ISSN 2409–4951(Online)
ISSN 2310–1008 (Print)

Ukrainian Journal of Food Science

Volume 6, Issue 1
2018

Kyiv 2018

Ukrainian Journal of Food Science publishes original research articles, short communications, review papers, news and literature reviews.

Topic covered by the journal include:

Food engineering
Food chemistry
Biotechnology, microbiology
Physical property of food
Food quality and safety
Health
Food nanotechnologies
Food processes
Economics and management
Automation of food processes
Food packaging

Periodicity of the journal – 2 issues per year (June, December).

Studies must be novel, have a clear connection to food science, and be of general interest to the international scientific community.

The editors make every effort to ensure rapid and fair reviews, resulting in timely publication of accepted manuscripts.

Ukrainian Journal of Food Science is Abstracted and indexated by bases:

EBSCO (2013)
Google Scholar (2013)
Index Copernicus (2014)
Universal Impact Factor (2014)
Directory of Open Access scholarly Resources (ROAD) (2014)
CAS Source Index (CASSI) (2016)
FSTA (Food Science and Technology Abstracts) (2018)

Reviewing a Manuscript for Publication. All scientific articles submitted for publication in "Ukrainian Journal of Food Science" are double-blind reviewed by at least two academics appointed by the Editors' Board: one from the Editorial Board and one independent scientist.

Copyright. Authors submitting articles for publication warrant that the work is not an infringement of any existing copyright and will indemnify the publisher against any breach of such warranty. For ease of dissemination and to ensure proper policing of use papers and contributions become the legal copyright of the publisher unless otherwise agreed.

Academic ethics policy. The Editorial Board of "Ukrainian Journal of Food Science" follows the rules on academic writing and academic ethics, according to the work by Miguel Roig (2003, 2006) "Avoiding plagiarism, self-plagiarism, and other questionable writing practices. A guide to ethical writing". The Editorial Board suggests to potential contributors of the journal, reviewers and readers to dully follow this guidance in order to avoid misconceptions in academic writing.

For a full guide for Autor please visit website at **http://ukrfoodscience.ho.ua**

Editorial office address:
National University of Food Technologies
Volodymyrska str., 68
Kyiv 01601
Ukraine

E-mail:
Ukrfoodscience@meta.ua

Editorial board

Contents

Improving the technology of cooked sausages using protein-mineral-hydrocarbon additive

Lyudmyla Peshuk, Oleksandr Gorbach, Oleg Galenko

National University of Food Technologies, Kyiv, Ukraine

Keywords:
Protein
Carbohydrates
Meat
Sausages
Chitosan

Article history:

Received 13.03.2018
Received in revised form 09.05.2018
Accepted 29.06.2018

Corresponding author:

Oleg Halenko
E-mail:
galen@i.ua

DOI:
10.24263/2310-1008-2018-6-1-3

Abstract

Introduction. Studies have been conducted to determine the effect of adding chitosan to a malted meat product with mechanically separated poultry meat.

Materials and methods. It is studied the technology of sausages with adding to the composition of poultry meat mechanically, serum protein concentrate, soy protein hydrated protein, animal protein, serum protein and developed protein-mineral carbohydrate supplement. Determination of amino acid composition was conducted in accordance with the method of ion exchange chromatography.

Results and discussion. Boiled sausage with a protein-mineral-hydrocarbon additive has higher consumer properties compared to control samples. The moisture content of minced meat which has been added to the chitosan, namely the soy protein, animal protein, serum protein, and protein-mineral-hydrocarbon additi. increases by 10–15%, which enables to increase the yield of the finished product and plan the product properties after the completion of the technological stages of production.

The addition of protein-mineral-hydrocarbon additi.in the amount of 10% in hydrated state positively affects the technological properties, it provides support for moisture, fat during the heat treatment process, which is important when used in the technology of boiled smoked products.

Cooked sausages has a balanced amino acid composition compared to control. In cooked sausages it is observed higher levels of valine (0.8%), lysine (by 0.91%), methionine (at 0.10%), threonine (at 0.54%), alanine (at 0.54%), aspartic acid (to 0.65%) and glycine (at 0.59%)in comparing with the control sample.

Conclusions. Chitosan when interacting with any animal protein increases the moisture content of the finished product 10–15%. Boiled sausage with mechanically separated poultry meat and protein-mineral-hydrocarbon additi has a well-balanced composition, it has high consumer properties and can be attributed to complete nutrition by content of essential amino acids.

Introduction

Due to the shortage of meat raw materials, proteins of plant and animal origin are widely used. These additives are used in the manufacture of all kinds of meat products, including delicacies, boiled smoked and smoked products. This tendency persists, which contributes to the expansion of the range of proposed additives, to improve their functional properties and to increase the level of safety, one of the criteria of which is the use (application) of genetically modified raw materials (Huang et al., 2011; Bou et al., 2009).

Proteins occupy an important place in the living organism, both in content in the cell and in the sense of life. Their share accounts for about 18% of human weight. Protein is an indispensable part of food and basic life. Soy and animal proteins allow you to make an equivalent replacement of non-sufficient precious raw materials (Richardson, 2002).

Meat from important food is the only source of valuable protein, which is an average of 18.0%, which is a nutritional value of the first category. Depending on the species, the anatomical part of the animal, fattening, age, animal breeds, the protein content of the meat can vary from 11.0% to 22% (Peña et al., 2009; Hutchison et al., 2012). Among the proteins of the meat isolated connective tissue and muscle, which are divided into myofibrillary and sarcoplasmic. The nutritional and technological value of meat is higher, the more muscle tissue in it, the proteins of which belong to high-tech and high-tech.

Among vegetable proteins, soybean is most widely used. It is designed to reduce the cost of finished products and stabilize the formulation. Animal proteins have a diverse origin (collagen, milk, blood plasma, etc.), which causes a variety of technological processes and a wider range of applications than soya analogues.

The aim of the presented research is to improve the technology of producing cooked sausages, balanced by the mechanically separated poultry meat and protein-hydrocarbon-mineral additive amino acid composition

Materials and methods

Materials for research were selected technology of cooked sausages with the addition of concentrate of serum protein (KSP), protein soy hydrated, animal protein, serum protein and protein-mineral-hydrocarbon additi. Chemical and physico-chemical methods of research were used in this work.

The articles of research are both new foods, selected to consideration in this work and industrial foods that is already used:

Methods, that allow to describe chemical composition, food and biological value, organoleptic, functionally-technological, structural and mechanical and economic indexes of research objects, were used in the process.

The sensory evaluation of quality of sausage products and ready-to-cook foods came true on a 5–ball scale.

A sensory estimation came true in a next sequence (Alison et al., 2011):

- original appearance – by a structure, by a picture on a cut, by even distribution of pieces of mushrooms in stuffing, by the type of shell;
- a color – by sight on the cut of intermediate product;
- a smell (aroma), taste and succulence – absence or presence of extraneous smell, aftertaste, degree of expressed of aroma of spicinesses and salinity determined;
- consistency – by pressing on good.

The water absorption capacity of the products was determined using a stainless steel mesh cabinet, the bottom and walls of which were covered with filter paper to prevent product losses. The glass was moistened with water, which was allowed to stretch for 20 minutes and then weighed. After that, 3 g of the sample was introduced into the glass, kept for 20 minutes in such a way that the upper level of the test sample placed in the glass was below the liquid level by 8–10 mm. After 20 minutes, the glass was removed from the water, held for 20 minutes for drainage and weighed (Weiss et al., 2010; Hoffmanm and Wiklund, 2006). Calculation of VAC (in% to dry balance) was carried out according to the formula:

$$x = \frac{m_2 - m_0 - m_n}{m_n \cdot (100 - W)} \cdot 10^4 \quad (1)$$

where m_2 – mass of the glass with the object under investigation after swelling in water, g;
m_0 – weight of a glass with a humidified sleeve, g;
m_n – weight of weight loss, g;
W – mass fraction of moisture in the investigated object, g.

Determination of amino acid composition was conducted in accordance with the method of ion exchange chromatography. Quality and quantitative determination of components consisted in dividing of them into separate components after the hydrolysis of proteins and determination of their quantitative estimation with the help of automatic analyzer of amino acids as T–339. Productions of firm "Mikrotechna", on polystyrene sulfonate ion exchange resins of "Ostion LJ ANB" in Li- citrate buffer one column mode (Peshuk and Galenko, 2011, 2014). The elutions of amino acids from a column conduct in turn by Li- by citrate buffers from pH 2,75±0,01; pH 2,95±0,01; pH 3,2±0,02; pH 3,8±0,02; pH 5,0±0,2. Amino acids rectifying with the help of solution of ninhydrin on a running photometer at a length of waves by 560 нм. The results of detection was registered oneself by a variplotter on a paper in form the peaks of absorption of light of ninhydrin-positive substances in an eluate, that in number in direct ratio concentrations of this substance in solution. Correlation of solution of ninhydrin reagent and eluents is 1 to 2; temperature of thermostatic T1=38,5 °C; T= 65 °C. The prototype was diluted in Li-citrate buffer by pH 2,2±0,02 and inflicted on a ion exchange column with the help of metering device. The quantitative estimation of хроматограм of pre-production model settles accounts in relation to standard mixture of amino acids of firm BioRaD. The amount of milligrams of every amino acid of Ai in the investigated solution calculates on a formula:

$$A_i = \frac{M_i \times S_i}{S_i^3}, \quad (2)$$

where A_i is mass part of i-th amino acid, mg/ 100 g of protein;
M_i is molecular mass of i-th amino acid;
S_i is area of peak of i-th amino acid on an aminogram from the investigated solution;
S_i^3 is an area of peak of i amino acid on an aminogram from solution of standard mixture of amino acids, that accords to one micromole.

Results and discussion

Consequently, it was selected as the main recipe components for the development of boiled sausages of balanced amino acid composition: poultry meat, mechanically separated poultry meat (MSPM), PMHA in the amount of 10%, milk powder, eggs, and spices. We conducted a determination of the level of introduction of poultry meat, MSPM, PMHA in an experimental way, namely the method of selecting the optimal from the point of view of both sensory, and the nutritional and biological value of the developed meat product. Different combinations of supplements were introduced into the experimental formulations: soy protein, animal protein, hydrated whey protein, soy protein, animal protein + chitosan, serum protein + chitosan, PMHA + chitosan № 1 and № 2, SPC + chitosan, SPC, and PMHA. The developed formulations are presented in Table 1 (Peshuk and Galenko, 2011).

Table 1

Recipes of developed sausage wares

Raw materials	Control	Soy protein	Animal protein	Hydrated whey protein	Soy protein	Animal protein + chitosan	Serum protein + chitosan	PMHA + chitosan № 1	PMHA + chitosan № 2	SPC + chitosan	SPC	PMHA
Name of raw material kg per 100 kg of raw material												
Poultry	63	58	58	58	58	58	58	58	58	58	58	58
MSPM	30	25	25	25	25	25	25	25	25	25	25	25
Eggs	3	3	3	3	3	3	3	3	3	3	3	3
Milk is dry	4	4	4	4	4	4	4	4	4	4	4	4
Serum protein concentrate										10	10	
Soy protein is hydrated		10			10							
Animal protein is hydrogenated			10			10						
Wheat protein				10								
PMHA							10	10				10
	Spices and materials, g per 100 kg of unsalted raw materials											
Chitosan					200	200	200	200				
Salt	2200											
Pepper is black	150											
Phosphates	300											

The general mandatory requirements for the quality of finished products are: high sanitary and hygienic status, organoleptic parameters, the level of nutrient balance with reduced energy value. Therefore, the next stage of the research was devoted to the comparative assessment of physico-chemical, biological, functional and technological indicators of finished products in comparison with the control sample of cooked sausage made in accordance with the standard (Peshuk and Galenko, 2014).

Proteins that are additionally introduced into the meat system affect the stabilizing effect of meat products, since meat products must have certain consumer properties: be juicy, tender, with distinct chewing ability and density.

MSPM has an elevated pH (6.8–7.0), which reduces the microbial stability of the raw material during storage. It is an inexpensive protein component of the recipes of semi-finished, boiled and smoked sausages. The high content of calcium ions contributes to the deterioration of the functional and technological properties of MSM, which negatively affects the stability of albuminous fat emulsions in the formulation, which can lead to the appearance of soup-fatty stomachs. Therefore, when using poultry meat in the formulation at the same time it is necessary to make stabilizers and emulsifiers.

Considering the functional and technological properties of minced meat systems, important of which are pH, water-binding ability (WBA), stability during storage, is of great importance when developing the technology of meat products. The quality of the water-binding ability of meat depends on the quality of processing. The use of meat with a low WBA leads to significant losses of moisture and water-soluble proteins during heat treatment, which significantly reduces the quality of finished products.

Therefore, we have previously conducted a comparative analysis of functional and technical indicators of forages systems to evaluate the technological properties of developed sausage products (Figure 1).

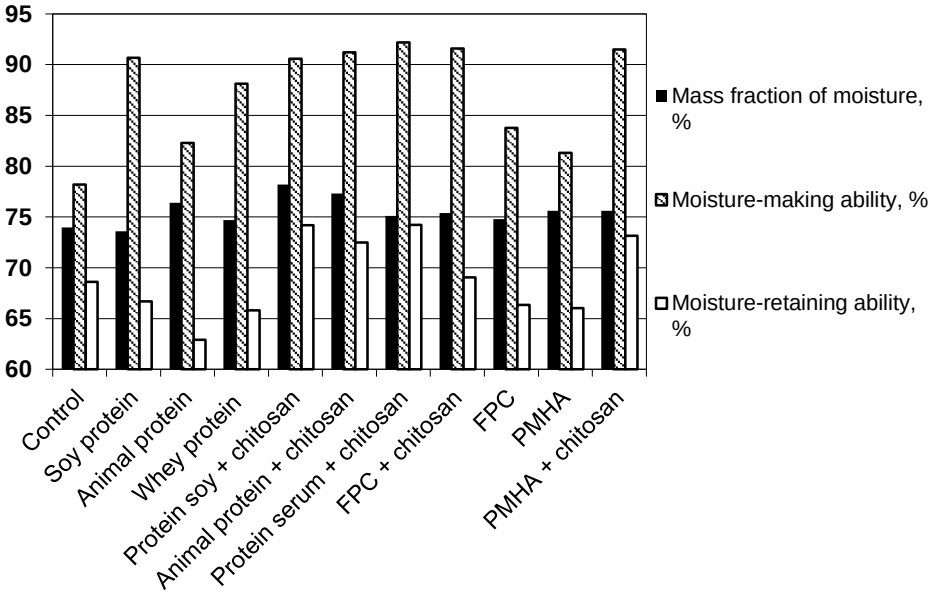


Figure 1. Functional and technical indicators of minced meat systems

From the conducted studies it was found that when the chitosan is added to the PMHA, the pH changes slightly in the alkaline side, which should increase the hydrophilicity of the meat proteins, which will increase the water-binding ability of the minced meat. Thus, the finished product will be more juicy and with better consumer characteristics.

It has also been established that the moisture-retaining ability of the minced meat containing chitosan, in particular, the soya protein, animal protein, serum protein and PMHA values increases by 10–15%, which enables to increase the yield of the finished product and plan the properties of the product after completion of technological stages of production (Hutchison et al., 2012).

The next stage of the research was the definition of functional and technological indicators of the finished product. In samples of sausage products with chitosan there is a slight change in pH in the alkaline side, which, as predicted, contributed to the increase of the hydrophilicity of meat proteins and, consequently, the increase of water-binding ability of minced meat, resulting in the finished product obtained more juicy (Table 2).

Table 2

Physico-chemical properties of cooked sausages

Sample	Indicators		
	pH	Mass fraction of moisture, %	WBA%, to total moisture
Control	7,05	73,97	95,46
Soy protein	7,01	73,60	90,68
Animal protein	7,01	76,41	82,30
Serum protein	6,90	74,70	88,12
SPC	6,92	74,80	88,76
PMHA	6,91	75,60	91,30
Soy protein + chitosan	6,95	74,20	90,57
Animal protein + chitosan	6,86	77,30	91,20
Whey protein + chitosan	6,85	75,10	92,17
SPC + hitosan	6,93	75,40	91,57
PMHA + hitosan	6,94	75,60	91,48

The conducting of studies water-binding ability (WBA) has shown that the introduction of PMHA in the amount of 10% in hydrated state positively affects the technological properties of minerals to retain moisture and fat during the heat treatment, which is important when using the technology of cooked sausages. A slight increase in the output of prototype finished products was noted. There were no significant changes between the control and experimental samples of cooked sausages in terms of physico-chemical composition (Richardson, 2002).

Cooked sausages has a balanced amino acid composition compared to control. In cooked sausages it is observed higher levels of valine (0.8%), lysine (by 0.91%), methionine (at 0.10%), threonine (at 0.54%), alanine (at 0.54%), aspartic acid (to 0.65%) and glycine (at 0.59%)in comparing with the control sample.

According to the content of essential amino acids ham meat guinea fowl close to egg protein, and according to the content of of amino acids as valine, isoleucine, leucine, lysine, alanine, arginine, aspartic acid, glycine, glutamic acid, tyrosine surpasses it.

This indicates that the cooked sausages and smoked guinea fowl meat have well balanced amino acid composition, it is characterized by high biological value and can be attributed to high-grade food for the content of essential amino acids (Peshuk and Galenko, 2014).

Conclusions

1. It is reported that chitosan when interacting with any animal protein increases the moisture content of the finished product 10–15%.
2. With the help of mathematical modeling method we optimized two recipes of guinea fowl meat products.
3. Using the method of mathematical modeling, we optimized the recipe of cooked sausages with protein-mineral-hydrocarbon additive.
4. The sausages of the balanced amino acid composition with mechanically separated poultry meat and protein-hydrocarbon-mineral additive, which received higher output of the finished product and the best consumer properties compared with the control sample, were investigated.
5. The calculations of economic efficiency provided the basis to recommend these elaborated ham for the introduction in meat processing enterprises of Ukraine, as the cost is 74 UAH / kg.

References

1. Jochen Weiss, Monika Gibis, Valerie Schuh, Hanna Salminen, (2010), Advances in ingredient and processing systems for meat and meat products, *Meat Science*, 86(1), pp. 196–213.
2. Hoffman L.C., Wiklund E., (2006), Game and venison – meat for the modern consumer, *Meat Science*, 74(1), pp. 197–208.
3. Alison J. McAfee, Emeir M. McSorley, Geraldine J. Cuskelly, Bruce W. Moss, Julie M.W. Wallace, Maxine P. Bonham, Anna M. Fearon, (2010), Red meat consumption: An overview of the risks and benefits, *Meat Science*, 84(1), pp. 1–13.
4. Huang S.C., Tsai Y.F., Chen C.M. (2011) Effects of wheat fiber, oat fiber on sensory and physico-chemical properties of Chinese-style sausages, Asian–Australian Journal of Animal Science, 24(6), pp. 875–880
5. Bou R., Codony R., Tres A., Decker E.A., Guardiola F. (2009), Dietary strategies to improve nutritional value, oxidative stability, and sensory properties of poultry products, Critical Review on Food Science and Nutrition, 49(9), pp. 800–822
6. Peshuk L., Galenko O. (2011), Gerodietic meat products technology enriched with calcium and phosphorus, *Food and Environment Safety*, X(4), pp. 18–23.
7. Richardson D.P. (2002), Functional Food and Health Claims, *The world of Functional ingredients*, 9, pp. 12–20.
8. Peshuk L., Galenko O. (2014), Use of collagenase in technology gerodietetic products , *Journal of food and packing science, technique and technologies*, 2(3), pp. 8–11.
9. Peshuk L., Galenko O. (2014), Rational use of the collagen, *Ukrainian Journal of Food Science*, 2(1), pp. 361–370.
10. Peña F., Bonvillani A., Freire B., Juárez M., Perea J., Gómez G. (2009), Effects of genotype and slaughter weight on the meat quality of Criollo Cordobes and Anglonubian kids produced under extensive feeding conditions, *Meat Science*, 83(3), pp. 417–422.
11. Hutchison C.L., Mulley R.C., Wiklund E., Flesch J.S. (2012), Effect of concentrate feeding on instrumental meat quality and sensory characteristics of fallow deer venison, *Meat Science*, 90(3), pp. 801–806.

