетания двоих концепций стоимостной для расчёта производственной себестоимости говядины и энергетической ценности говяжьих субпродуктов в соотношении с энергетической ценностью говядины. Определение производственной себестоимости на субпродукты можно рассчитать на основе: энергетической ценности (калорийности) или потребительской ценности (уровень содержания белка, жира, углеводов в продукте).

Выводы. Предложенные методические подходы к определению внутрипроизводственных цен на предприятиях рассчитаны на снижение оптовых цен на мясную продукцию, что будет способствовать формированию эффективной ценовой политики и улучшению реализации продукции.

Ключевые слова: *цена, ценообразование, продукция, предприятие.*

Использование опыта в управлении спиртовой промышленности Украины

Людмила Шевченко

Национальный университет пищевых технологий, Киев, Украина

Введение. Данное исследование посвящено решению проблемы ограниченности рынка для украинского этилового спирта. Евроинтеграция и применения зарубежного опыта и внедрение отдельных аспектов и положений Европейской стандартизации может иметь положительное влияние, а именно возможность выхода на новые рынки сбыта и возможность диверсифицировать методы получения прибыли.

Материалы и методы. Для исследования проблемы, мы использовали теоретический метод для анализа понятийной базы. Используя метод статистического анализа иностранных торговых партнеров Украины в 2015 году, мы проанализировали соотношение экспортных операций по регионам Украины. Используя методы прогнозирования и моделирования, мы можем предсказать положительный эффект от диверсификации рынков сбыта.

Результаты. Европейская интеграция предоставляет Украине преференциальный доступ на крупнейший рынок в мире с 500 млн. клиентов и с ВВП на уровне 14 трлн евро. Это может помочь Украине занять стабильную позицию экспортера этилового спирта и спиртосодержащих жидкостей.

Для этого необходима полная реформа отрасли. При изучении потребностей европейского рынка определилась необходимость производства спирта с концентрацией меньше 80 об, %. ГП «Укрспирт» имеет возможность получить тарифные квоты, которые действуют по принципу "первый пришел, первый получил" на экспорт. В 2016 году ГП «Укрспирт» сможет экспортировать 27 тыс тонн спирта и других спиртосодержащих жидкостей по коду 2207 и 2208. Наиболее важным аспектом для ГП «Укрспирт» является получение лицензии по коду 2208 на поставку спирта с концентрацией меньше 80 об, % в европейские страны. Следующим шагом необходимо определить количество заводов, которые находятся ближе к западной границе Украины с целью сокращения затрат на логистику. Таким образом, эти заводы должны быть реконструированы, для обеспечения конкурентоспособности продукции. Необходимо внедрить энергоэффективные технологии и оборудование, которые снизят потребление топлива на 30%. Эти меры охватят потребности европейского рынка в спирте и предоставят возможность диверсифицировать производство ГП «Укрспирт» и увеличить объем запланированных и реальных доходов.

Вывод. Применяя инностранный опыт возможно дополнительно привлечь 20-30% мощностей украинских спиртовых заводов и как следствие увеличение валютных поступлений в размере около 15 млн. долларов США. Таким образом, возможно возрождение спиртовой отрасли благодаря диверсификации рынков сбыта.

Ключевые слова: *рынок, спирт, управление.*

Аграрный сектор Украины: обзор преимуществ и способов улучшения негативных сторон

Ксения Омельченко
Национальный университет пищевых технологий, Киев, Украина

Введение. Исследование является объективным, чтобы проанализировать состояние аграрного сектора Украины, выяснить слабые и сильные стороны отрасли и предложить пути повышения эффективности его работы.

Материалы и методы. Такие методы, как: экстраполяции, научной абстракции, синтеза, анализа, сравнения и дедуктивного метода были использованы в статье. Для анализа были использованы уточнения основных выгод и недостатков реформ в агропромышленном комплексе. Были определены основные направления реализации земельной реформы.