Physical characteristics of functional biscuits enriched in einkorn flakes

Ivan Dimov[1], Viktorija Stamatovska[2]

1 – Trakia University, Stara Zagora, Bulgaria
2 – St. Kliment Ohridski" University of Bitola, Macedonia

Keywords:

Einkorn
Flaking
Functional
Biscuits

Article history:

Received 29.01.2018
Received in revised form 26.05.2018
Accepted 29.06.2018

Corresponding author:

Ivan Dimov
E-mail: ivendi_81@abv.bg

DOI:
10.24263/2310-1008-2018-6-1-4

Abstract

Introduction. The modern tendencies related to the consumption of functional food suggest that the einkorn is a cereal which can play an important role in human nutrition.

Materials and methods. The following basic materials were used for the production of biscuits: whole grain einkorn (*Triticum monoccocum* L.) flour and einkorn flakes. The manufacturing of the biscuits, as well as the determination of their physical properties (baking loss and volume) was carried out according to AACC Method 10-50D. Biscuits color was determined by spectral method using tintometer produced by Lovibont Tintometer RT 100 Colour in the CIE Lab system.

Results and discussion. During the baking, water present in the formed dough evaporates which gives biscuits of characteristic structure. The greatest baking losses showed the biscuits made from 100% einkorn flour (15.16±1.01%) and the smallest – these made from 100% einkorn flakes (9.54±1.22%), with the diference beteen the two samples being 5.62%.

The results obtained for the baking losses of the biscuits made from 100% flakes produced are statistically significant ($p<0.05$).

The data on the volume of the biscuits produced show that the largest volume had the biscuits made from 100% einkorn flour (79.00±0.50 cm^3).

All the samples of biscuits had colors in the green and yellow spectrum and the lightest ones were these produced from 100% einkorn flakes.

The differences between the individual samples were insignificant.

Conclusions. The increase of the amount of einkorn flakes added to einkorn flour results in slightly lower baking losses and volume of baked biscuits, and a lights biscuits color.

Introduction

The modern tendencies related to the consumption of functional food suggest that the einkorn is a cereal which can play an important role in human nutrition. This is especially true by the development of new specialized nutritional products of higher quality with respect to their nutritional value. In modern world, the food we consume must, besides providing the necessary energy and nutrients, also have positive effect on human health [1].

Consumer interest in healthy eating is targeted on certain foods and food ingredients [2].

Einkorn was domesticated more than 10 000 years ago, most probably in the Karakadak mountains in southeastern Turkey and its cultivation spread to Europe during the agricultural revolution. Nowadays, einkorn is grown in the mountain regions of the mediterranian (Turkey, Balkan countries, southern Italy, southern France, Spain and Morocco). Recently, the tendency toward development of sustainable agriculture has elad to increased attention to the nutritious aspects of food. This resulted in rediscovery of some forgotten cultures like einkorn. Despite the low yield (about trice less than bread wheat), Regardless of its low yields (about a third from the bread wheat), there has been significant recovery of the cultivation of this kind of wheat in some countries (France, Germany, Austria, Hungary, Bulgaria and Italy) [3].

Einkorn (*Triticum monococcum* L. ssp. *monococcum*) is a diploid species (2n=2x=14 chromosomes) of hulled wheat and it is close relative of durum wheat. Recent studies highlight its good nutritional qualities when consumed by humans [4,5].

Lately, the flaked products are more and more widely used. They are contained in many food products used as snacks. They are used as supplement in bread, bakery and confectionery, including the production of biscuits [6].

The process of preparation of flaked products is as follows:

1. Cleaning and sorting – before the processing, cereals are cleaned and sorted. Cleaning removes unwanted ingredients like grain from other crops, pebbles, sand, etc. simultaneously, the grains are sorted according to their quality. The shriveled, broken and unripe grains are removed by blowing with hot air.
2. Hulling – the aim is to remove the hull of the grains and obtain dehulled ones. This is done by rolling between rubber belts (rolls) so the hull is removed without damaging the kernel. The kernels are then blown with air to remove the remaining hulls.
3. Brushing – the dehulled grains are the brushed with brushes.
4. Heating – the grains are heated to 100ºC in special furnaces. By t his operation, the surface moisture increases and condenses. The vapor obtained deactivates the enzymes contained in the grains. The starch turns to paste.
5. Drying and fractionation – drying is carried out in special desiccators where the moisture content in the grains decreases and they can now be stored. The, the grains are separated into two fractions according to their size.
6. Rolling – by this process, flakes of various sizes are obtained by pressing the grains between rolls. The process of rolling involves the use of water vapor which softens the grains.
7. Drying and packing –the flaked products should be dried before packing until moisture content in them remains ca. 11%; then they are packed in suitable packings [7].

Biscuits are bakery products which most often are made from flour, fats and sugar. Various types of biscuits are offered on the market but today, when people wish to eat healthy food, it is necessary to produce “functional” biscuits [8].

It is considered that biscuit production accounts for an important part of the food industry production in most countries around the world. They have great nutritional value, especially when the raw materials used for their production are rich in fats and proteins [9]. Their important role and importance can be attributed to at least four key factors: Тяхното важно място и значение, може да се дължи най-малко на четири ключови фактора:relatively long shelf life; great variety; human desire and predisposition to sugar and chocolate, as well as their comparatively low price [10].

The aim of the present paper is to study the effect of flaked einkorn (*Triticum monococcum* L.) on some physical properties in biscuits produced from whole grain einkorn flour (base flour) to which einkorn flakes are added in quantities 30%, 50%, 70%and 100%at the expense of the base flour.

Materials and methods

Materials

The following materials were used for the production of biscuits: whole grain einkorn (*Triticum monoccocum* L.) flour and flaked einkorn produced in the Plovdiv region, saccharose and glucose in the form of glucose solution (as sweeteners), cow butter, sodium bicarbonate and cooking salt – purchased from the market, drinking water from the public water supply network complying with the requirements of Regulation № 9 [11].

Methods

Production of biscuits

The manufacturing of the biscuits, as well as the determination of their physical properties (baking loss and volume) was carried out according to AACC Method 10-50D [12].

Colours of biscuits

Biscuits color was determined by spectral method using tintometer produced by Lovibont Tintometer RT 100 Colour in the CIE Lab system. The average of several measurements was taken. The general change of color was calculated by formula (1) [13].

$$\Delta E = \sqrt{(L - L_0)^2 + (b - b_0)^2 + (a - a_0)^2} \quad (1)$$

where: the indicators with index 0 refer to the baked biscuits and the other ones – to the raw dough.

The parameter ΔE shows the relationship between the human perception of biscuit color and the total change of color (Table 1).

Table 1

Relationship between the human perception of biscuit color and the total change of color (ΔE) [14]

Human perception	(ΔE)
No great difference	<2
Very small perceptible difference	0.2 ÷ 1
Small perceptible difference	1 ÷ 3
Medium perceptible differences	3 ÷ 6
Great perceptible differences	>6

Statistical analysis

The results obtained from the analyses are presented in tables and figures and their statistical processing was performed using XL Stat and Microsoft Excel 2013. In the XL Stat software, the analysis of the main factors (Main effects ANOVA) was employed, as well as the Fisher criterion for the least statistically significant differences (LSD) at significance factor of 95% ($p<0.05$).

Results and discussion

The innovations in the production of biscuit applied in the recent decade are oriented to the making of biscuits with reduced content of sugars, substitution of sugars with sweeteners, use of fats of different properties, as well as enrichment of the biscuits with additives with functional properties [8]. Table 2 shows some physical characteristics (baking loss and volume) of the biscuits manufactured.

Table 2

Physical characteristics of biscuits

Biscuits/Properties	Baking loss (%)	Volume (cm^3)
100%E	15.16 ± 1.01^{a}	79.00 ± 0.50^{a}
70%E + 30%EF	14.10 ± 0.52^{a}	53.00 ± 1.48^{b}
50%E + 50%EF	12.98 ± 0.63^{b}	52.93 ± 1.33^{b}
30%E + 70%EF	13.03 ± 0.96^{ab}	52.33 ± 1.27^{b}
100%EF	9.54 ± 1.22^{b}	51.33 ± 1.53^{b}

**E – einkorn flour; EF – einkorn flakes. **The data presented are the average of 5 consecutive measurements±the standard deviation. ***Values in the same column with different exponents (a-b) have statistically significant difference ($p<0.05$) ANOVA, Fisher`s LSD.*

During the baking, water present in the formed dough evaporates which gives biscuits of characteristic structure [14,15]. It can be seen from Table 2 that the greatest baking losses showed the biscuits made from 100%E (15.16±1.01%) and the smallest – these made from 100%EF (9.54±1.22%), with the diference beteen the two samples being 5,62%. I.e., the use of EF for production of biscuits results in decrease of the losses by the baking of the final product. It was found also for the samples made from combination of flour and flakes that the baking losses decrease insignificantly with the increase of einkorn flakes content in biscuit composition. One exception from the general tendency are the biscuits containing 70%EF but the difference compared to the previous sample (50%EF) is quite small and within the standard deviation. The results obtained for the baking losses of the biscuits made from 100%EF are statistically significant ($p<0.05$).

The data on the volume of the biscuits produced (Table 2) show that the largest volume had the biscuits made from 100% einkorn flour (79.00±0.50 cm^3). These data are statistically significant compared to the others ($p<0.05$). it was established also that even with the smallest amount of einkorn flakes added (30%), the volume of the biscuits manufactured significantly decreases compared to these made from 100% einkorn flour (the volume decreased by 26 cm^3). The increase of the einkorn flakes content above 30% resulted in insignificant decrease of biscuit volume.

The values of bisuits color measured by the CIE L*a*b* system are presented in Table 3.

Table 2

Colour of biscuits measurend with CIE Lab system

Biscuits/Parameter	L*	a*	b*	ΔE
100%E	49.81±1.82	2.79±1.75	22.53±2.92	6.02±0.02
70%E + 30%EF	48.47±0.21	4.34±1.83	23.54±2.42	5.44±2.32
50%E + 50%EF	48.48±1.28	2.86±1.80	21.60±3.17	5.00±2.22
30%E + 70%EF	48.49±1.52	4.86±0.97	23.99±1.55	4.85±2.18
100%EF	54.01±2.11	3.03±0.04	20.61±0.06	4.23±1.40

**E – einkorn flour; EF – einkorn flakes. **the data presented are the average of 5 consecutive measurements±standard deviation*

The parameter **L*** show the lightness of the color. The closer its value is to zero, the darker is the color of the object studied. If the value of this parameter is close to 100, then the object studied looks brighter [16]. As can be seen from Table 3, the values of color of the biscuits produced from mixture of E+EF were almost the same but lower than these for the samples made from 100% einkorn and 100% einkorn flakes, i.e. the latter appear lighter. The highest values of this parameter had the biscuits made from 100%EF (54.01±2.11), i.e. they were the lightest while the lowest values sjowed the biscuits produced from 30%E and 70%EF (48.49±1.52), i.e. they were the darkest.

The value of the parameter **a*** in the CIE L*a*b* system define whether the color of the object studied is red or green. If the value of this parameter is positive then the color of the object studied is green, if they are negative, then the color of the biscuits is red [16]. It can be seen from the Table that the highest value of this parameter had the biscuits made

from 30%E and 70%EF (4.86±0.97) and the lowest value – these made from 100%E (2.79±1.75) but the differences are quite small. Obviously, all the samples studied had green color.

The value of the parameter **b*** show whether the color of the object studied is blue of yellow. If the value is negative, then the object studied is blue and if positive, its color is yellow [16]. It can be seen from the results shown in Table 3 that the highest value of **b*** had the biscuits made from 30%E and 70%EF (23.99±1.55) and the lowest value had the biscuits made from 100%EF (20.61±0.06). the differences are very small. With respect of this parameter, the biscuits obviously had yellow color.

The parameter **ΔE** shows the relationship between the human perception of biscuits color and the total change of the color. As can be seen from Table 3, the values of this parameter decrease with the increase of the amount of EF in the biscuits.

The values determined, considered with respect to the definitions in Table 1, indicate that all type of biscuits can be classified in the group "medium perceptible differences" of biscuits color, even these produced from 100% einkorn, since it was assumed that their value of $\Delta E = 6.02$ exceeds the boundary value ($\Delta E = 3–6$) and this difference is within the range of the standard deviation.

Conclusion

It was concluded from the studies carried out that the increase of the amount of einkorn flakes added to einkorn flour results in slightly lower baking losses and volume of baked biscuits. The highest volume had the biscuits without einkorn flakes (100%E). substantial decrease of biscuits volume was observed even with the addition of the smallest quantity of einkorn flakes (30%) to the recipe. The baking losses are significantly smaller (by about 3,5%) for the biscuits manufactured from 100%EF compared to the other samples where the difference was only 1%.

All the samples of biscuits had colors in the green and yellow spectrum and the lightest ones were these produced from 100% einkorn flakes. The differences between the individual amples were insignificant.

References

1. Komolka P., Górecka, D., Szymandera-Buszka K., Jędrusek-Golińska A., Dziedzic K. Waszkowiak K. (2016), Sensory qualities of pastry products enriched with dietary fi ber and polyphenolic substances, *Acta Sci. Pol. Technol. Aliment.*, 15(2), pp.161–170.
2. European Commission (2010), Functional Food, *Directorate-General for Research*, http://www.eurosfaire.prd.fr/7pc/documents/1276590504_functional_foods_en_publi_ce.pdf.
3. Hidalgo A., Brandolini A. (2013), Nutritional Properties of einkorn wheat (Triticum monococcum L.), *Journal of the Science of Food and Agriculture*, 94(4), pp. 601–612.
4. Hidalgo A., Brandolini A. (2008), Protein, ash, lutein and tocols distribution in einkorn (Triticum mono coccum L. subsp. Monoccum) seed Fractions, *Food Chemistry*, 107(1), pp. 444–448.
5. Nakov Gj., Stamatovska V., Necinova Lj., Ivanova N., Damyanova S. (2016), Nutritional properties of einkorn wheat (*Triticum monococcum* L.). *Proceeding of 55th Science Conference of Ruse University*, pp. 381–384.

6. Goudar G. Sathisha G.J. (2016), Effect of extrusion and flaking on the retention of nutrients and phenolic compounds in millet grains, *International Journal of Food Science and Nutrition,* 1(4), pp. 08–11.
7. Božjakovina PJ BIVITA (2017), HACCP Studija, *Dijagrami tijeka*, Hrvatska.
8. Nakov Gj. Stamatovska V., Ivanova N., Damyanova S., Godjevargova Tz., Koceva Komlenić D. (2018), Psysicochemical characteristics of functional biscuits and In vivo determination of glucose in blood after consumption of functional biscuits, *Journal of Hygienic Engineering and Design*, 22, pp. 25–32.
9. Sulieman E., Mohammed A., Elkhalifa E. (2008), Evaluation of the chemical and sensory characteristics of biscuits supplemented with soybean flour, *Gezira Journal of Agricultural Science*, 6(1), pp. 97–107.
10. Manley D. (2000), Technology of biscuits, cracker and cookers, *Woodhead Publishing Limited*, Cambridge.
11. Regulation № 9 from March 16, 2001 of the quality of the water intended for drinking and household purposes.
12. AACC Method 10-50D (2000), *Baking Quality of Cookie Flour, Approved Method of the American Association of Cereal Chemists, 10th ed.* AACC, ST. Paul.
13. Budžaki, S., Koceva, Komlenić, D., Lukinac, Čačić, J., Čačić, F., Jukić, M. & Kožul, Ž. (2014), Influence of cookies composition on temperature profiles and qualitative parameters during baking, *Croat. J. Food Sci. Technol.,* 6(2), pp. 72–78.
14. Nakov, Gj., Koceva, Komlenić, D., Stamatovska, V., Jukić M. (2017), Influence on time of baking and different role of barley flour on the colour of the biscuits, *Journal of Hygienic Engineering and Desing,* 21, pp. 90–95.
15. Nakov Gj. (2017), Physucal Characteristics of Functional Biscuits, *Proceedings of University of Ruse*, 56(10.2), pp.125–129.
16. Konica Minolta, Available at: https://sensing.konicaminolta.us/blog/identifying-color-differences-using-l-a-b-or-l-c-h-coordinates

Influence of sugars on the formation of structural and mechanical characteristics of of agar polysaccharides' gels

Antonella Dorohovich[1], Olena Goncharuk[2], Dariia Matias[1], Julya Kambulova[1]

1 – National University of Food Technologies, Kyiv, Ukraine
2 – Institute of Surface Chemistry of National Academy of Sciences of Ukraine, Kyiv

Keywords:

Gel
Agar
K-carrageenan
Structure
Strength

Article history:

Received 16.03.2018
Received in revised form 20.04.2018
Accepted 29.06.2018

Corresponding author:

Dariia Matias
E-mail: matyasd@ukr.net

DOI:
10.24263/2310-1008-2018-6-1-5

Abstract

Introduction. The current scientific task is to establish differences in structural and mechanical characteristics of agar and k-carrageenan gels with different types of sugars (saccharose, glucose, fructose, lactulose).

Materials and methods. Structural and mechanical characteristics of agar polysaccharides' gels (agar, k-carrageenan) are the instantaneous springy modulus, elastic modulus, springy, elastic and plastic deformation. They were investigated by method of tangential displacement of the plate. There were used model systems of gels on agar and k-carrageenan with saccharose, glucose, fructose and lactulose.

Results and discussion. Gels of agar polysaccharides can withstand different maximum loads depending on the type of sugar. The instantaneous springy modulus had the highest values in gels with saccharose, both on agar and on k-carrageenan, and the values of the modulus of elasticity were higher for gels with monosaccharides. In our opinion, the differences are explained by the difference in the spatial structure and molecular weight of sugars, which imprints on the ability to bind water, that is, hydration ability. Values of total deformation depend on the type of gel: for agar and k-carrageenan gels on different sugars the dependences are different. The greatest value of the total deformation of agar gel has a sample with saccharose – 42.38 c.u. For k-carrageenan gels, the greatest value is the total deformation with monosaccharides. In this case, both agar and k-carrageenan samples with saccharose have higher values of the springy deformation index than the total number of elastic and plastic deformations. However, independently of the polysaccharide, the use of glucose and fructose gives elasticity and plasticity to gel. Adding lactulose to agar polysaccharides' systems leads to a strengthening of the structure of the formed gel, as evidenced by higher values of the force of maximum load for each system.

Conclusions. The individual influence of saccharose, glucose, fructose, lactulose on the structural and mechanical characteristics of gels of agar and k-carrageenan has been established. Disaccharides in general cause greater springy modulus, while monosaccharides cause greater modulus of elasticity of systems and an increase in the total proportion of elastic and plastic deformation.

Introduction

The main raw material for the production of gel-like confectionery products is gel formers of polysaccharide origin, especially agar polysaccharides – agar and k-carrageenan. They form the structure of products in combination with high sugar content [1–3].

In literary sources, the formation of agar polysaccharides' gel is described predominantly with saccharose and the conditions of gel formation and the effect on the formation of the structure of the gel with such sugars as glucose, fructose and lactulose are described insufficiently [4–7]. In this regard, there is a great scientific and practical interest in the study of differences in the formation of structural and mechanical characteristics of agar polysaccharides' gel with different sugars.

Let's consider the conditions of their gel-formation in detail and determine the role of sugars in this mechanism.

Agar or agarose is a complex mixture of sulfated polysaccharides, the main fraction of which is the neutral polysaccharide agarose, which forms a strong gel [8, 9]. Agar gels are formed by the mechanism of cold hardening. Gel-formation is determined exclusively by hydrogen bonds, the presence of which contributes to the formation of single and double helixes. These left-handed spirals are stabilized by water molecules inside the double-helix cavity and by external hydroxyl groups, which makes it possible to aggregate up to 10000 spirals and form microdomains from spherical microgels. The formed gels, as a rule, are solid, fragile, have clearly defined forms, are prone to syneresis and show hysteresis [10].

There is no need for sugar to form an agar gel. Indeed, scientists [11] studied the effect of introduced into the system sugar in a wide range of concentrations. It has been found that an increase in the sugar content leads to a significant increase in the deformation of the gel, reducing the temperature of the gel formation.

Such patterns are associated with the destruction and reorganization of transverse bonds of agarose into a more homogeneous physical grid with the presence of sugars. An increase in the elasticity of the gel was also noted, indicating the formation of a much weaker structural grid and the absence of syneresis.

However, there is evidence [12] that the gel-forming properties of low sulfur agar are enhanced in systems with more than 60% of saccharose. The authors suggest that this synergism is explained by the different inclination of the helix, which depends on the number and distribution of ether sulfate groups.

Carrageenan is a macromolecular linear polysaccharide consisting of repeating disaccharide galactose–3,6–anhydrogalactose fragments (sulfated and non-sulfated), linked by α- (1,3) and (1,4) -β-D-glycosidic alternating rows [13, 14].

Carrageenan gels are formed by the mechanism of ionotropic gel-formation in combination with the mechanism of cold hardening [15]. Gelation involves twisting the polysaccharide chains into helix due to the presence of K^+ or Ca^{2+} ions when cooled. Subsequently, cations contribute not only to the formation of a spiral form of molecules, but also to the coupling of spirals in the zone of connection [16, 17]. Adding additional ions to the system increases the stability of the spiral and promotes its aggregation [18].

Commercially available carrageenans are known as k-kappa, j-yota and λ-lamda, they are obtained artificially and do not exist in isolation in the environment [19]. All of them have very different texture due to differences in the number of sulfate structural groups. Typically, k-carrageenan forms solid brittle gels, in the concentration of gel-former of 0.5–3% [20, 21].

Scientists [22] studied the effect of saccharose and glucose on the dynamic viscosity and springiness of k-carrageenan gels by differential scanning calorimetry. It has been established

that Young's dynamic module E 'and the melting point of k-carrageenan gels increased with increasing sugar content, since the amount of heat absorbed during formation of 1 mole of compound zones increased with increasing sugar concentration. It has been suggested that sugars can create zones of connection and stabilize the structure of the bonding zones, but excessive addition of sugars paralyzes the free water that is necessary to form bonding zones.

The thermoreversal gel-formation of water k-carrageenan solution with saccharose (up to 30% by weight) has been investigated using small and large deformation oscillatory rheology [23]. It has been found that saccharose increases the temperature of gel-formation (from 36.8 °C to 52.8 °C) and the melting point (from 51.2 °C to 67.3 °C) to a higher level and enhances the gel net. Studies have shown that, when saccharose is added, tighter and thicker structures of k-carrageenan fibrils are formed. The displacement of the band of infrared spectroscopy of G4S of k-carrageenan and the loss of the vibration band of the free hydroxyl group in saccharose showed the interaction between saccharose and k-carrageenan molecules.

Thus, the information in literary sources, regarding the influence of sugars on the formation of agar polysaccharides' gels is presented rather limited and refers to interactions only with saccharose. Therefore, when developing the technology of products with a gel-like structure and with different types of sugars (glucose, fructose, lactulose), it is important to consider the individuality of each sugar and determine its effect on gel formation and structural and mechanical characteristics of gels. This requires series of experimental studies.

Materials and methods

Materials

To prepare the model gel samples, white crystalline sugar (Agroprodinvest, Ukraine), glucose (Twell Sansino, China), fructose (Vitamin, Ukraine), lactulose (STADA Arzneimittel AG, Germany) agar 1200 (Rokogel, Spain) and k-carraginan purified (Budenheim, Germany) have been used.

Preparation of model systems

In the studies model systems of gels on agar and k-carrageenan have been used: with saccharose (M1, M4), glucose (M2, M5), fructose (M3, M6) (Table 1), and also model systems of gels with lactulose. Lactulose was introduced to replace saccharose (M7, M10), glucose (M8, M11), fructose (M9, M12) in the amount of 10 g of DM / 100 g of gel. Model samples were prepared according to the following scheme: agar was first poured by cold water and left for 20 minutes to swell, then sugar was added, and the mass was boiled to a content of dry matter (DM) of 60%, poured into cuvette with a corrugated plate, cooled and left for gel-formation for 24 hours at t = 18±2°C. For k-carrageenan gels all dry ingredients were mixed, potassium chloride was added additionally in the ratio of 0.1:1 to the polysaccharide and the mass was boiled to 60% of DM, was poured into cuvette with a corrugated plate, was cooled and left for gel-formation for 24 hours at t = 18±2°C.

Table 1

Model samples of gels

Abbreviation	Composition of the components of the system	Prescription ratio of system components, g / per 100 g
M1	agar, saccharose	1.0:60.0
M2	agar, glucose	1.0:60.0
M3	agar, fructose	1.0:60.0
M4	k-carrageenan, saccharose, potassium chloride	0.6:60.0:0.06
M5	k-carrageenan, glucose, potassium chloride	0.6:60.0:0.06
M6	k-carrageenan, fructose, potassium chloride	0.6:60.0:0.06
M7	agar, saccharose, lactulose	1.0:50.0:10.0
M8	agar, glucose, lactulose	1.0:50.0:10.0
M9	agar, fructose, lactulose	1.0: 50.0:10.0
M10	k-carrageenan, saccharose, potassium chloride lactulose	0.6:50.0:0.06:10.0
M11	k-carrageenan, glucose, potassium chloride lactulose	0.6:50.0:0.06:10.0
M12	k-carrageenan, fructose, potassium chloride lactulose	0.6:50.0:0.06:10.0

The structural-mechanical characteristics were determined in the formed gels by the method of tangential displacement of the plate.

Method of tangential displacement of plate

Method of tangential displacement is based on the immersion of the corrugated plate in a newly prepared research system, where after complete structuring of the sample, load is applied from minimum to maximum (with a clear step of variation for each polysaccharide), while fixing graphically the change of deformation in time. A plate is suspended to a quartz or glass spiral spring with a solid thread, connected to laboratory scales (the Vailer-Rebinder method). Applied efforts (load on a cup of scales or lowering the table down in the case of a stretch of the spring) cause displacement of the corrugated plate. Data registration is carried out using an automatic device and a computer program in the form of a curve "deformation – time". On the basis of the obtained curve, values are calculated that characterize the springy-plastic properties of gels. The application of this device allows to obtain a number of curves $\varepsilon = f(\tau)$ quickly (Figure 1), after processing them all other springy-plastic-viscous constants – modulus of instantaneous springyness, modulus of elasticity, general, elastic, springy and plastic deformation are found.

The plate is always set precisely in the middle of the cuvette, in which the investigated system is located. The plate area on both sides should be 10 cm^2. The size of the cuvette is 2×4. For such dimensions, the development of deformation completely passes in the studied systems and the calculation of structural and mechanical constants is simplified (a = 1 cm, S = 10 cm^2). The time for structuring all samples is 24 hours. By short-term sample loads, the weight of the first load is selected with gradually increasing weight. Curve $\varepsilon = f(\tau)$ is

recorded during 5 minutes, then the load is removed and after 5 minutes load again, increasing the weight of samples on the cup. Loading and unloading continues until the destruction of the structure – the onset of a conditionally springy rupture, and the stretching of the plate from the sample. The loads are carried out in a way to obtain a minimum of 6–8 deformation curves provided that all the systems under study are measured in a single load range. The resulting curves are interpreted using the «OriginPro» program. The loading ***p (r),*** on the unit area of the plate, is expressed by the voltage of the displacement ***P (Pa)*** and is calculated by the formula:

$$P = \frac{F}{S}$$

where F = mg is load; m is weight, kg; g is acceleration of the earth's gravity, m/s^2, S is area of the plate, m^2 (S = 10^{-3} m^2).

According to the "deformation-time" curve, springy, elastic and plastic deformations are found for each prototype and the instantaneous springy and elasticity modules are calculated.

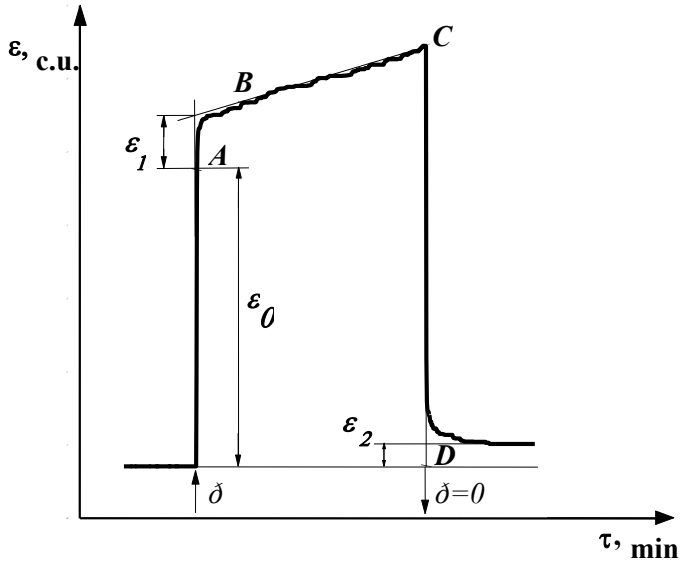


Figure 1. The "deformation-time" curve for an springy-plastic body

The springy deformation **ε₀,** which arises at the moment of applying the load (τ = 0) and disappears after lifting the load at the speed of sound, is characterized by the magnitude of the conditional-instantaneous springy modulus E1, which is calculated by the formula:

$$E1 = \frac{P}{\varepsilon_0}$$

The elastic deformation **ε₁**, representing the process of springy aftereffect while maintaining a constant load (p = const) for several minutes, is characterized by the elastic modulus E2, which is calculated by the formula:

$$E2 = \frac{P}{\varepsilon_1}$$

The elasticity of the gels is due to the stretching of the hydrocolloids' macromolecules shuffled into the balls, which return to the initial state after the removal of the load. The elastic ε_1 and springy ε_0 deformations are mechanically reversible. When lifting the load (p = 0) the process goes in the opposite direction and the system returns to the initial state. If the load exceeds the springy limit, a springy gap occurs, or there is a plastic deformation ε_2. In this case, after the instantaneous springy deformation ε_0, along with the decaying springy effect on the AB region, a gradual increase in plastic deformation occurs. The next rectilinear section BC is due to the constant value of plastic deformation (flow). When lifting the load (p = 0), the system does not return to the initial state, but differs from the initial value of the residual plastic deformation ε_2. The area CD determines the value of the total deformation of the system in conditional units.

For the correct characterization of the springy-plastic properties of gels, modules are generalized by building the dependences $E_1 = f(P)$, $E_2 = f(P)$, and extrapolating the values of the modules to P = 0.

The value of springy, elastic and plastic deformation is presented in percentage terms to general deformation, in order to facilitate their perception.

Results and discussion

The type of the structure-forming agent and the mechanism of its gel formation determines the nature of the structure of the formed gel [24, 25]. And the structural and mechanical properties of gel will depend on the individual effects of sugar used in the system. The results of the determination are presented in the Figure 2 and show that agar polysaccharides' gels can withstand different loads depending on the type of sugar.

Thus, agar gels (sample № 1) with saccharose, glucose, fructose can withstand the same load of 2449.3 Pa, and gels of k-carrageenan (sample № 2) have dependence of the strength on sugar: with saccharose – 1126.3 Pa, with glucose – 920.5 Pa, with fructose – 1028.2 Pa. This suggests that sugars play a less significant role in the mechanism of agar formation in comparison with k-carrageenan [26, 27]. Samples of k-carrageenan and monosaccharides are inferior to samples on saccharose due to the strength of their structure. And fructose can withstand greater load than glucose.

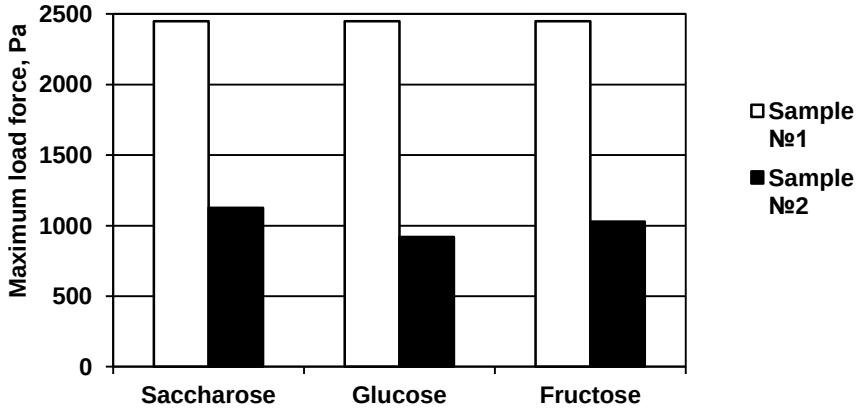


Figure 2. Maximum load force on agar and k-carrageenan gel

In addition, model systems are characterized by various structural and mechanical indicators: springyness, elasticity, plasticity. The instantaneous springy modulus (E1), which characterizes the instantaneous springy deformation that occurs at the moment of loading, and the elastic modulus (E2), which characterizes the springy aftereffect in time, are presented in the Table 2 for the experimental samples.

Table 2

Springy-plastic characteristics of model gel samples

Sample	Module, kPa (P=0)	
	of instantaneous springiness, E1	of elasticity, E2
M1	218.67	438.70
M2	168.78	612.13
M3	117.10	950.45
M4	158.98	125.96
M5	144.53	325.28
M6	99.74	600.00

It has been determined that saccharose gels in the system on agar as well as on k-carrageenan have the largest instantaneous springy module. For example, in model systems on agar with saccharose (M1) the value of E1 is 218.67, kPa, with glucose (M2) – 168.78 (23% less), with fructose (M3) – 117.10 (by 46% less) kPa; in the model systems on k-carrageenan with saccharose (M4), the E1 value is 158.98 kPa, glucose (M5) – 144.53 kPa (10% less), fructose (M6) – 99.74 kPa (37% less)

The values of the modulus of elasticity have an inverse relationship. Thus, saccharose gels in agar polysaccharides' systems have the smallest modulus of elasticity. For example, in model systems on agar with saccharose (M1), the E2 value is 438.7 kPa, with glucose (M2) – 612.13 kPa (more by 39%), with fructose (M3) – 950 kPa (more by 117%); in the model systems on k-carrageenan with saccharose (M4) the value of E2 is 125.96 kPa, with glucose (M5) – 325.28 kPa (more by 158%), with fructose (M6) – 600 kPa (more by 376%)

More specifically, the effect of sugars on the springy-plastic characteristics of agar or k-carrageenan gels is due to the correlation between the types of deformation under the action of the same loading for samples is given in Table 3.

It was found that among samples of agar gels, the greatest value of total deformation has a sample with saccharose (M1) – 42.38 c.u., glucose sample (M2) – 28.85 c.u., with fructose (M3) – 28.87 c.u., which is 32% less.

In our opinion, such patterns confirm the peculiarities of the structure-formation of the polysaccharides themselves. As indicated in the literary review, sugars negatively affect the formation of a three-dimensional grid of agar gel, preventing the formation of hydrogen bonds necessary for cross-linking polysaccharide chains. Saccharose, which has a higher molecular weight, a greater total amount of hydrogen reactive groups, prevents the interconnection of agar macromolecules. In turn, the molecules of monosaccharides with less hydrophilic bonds will have a less negative effect on the interaction of agar molecules and the formation of a gel net, which affects the resulting lower values of total deformation.

Table 3

Degree and character of deformation of model gel samples

Sample	Shear stress which is compared to P, Pa	Deformation			
		general c. u.	springy, %	elastic, %	plastic, %
M1	2449.31	42.38	86.44	8.20	4.06
M2		28.85	77.52	17.12	5.36
M3		28.87	74.14	21.60	4.26
M4	783.31	31.35	69.57	27.90	2.53
M5		37.96	67.83	25.06	7.11
M6		36.95	59.86	33.11	7.03

For k-carrageenan gels, there is an inverse relationship: the total deformation of the sample with saccharose (M4) is the smallest – 31.35 c.u.; with glucose (M5) – 37.96 c.u., which is 21% higher; with fructose (M6) – 36.95 c.u., more by 18%.

In the ionotropic gel-formation mechanism of k-carrageenan, cross-linking of polysaccharide molecules occurs at a higher rate due to the formation of potassium bridges. Therefore, the presence in large concentrations of sugar does not inhibit gel- formation, and directly affects the degree of binding of free water. Keeping a larger number of water molecules in the matrix space of the k-carrageenan gel, saccharose forms a stronger structure than gels with monosaccharides.

It is determined that the greatest value of the total deformation for all experimental samples has the springy fraction. In this case, both agar and k-carrageenan samples with saccharose (M1, M4) have higher values of the springy deformation index than the total amount of elastic and plastic deformations. It is also confirmed organoleptically – gel with saccharose has more brittle and firm consistency than with monosaccharides, which are characterized by greater elasticity and plasticity. We suggested that greater elasticity and plasticity of gels with monosaccharides are associated with a lower degree of water in the system, as in the case of pectin gels [28].

Thus, the obtained results confirm literary data of the influence of sugars on the formation of agar polysaccharides' gel. It has been found that glucose and fructose have less pronounced effect on the mechanism of agar gel-formation in comparison with saccharose, which contributes to its strength, and in k-carrageenan gels, on the contrary, under the influence of monosaccharides introduced into the system, general deformation increases. However, regardless of the polysaccharide, the use of glucose and fructose give the elasticity and plasticity to the gel.

Determination of the influence of lactulose on the structure of gels was investigated by replacing it with 10 g of sugar, saccharose, glucose, fructose. The same amount is the maximum recommended daily intake of lactulose as a prebiotic. The influence of lactulose on the structural and mechanical characteristics of agar polysaccharides' gels is presented in Figure 4.

It was established that the addition of lactulose to systems with agar polysaccharide leads to a strengthening of the structure of the formed gel, as evidenced by higher values of the maximum load strength maintained by each system.

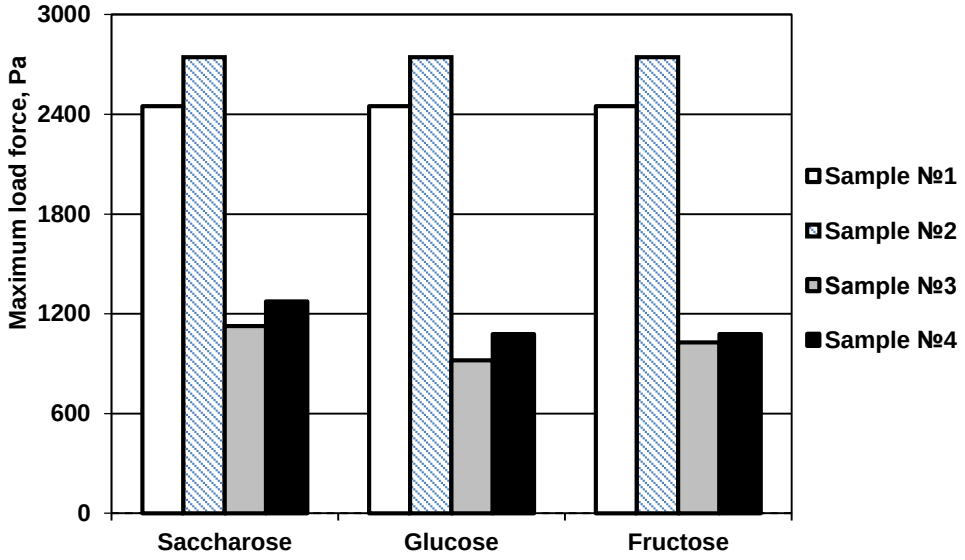


Figure 4. Maximum loading force on agar and k-carrageenan gels without and with addition of lactulose

For example, the loading force of agar gel with saccharose, glucose and fructose (sample № 2) increases by 11% – up to 2714.01 Pa, compared to the basic samples (sample № 1); k-carrageenan gel (sample №4) with saccharose – by 13%, up to 1273.11 Pa, with glucose and fructose – up to 1077.41, 19% and 5%, relative to basic samples of gel (sample № 3). We assume that the addition of sugar, which has a higher molecular weight, will have a greater impact on the viscosity and density of solutions, which leads to the strengthening of the system as a whole. Particularly noteworthy is the strengthening of the structure of gels with monosaccharides, which in our opinion is associated with an increase in the total number of hydration of sugars, and consequently – greater binding of water and structuring of the system.

The confirmation of the above results was also found in the analysis of the nature of deformation of samples of gels, Figures 5–6**.**

The introduction of lactulose into samples of agar gels leads to an increase in the proportion of springy deformation in the sample with saccharose (M7) by 5.2%, with glucose (M8) and fructose (M9) by 15.4% and 18.0%, respectively. While the proportion of elastic deformation naturally decreases for samples with monosaccharides (M8 and M9) by 72.6% and 63.3%, respectively. It is also organoleptically noted that the consistency of gels with the addition of lactulose becomes more solid and fragile, which confirms the results of increasing the springyness of the system.