Результаты и обсуждения. Более двух третей (71,2%) от общей площади земель Украины являются землями сельскохозяйственного назначения, по сравнению с лишь 13,2% в России и 44,3% в ЕС. Пахотные земли в 32,5 миллиона гектаров имеет самую большую площадь в Европе после России, что составляет 56,1% от общей площади земель - самый высокий процент в Европе после Дании. Около 80 процентов сельскохозяйственных площадей Украины являются землями сельскохозяйственного назначения, две трети которых богаты черноземом. Первичные пищевые продукты урожая в Украине ячмень, кукуруза, картофель, соевые бобы, сахарная свекла, и пшеница.

Основные проблемы, которые мы можем определить в секторе являются кредитные проблемы, проблемы занятости, недостатки механизмов государственного регулирования развития аграрного сектора экономики Украины, инвестиционного климата, имущественных прав, коррупции, устаревшей техники и недостаточной технической базы на фермах для хранения, усадки поголовья скота, формирование и

—— Abstract ——

эффективное использование физического капитала в сельскохозяйственных предприятиях в изменяющихся рыночных условиях, отсутствие полной реализации аграрных реформ, сложная, постоянно меняющаяся сетка налоговой системы страны. Теоретически говоря, разумная земельная реформа в Украине может привести к сельскохозяйственному буму в стране и государство может стать «житницей Европы».

Правительство Украины установило цели аграрной реформы. Так, были определены пять направлений: земельная реформа и реформа отношений собственности в АПК; создание новых хозяйствующих субъектов на основе коллективных сельскохозяйственных предприятий, использующих частную собственность и собственность на землю; формирование рыночной инфраструктуры в АПК; модернизация производства, создание конкурентоспособных сельскохозяйственных предприятий; совершенствование механизмов государственного регулирования в сельскохозяйственном секторе. Государственная поддержка может быть структурирована в четырех крупных блоках: освобождение от НДС для сельскохозяйственного производства, прямых субсидий, общих услуг и фиксированного сельскохозяйственного налога.

Выводы. Дальнейший прогресс, который направлен на повышение эффективности сельского хозяйства Украины, требует постоянной постепенной реструктуризации сельскохозяйственных предприятий на более мелкие автономные единицы, которые будут основаны на частной собственности на землю и имущество, с четкой формулировки процедур, которые позволяют лицам и небольшим группам людей с долей земли и активов существовать. Так же важно освоение земель и рынков сбыта с целью создания функционирующей рыночной инфраструктуры для предоставления конкурентных маркетинговых и финансовых услуг в этой сфере.

Ключевые слова: *АПК, реформирование, рынок, земля.*

Процессы и оборудование пищевых производств

Процесс сушки бумаги для гофрирования (флютинга) с применением энергии излучения

Виктор Марчевский, Олег Новохат, Алексей Цепкало
Национальный технический университет Украины
«Киевский политехнический институт», Киев, Украина

Вступ. Растущий спрос рынка в гофротаре требует увеличения производства флютинга, что лимитируется процессом сушки. Поэтому интенсификация сушки путем использования новых источников тепла и уменьшение выбросов в атмосферу является актуальной проблемой.

Материалы и методы. Предметом исследования является процесс сушки флютинга с применением инфракрасного излучения. Объектом исследования является кинетика процесса сушки флютинга с применением инфракрасного излучения. Эксперименты проведены на образцах флютинга марок Б-0, Б-1 и Б-2 согласно технических условий Украины ТУ У 21.1-31812534-023:2009 (112, 125 и 140 г/м^2), а также на образцах с нестандартного флютинга с увеличенной массой квадратного метра 200 г/м^2. Использованы методы математического моделирования и экспериментальные исследования на компьютеризированной опытной установке, выполнена статистическая обработка полученных результатов.

Результаты и обсуждение. Экспериментальные кривые сушки и основные параметры процессу с достаточной точностью аппроксимируются предложенным математическим описанием. Среднеквадратические отклонения расчетных и экспериментальных значений по влагосодержанию не превышают 0,04 кг/кг, что позволяет осуществлять расчеты сушки флютинга при плотности теплового потока до 35 кВт/м^2.