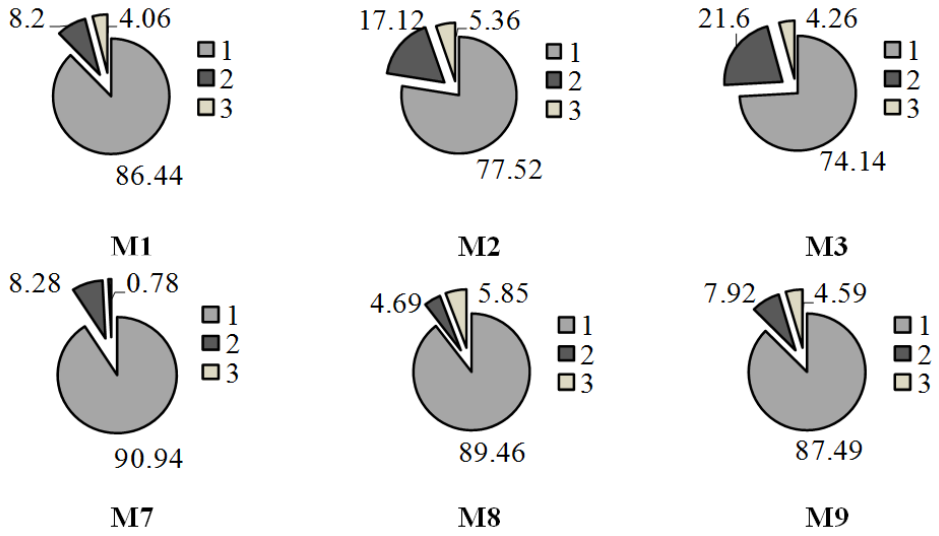


Figure 5. Deformation (1-springy, 2-elastic, 3-plastic) of basic (M1-M3) samples of agar gels and with the addition of lactulose (M7–M9)

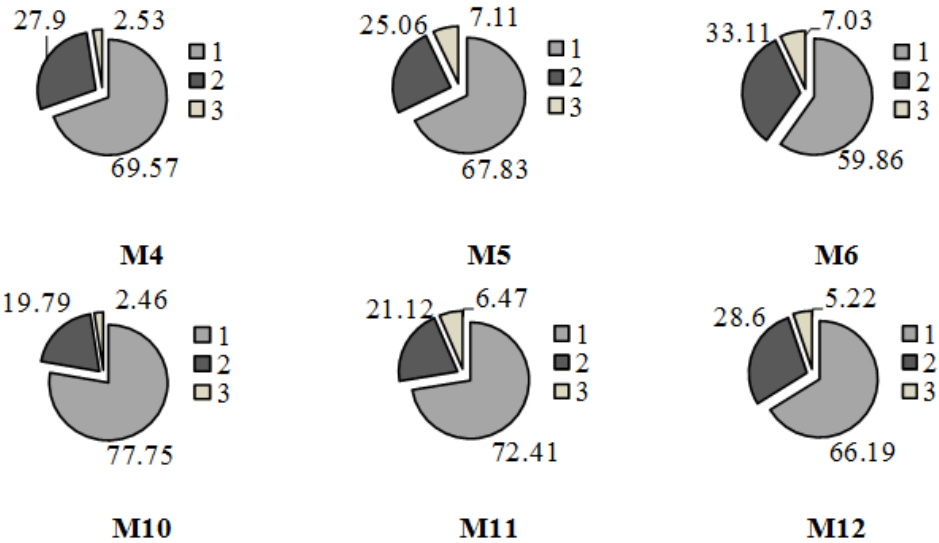


Figure 6. Deformation (1-springy, 2-elastic, 3-plastic) of basic (M4–M6) samples of k-carrageenan gels without and with addition of lactulose (M10-M12)

The addition of lactulose into samples of k-carrageenan gels has a similar effect to agar gels: the proportion of springy deformation increases in the sample with saccharose (M10) by 10.5%, with glucose (M11) and fructose (M12) – by 6.3% and 9.5%, respectively. While the proportion of elastic deformation naturally decreases for samples with saccharose (M10) by 29.0%, samples with monosaccharides (M11 and M12) by 15.7% and 13.6%, respectively.

Conclusion

Based on the obtained results, the following conclusions can be made:

1. It has been established that gels of agar polysaccharides can withstand different maximum loads depending on the type of sugar. Examples of k-carrageenan and monosaccharides are inferior to samples with saccharose, which in our opinion is due to different molecular weight and solubility of sugars. In the model agar gel systems with any experimental sugar the magnitude of the applied load is the same. That is, sugar in the mechanism of agar formation plays a smaller role.
2. It has been determined that the instantaneous springy modulus had the highest values in gels with saccharose, both on agar and on k-carrageenan, and the values of the modulus of elasticity were higher for gels with monosaccharides. In our opinion, the differences are explained by the difference in the spatial structure and molecular weight of sugars, which imprints on the ability to bind water, that is, hydration ability.
3. It has been established that the values of total deformation depend on the type of gel: for agar and k-carrageenan gels on different sugars the dependences are different. The greatest value of the total deformation of agar gel has a sample with saccharose – 42.38 c.u. For k-carrageenan gels, the greatest value is the total deformation with monosaccharides. In this case, both agar and k-carrageenan samples with saccharose have higher values of the springy deformation index than the total number of elastic and plastic deformations. However, independently of the polysaccharide, the use of glucose and fructose gives elasticity and plasticity to gel.
4. Adding lactulose to agar polysaccharides' systems leads to a strengthening of the structure of the formed gel, as evidenced by higher values of the force of maximum load for each system. Particularly noteworthy is the strengthening of the structure of monosaccharides. The obtained results, in our opinion, are related to an increase in the total number of hydration of sugars, and hence to a greater binding of water and structuring of the system.

References

1. Belitz H.-D., Grosch W., Schieberle P. (2009), *Food Chemistry. 4th revised and expanded edition*, Springer-Verlag, Leipzig.
2. Gorzynski-Smith J. (2008), *Organic chemistry. 2th edition*, McGraw-Hill, New York.
3. Cui S.W. (2005), *Food Carbohydrates. Chemistry, physical properties and applications*, CRC Press, New York.
4. O'brien-Nabors L. (2001), *Alternative Sweeteners, Third edition (Food science and technology)*, CRC Press, New York.
5. Hull P. (2010), *Glucose syrups: technology and applications*, Wiley-Blackwell.

6. Mitchell H. (2006), *Sweeteners and sugar alternatives in food technology*, Blackwell Publishing, Oxford.
7. Saarela M., Kallamaa K., Mattila-Sandholm (2003), The effect of lactose derivatives lactulose, lactitol and lactobionic acid on the functional and technological properties of potentially probiotic Lactobacillus strains, *Int. Dairy J.*, 13, pp. 291–302.
8. Gliksman M. (1983), *Food hydrocolloids 3–4*, CRC Press.
9. Armisen R., Galatas F. (2000), Extraction of Agar. In handbook of hydrocolloids, *Phillips GO and PA Williams*, 24.
10. Nishinari K., (2000), Handbook of hydrocolloids, *Woodhead Publ.*, pp. 247–267.
11. Normand V., Aymard P., Lootens D. (2003), Effect of sucrose on agarose gels mechanical behavior, *Carbohydrate Polymers*, 54(1), pp. 83–95.
12. Imeson A. (2009), *Agar. Food stabilisers, thickeners and gelling agents*, pp. 31–49.
13. Imeson A.P. (2000), Handbook of hydrocolloids, Carrageenan.
14. Nussinovich A., Avi G. (2015), *Hydrocolloid carrier beads with inert filler material, U.S. Patent No. 8,932,634. 13 Jan. 2015*, U.S. Patent and Trademark Office Washington,
15. Belton P.S., Chilvers G.R., Morris V.J. (1984), Effects of group I cations on the gelation of iota-carrageenan, *International Journal of Biological Macromolecules*., 6(6), pp. 303–308.
16. Saha D., Bhattacharya S. (2010), Hydrocolloids as thickening and gelling agents in food: a critical review, *Journal of food science and technology*, 47(6), pp. 587–597.
17. Rachas, C. (1984). Mechanism of Gel Formation in kappa-carrageenan Biopolymers, *Food hydrocolloids*, 23, pp. 733–746.
18. Morris E.R., Rees D.A., Robinson G. (1980), Cation-specific aggregation of carrageenan helices: domain model of polymer gel structure, *Journal of molecular biology*, 138, pp. 349–362.
19. Hoefler A. C. (2004), Hydrocolloids: Practical guides for the food industry, *St. Paul, MN: American Association of Cereal Chemists*, pp. 27–41.
20. Campo V.L., Kawano D.F., da Silva D.B. (2009), Carrageenans: biological properties, chemical modifications and structural analysis – a review, *Carbohydr. Polym*., 77, pp. 167–180.
21. Berth G., Vukovic J., Lechner M.D. (2008), Physicochemical characterization of carrageenans – a critical reinvestigation, *J. Appl. Polym. Sci*., 110, pp. 3508–3524.
22. Williams A., (1990), k-Carrageenan gels: Effect of sucrose, glucose, urea, and guanidine hydrochloride on the rheological and thermal properties, *Journal of Agricultural and Food Chemistry*, 38(5).
23. Yang Z. (2017), Effects of sucrose addition on the rheology and microstructure of k-carrageenan gel, *Food Hydrocolloids*.
24. Imeson, A. (2010), *Food Stabilisers, Thickeners and Gelling Agents*, Wiley-Blackwell.
25. Stephen A.M., Philips G.O., Williams P.A. (2006), *Food polysaccharides and their applications, 2th edition*, CRC Press, Boca Raton.
26. Boral S., Saxena A., Bohidar H.B. (2008), Universal growth of microdomains and gelation transition in agar hydrogels, *J. of Physical Chemistry B*, 112(12), pp. 3625–3632.
27. Matsuo M., Tanaka T., Ma L. (2002), Gelation mechanism af agarose and k-carrageenan solutions estimated in terms of concentration fluctuation, *Polymer*, 43, pp. 5299–5309.
28. *The functional properties of sugar on a technical level. Danmark: Nordic Sugar*, Available at: http://www.nordicsugar.com/fileadmin/Nordic_Sugar/ Brochures_ factsheet_policies_news/Download_center/Functional_properties_of_sugar_on_a_technical_level/Functional_prop_on_tech_level_uk.pdf

Copra oil: chemistry, production. An extensive review on Indian specifications and functional aspects.

G.V. Pavan Kumar, N.V.V.S.S. Lakshmi, Ch. Deena, B. Bhavani, P. Rajendra Kumar

Koringa College of Pharmacy, Korangi, India

Keywords:
Coconut
Copra
Oil
Chemistry
Application
Functional

Article history:

Received 14.03.2018
Received in revised form 02.06.2018
Accepted 29.06.2018

Corresponding author:

G.V. Pavan Kumar
E-mail: drgvpawankumar@gmail.com

DOI:
10.24263/2310-1008-2018-6-1-6

Abstract

Introduction. This research attempts to scientifically review the Chemistry and therapeutic benefits of Coconut oil, also commonly known as Copra oil.

Materials and methods. Review is based on the modern scientific literature analysis.

Results and discussion. VCO, the purest form of coconut oil is essentially colorless and free from rancidity. VCO differs from natural coconut oil in the process of extraction. While the latter is extracted by cold milling or cold compression of copra (another name for dried coconut kernels), the former is extracted from coconut milk obtained from fresh coconuts. Natural or mechanical means are used to obtain the oil. Heat may or may not be used for extraction. The oil is not subject to chemical refining, bleaching or de-odorizing. Further processes such as fermentation, and centrifugal separation, refrigeration, and enzyme action, enables the separation of the oil from water or moisture. In some cases, micro-expelling is used i.e. boiling the fresh coconut oil, followed by evaporating the water / moisture or by direct cold compression of fresh dried coconut meat .The aroma of the fresh coconut can vary from mild to intense depending on the method employed for oil extraction.

The total production of edible grade coconut oil in India is about 400000 tons. Rotaries and expellers are used for Coconut oil production in India by crushing the dry coconuts (known as copra) for recovery of oil. VCO mainly consists of medium chain triglycerides (MCT), which are resistant to peroxidation. They differ from animal fat which consists of long chain saturated fatty acids and is the one main risk factor for cardiac complication. Medium chain fatty acids (MCFA) differ from long chain fatty acids in that they actually help to protect against heart disease. MCFA have been reported to lower the risk of both atherosclerosis and heart disease.

Conclusion. A number of health benefits have been attributed to this oil. These include benefits in skin care, hair care, stress relief, weight loss and cholesterol level maintenance, immunomodulatory effects, cardiovascular uses, and more recently in Alzheimer's disease. Coconut oil has a long shelf life and is used in baking industries, processed foods, infant formulas, pharmaceuticals, cosmetics and as hair oil.

Introduction

Coconut is a plant in the Palmae family. For thousands of years tropical countries have used coconut from the tree (*Cocos nucifera* Linn), Family Aracaceae (*palm* family) as an integral part of their diet and livelihood. Known as "*kalpa vriksha*", in Sanskrit, this interprets as the palm which supplies all the necessities of life.In Indian traditional medicine, the coconut has been used as a medicinal plant for centuries. Coconut milk helps solve urinary problems, gallstones, and hematemesis. Coconut oil has been used as a burn wound remedy [1]. *Coconut oil* or *Copra oil* is an edible oil extracted from the kernel of mature coconuts of the coconut palm.Coconut oil also appears to promote the immune system response. Feeding coconut oil completely abolishes the expected immune factor responses to endotoxin and diminishes the production of proinflammatory cytokines *in vivo* [2, 3]. Recently, the biological properties of virgin coconut oil (VCO) have been widely investigated. It has been found that lauric acid is an effective compound in VCO. Lauric acid is the precursor of monolaurin [4], which has been shown to modulate immune cell proliferation [5] and possess antimicrobial activity [6]. Inflammation involves many other processes of the immune system; for example, during both acute and chronic inflammatory response, the immunological component cells are activated in response to foreign organisms or antigenic substances [7]. Recent studies point to the important role of inflammation in a wide variety of human diseases that are not primarily disorders of the immune system. These include cancer, atherosclerosis, ischemic heart disease, and some neurodegenerative diseases such as Alzheimer's disease [8–14].All parts of the coconut palm are useful, with significant economic value.

Specification for coconut oil

Indian-Standard IS: 6220–1971 specifies the quality parameters of copra for grading for different uses in India. This standard prescribes the methods of grading and the requirements of copra for extraction of oil and for table use, together with methods of sampling and test. The 3 types of copra are defined: type 1 (grades 1, 2 and 3), ball copra for table purpose; type 2 (grades 1 and 2), cup copra for table purpose;and type 3 (grades 1, 2 and 3), milling copra for oil extraction. The material shall be the kernels obtained from the fruits of *Cocos nucifera Linn*. Requirements cover physical and chemical properties, packing, marking, sampling and test.

Chemistry and properties

In the 1920s and 1930s it was discovered that coconut oil differed from other fats and oils in that it was found to be composed predominantly medium chain triglycerides. The composition of Fatty acids in VCO as determined by Gas Liquid Chromatography include Saturated fats: Lauric acid (45% to 52%) , Myristic acid (16% to 21%), Palmitic acid (7% to 10%), Caprylic acid (5% to 10%), Capric acid (4% to 8%), Stearic acid (2% to 4%), Caproic acid (0.5% to 1%) and Palmitoleic acid (in traces) and Unsaturated fats: Oleic acid (5% to 8%) , Linoleic acid (1% to 3%) and Linolenic acid (up to 0.2%). VCO is colourless, free of rancidity and has a specific fresh natural coconut aroma and the specifications which should meet by the Virgin Coconut Oil listed in the Table 1.

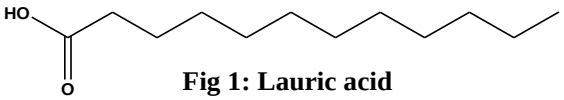


Fig 1: Lauric acid

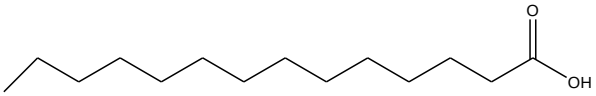


Fig 2: Myristic acid

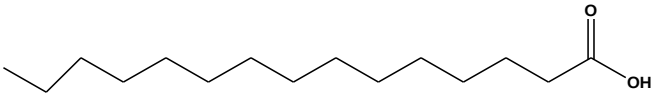


Fig 3: Palmitic acid

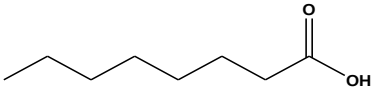


Fig 4: Caprylic acid

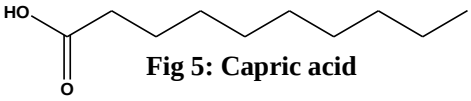


Fig 5: Capric acid

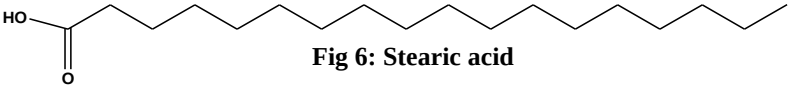


Fig 6: Stearic acid

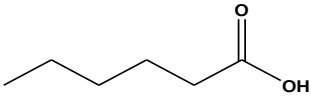


Fig 7: Caproic acid

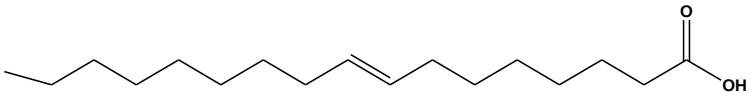


Fig 7: Pamitoleic acid

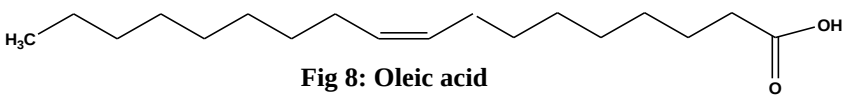


Fig 8: Oleic acid

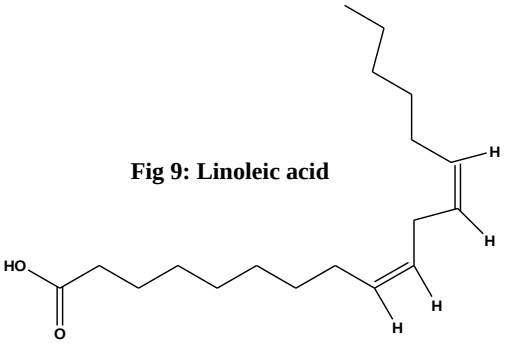


Fig 9: Linoleic acid

Table 1

Table–1 Indian specification for coconut oil

	Expressed				Solvent Extracted		
Characteristics	**Refined Grade**	**Grade 1A (Raw)**	**Grade 1B (Raw)**	**Grade 2 (Raw)**	**Refined Grade**	**Semi Refined**	**Grade 1 (Raw)**
Moisture & insoluble impurities (max) (%)	0.1	0.25	0.25	0.25	0.1	0.25	1.0
Colour Lovibond colour scale in Y+5R	2	4	11	30	2	10	30
Refractive index at 40°C	1.4480 – 1.4490	1.4480 – 1.4490	1.4480 – 1.4490	1.4480 – 1.4490	1.4480 – 1.4490	1.4480 – 1.4490	1.4480 – 1.4490
Specific gravity at 30 °C/30 °C	0.915 – 0.920	0.915 – 0.920	0.915 – 0.920	0.915 – 0.920	0.915 – 0.920	0.915 – 0.920	0.915 – 0.920
Saponification value (min)	250	250	250	250	250	250	250
Iodine value (wijs)	7.5–10	7.5–10	7.5–10	7.5–10	7.5–10	7.5–10	8.0 –13
Acid value (max)	0.5	2.0	6.0	8.0	0.5	1.0	10
Unsaponifiable (max)	0.5	0.8	0.8	0.8	0.5	0.8	1.0
Polenske value (min)	13.0	13.0	13.0	-	13.0	-	-
Flash point, °C (min)	-	-	-	-	225	100	90

Materials and methods

Review is based on the analysis of scientific literature.

Results and discussion

Common methods of production of coconut oil

Different types of coconut oil for edible purposes are available viz, virgin coconut oil from wet coconuts (unrefined grade); coconut oil from dry coconuts (unrefined grade); and coconut oil by solvent extraction method (refined from coconut expeller cake). Virgin coconut oil is claimed to have more health benefits compared to coconut oil extracted from copra.

Copra milling by traditional methods

The extraction of oil from copra is one of the oldest seed crushing operations. In India and Sri Lanka copra is still crushed for oil extraction in the primitive chekkus as well as in rotary ghanis, expellers and hydraulic presses. The chekku is a fixed wooden or stone mortar inside which revolves on a hard wooden pestle. The pestle is attached to a long pole which is moved round via bullocks, donkey or by human labor. About 20–40 kg of copra can be handled by a chekku.

Copra processing by continuous pressing

This is done with the help of expellers. The oil expeller is essentially a mechanical screw press in which the oil is expelled from the copra by the pressure exerted by a continuous rotating warm shaft in the barrel or cage of the press. The barrel is built with openings to allow the escape of oil and these can be adjusted according to the type of seed being crushed.

Hydraulic presses

These are used in the large installations. They are of two main types-open or Anglo-American presses and the closed or cage type presses. In this the space between the plates above ram and the head is divided by plates between which copra is put wrapped in press clothes.The common method is to extract oil from copra or the dry coconuts.Conventionally coconut oil is produced by expelling dry copra, followed by refining during which oil is exposed to high temperature. The copra based refined coconut oil or the solvent extracted and refined coconut oil will have a bland taste due to the refining processes.

Wet coconut processing

The wet coconuts are subjected to pressing to ooze the oil out along with coconut milk. This is processed afterwards without employing heat, shear, chemicals, refining and is known as virgin coconut oil. Virgin coconut oil has applications in pharmaceuticals and cosmetics. It is colorless with characteristic coconut flavor and finds several applications in medicinal, cosmetics and cooking purposes. Traditionally, virgin coconut oil is produced by fermentation method, where coconut milk expelled from freshly harvested coconuts is fermented for 24–36 hr, and during this period, the oil phase gets separated from aqueous phase. Further, the resulting wet oil is slightly heated for a short time to remove the moisture and finally filtered. The main disadvantages of this process are low oil recovery and fermented odor, which masks the characteristic coconut flavor of the oil.

Physico-chemical characteristics of coconut oil

Solubility

Coconut oil is insoluble in water. At temperature above its melting point it is completely miscible with most of the non-hydroxylic solvents such as light petroleum, benzene, carbon tetrachloride etc. In alcohol,coconut oil is more soluble than most common fats and oils.

Chemical composition

Coconut oil contains a high proportion of glycerides of lower chain fatty acids.The oil is highly stable towards atmospheric oxidation.The oil is characterized by a low iodine value high saponification value, high saturated fatty acids content and is a liquid at room temperatures of 27°C.

Table 2

Physico-chemical Characteristics of coconut oil

Appearance Odour	**Virgin coconut oil from wet coconut** **Colorless Coconut smell**	**Unrefined coconut Oil from copra** **Slight brownish Coconut smell**	**Refined coconut oil** **Colourless Odourless**
Melting point °C	24	24	24
Moisture (%)	<0.1	<0.1	<0.1
Iodine value (cg I2/g)	12–15	12–15	10–12
Peroxide value (meq. O_2/kg)	0–1	0–1	0–1
Saponification value(mg KOH/g)	245–255	245–255	250–255
Phospholipids(%)	0.1	0.1	0.0
Unsaponifiable matter(%)	-	0.42%	0.19%
Tocopherols mg/kg	150–200	150–200	4–100
Phytosterols mg/kg	-	400–1200	-
Total phenolics mg/Kg	640	618	20
Fatty acid composition(relative%)	-	-	-
Saturates	92.0	92.0	92.0
Monounsaturates	6.0	6.0	6.0
Polyunsaturates	2.0	2.0	2.0

Unsaponifiable matter

All natural fats contain minor quantities of substance other than fatty acid glycerides. The unsaponified constituent is mostly sterols.The unsaponifiable constituent of coconut oil include a small amount of tocopherols and phytosterols.

Chemistry of fatty acids and triglycerides

Medium chain triglycerides

MCTs are a class of lipids in which three saturated fats are bound to a glycerol backbone. What distinguishes MCTs from other triglycerides is the fact that each fat molecule is between six and twelve carbons in length [16]. MCTs are a component of many foods, with coconut and palm oils being the dietary sources with the highest concentration of MCTs. MCTs are also available as a dietary supplement [17]. MCTs have a different pattern of absorption and utilization than longchain triglycerides (LCTs) that make up 97 percent of dietary fats. For absorption of LCTs to occur, the fatty acid chains must be separated from the glycerol backbone by the lipase enzyme. These fatty acids form micelles, are then absorbed and reattached to glycerol, and the resultant triglycerides travel through the lymphatics *en route* to the bloodstream. Up to 30 percent of MCTs are absorbed intact across the intestinal barrier and directly enter the portal vein. This allows for much quicker absorption and utilization of MCTs compared to LCTs. MCTs are transported into the mitochondria independent of the carnitine shuttle, which is necessary for LCT mitochondrial absorption. Oxidation of MCTs provides 8.3 calories per gram, while LCTs provides 9.2 calories per gram [18].

Nutritional effects of coconut oil blends

Bellenand *et al* [19] studied the effects of coconut oil on heart lipids and on fatty acid utilization in rapeseed oil. The cardiac lipidosis was proportional to the content of erucic acid in the diet. At 60 days, the high level of 22:6 in the cardiac phospholipids of rats fed rapeseed oil was reduced by the addition of sunflower oil but not by coconut oil. Thus, the blending of rapeseed oil with coconut oil apparently is less desirable than that of rapeseed oil and sunflower oil. McCutcheon *et al*[20] studied the cardiopathogenicity of rapeseed oils and oil blends differing in erucic, linoleic and linolenic acid content on male Wistar rats using semipurified diets. Lowest lesion incidence was obtained with safflower oil and hydrogenated coconut oil. It has been postulated that linolenic acid plays a role in the etiology of cardiac necrosis observed when rats are fed diets containing low erucic acid rapeseed oils.

Theuer [21] developed fat compositions for infant formulas containing vegetable fats with a fatty acid simulating that of human milk. Grandadam [22] developed processes to recover the proteins of the coconut from copra cake, or directly from fresh coconut meat by different processes. The improved Itipat process of double pressing allows recovery of 93.45% of the oil and 91.9%. Aliwalas [23] studied the following process for oil extraction from coconut meat: (i) wet method(using a De Laval centrifuge), (ii) hydraulic pressing, (iii) pressing plus solvent extraction, (iv) filtration extraction (direct solvent extraction). Oil extraction efficiencies obtained were: (i) 79.56% (increased to 96.3% by subsequent solvent extraction), (ii) 76.47%, (iii) 99.65%, (iv) 96.58. Protein contents of isolates from (i) ranged from 59 to 75%. Protein efficiency ratio (PER) biological value (BV), true digestibility (TD) and net protein utilization (NPU) of coconut flour from (ii), (iii) and (iv) were: PER 2.42, 2.55, 2.42; BV 77,84, 79; TD 76, 74, 72; NPU 68, 64, 66. Values for coconut isolate prepared by heat coagulation of cream or aqueous portion of fresh coconut milk from (i) were: PER 1.50, 2.20; BV 72, 80; TD 88, 92; NPU 59, 65. The traditional rural method gave an oil extraction efficiency of 82.45, and a protein isolate with PER 1.25, BV 62, TD 86 and NPU 58. Reena Rao and Lokesh [24,25], Anitha Nagaraju and Lokesh [26,27] and Reena and Lokesh [28] have used immobilized lipase systems for the synthesis of structured lipids from coconut oil and omega 6 and omega 3 fatty acids and carried out nutritional evaluation of the

same in rats. They found beneficial effects in the lipid profile after enzymatic acidolysis of coconut oil with omega 6 and omega 3 fatty acids.

Clinical Applications

Virgin coconut oil (VCO) has been consumed worldwide for various health-related reasons and some of its benefits have been scientifically evaluated.

Antioxidant and Antistress Activity

A study carried out by Yeap SK *et al* evaluated the antistress and antioxidant effects of virgin coconut oil *in vivo*. VCO reduced lipid peroxidation and increase the activity of SOD in the serum of mice undergoing the forced swim test and the brains of mice subjected to chronic cold restraint[29]. VCO has been reported to be rich in polyphenols and these contribute to the increased antioxidant enzyme levels, which in turn reduces inflammation and lipid peroxidation in VCO-treated mice. Restoration of brain antioxidant levels hinders further neuronal damage thereby preventing subsequent monoamine depletion[30]. The potential of VCO to prevent exercise- and chronic cold restraint stress-induced damage and to restore the antioxidant balance was demonstrated and this was attributed to the polyphenols and medium-chain fatty acids present in VCO. In another study on the comparative effect of VCO with copra oil, olive oil and sunflower oil on endogenous antioxidant status and paraoxonase–1 activity in ameliorating the oxidative stress in rats, findings revealed that dietary VCO improved the antioxidant status as compared to the other three oil- fed groups, as was evident from increased catalase, superoxide dismutase, glutathione peroxidase and glutathione reductase activities in tissues[31].

Hepatoprotective activity

Several studies have reported the antioxidant activity of VCO. Oxidative stress induced by the generated free radicals plays a lead role in the development of hepatic toxicity[32]. A study was conducted on hepatoprotective activity of VCO on 2, 4–Dichlorophenoxyacetic acid (2, 4–D) induced liver damage in rats[33]. Rats treated with 2, 4–D showed a significant liver damage with increased serum transaminases and alkaline phosphatase enzymes activities, hepatic lipid peroxidation and liver free fatty acids. Serum total protein, albumin, hepatic superoxide dismutase and glutathione peroxidase enzymes activities were significantly reduced. Inflammation and necrosis were observed in liver sections of treated rats. VCO oil treated animals showed an improvement in hepatic antioxidant enzymes, serum transaminases activities and liver free fatty acids levels which was confirmed by histopathological examination, thereby establishing the hepato protective activity of VCO[34].

Anti-inflammatory, analgesic, and antipyretic activities of VCO

A study conducted by Intahphuak et *al*, evaluated the anti-inflammatory, analgesic, and antipyretic effects of VCO in rats using ethyl phenyl propiolate-induced ear edema and carrageenan and arachidonic acid-induced paw edema. VCO was found to possess moderate anti-inflammatory effects.Through reduction of the transudative weight, granuloma formation, and serum alkaline phosphatase activity, VCO exhibited an inhibitory effect on chronic inflammation. In acetic acid-induced writhing, the model for analgesic activity and

for yeast-induced hyperthermia for antipyretic activity, VCO showed a moderate analgesic and antipyretic effect[35].

Wound Healing Effect

Wound healing is a complex process where the skin or other body tissue repairs itself after injury. The oil of *Cocos nucifera* has been reported to be an effective wound healing agent[36]. Nevin *et al* studied the effect of topical application of virgin coconut oil on skin components and antioxidant status during dermal wound healing in young rats. In their study, animals were treated for 10 days with VCO, 24 hours after creation of the wound. VCO's healing activity was evaluated by monitoring time for complete epithelization in addition to various parameters of the wound's granulation tissue. Solubility pattern of collagen, glycohydrolase activity and granulation tissue histopathology were also studied. Animals treated with VCO showed much faster wound healing activity, indicated by a decreased time in complete epithelization and higher levels of various skin components. The significant increase of Pepsin-soluble collagen and glycohydrolase activities observed indicated higher collagen cross- linking and its turnover. They concluded that the wound healing activity of VCO may be a cumulative effect of various minor biologically active components present within [37].

Effect on Dermatitis

Atopic dermatitis (AD) is a chronic skin disease characterized by features of defective epidermal barrier function and inflamed cutaneous layer. In this condition trans epidermal water loss (TEWL) is increased and the ability of the stratum corneum to hold water is impaired. This leads to decreased skin capacitance and hydration. A study by Evangelista *et al* investigated the topical effect of VCO on SCORAD index, trans epidermal water loss, and skin capacitance in mild to moderate pediatric atopic dermatitis using a randomized controlled trial design. A total of 117 patients included were evaluated at baseline, and then at 2, 4, and 8 weeks respectively. The results concluded the superiority of VCO over mineral oil among pediatric patients with mild to moderate AD [38].

Use as an Ocular Rewetting Agent

Dry eye is a symptom caused by the lack of quality /quantity of tears or defect on the ocular surface area. That leads a condition of discomfort, visual disturbance; tear film instability, increased osmolality of the tear film and inflammation of the ocular surface, which ameliorate the damage to the ocular surface. Among all the therapeutic option for dry eyes, artificial tears is the mainstay for the initial management of dry eye patient. Due to the complexity of tear film, it is difficult to manufacture tears that would be similar to that of the human eye. Several brands of artificial tears are commercially available, that would consist of Hydroxypropyl methyl cellulose, Poly vinyl alcohol, sodium hyaluronate and oil based tears. A previous study showed that liposomal spray applied on closed eye lid had increased the thickness of lipid layer and also significantly increased the tear film stability. On account of this study Dept. of Optometry and vision science at Malaysian University evaluated the usage of VCO as a supplement for tear film. A pilot study was carried out on the efficacy of VCO as an ocular rewetting agent on Rabbit eyes. VCO was found to be safe in the dry eye and its anti-inflammatory property was attributed to be responsible for its significant beneficial effect in the management of dry eyes[39].

Effect on Alzheimer's disease

In the neurological disorder Alzheimer's disease (AD), memory loss and cognitive decline occurs because of death of brain cells. The neurodegenerative disease starts as mild dementia getting progressively worse**.** In the brain, the lipid macromolecule, cholesterol is utilized as an antioxidant, for structural scaffolding of the neural network, as an electrical insulator (to prevent ion leakage), and as a functional membrane component. Cholesterol is utilized in the wrapping and synaptic delivery of the neurotransmitters and also plays an important role in the formation and functioning of synapses in the brain. Several studies[40] have proven the lack of cholesterol in the brains of AD patients. In contrast, a positive correlation (better memory function and reduced dementia) was observed between high cholesterol levels and longevity in a population above 85 years old . A study appearing in the American Journal of Cardiology in February 2011 suggested that a diet with adequate amounts of saturated fat is essential to maintain HDL high cholesterol levels. Those with deficiencies and suffering from neurological disorders needed to consider a diet that is high in saturated fat. The saturated fat of coconut oil provides the brain with an alternate source of energy in ketones. Ketones are high energy fuels that nourish the brain. Fasting /starvation can trigger the production of ketones. Ketones are also formed by the conversion of medium chain fatty acids in certain foods. Coconut oil is nature's richest source of these medium chain triglycerides (MCTs) [41]. A study done in 2004 took MCTs from coconut oil and put them into a drink that was given to Alzheimer's patients while a control group took a placebo. They observed significant increases in levels of the ketone body beta-hydroxybutyrate (beta-OHB) 90 minutes after treatment. When cognitive tests were administered, higher ketone values were associated with greater improvement in paragraph recall with MCT treatment relative to placebo across all subjects [42].

Effect on blood pressure elevation

Hypertension or elevated blood pressure is the main risk factor for cardiovascular complications such as coronary heart disease, atherosclerosis, and stroke. Many studies to prevent the elevation of blood pressure have been carried out. Badlishah Sham Nurul-Iman *et al* carried out a study on Effect of VCO on prevention of blood pressure elevation and Improves Endothelial Functions in rats fed with repeatedly heated palm oil. This study explored the effects of virgin coconut oil (VCO) in male rats fed repeatedly with heated palm oil on blood pressure, plasma nitric oxide level, and vascular reactivity. In their study elevation of blood pressure was created by the repeated feeding of heated palm oil. On overheating, the free radicals that were generated induced oxidative stress within the blood vessel, affecting the NO level in the endothelial cells. In male rats, supplementation with repeatedly heated palm oil VCO was found to prevent blood pressure elevation and to also decrease nitric oxide deactivation. In addition, VCO did not influence relaxation but decreased vasoconstriction of the endothelium [43].

Immunomodulatory effect

In 1966, Jon Kabara discovered that Medium Chain Fatty Acids (MCFA's) of virgin coconut oil are incredible for antimicrobial properties that kill harmful viruses, bacteria, fungi, and parasites. When MCFA's are digested, they break down into free fatty acids and monoglycerides[44] .Lauric Acid, Capric acid, and Caprylic acid are the important medium chain fatty acids present in coconut oil that possess antimicrobial activity. Their

monoglyceride form, monolaurin, monocaprylin, and monocaprin hinder microbes from terrorizing the immune system. Individually, these fatty acids act on microbes in different ways. Some may kill a particular organism that causes fungal infections but may not be as useful on other microbes. Unitedly, however they act as a highly powerful defence against diseases. Monolaurin (monoglyceride form of lauric acid) is considered to have the best antiviral, antifungal, and antibacterial effect[45]

Effect on blood sugar control

A study on Insulinotropic potency of lauric acid: a metabolic rationale for medium chain fatty acids (MCFA) in TPN formulation by Garfinkel M et al proved that the effect of MCFA on insulin secretion depends upon its chain length. Among all MCFA capric acid (C10) and lauric acid were observed to display the most potent effects on insulin secretion [46]. Another study proved that, as compared to other oils, coconut oil in the diet enhanced insulin action and improved binding affinity [47].

Effect on weight loss

A study conducted on the effect of dietary medium- and long-chain triacylglycerols (MLCT) on accumulation of body fat in healthy humans by Kasai M *et al* proved that a daily intake of MLCT diet could cause a reduction in body weight and body fat accumulation. Volunteers in a double-blind study for 12 weeks, consumed daily at breakfast, test bread, with 1.7 g MCFA, bread made with long-chain triacylglycerols (LCT) was consumed by the control group. A significant decrease of body weight and amount of fat, with a significant decrease in serum total cholesterol was observed in the test group [48]. In another study on the effect of dietary supplementation with coconut oil on the biochemical and anthropometric profiles of women with abdominal obesity (waist circumferences (WC) >88 cm) the intake of dietary supplement with VCO was observed to decrease the amount of abdominal fat [49].

Healing properties of coconut oil

Coconut oil is antiviral, antifungal (kills yeast too) and antibacterial. It attacks and kills viruses that have a lipid (fatty) coating, such as herpes, HIV, hepatitis C, the flu, and mononucleosis. It kills the bacteria that cause pneumonia, sore throats, dental cavities, urinary tract infections, meningitis, gonorrhea, food poisoning and many more bacterial infections [50]. It kills the fungus/yeast infections that cause candida, ringworm, athletes foot, thrush, jock itch and diaper rash.

Conclusion

Coconut oil is consumed in tropical countries for thousands of years. Studies done on native diets high in coconut oil consumption show that this population is generally in good health. Coconut oil has a long shelf life and is used in baking industries, processed foods, infant formulas, pharmaceuticals, cosmetics and as hair oil. The oil contains 92% of saturates consisting of medium chain fatty acids in the form of triglycerides, and about 8% of unsaturates consisting of oleic and linoleic acids as triglycerides. The oil has a small amount of unsaponifiable matter (<0.5%), is colourless and has a odour typical of the coconuts. The oil has small amounts of tocopherols and tocotrienols and phytosterols. The oil is known to

have antiviral and antibacterial effects and excellent healing properties. It gets easily absorbed in the body and is a nature mimic of the human breast milk fat and hence used in infant formulae. With all these good quality attributes, the side effects of the oil has also been reported especially in cardiovascular diseases due to the presence of less of unsaturated fatty acids in the triglycerides of the oil. It is hypothesized that due to lower amount of PUFA, there is a possibility of atherogenecity development during long term usage of the oil. However, more research is needed to clearly understand the many good effects of the oil.