С увеличением плотности лучевых тепловых потоков с 2 кВт/м^2 до 35 кВт/м^2 общее время сушки флютинга уменьшается более, чем в 20 раз.

Критическая величина плотности теплового потока ограничена ростом температуры флютинга во втором периоде. Поэтому при плотности теплового потока более 35 кВт/м^2 процесс сушки флютинга следует осуществлять только к концу первого периода, продолжительность которого увеличивается по увеличению плотности теплового потока.

Выводы. Кинетические закономерности и основные параметры процесса сушки флютинга с применением инфракрасного излучения, которые полученные в работе, позволят выполнять расчеты, необходимые для проектирования промышленных процессов сушки флютинга и эффективного оборудования для их осуществления.

Ключевые слова: инфракрасное излучение, сушка, флютинг, влагосодержание.

Одновременный расчет нестационарного распределения температур в системе ячеек: «больший кристалл сахара–раствор сахарозы большего кристалла–меньший кристалл сахара–раствор сахарозы меньшего кристалла–утфель» а также концентраций сахарозы в ячейках межкристальных растворов этой же системы в зависимости от времени уваривания сахарного утфеля

Тарас Погорелый

Национальный университет пищевых технологий, Киев, Украина

Введение. В данной роботе реализован один из следующих этапов создания математической модели процесса кристаллизации сахарозы.

Материалы и методы. Для одновременного решения системы из 7 нестационарных задач теплопроводности по каждой отдельной области с постоянными и с переменными теплофизическими коэффициентами, а также трех отдельных нестационарных задач диффузионного массообмена для четырех областей межкристальных растворов сахарозы с постоянными и с переменными коэффициентами диффузионного массообмена были применены численные методы (метод контрольного объема).

Результаты и обсуждение. Для десяти случаев относительного времени уваривания сахарного утфеля $\tau/\tau_{ц}$ ($\tau/\tau_{ц}$ = 0,15; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9; 1,0) на основании решения системы нестационарных дифференциальных уравнений в частных производных параболического типа найдено распределение температур в каждой области рассматриваемой системы ячеек. При относительном времени уваривания сахарного утфеля $\tau/\tau_{ц}$ = 0,15 температуры равны: для левой области межкристального раствора сахарозы большего кристалла 99,547 °С при постоянных коэффициентах и 99,479 °С при всех переменных коэффициентах; для большего кристалла сахара 94,799 °С при постоянных коэффициентах и 94,409 °С при всех переменных коэффициентах; для правой области межкристального раствора сахарозы большего

кристалла 90,234 °C при постоянных коэффициентах и 89,640 °C при всех переменных коэффициентах; для левой области межкристального раствора сахарозы меньшего кристалла 89,485 °C при постоянных коэффициентах и 88,820 °C при всех переменных коэффициентах; для меньшего кристалла сахара 87,325 °C при постоянных коэффициентах и 86,630 °C при всех переменных коэффициентах; для правой области межкристального раствора сахарозы меньшего кристалла 85,285 °C при постоянных коэффициентах и 84,590 °C при всех переменных коэффициентах; для утфеля 75,107 °C при постоянных коэффициентах и 75,098 °C при всех переменных коэффициентах. Одновременно с этим найдено распределение концентраций в каждой области межкристального раствора сахарозы рассматриваемой системы ячеек. При относительном времени уваривания сахарного утфеля $\tau/\tau_\text{ц} = 0,15$ концентрации равны: для левой области межкристального раствора сахарозы большего кристалла 82,710% при постоянных коэффициентах и 82,274% при всех переменных коэффициентах; для правой области межкристального раствора сахарозы большего кристалла 80,400% при постоянных коэффициентах и 79,893% при всех переменных коэффициентах; для левой области межкристального раствора сахарозы меньшего кристалла 80,269% при постоянных коэффициентах и 79,765% при всех переменных коэффициентах; для правой области межкристального раствора сахарозы меньшего кристалла 79,418% при постоянных коэффициентах и 79,026% при всех переменных коэффициентах.