References

1. Chaichit C. (2004), *Thai Herbs and Herbal Products*. Bangkok, Srimuang Printing Co., pp. 155–156.
2. Wan J.M., Grimble R.F. (1987), Effect of dietary linoleate content on the metabolic response of rats to *Escherichia coli* endotoxin, *Clin Sci*, 72, pp. 383–385
3. Sadeghi S., Wallace F.A., Calder P.C. (1999), Dietary lipids modify the cytokine response to bacterial lipopolysaccharide in mice, *Immunology*, 96, pp. 404–410.
4. Pereira C.C., Da Silva M.A., Langone M.A. (2004), Enzymatic synthesis of monolaurin, *Appl Biochem Biotechnol*, 113–116, pp. 433–445.
5. Witcher K.J., Novick R.P., Schlievert P.M. (1996), Modulation of immune cell proliferation by glycerol monolaurate, *Clin Diagn Lab Immunol*, 3, pp. 10–13.
6. Bergsson G., Steingrímsson Ó., Thormar H. (2002), Bactericidal effects of fatty acids and monoglycerides on *Helicobacter pylori*, *Int J Antimicrob Agents*, 20, pp. 258–262.
7. Wagner W, Khanna P, Furst DE (2004), Nonsteroidal anti-inflammatory drugs, disease-modifying antirheumatic drugs, nonopioid analgesics, and drugs used in gout. In, Katzung B.G., ed., *Basic & Clinical Pharmacology*, 9th ed. Singapore, McGraw-Hill, pp. 576–603.
8. Kumar V., Abbas A.K., Fausto N. (2005), Acute and chronic inflammation. In, Kumar V., Abbas A.K., Fausto N., ed., *Robbins and Cotran Pathologic Basis of Disease*, 7th ed. Philadelphia, Elsevier Saunders, pp. 47–86.
9. Philippine National Standard for virgin coconut oil (VCO) Bureau of Product Standards (2004), Department of Trade and Industry, Philippine, PNS/BAFPS 22.
10. Marina A.M., Che Man Y.B., Amin I. (2009), Virgin coconut oil, emerging functional food oil, *Trends Food Sci* Technol, 20(10), pp. 481–487.
11. Marina A.M., Che Man Y.B., Nazimah A.H. (2009), Chemical properties of virgin coconut oil, *J Am Oil Chem Soc*, 86, pp. 301–307.
12. Bezard J., Bugaut M., Clement G. (1971), Triglyceride composition of coconut oil, *J. Am. Oil Chem. Soc*, 48(3), pp. 134–139.
13. Conrado S. Dayrit. (2003), Coconut oil, Atherogenic or Not? (What therefore causes Atherosclerosis?), *Philipp J Cardiol*, 31(3), pp. 97–104.
14. Import of vegetable oils, The Solvent Extractors' Association of India, Mumbai, India, Available at: http//www.seaofindia.com.
15. (1968), Specification for coconut oil. Ceylon, Ceylon-Standard, CS 32, 1968 24pp. Bureau of Ceylon Standards.
16. Babayan V.K. Medium chain triglycerides. (1988), *In dietary fat requirements in health and development. (CJ Beare- Rogers, ed)*, AOCS press, Champain, pp. 73–86.
17. Heydnger J.A., Nakhasi D. K. (1966), Medium chain Triacylglycerols, *J. of Food Lipids*, 3, pp. 251–257.

18. Ralph Hoahland, George G. Snider, (1943), Digestability of certain higher saturated fatty acids and triglycerides, *J. Nutri*., 26(3), pp. 219–225.
19. Bellenand J.F., Baloutch G., Ong N., Lecerf J., (1980), Effects of coconut oil on heart lipids and on fatty acid utilization in rapeseed oil. Lipids, 15(11), pp. 938–943.
20. McCutcheon J.S., Umermura T., Bhatnagar M.K., Walker B.L., (1986), Cardiopathogenicity of rapeseed oils and oil blends differing in erucic, linoleic and linolenic acid content. Lipids, 11(7), pp. 545–552.
21. Theuer R.C. (1981), *Fat compositions for infant formulas, US Patent 4*, 282, 265.
22. Grandadam Y., (1973), The proteins of the coconut, *Industries Alimentaires et Agricoles*, 90(9/10), pp. 1253–1268.
23. Aliwalas A.R., Gonzales A.L., Claudio T.R., Benet R., (1969), A study of the wet and dry methods of extracting oil from coconut meat, *Phillip. J. Sci*., 98(2), pp. 139–149.
24. Reena Rao, (2001), *Enzymatic synthesis of structured lipids by immobilized lipase systems in organic solvents. Ph.D. Thesis*, CFTRI, University of Mysore, Mysore.
25. Reena Rao, Lokesh B.R., (2003), Nutritional evaluation of an omega 6 fatty acid containing structured lipid synthesized from coconut oil, *Lipids, Mol. and Cell. Biochem*., 248 (1–2), pp. 25–33.
26. Anitha Nagaraju, and B.R. Lokesh, (2007), Interesterified coconut oil blends with groundnut oil or olive oil exhibit greater hypocholesterolemic effects compared with their native physical blends in rats, *Nutri. Res*., 27, pp. 580–586.
27. Anitha Nagaraju, B.R. Lokesh, (2008), Rat fed blended oils containing coconut oil with groundnut oil or olive oil showed an enhanced activity of hepatic antioxidant enzymes and a reduction in LDL oxidation, *Food Chem*., 108 , pp. 950–957.
28. Malongil B. Reena, Belur R. Lokesh, (2007), Hypolipidemic effect of oils with balanced amounts of fatty acids obtained by blending and inter esterification of coconut oil with rice bran oil or sesame oil, J. Agric. Food Chem., 55, pp. 10461– 10469.
29. Nevin K.G., Rajamohan (2006), Virgin coconut oil supplemented diet increases the antioxidant status in rats, *Food Chem*, 99, pp. 260–266.
30. Arunima S., Rajamohan T. (2013), Effect of virgin coconut oil enriched diet on the antioxidant status and paraoxonase 1 activity in ameliorating the oxidative stress in rats – a comparative study, *Food Funct.* 4(9), pp. 1402-9.
31. Otuechere C.A., Madarikan G., Simisola T., Bankole O., Osho A. (2014), Virgin coconut oil protects against liver damage in albino rats challenged with the anti-folate combination, trimethoprim-sulfamethoxazole, *J Basic Clin Physiol Pharmacol*, 25(2), pp. 249–53.
32. Hanaa M. Abd E.F., Lamiaa A.A.B. (2013), Hepatoprotective Effect of Olive and Coconut oils against Oxidative Stress- Induced by 2, 4 Dichlorophenoxyacetic Acid, *Indian J Appl* Res , 3, 12, pp. 42-46.
33. Zakaria Z.A., Rofiee M.S., Somchit M.N., Zuraini A., Sulaiman L.K., The L.K., Salleh M.Z., Long K. (2011), Hepatoprotective activity of dried- and fermented-processed virgin coconut oil, *Evid Based compl Alt Med* , pp. 142739–48.
34. Intahphuak S, Khonsung P, Panthong (2010), A.Anti-inflammatory, analgesic, and antipyretic activities of virgin coconut oil, *Pharm Biol* , 48(2), pp. 151–7.
35. Burn wound healing property of *Cocos nucifera* (2008), An appraisal, *Indian J Pharmacol*, 40(4), pp. 144–146.
36. Nevin K.G., Rajamohan T. (2010), Effect of topical application of virgin coconut oil on skin components and antioxidant status during dermal wound healing in young rats, *Skin Pharmacol Physiol***,** 23(6), pp. 290–7.

37. Evangelista M.T., Abad-Casintahan F., Lopez-Villafuerte L. (2014), The effect of topical virgin coconut oil on SCORAD index, trans epidermal water loss, and skin capacitance in mild to moderate pediatric atopic dermatitis, a randomized, double-blind, clinical trial, *Int J Dermatol*, 53(1), pp. 100–8.
38. Haliza A.M., Sharanjeet K., Ahmad R.G., Ng. Chinn H., Nor H. S. (2014), The Efficacy of Virgin Coconut Oil as Ocular Rewetting Agent on Rabbit, *Evid Based compl Alt Med* , pp. 135987.
39. Seneff S., Glyn W., Luca M. Nutrition and Alzheimer's disease (2011), The detrimental role of a high carbohydrate diet, *Eur J Intern Med*, 22(2), pp. 134–40.
40. Rahilly T.C.R., Spiro A.,Vokonas P., Gaziano J.M. (2011), Relation between High-Density Lipoprotein Cholesterol and Survival to Age 85 Years in Men, *Am J Cardiol*, 107(8), pp. 1173–7.
41. Reger MA, Henderson ST, Hale C, Cholerton B, Baker LD, Watson GS, Hyde K, Chapman D, Craft S. (2004), Effects of beta-hydroxybutyrate on cognition in memory-impaired adults, *Neurobiol Aging*, 25, 3, pp. 311–4.
42. Badlishah S Nurul-Iman, Yusof Kamisah, Kamsiah Jaarin, Hj Mohd Saad Qodriyah (2013), Virgin Coconut Oil Prevents Blood Pressure Elevation and Improves Endothelial Functions in Rats Fed with Repeatedly Heated Palm Oil, *Evid Based Compl Alt Med*, (5), pp. 629329.
43. Ogbolu D.O., Oni A.A., Daini O.A., Oloko A.P. (2007), In vitro antimicrobial properties of coconut oil on Candida species in Ibadan, Nigeria, *J Med Food*, 10(2), pp. 384–7.
44. Shilling M., Matt L., Rubin E., Visitacion M.P., Haller N.A., Grey S.F., Woolverton C.J. (2013), Antimicrobial effects of virgin coconut oil and its medium-chain fatty acids on Clostridium difficile, *J Med Food*, 16(12), pp. 1079–85.
45. Garfinkel M., Lee S., Opara E.C., Akwari O.E. (1992), Insulinotropic potency of lauric acid, a metabolic rationale for medium chain fatty acids (MCF) in TPN formulation, *J Surg Res*, 52(4), pp. 328–33.
46. Ginsberg B.H, Jabour J, Spector A.A. (1982), Effect of alterations in membrane lipid unsaturation on the properties of the insulin receptor of Ehrlich ascites cells, *Biochim. Biophys. Acta*, 690(2), pp.15.
47. Kasai M., Nosaka N., Maki H., Negishi S., Aoyama T., Nakamura M., et Al. (2003), Effect of dietary medium- and long-chain triacylglycerols (MLCT) on accumulation of body fat in healthy humans, *Asia Pac J Clin Nutr*, 12(2), pp. 151–60.
48. Assuncao ML, Ferreira HS, dos Santos AF, Cabral CR Jr, Florencio TM. (2008), Effects of dietary coconut oil on the biochemical and anthropometric profiles of women presenting abdominal obesity, *Lipids*., 44(7), pp. 593–601.
49. Kabara J.J. (2011), *Health oils from the tree of life. Nutrition and health aspects of coconut oil.*
50. Lim Sylianco C.Y. (1987), Anticarcinogenic effects of coconut oil, Phillip. *J. Coconut Studies*, 12(2), pp. 89–102.

Investigation of nutrients properties of meat pastes using vegetative raw materials

Oksana Moskaliuk[1], Oleksandra Haschuk[1], Liudmyla Peshuk[1], Liudmyla Sineok[2], Oleg Galenko[1]

1 – National University of Food Technologies, Kyiv, Ukraine
2 – Institute of Gerontology after D. F. Chebotareva NAMS of Ukraine, Kyiv, Ukraine

Keywords:
Meat
Pastes
Vegetative
Fatty acid
Transformability

Article history:

Received 21.12.2017
Received in revised form 11.02.2018
Accepted 29.06.2018

Corresponding author:

Oleg Galenko
E-mail:
galen@i.ua

DOI: 10.24263/2310-1008-2018-6-1-7

Abstract

Introduction. The researched meat pastes for health-preventive nutrition using mushroom raw materials and phytocomplex of sprouted grains of cereal crops.

Materials and methods. The study of the fatty acid composition of the developed pates was carried out by chromatography of high resolution. To confirm the nutrients adequacy of the researched formulations of the "Mushroom" paste and the paste with the phyto-complex "CHOICE", studies were conducted digestibility in conditions in vitro of the *Tetrahymena pyriformis* ciliary infusoria in the Fuks-Rosenthal chamber. Clinical studies of the pastes with mushroom raw material were conducted with the participation of the elderly in the general-therapeutic department of the clinic.

Results and discussion. The method of chromatography of high-level ability has established the group fatty acid composition of the pastes using mushroom raw materials and phytocomplex of germinated grains of cereal cultures and found that the content of monounsaturated acids in developed paste is about 35% and saturated – only 23% in all investigated samples. Analyzing the content of PUFAs, it is important to note their stable high content in all four recipes, regardless of the type of ingredients added. However, the formula with mushroom raw material has the highest total PUFAs content – 41.92% and at the same time the highest content of essential linolenic acid – 1.55%.

The results digestibility in conditions in vitro indicate that Mushroom Paste has a higher relative biological value and a better digestibility than the control sample more on 3.5%, and the paste with the phyto-complex "CHOICE" more on 2.1%.

According to the results of the research, the effectiveness and safety of the paste "Mushroom" has been determined and the possibility of eliminating vitamin B_{12} deficiency during use has been determined.

Conclusions. The analysis of the research results testifies to the nutrients adequacy of the researched pates with the use of mushrooms raw materials and phytocomplex of sprouted grains of cereals for health and health-preventive nutrition.

Introduction

The ability to work, health and active creative longevity of a person is directly dependent on the way of his life and the nature of nutrition, which should be rational, balanced and to ensure the physiological needs of the organism. Currently, human life is very closely related to the impact of various unfavorable environmental factors, which leads to stress and certain negative changes in the body and health. Among them is also the lack of necessary nutrients: protein, trace elements, vitamins. In addition, various diseases, smoking and alcohol use also affect the absorption and metabolism of vitamins, especially vitamins B_6 and B_{12}. In order to enhance the immune functions of the body, science offers innovative ways. The growing interest in so-called "healthy food" necessitates the production of products that not only satisfy the physiological needs of the body in nutrients and energy, but also provide preventive and curative action. The principles of nutrition should consist in the use of products that are relatively easy to assimilate and diverse, also in terms of chemical composition and prophylactic orientation, it is possible to take into account the prevention or slowdown of the development of diseases. The development of technologies for the production of high-grade, nutritiously balanced products that provide adequate nutrition to the elderly should be a priority concept for the development of the food industry. Developing foods for special nutrition is a way through which you can change the composition of the product in such a way as to positively affect the health of a person, strengthening it by regulating certain metabolic processes in the body [1].

According to the results of the research of poultry meat and poultry products were developed for health and preventive nutrition "Mushroom" – with cooked oyster mushrooms – 15%, "Special" – with mushroom biomass of oyster mushrooms- 3% and with phytocomplex of sprouted grains of cereal crops – 15% [2].

Meat Pastes, where meat is the main ingredient, is in demand due to its high nutritional value, a pleasant special taste and a delicate consistency. Liver is added to the meat paste to enhance the biological value, providing a delicate taste and a rich color. The smearing consistency of paste is achieved by special methods of processing the raw materials and selecting the ingredients of the formulation. Traditional meat paste formulations are evaluated mainly for organoleptic parameters and energy value, without taking into account the product's balance on chemical composition.

Poultry meat is assimilated by 94–96%, fatty tissue (5.2%) is characterized by a high content of polyunsaturated fatty acids. The liver is rich in iron-containing proteins – ferrin and ferritin, which serve as a source of iron for the synthesis of hemoglobin. It contains nitrogenous extractives, as well as vitamins and minerals. It contains especially choline, biotin, vitamin A (50 mg%), C (25–40 mg%), niacin, and also includes all vitamins of group B. Given the chemical composition of the liver is widely used in therapeutic nutrition for anemia, radiation illness, general weakening and reduced hematopoiesis of the body.

The use of vegetable protein becomes topical for the domestic meat processing industry, which lacks the traditional raw material resources. In this regard, the role of products from natural plant materials, in particular fungi, is increasing. Mushroom proteins occupy an intermediate position between proteins of plant and animal origin. Mushrooms are also called "vegetable meat", they contain glycogen and do not have cholesterol, their taste resembles the taste of meat, due to the high content of glutamine amino acid. Mushrooms have a unique balanced composition of all the biologically valuable food components: proteins, fats, carbohydrates, vitamins, and trace elements. BAS mushrooms normalize appetite, increase immunity, lower cholesterol low density, reduce the risk of heart attack and prevent the onset of atherosclerosis, affect the development of memory and activate mental activity of man. Mushrooms have radioprotective properties. In the processing of fungi, there remains a significant number of non-standard and non-standard

specimens that can be successfully used as protein-rich feedstocks. As a result of scientific research and on the basis of complex experimental research, the possibility of using cultured mushrooms in the recipes of meat pates was proved [2].

Germinated grains of cereal crops – a product that contains natural antioxidants, which is much more useful than synthetic drugs. The introduction of sprouted grains in minced meat products will enable to stimulate metabolism and hematopoiesis, increase immunity, compensate for vitamin and mineral deficiency, normalize the acid-base balance, help clear the body from slags and slow down aging processes. The enzymes formed in sprouted grains split complex substances (proteins, fats, carbohydrates) into simpler (amino acids, fatty acids, simple carbohydrates). When consuming meat products using sprouted grains, the human body spends less energy on digestion and assimilation of food. [3, 4, 5, 6].

Materials and methods

For the practical regulation of the biological value of developed pates, their group fatty acid composition was determined by high resolution chromatography method.

In order to confirm the nutrients adequacy of the developed meat pastes, the study of digestibility in conditions in vitro were conducted using the Tetrahymena pyriformis ciliary infusoria in the Fuks-Rosenthal chamber. Clinical studies were also conducted to determine the effectiveness and safety of products and the relationship between the level of vitamin B_{12} in the blood and the possibility of correcting it with the help of developed meat paste**.**

One way of examining the degree of digestion of proteins by proteolytic enzymes of the gastrointestinal tract, which determines the biological value of food products, is to conduct experiments on cell cultures, whose representatives are the simplest. The ciliary infusoria Tetrahymena pyriformis in the morphological aspect is a cell, and in the physiological – a holistic organism. In order to determine the digestibility in conditions in vitro developed pates in comparison with the control sample, the relative biological value was determined in accordance with the guidelines for the use of the Tetrachymena pyriformis ciliary infusoria. Unicellular organisms have much less enzyme systems than humans and are generally easier in structure. Infusoria (these are single cell eukaryotic organisms having a nucleus) can be considered as an integral biological sensor with certain parameters suitable for food bioassays.

To do this, from each sample, samples were taken and prepared,we prepared separately nutrient media and introduced into them samples of paste. Then we have grown a test cultures in the culture medium, cultivated at a temperature of 20–25 °C, then counting cells that had grown over four days of cultivation in the Fuchs-Rosenthal counting chamber.

By the number of cultured cells in the Fuchs-Rosenthal chamber, the relative biological value of the product was determined, which was determined by the ratio of cells grown on the investigated products to the number of infusions in the control case with casein. The experimental error was 0.3%.

It was explained to patients about the peculiarity of the study and the nature of the product, after which each of them signed an informed consent to participate in this study.

In the study, we used a comprehensive survey that would reveal the effect of the proposed product on health indicators (liver, kidney, digestive and lipid metabolism), as well as an opportunity to find out the possibility of eliminating vitamin B_{12} deficiency. The proposed product (paste) was taken by patients during the entire period of stay in the hospital (21 days) by 50 g every other day.

Results and discussion

Researched recipes of meat and poultry meat-based pastes for health and preventive nutrition: "Mushroom" – with cooked oyster mushrooms – 15%, "Special" – with mushroom biomass of oyster mushrooms – 3% and with phytocomplex of sprouted grains of cereal crops — 15%.

The study of the chemical composition of the developed pates showed that the nutritional value of new formulations meet the requirements that are put forward to this assortment group. Physicochemical indices showed that the developed pastes have a low mass fraction of fat, high protein content, which leads to a decrease in energy value [3, 4].

An analysis of the amino acids has shown that the prototype contains all the essential amino acids necessary. In polycomponent systems of developed pastes limiting amino acid is valine + isoleucine, which is typical of forcemeat with plant material [2, 4].

The biological value of fats is determined by the content of polyunsaturated fatty acids (PUFAs). For a person, the essential fatty acids are linoleic C 18:2 and linolenic C 18:3, which belong to essential nutrients. Lack of food intake of linoleic and linolenic acids causes a violation of the regulation of metabolic processes in cell membranes, as well as in the processes of energy formation in mitochondria. PUFAs help accelerate the exchange of cholesterol in the body, slow down the formation of low-density atherogenic lipoprotein, and reduce the synthesis of triglycerols. The external manifestation of PUFA deficiency is a change in the skin condition (dryness, peeling, eczema, hyperkeratosis), increased susceptibility to ultraviolet rays, the appearance of peptic ulcers in the stomach and duodenum, caries of the teeth, arthritis. Recent advances in science deeper reveal the functions of fats in the human body and determine the changes in the norms of their consumption with food [9].

For the practical regulation of the physiological value of developed pastes, their group fatty acids composition was established by the method of chromatography of high resolution. The fatty fraction of the developed pastes contains all groups of fatty acids, but their content is uneven (Table 1).

It was found that the addition of mushroom and vegetable raw materials does not cause fundamental changes in the content of certain fatty acids. It has been established that about 2/3 of the total content of fatty acids is unsaturated, which is a positive factor in the balance of the diet.

In order to ensure the functional properties of developed pastes, it is important not only quantitative but also qualitative composition of fats, especially the content of polyunsaturated fatty acids with a definite placement of double bonds with cis configuration. The main biological indicators of the fatty acid composition of the studied pastes are given in Table 2.

Table 1

Fatty acids composition of the studied pastes, % of the sum of fatty acids

Fatty acids	Samples			
	Control	**No. 1 "Mushroom"**	**No. 2 «Special»**	**No. 3 phytocomplex "CHOICE"**
C 8:0	0,01	0,01	0,01	0,01
C 10:0 Capric	0,01	0,02	0,01	0,01
C 12:0	0,06	0,03	0,03	0,03
C 14:0	0,37	0,11	0,36	0,37
C 14:1	0,07	0,08	0,08	0,07
C 15:0	0,06	0,06	0,06	0,06
C 16:0	16,68	16,05	16,90	16,76
c9–C 16:1	0,31	0,47	0,32	0,30
c7–C 16:1	2,79	2,91	2,91	2,90
C 17:0	0,10	0,10	0,11	0,11
C 17:1	0,05	0,05	0,05	0,05
C 18:0	6,10	6,01	6,02	5,67
C 18:1w12t Petroselaidic	-	0,15	0,15	0,14
c11-C 18:1 Vaccenic	1,31	1,02	1,32	1,30
C 18:1w9c Oleic	30,36	30,91	30,61	30,68
9,12- t, c-C18:2	0,15	0,13	-	0,01
C 18:2w6c Linoleic	37,42	37,47	37,27	37,88
C 20:0	0,15	0,15	0,15	0,15
C 20:1w9	0,07	0,07	0,07	0,07
C 20:1w11	0,30	0,31	0,30	0,30
C 18:3w6	0,23	-	-	0,19
C 18:3w3 a-Linolenic	1,30	1,55	1,34	1,37
c9t11-C18:2	0,12	0,12	0,12	-
t10c12-C 18:2	0,01	0,01	0,01	0,01
11,14– c C 20:2	0,22	0,14	0,22	0,20
C 20:3w6	0,17	0,17	0,17	0,15
C 20:4w6 Arachidonic	1,17	1,08	1,08	0,84
C 20:5w3c	0,02	0,02	0,02	0,07
C 22:0	0,17	0,17	0,17	0,18
C 22:5w3	0,06	0,06	0,07	0,05
C 23:0	-	-	-	0,01
C 24:0	0,06	0,06	0,06	0,06
C 24:1	0,02	-	-	-
C 22:6w3	-	-	-	0,04
Total	100,00	100,00	100,00	100,00

Table 2

Biological parameters of fatty acids composition of investigated pastes, % of the sum of fatty acids

Name	Samples			
	Control	No. 1 "Mushroom"	No. 2 «Special»	No. 3 phytocomplex "CHOICE"
Value of groups of fatty acids				
SFAs	23,78	23,35	23,88	23,41
MUFAs	35,46	34,74	35,79	35,82
PUFAs	40,76	41,92	40,33	40,77
The content of essential acids				
Linoleic C 18:2	37,42	37,47	37,27	37,88
Linolenic C 18:3	1,30	1,55	1,34	1,37
The content of anti-food fatty acids				
C 18:1 trans	0,16	0,15	0,15	0,14
C 18:2 trans	0,02	0,03	0,02	0,02

Analyzing the data in Table 2, it was found that the content of mono-unsaturated acids is about 35% and saturated – only 23% in all of the samples under study. This confirms the preventive effect of the developed pates, since from the point of view of the prevention of age-related diseases, the content of unsaturated fats should be as high as possible. Analyzing the content of PUFAs, it is important to note their stable high content in all four recipes, regardless of the type of ingredients added. However, the formula for "Mushroom" paste differs by the highest total content of PUFAs – 41.92% and at the same time the highest content of essential linolenic acid – 1.55%. This, obviously, can be explained by the peculiarity of the fatty acid composition of the added additive, since fungi contain 1.3–2.7% fat, which 67% consists of polyunsaturated acids. It is established that the content of fatty acids in trans-form is insignificant and does not exceed their background level for all studied formulations [10].

In order to determine digestibility in conditions in vitro of the developed pates in comparison with the control sample, the relative biological value was determined in accordance with the guidelines for the use of the Tetrachymena pyriformis ciliary infusoria.

By the number of cultured infusion cells in the Fuks-Rosenthal chamber, the relative biological value of the product was established (Table 3).

Table 3

Relative biological value of developed pates

Pastes	Protein, %	The number of cells, cells / mm^3	Relative biological value*, %
Control "To breakfast"	20,24	185,85	52,864
Paste "Mushroom"	20,16	198,45	56,448
Paste with phytocomplex "CHOICE"	14,41	191,27	54,983

***** – in relation to the standard (casein)

The analysis of the results obtained (Table 3) shows that "Mushroom" Paste has a higher relative biological value compared tthan the control sample more on 3.5%, and the paste with the phyto-complex "CHOICE" more on 2.1%. This means that in the mushroom pates and phyto-complex "CHOICE", the vital functions of the simplest cells are activated faster, and it contributes to the better digestibility of the product.

Meat products with high content of vitamin B_{12} have a health-preventive function, because cianocobalamin (vitamin B_{12}) promotes increased non-specific resistance of the body to bacterial infection, has an immunomodulatory effect, based on the effect on the exchange of nucleic acids and proteins. Vitamin B_{12} deficiency is manifested by macrocytic hyperchromic anemia with characteristic bone marrow changes, neurological symptoms as a result of multiple lesions of the spinal cord. Investigation of the vitamin content of the researcher paste with mushroom raw material showed that the content of B12 is – 32.0±0.3 μg/100 g, compared with the control – 24.5±0.2 μg/100 g.

It has been established that the daily requirement of vitamin B_{12} for the elderly is 2.4 μg per day, since the level of fat-soluble vitamins and carotenoids in the plasma, as a rule, increases with age, with the exception of vitamin D, while the level of water-soluble vitamins decreases, especially vitamins B_6 and B_{12}.

At the beginning of the medical biology study, we determined the level of vitamin B12 in the blood of patients. After conducting the necessary course of consumption of paste with mushroom raw material, a re-examination of patients was carried out to determine changes in vitamin B_{12} (cobalamin) indices in the blood. At the same time, they followed the change in the state of the human organism, from the consumption of the product.

Among the 15 people (65% of survey), the content of vitamin B_{12} in the blood was below 150 pg/ml, with an average blood vitamin content of 139 (104–177) pg/ml, indicating a shortage of cobalamin in the elderly population. During the survey, it was found that the use of 50 grams of paste per day would provide 8 micrograms / day of vitamin in addition to the main diet, and if you consider that the average consumption of vitamin B_{12} with food in the examined patients was 5.8 (4.6–9.1) μg/day, the use of paste for 3 weeks will contribute to a significant increase in the content of vitamin B_{12} in the blood. Biochemical data showed that blood glucose, creatinine and uric acid levels did not change under the influence of the paste, but the decrease in urea was noted, due to the improvement of protein metabolism in the body under the influence of additional vitamin B_{12} intake and valuable protein (essential amino acids), since it is known that deficiency of vitamins and especially essential amino acids in elderly people leads to increased protein degradation and increased excretion of nitrogenous compounds.

Conclusions

According to the results of scientific research, meat pastes for health-preventive nutrition were obtained, in which the content of mono-unsaturated acids is about 35%, and saturated – only 23%. The formula with mushroom raw material has the highest total PUFAs content – 41.92% and at the same time the highest content of essential linolenic acid – 1.55%.

The results of the study on the digestibility of developed pastes with the use of the Tetrahymena pyriformis ciliary infusoria in vitro indicate that the "Mushroom" "Mushroom" Paste has a higher relative biological value compared tthan the control sample more on 3.5%, and the paste with the phyto-complex "CHOICE" more on 2.1%. This means that in the mushroom pastes and phyto-complex "CHOICE", the vital functions of the simplest cells are activated faster, and it contributes to the better digestibility of the product.

In the developed paste "Mushroom", vitamin B_{12} is found in an accessible form for human body of the elderly and is easily absorbed from the gastrointestinal tract into the blood, all patients well tolerated the ingestion of paste, no side effects were detected. The use of paste contributes not only to the elimination of vitamin B_{12} deficiency, but also significantly improves the biochemical parameters of albuminous and, especially, lipid metabolism in the elderly and may be recommended for inclusion in the diet as an additional source of vitamin B_{12} in order to improve the health status.

References

1. Gavalko G., Peshuk L, Sineok L., Romanenko M., Gashchuk A. (2015), Effect of gerodietic meat pate on biochemical parameters in the elderly: the role of vitamin B_{12}, *Advances in gerontology*, 28(3), pp. 571–578.
2. Peshuk L., Gashchuk O., Moskalyuk O., Gagach I. (2014), Development of meat herodic products – a priority on scientific discipline, *Visnyk of the Sumy National Agrarian University*, 2/2(25), pp.187–190.
3. Moskalyuk O., Peshuk L., Gashchuk A., Chernyushok O. (2017), Development of meat pate of high biological value, *Food industry: science and technology*, 4(38), pp. 9–13.
4. Moskalyuk O., Gashchuk O., Peshuk L. (2017), Development of pates using phytocomplex of cereal crops "Choice", *Naukovi pratsi NUHT*, 23(4), pp. 238–243.
5. Jussi L. (2015), Enzymes of sprouted whet and their possible tehchnological significance, *Paivi Kanerva, Chonggang Zhang, Tuula Sontag-Strohm*, Chapman&Hall, pp. 143–144.
6. Salovaara H., Michael G. (2016), Growth features of PbS crystals grown in silica gels, *Journal of Crystal Growth*, 6, pp. 214.
7. Mnerie D., Gaceu L., Gubenia O., Shamtsyan M., Birca A., Mnerie G.V. (2016), Comparative study on the evolution of the food labeling quality in some countries from the Black Sea Region, *Journal of Hygienic Engineering and Design*, 14, pp. 60-65
8. Kremena Nikovska, Galina Stefanova, Lyubomir Stefanov, Stanka Damyanova, Albena Stoyanova, Oleksii Gubenia (2018), Influence of adding of laurel essential oil extracts on salad dressings properties, *Ukrainian Food Journal*, 6(3), pp. 433–442
9. Knapp H. (2003), Physiologi calandbiochemicale ffectsof n–3 fattyasidsinma, *Essential Fatty Acidsand Eicosanoids*, AOCS Publications, pp. 330–333.
10. Clarke R., Lewington S. (2006), British Nutrition Foundationin formation sheetont rans-fattyacids, *British Medical Journal*, 333, pp. 214.
11. Telychkun V.I., Gavva O.M., Telychkun Yu.S., Gubenia O.O., Desyk M.H., Chepeliuk O.M. (2017), *Tekhnolohichni kompleksy kharchovykh vyrobnytstv*, Stal, Kyiv.
12. M. O'Keeffe (2005), Food and nutritional analysis | Meat and Meat Products, *Encyclopedia of Analytical Science*, Elsevier, pp. 302–312.
13. Tingting Liu, Nazimah Hamid, Kevin Kantono, Loveena Pereira, Scott O. Knowles (2016), Effects of meat addition on pasta structure, nutrition and in vitro digestibility, *Food Chemistry*, 213, pp. 108–114

Formation of quality and safety of offal sausages

Lina Bilyk, Natalia Popova

National University of Food Technology, Kyiv, Ukraine

Keywords:

Meat
Raw
By-products
Sausages
Quality
Safety

Article history:

Received 29.01.2018
Received in revised form 26.05.2018
Accepted 29.06.2018

Corresponding author:

Natalia Popova
E-mail:
Nata_2506@ukr.net

DOI:
10.24263/2310-1008-2018-6-1-8

Abstract

Introduction. The research was carried out to determine the influence of the method of packaging sausages on the period of their storage.

Materials and methods. The research was carried out on the samples of offal sausages. These samples are made in production conditions. The pH of sausages and moisture content were studied. The pH level was investigated by potentiometric method, dry content was investigated in the sausage moisture content.

Results and discussion. The water content of the product is closely related to the stability of the product during storage and its transportability, as well as the suitability for further processing, as excess moisture promotes the flow of enzymatic and chemical reactions, activates the activity of microorganisms, including those that cause damage to the product, in particular its mold. In this regard, the moisture content in the product determines the terms and conditions for its storage.

The optimum moisture content in off-sausage is 52%.

The moisture content of sausage can be influenced by various factors, such as temperature and storage conditions, the type of packaging chosen for sausage wares, and the terms of its storage.

In the course of the research carried out, this indicator changed as follows:

in the control sample did not go beyond the norm, in fresh sausage, without packaging for 6 days, the storage rate decreased to 44%, in frozen – to 50. In sausage, which was stored in a plastic bag, the mass fraction of moisture increased to 55%, and in sausage in parchment up to 53%.

pH is an indicator of the degree of freshness of sausage products. The value of active acidity plays an important role in the storage of sausage products. Changing this indicator in the direction of alkaline environment indicates the beginning of the development of microorganisms and the beginning of damage to sausage.

The optimum pH value for offal sausage is 6–7.

In the analysis of the samples studied, the following results were obtained:

fresh sausage without packaging (6 days study) – 7, frozen sausages – 6.5, sausages in a plastic bag – 7.5, sausages in parchment – 7.2.

Conclusions. The formation of the qualitative and safe product is affected by a number of indicators such as moisture content and pH of the product. In this case, it is important to choose a quality and efficient packaging. According to the conducted researches, the best packaging method is parchment packing.

Introduction

Today, meat and sausage products market is experiencing both negative and positive changes. According to the technical report, among the negative ones can be distinguished such as: depressed state of the meat market; large-scale using of cheap imported raw materials as an alternative to more expensive domestic; increase in energy prices and the main components of the sausage production; constant fluctuation (increase) prices of finished products; reduction of qualitative and taste indicators in pursuit of a mass consumer with low solvency; monopolization of the market – crowding out of the network of small and mediumsized producers; the export of domestic sausage products remains in perspective. The positive changes concern with: renovation of production facilities; the desire of produce in the manufacturing of competitive products from high quality raw materials; the activation of brand products and the expansion of assortment presence in the middle and low-end segments; an increase in the volume of production of fine-packed products, as well as smoked and dried sausages in branded packaging; the introduction of new national standards for meat and meat products that allow the release of new names of sausage products. All these positive/negative trends strongly affect the industry. For producing of high-quality products manufacture should use all possible measures.

One of such measures is to improve the quality of the production sausage products, namely, offal sausages which, due to its high taste, low cost and consumer properties has high demand among the population. The consumption of offal sausages, in the total amount is almost 40%.

The influence of the method of packaging offal sausages for the period of their storage is still not established. The aim of this study was to determine the influence of the method of packaging sausages on the period of their storage.

Materials and methods

The research was carried out on the samples of offal sausage containing in its composition pigs' buckies, fancy beef, starch and spices. These samples are made in production conditions.

The main physical and chemical parameters that reflect the possible processes of deterioration of the product were selected pH and moisture content. In this case, research methods such as potentiometric, for determination of pH and drying method for determination of moisture content were used.

The essence of the potentiometric method is to measure the difference between the electromotive force of two electrodes. One of them is a measuring one, and the other one is auxiliary. In addition, both of these electrodes should be placed in the test solution. Consequently, the method of analysis is based on the measurement of the EMF of the galvanic elements. Under these elements just understand the connection of two electrodes, one of which, as it was spoken earlier, an indicator, and the other is necessary for comparison.

To determine the pH, add 2 g of the crushed product to the porcelain mortar, add 2.5 g of fine roasted sand and 6 g of ethanol. Rubbing the mortar for 4 minutes and filtering through a folded filter. 3–4 drops of filtrate by a glass rod on a prism of a refractometer and record the results.

To determine the mass fraction of moisture, the most accurate results are obtained by drying the product to a constant mass at 100–105 °C in the drying cabinet. This method refers to arbitration, which determines the correctness of all newly developed methods.

To accelerate drying, it is recommended to increase the porosity of the product by mixing it with solid material (sand) and reducing the thickness of the drying layer. The weight of the product is weighed, ground and calculated according to the appropriate formula.

The moisture content in the material is characterized by an indicator of the mass fraction of moisture (W) – it is expressed in percentage of the ratio of the weight difference of the product type before and after drying to the weight of the sample prior to drying $W= (m_1-m_2/m_2)* 100\%$, where m_1 – weight of weight loss before drying, g; m_2 – weight of weight loss after drying, g.

In an aluminum bake, pour the sand in an amount that is 2–3 times the weight of the product (3 g), put a glass patch and dry for 30 minutes at a temperature of 150 degrees for the celcius. In the dry sand bake add the weight of the product and mix with a glass rod. Put the resulting mixture in a drying oven for drying. We dry for 1 hour. Cool in a desiccator and weigh. The results are calculated according to the formula.

Currently, consumers prefer to import producers, as there is a misconception about the poor quality of domestic products. The main task of modern meat processing enterprises is gaining popularity on the market by manufacturing high-quality and safe products with minimal losses.

During the processing of cattle (cattle) significant waste of secondary raw materials is created that is not sufficiently fully and rationally used for food purposes. It is known that about 1/3 of the total amount of raw materials of the meat industry is byproducts, blood, bones and others. These all products contain a significant amount of animal protein. Industrial processing of by-products, in comparison with their implementation not in the processed form, allows you to increase profits in general more than 10 times. Consequently, the use of offal raw materials is one of the possible ways of setting up rational production.

However, despite the obvious economic effect, the processing of by-products for food purposes constrains the idea of their low nutritional and biological values, the complexity and low efficiency of methods and techniques for their food processing and processing.

Offal sausages include edible secondary slaughter products. By their nutritional value they are divided – on by-products I and II categories. To category 1 include byproducts that are equated with meat – tongue, liver, kidneys, brains, heart, udder, diaphragm, meat-eating tail, meat oblique. Category II includes less valuable offspring – pork scab, stomach, calico, sichug, lungs, beef heads without tongue to the brain, trachea, spleen, swine legs and ears, pylon joint, lips, beef ears, meat-and-bone pig's tail. Offal sausages contain an average protein of 9–17, fat – 1,2–16%. The energy value of their 410–1402 kJ.

According to studies of the chemical composition of by-products, they contain significant resources of animal protein: in the spleen, lungs, scars, squish, calcium, esophagus – 15–19%, ears and lips – 21–25%. Of which valuable protein – in the spleen – 13,2%, in the lungs and esophagus – 10% [3] . By-products have a positive effect on juicing and the motor function of the stomach and intestines, and, moreover, collagen is a source of natural fibers that are healthy for health.

Specific for collagen properties are increased water and fat retaining ability, gel-forming ability to expand the scope of application of collagen-containing by-products [5].

They can be used as a filler for raw materials when cooked sausages (cooked and semi-smoked), meat loaves and chopped semifinished products. The highest amount of collagen is found in the scar, lips and ears – respectively 50%, 66% and 71% of collagen to the total protein.

Results and discussion

The quality and safety of offal sausages form organoleptic, physico-chemical, microbiological parameters, form the maximum permissible levels of the content of toxic elements, and the content of radionuclides.

Requirements for organoleptic parameters of offal sausages

According to organoleptic parameters, sausages must meet the following standards:

The surface of the loaves – clean, dry, without spots, glabrations, shell damage and stuffed stuffing, the consistence is elastic, the appearance of minced meat on the cut – the minced meat is uniformly mixed, from pink to dark red, without gray spots and cavities and contains pieces of fat, pork , breasts, beef or lamb fat, tanks (sacks), etc. It is allowed to reject the size of individual pieces at the cut of their diagonal.

Taste and smell – taste pleasant, slightly sharp, salty, with a pronounced aroma of spices and smoked, with the smell of garlic or without it, without foreign taste and smell.