Вывод. Найдено одновременное нестационарное распределение температур в системе ячеек, которая представлена в виде семи одномерных областей и, соответственно этому, найдено распределение концентраций в четырех областях межкристальных растворов сахарозы этой же системы ячеек.

Ключевые слова: *сахароза, концентрация, ячейка, раствор, кристалл, утфель.*

Влияние конструктивных особенностей гидроциклонного аппарата на процесс осветления пивного сусла

Леся Марцинкевич[1], Максим Шпак[1], Сергей Удодов[1], Дмитрий Рындюк[1,2]

1 - Национальный университет пищевых технологий, Киев, Украина
2 – Национальный технический университет Украины «Киевский политехнический институт», Киев, Украина

Введение. З целью повышения качества осветления пивного сусла и сокращения время прохождения процесса проведены исследования процесса осаждения взвешенных частиц в рабочем объеме гидроциклонного аппарата (вирпула).

Материалы и методы. Исследование процесса осветления пивного сусла проводились в программном комплексе, основанном на методе конечных объемов, предназначенном для моделирования трехмерных течений жидкостей и газа в технических и природных объектах, а также визуализации этих течений методами компьютерной графики. Исследование проводилось на следующих моделях гидроциклонного аппарата: с классической формой днища (плоское), конической вставкой, двумя цилиндрическими вставками и подачей сусла на каждую из вставок, с коническим днищем и радиальными направляющими вставками.

Результаты и обсуждение. Сусло в гидроциклонном аппарате приобретает вращательное движение, которое обеспечивается тангенциально установленным патрубком подачи продукта. Образованный вихревой поток способствует тому, что

частицы оседают, образуя тарелку белкового осадка. Важную роль в процессе осветления играет скорость подачи сусла в аппарат, то есть скорость на выходе из сопла входного патрубка. Если скорость превышает 3,5 м/с, то продукт испытывает значительные касательные напряжения, что приводит к образованию мелкодисперсных частиц, которые в гидроциклонном аппарате не осаждаются. Также было исследовано касательные напряжения (τ), которые возникают в сусле во время его подачи. При превышении значения $\tau \geq 50$ Па начинается разрушение частиц белкового осадка.

Выводы. Результаты исследований доказывают целесообразность подачи рекомендаций для внедрения в производство гидроциклонного аппарата с радиальными направляющими вставками. Это позволит сократить время осветления и улучшить качество пивного сусла.

Ключевые слова: *гидроциклон, вирпул, пивное сусло, осветление.*

Теоретическое обоснование возможности интенсификации и ресурсосбережения процесса кондуктивного жарения мясных натуральных изделий

Вячеслав Скрыпник

Полтавский университет экономики и торговли, Полтава, Украина

Введение. Процесс кондуктивного жарения мясных натуральных изделий является энерго- и ресурсозатратным. Теоретически рассмотрены возможности интенсификации и ресурсосбережения процесса.

Материалы и методы. Использовался аналитический метод исследования опубликованных экспериментальных и теоретических данных.

Результаты и обсуждение. Для повышения энергетической эффективности и ресурсосбережения процесса кондуктивного жарения мясных натуральных изделий рассмотрены возможные факторы интенсификации. Повышение температурного уровня процесса более 423 К нежелательно из-за образования гетероциклических аминов в поверхностном слое изделия. Интенсификация процесса становится возможной в случае двустороннего подвода теплоты и использования физических и электрофизических методов воздействия на сырье.

Действие давления или электрического тока переменной частоты в процессе кондуктивного жарения приводит к образованию в мясе эффективного слоя, меньшего начальной толщины полуфабриката, с теплопроводными свойствами жидкости.

Использование функционально замкнутого объема в процессе двустороннего жарения мяса с высоким содержанием соединительной ткани под давлением на уровне предельного для этого мяса позволяет сохранить нативную влагу, количества которой достаточно для гидролиза коллагена в необходимой мере.

Процесс двустороннего жарения мяса под воздействием физических и электрофизических методов по времени предложено разделить на три основные стадии. Наиболее значимой в общих энергетических затратах является вторая, при которой теплота передается через поверхностный слой мяса вследствие фазовых преобразований водяного пара, образующегося благодаря выведению влаги в поверхностные слои продукта к поверхностям жарения. Обоснованно аналитическую модель процесса.

—— *Abstract* ——

Выводы. Впервые обоснованы факторы интенсификации, аналитическая модель процесса кондуктивного жарения мясных натуральных изделий, в т.ч. и с высоким содержанием соединительной ткани.

Ключевые слова: *жарения, кондукция, мясо, давление, электрический ток.*

Математическая модель процесса сушки плодовых частиц

Дмитрий Коломиец, Татьяна Роман, Лилия Харченко,
Мария Ротай, Александр Мазуренко
Национальный университет пищевых технологий, Киев, Украина

Введение. Для оптимизации параметров сушки и получения готовой продукции высокого качества важно иметь достоверную математическую модель тепломассообмена в слое высушиваемого продукта.

Материалы и методы. На основе анализа известных многочисленных математических моделей, представленных исследователями в виде уравнений регрессии экспериментальных данных, решали упрощенную задачу внутреннего влагопереноса для различных частных случаев, сочетая при этом общую теорию с более простыми, частными моделями процессов сушки влажных материалов.

Результаты и обсуждение. При разработке модели сушки плодовых продуктов в мягких режимах за основу было принято одно из самых простых предположений о кинетике процесса сушки - жидкость внутри пористой структуры перемещается относительно свободно, испарения жидкости осуществляется только с внешней поверхности тела, а влага, которая изымается в течение процесса сушки, подводится к поверхности испарения из внутренних зон материала при малом градиенте влагосодержания. Это позволило разработать математическую модель в виде дифференциальных уравнений сохранения влаги, теплоты и изменения фильтрационного потенциала переноса, которые описывают, соответственно, нестационарные поля влагосодержания, температуры и общего давления капиллярно-пористого тела при постоянных коэффициентах переноса.

На базе известных математических моделей сушки влажных материалов в тонком слое продукта, и использовании положений современной теории внутреннего массопереноса, основанный на понятии единого потенциала переноса влаги, для слоя продукта в форме неограниченной пластины было решено уравнение перемещения границы раздела влажное тело - пространство сушки в мягких режимах сушки. При таких условиях сушки переносом влаги за счет градиента давления можно пренебречь, поэтому при выбранных граничных условиях решали задачу Стефана для совместных процессов переноса влаги и тепла внутри влажного материала при сушке, то есть краевую задачу для системы двух дифференциальных уравнений второго порядка. Результаты расчета перемещения границы раздела влажное тело - пространство сушки по предложенной модели удовлетворительно согласуются с результатами экспериментального исследования.

Выводы. Использование разработанной модели сушки плодовых долей улучшит качество как регулирования процесса сушки, так и готового продукта.

Ключевые слова: *сушка, плод, тепломассоперенос, модель.*

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Всі елементи після року видання розділяються **комами**.

Приклади:

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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.

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1. Harris L. (1991), *Money theory*, McGraw-Hill Companies, Hardcover
2. Rob Steele (2004), *Understanding and measuring the shelf-life of food*, CRC Press.

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2. Kirianova H.A. (2008), Udoskonalennia tekhnolohii termostabilnykh zheleinykh nachynok shliakhom ratsionalnoho vykorystannia hidrokoloidiv roslynnoho ta mikrobnoho pokhodzhennia: PhD tethis, NUHT, Kyiv.
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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%20 Is.2.pdf
2. (2013), *Svitovi naukovometrychni bazy*, available at: http://www1.nas.gov.ua/publications/q_a/Pages/scopus.aspx