The shape and size of the loaves – the loaves are straight or slightly curved in length from 15 cm to 50 cm, in the belly – scratched bars in length from 15 cm to 35 cm

Physico-chemical parameters must meet the requirements given in Table 1.

Table 1

Physico-chemical parameters of sub-product sausage

№	Name of indicator	Characteristic and norm
1.	Mass fraction of moisture, %	55
2.	Mass fraction of protein, %	13
3.	Mass fraction of fat	45
4.	Mass fraction of kitchen salt, %	4,5
5.	Mass fraction of sodium nitrite, %	0,005
6.	Mass fraction of starch, %	4,5
7.	Temperature in the breadth of the loop, during release in the implementation	from 0 to 12

Microbiological indicators are given in Table 2.

Table 2

Microbiological indicators of offal sausages

Microbiological indicators	Norma
Bacteria of the group of intestinal sticks (BGKP), in 1.0 g of the product	not allowed
Sulfonating cholestridia: – 0.01 g of the product	not allowed
Staphilococus aureus in 1,0 g of the product	not allowed
Pathogenic microorganisms, in particular bacteria of the genus Salmonella, in 25 g of the product.	not allowed
L.Monocytogenes, in 25 g of the product.	not allowed

The maximum permissible levels of the content of toxic elements of offal sausage must not exceed the standards specified in Table 3.

Table 3

Maximum permissible levels of the content of toxic elements

Name of toxic element	Maximum permissible levels
Lead	0.50
Cadmium	0,05
Mercury	0,03
Copper	5,00
Zinc	70,00
Arsenic	0,10

The content of radionuclides in sausages should not exceed the permissible levels set by the PL: ^{137}Cs – 200 Bq / kg; ^{90}Sr r – 20 Bq / kg.

Also, the quality and safety of the product is influenced by the way of its packaging.

The study of the terms of storage of offal sausage, depending on the method of packaging, was conducted.

The most popular types of packaging are vacuum packaging or packaging in the MGS environment [9]. Modified gas medium (MGS) is a mixture of gases that are present in the usual atmosphere, but the content of one or two gases that slow down the process of food spoilage increases with respect to the usual air cushion. Nitrogen serves as a filler to reduce the concentration of other gases inside the package, as well as prevents the packaging from swirling with the dissolution of carbon dioxide in the product. Oxygen slows the growth of anaerobic pathogenic fungi, but in many cases, it does not directly affect the increase in shelf life. So, as a result of scientific studies, it was found that for storage of the properties of meat for 6 days, you can use a mixture of MGS with 20%

carbon dioxide and 80% oxygen. Carbon dioxide prevents the reproduction of pathogenic bacteria and fungi, and oxygen allows you to save the fresh red color of the meat, prevents the transition of muscular red dye in brown methymoglobin.

The object of the study was semi-smoked sausage.

The control sample was selected sausage of second-class offal, which was produced by PJSC "Kozyatynsky meat-packing plant", and differs from other sausage products by the fact that it includes such by-products as tanks of pork and headed beef.

Store data for sausage products, usually at a temperature not higher than 6 °C and 75–80% relative humidity. The term of sales of sausages is 6 days.

When storing the product in refrigerating chambers, at a temperature of –14 °C, it is stored much longer, but the appearance, the value of such a product will already be broken.

Sausage shell and packaging directly affect how much it can be stored. Material for the production of sausage can be both natural and artificial raw materials.

Natural materials can serve as intestines of different animals – lamb, pork, beef, etc. Artificial membranes are mainly made from various plastics, viscose, cellulose, and sometimes tissue. It is these shells most often used in production, since boiled sausage in them has a much longer shelf life.

The most common of artificial coatings is a shell of polyamides components that have high strength and reliability. In addition, they have antibacterial properties and do not allow to enter the microbes and bacteria, resistant to the radiation of UV-protecting light

product from premature spoilage, and their low ability to pass gaseous substances do not allow foreign smells to spoil the aroma of sausage and prevents penetration of excess moisture.

Sausage cooked in a similar shell can store freshness for about 2 weeks, but once its integrity is broken, the product will need to be taken in the next few days.

The research was conducted for 6 days, the control points of the tests were 2, 4 and 6 days. The samples under investigation were 4, that is, a sample of sausage sub-product without packaging, in polyethylene packaging, in parchment and a sample stored in a freezing chamber at a temperature of -7 °C.

During the study, the quality of sausage during the storage of sausage was determined by the content of the mass fraction of moisture and the level of pH, which is not standardized in this type of sausages, but is an indicator that indicates the degree of freshness of sausage products. The value of active acidity plays an important role in the storage of sausage products. Changing this indicator in the direction of alkaline environment indicates the beginning of the development of microorganisms and the beginning of damage to sausage.

During storage, the organoleptic parameters of offal sausages also changed (results of the state of sausages stored in parchment, polyethylene and without packaging for 6 days storage):

Baton surface – wet, sticky, consistency – elastic,

taste and smell – there is an extraneous flavor and smell.

The sausage wares stored in the freezer chamber changed their color from reddish to light brown.

Changing the moisture content during storage is a natural process. This is due to mass exchange, with the important role played by the degree of binding of moisture in the product [4].

Mass fraction of moisture of the offal sausage

The results of the research are presented in Table 4.

Table 4

Results of the study of the mass fraction of moisture of the offal sausage

Experimental sample	Mass fraction of moisture, %			
	Duration of storage			
	Control sample	2 days	4 days	6 days
Fresh sausage, without packaging	52	51	46	44
Frozen sausage		52	52	51
Sausage in a plastic bag		52	53	55
Sausage in parchment		52	52	54

After analyzing the data obtained, we can conclude that the mass fraction of moisture of fresh sausage, without packaging decreased, as the product without packaging is characterized by drying out. The bulk of the moisture content of frozen sausages decreased, the polyethylene increased significantly and increased slightly in parchment, as this type of packaging was able to accumulate moisture.

Active acidity of the offal sausage

According to the results of the study of active acidity, it was found that frozen sausage does not change the active acidity, so the processes of damage do not occur, fresh sausage, which was stored without increasing the pH. In sausage, which is stored in polyethylene and parchment, the index of acidity also increases significantly significantly, hence the possible processes of damage.

The results of active acidity studies are presented in Table 5.

Table 5

Results of study of active acidity of sausage subproduct

Experimental sample	Active acidity			
	Duration of storage			
	Control sample	2 days	4 days	6 days
Fresh sausage, without packaging	6–7	6,5	6,8	7
Frozen sausage		6,5	6,5	6,5
Sausage in a plastic bag		6,8	7,0	7,5
Sausage in parchment		6,78	6,90	7,2

Consequently, 4 samples of offal sausage , namely sausage without packaging, frozen, in polyethylene packaging and in parchment, were investigated. As a result of researches it was discovered that the maximum shelf life of off-product cooked sausages is 6 days, at a temperature from 0 to +6 °C. When frozen sausages, quality indicators remain stable, therefore freezing is effective for extending the storage period of sausages, but at the same time the food value of the product is lost.

The use of polyethylene for packaging is possible, but in this case the product does not behave as stable: moisture content increases significantly, thus accelerating the process of deterioration. So the use of this kind of packaging is not effective. Packing in parchment is the best way to pack.

Conclusions

Production of meat and meat products is an important component of the food industry, and its development depends on solving a number of problems: provision of domestic livestock feed to the feed base; optimization of the assortment of production of meat processing products of the domestic producer in accordance with the needs of the market, as well as the formation of a quality and safe product. In this case, it is extremely important to select a quality and efficient packaging of the product. According to the research, the best option is packaging of the product in parchment, because when using such packaging, the quality parameters of the product, such as moisture content and pH are stable.

References

1. Kundileeva G. (2012), Esential problems of development of meat sector in agriculture in Ukraine International Conference on European Science and Technology, Munich, pp. 482–485.
2. Kholod A. The problems and prospects of meat production in Ukraine, NUFT, Kyiv.
3. Pavelko V., Hrybkov S., Zaslsvsky A., Dmytrenko D. (2016), Mathematical modeling of thermal processing of meat products, Food and Environment Safety, 15(4), pp. 329–333.
4. Essien E. (2003), *Sausage manufacture. Principles and practice*, Woodhead Publishing & Boca Raton, CRC Press.
5. Feiner G. (2006), *Meat products handbook. Practical science and technology*, CRC Press.
6. Yi-Chen Lee, Yi-Fen Chen, Ya-Ling Huang, Hsien-Feng Kung, Yung-Hsiang Tsai (2016), Hygienic quality, adulteration of pork and histamine production by Raoultella ornithinolytica in milkfish dumpling, *Journal of Food and Drug Analysis*, 24 (4), pp. 762–770.
7. Warriss P.D. (2000), *Meat science, An introductory text*, CABI Publishing.
8. Kuzmin O., Suikov S., Niemirich O., Ditrich I., Sylka I. (2017), Effects of the water desalting by reverse osmosis on the process of formation of water-alcohol mixtures.^{1}H NMR spectroscopy studies, *Ukrainian Food Journal*, 6(2), pp. 239–257.
9. Snezhko A.G., Fedotova A.V. (2008), The use of nanotechnology for the packaging of meat products, *Meat Industry*, 2, pp. 22–24.
10. Kenneth W. McMillin (2017), Advancements in meat packaging, *Meat Science*, 132, pp. 153–162.
11. Steven M. Lonergan, David G. Topel, Dennis N. Marple (2019), Chapter 15: Packaging for meat and meat products, *The Science of Animal Growth and Meat Technology (Second Edition)*, pp. 255–269
12. Telychkun V.I., Gavva O.M., Telychkun Yu.S., Gubenia O.O., Desyk M.H., Chepeliuk O.M. (2017), *Tekhnolohichni kompleksy kharchovykh vyrobnytstv*, Stal, Kyiv.
13. Litovchenko I., Taran V., Beseda S., Hadjiiski W. M., Stefanov S.V. (2011), Computer modelling of movement of meat raw material on pipelines, *The 7th International Conference «Integrated systems for agri-food production»*, Nyiregyhaza, Hungary, pp. 211–214.
14. Fellows P. (2013), *Food processing technology. Principles and Practice. Second Edition*, CRC Press.
15. Brennan J. G., Alistair S.G. (2011), *Food Processing Handbook, 2nd Edition*, Wiley-VCH Verlag GmbH & Co.
16. Holah J., Lelieveld H.L.M. (2011), *Hygienic Design of Food Factories*, Elsevier
17. Kennedy S. (2017), *Food Protection and Security. Preventing and Mitigating Contamination during Food Processing and Production*, Woodhead Publishing.
18. Lelieveld H., Holah J., Gabrić D. (2016), *Handbook of Hygiene Control in the Food Industry (Second Edition)*, Elsevier.

Comparative characteristics of ethapolan and xanthan exopolysaccharides as agents for the increasing secondary oil extraction

Mykola Ivakhniuk, Tetyana Pirog

National university of food technologies, Kyiv, Ukraine

Keywords:

Acinetobacter sp. IMV B-7005
Xanthomonas campestris
Exopolysaccharide
Cultivation
Oil

Article history:

Received 26.03.2018
Received in revised form 03.06.2018
Accepted 29.06.2018

Corresponding author:

Mykola Ivakhniuk
E-mail:
Ivahniuk@ukr.net

DOI: 10.24263/2310-1008-2018-6-1-9

Abstract

Introduction. The purpose of research – to compare the cost of nutrient mediums for obtaining culture fluids of *Acinetobacter* sp. IMB B-7005 and *Xanthomonas campestris* strains (xanthan gum producers) for its using in the secondary oil extraction.

Materials and methods. Calculation of the culture fluid amount and the cost of nutrients for the ethapolan (producer – *Acinetobacter* sp. IMB B-7005) and xanthan (producers of *Xanthomonas campestris* strains) exopolysaccharides production as oil extraction agents for 262 oil wells of Oil and Gas Production Administration "Okhtyrkanaftogas" of JSC "Ukrnafta" was carried out taking into account the following parameters:4 times treatment per year of wells with the 15 m^3 of EPS solution with its concentration 0,05%).

Results and discussions. On the basis of the data on the concentration of synthesized polysaccharides by strains-producer, the annual need for a culture fluid (545–1849 m^3) was calculated for the treatment of wells of the OGPA "Okhtyrkanaftogas" and the amount of product per fermentation cycle according to selected technologies.

Theoretical calculations have shown that costs for the nutrient medium preparing for *Acinetobacter* sp. IMB B-7005 culture fluid obtaining on waste sunflower oil after frying meat, necessary for increasing secondary oil extraction at "Okhtyrkanaftogas" wells in 1.8–5.4 times less than in the case of ethapolan obtaining on C_2-C_6 substrates, molasses or their mixtures.

Comparison of nutrient medium cost for the preparation of ethapolan and the most famous polysaccharide xanthan obtained on molasses on technical glycerine was made. The cost of polysaccharide xanthan obtaining (in amount that would provide oil extraction in equivalent quantity like in case of ethapolan using) in 12.7–16.7 times higher compared to the ethapolan obtaining.

Conclusion. Obtained results confirm the economic feasibility of the ethapolan synthesis on waste oil for the polysaccharide using in secondary oil production in comparison with the technologies for xanthan obtaining.

Introduction

The main part of the oil fields in Ukraine is now entering the final stage of development, characterized by high watering of extracted petroleum and falling rates of production. The development of oil deposits is maintained by sustentation of reservoir pressure by injected in it water, which leads to regular wells watering, a sharp decline of oil yields and, as a consequence, stopping of such wells. The course of this process is connected, first of all, with the inhomogeneity of the collector in terms of permeability, porosity, presence of cracks, both technogenic and natural origin. It should be noted that the residual oil reserves are concentrated in the impermeable part of the collector [1].

Existing methods (pump, compressor, fountain) of oil production are imperfect, as they allow to get 40–60% of geological oil reserves. That is why polymers of high viscosity are widely used in the oil industry [1–3].

As a result of many years of researches (from the 1960's) and industrial testing of polymers in the intensification of oil production, a number of requirements have been formed to it [2–4]: rapid and complete solubility in water, stability of physico-chemical properties of the polymer in time and under temperature influence, resistance to salts in reservoir waters, effective increase of water viscosity at low concentrations.

In comparison with synthetic polymers, exopolysaccharides (EPS) of microbial origin have a number of significant advantages, including those that allow them to be used in very harsh conditions, where synthetic polymers using is ineffective [3]. Thus, EPS are stable at temperature range of 100–120 ˚C, and some retain their properties even at 150 ˚C, which is corresponds to the temperature range of the oil deposits. EPS are stable in a wide range of pH, both in acidic and alkaline environments. The benefit of microbial polysaccharides, compared with other reagents, can be their safety for both humans and the environment [3].

Despite a number of attractive properties of microbial polysaccharides, there are some factors that inhibit their industrial production. Currently, the cost of polysaccharides of microbial origin is still high, which is due to the high costs of biosynthesis and product allocation. Therefore, studies aimed to solve these problems are among the main in biotechnology of the EPS.

Domestic polysaccharide of multifunctional purpose – ethapolan (producer *Acinetobacter* sp. IMB B-7005) complies with the abovementioned requirements, in addition, using pilot-industrial series of culture fluid containing ethapolan for secondary oil extraction at the production oil wells of PJSC "Bashneft" had shown obtaining of additional 240 tons of oil under applying 1 ton of ethapolan [5].

This exopolysaccharide has several advantages over other EPSs, including the most famous polysaccharide xanthan (producer *Xanthomonas campestris*) [5]: higher viscosity of aqueous solutions, increasing viscosity in the presence of single- and bivalent cations, in the system Cu^{2+}-glycine and at low pH values, a significant increase of viscosity in zones of low shear rates, ethapolan can stabilize emulsions of water with oil and other hydrocarbons due to the presence of a lipophilic part in its molecule.

The purpose of the research – to compare the cost of nutrient mediums for obtaining culture fluids of *Acinetobacter* sp. IMB B-7005 and *X.campestris* strains (xanthan gum producers) for its using in the secondary oil extraction.

Materials and methods

For a comparative assessment of the effectiveness of using polysaccharides ethapolan (producer *Acinetobacter* sp. IMV B-7005) and xanthan (strains-producers *X. campestris* MTCC 2286 [6], *X. campestris* 2103 [7]) for secondary oil extraction, the cost of nutrients was compared according to different technologies for obtaining these biopolymers.

Calculation of the amount of EPS-containing culture fluid was carried out for the Oil and Gas Production Administration "Okhtyrkanaftogas" of JSC "Ukrnafta", which owns 262 oil wells in its fund [http://www.rada.com.ua/rus /catalog/8205] on the basis of the technology of microbial polysaccharides using in the oil production, described in the patent "The method of isolation of the formation water inflow" (USSR Pat. No. 1726732A1SU). According to the patent for the intensification of secondary oil extraction for one oil well, solution of culture fluid with a concentration of EPS not less than 0,05% (mass fraction of carbohydrates), the volume of which is 15 m^3, is using.

Technologies of ethapolan and xanthan obtaining

Technologies of ethapolan obtaining are shown in Table 1.

Calculation of culture fluid amount

Based on the concentration data of the synthesized polysaccharides given in Tables 1 and 2 and patent No. 1726732A1 SU data, the annual amount of culture fluid required for the treatment of 262 wells of "Okhtyrkanaftogas" was calculated.

Calculation of the annual amount of culture fluid (G) was carried out according to the formula:

$$G = 15000 \times 0.5 \times 262 \times 4 / X_{EPS} \times 1000 \quad m^3 \qquad (1)$$

where 15000 – required amount of culture fluid solution for processing one oil well in accordance with the patent №1726732A1 SU, l; 0.5 – concentration of polysaccharide solution, g/l; – quantity of oil wells of "Okhtyrkanaftogas", pcs; 4 – number of wells processing per year; X_{EPS} – concentration of polysaccharide in a culture fluid, g/l; – coefficient of liters conversion into m^3;

Taking into account the total losses, the **annual amount of post-fermentation fluid (G_{an})** was calculated according to the formula:

$$G_{an} = G/(1–0.3+0.1) \quad m^3 \qquad (2)$$

where 0.3 – losses of the target product during biosynthesis;

0.1 – possible cases of non-sterile fermentation process.

Calculation of the culture fluid amount per cycle of fermentation (Gcyc) was carried out according to the formula:

$$Gcyc = G_{an} \times Tcyc / W \times 24 \quad m^3 \qquad (3)$$

where W – number of working days per year (300 days); Tcyc – the cycle of the fermenter, which includes the time of basic fermentation (30 h) and the time of fermenter preparation to work (10 h).

On the basis of Gcyc, the **number of stages of inoculum preparation** (N):

$$N = Gcyc \times n \qquad (4)$$

where n – amount of inoculum, given in the notes of Tables 1 and 2 for every technology.

At the next stage, the cost of the nutrient medium was calculated, in order to obtain the culture fluid for the fermentation cycle, taking into account the costs of the inoculum receiving.

The prices (for the period of November 2017) of the mediums components in accordance with the catalog «Tehnohmya» [https://tehnohmya.uaprom.net], «Promkin» [https://zp.prom.ua/ua/c 2353605–fop-promkin.html] and site [https://flagma.ua] were used for calculations.

According to the literature [6, 7], mediums which are shown in Table 2 were used for *X.campestris* cultivation.

Table 1

Characteristics of ethapolan obtaining technologies

Technology	Growth substrate	Concentration (%) of carbon source for		Mineral salts, g/l	EPS concentration, g/l	Literature
		inoculum preparation	biosynthesis			
№1 basic	ethanol	1.0	1.0	KH_2PO_4–6.8 KOH–1.8 KCI–1.4 NH_4NO_3–0.6 $MgSO_4$–0.4×$7H_2O$ yeast autolysate – 0.25	4.25	[8]
№2	ethanol+ glucose	ethanol, 0.5	ethanol, 0.75+ glucose, 0.75	KH_2PO_4–6.8 KOH–1.8 NH_4NO_3–0.6 KCI–1.4 $MgSO_4$–0.4×$7H_2O$ yeast autolysate – 0.25	8.3	[9]
№3	ethanol+ molasses	ethanol, 0.5	ethanol, 0.75+ molasses, 0.75	KH_2PO_4–3.4 KOH–0.9 $MgSO_4$–0.4×$7H_2O$ yeast autolysate – 0.25	8.35	[10]
№4	sodium acetate+ molasses	sodium acetate, 0.7	sodium acetate, 1.1+ molasses, 0.75	KH_2PO_4 –2.0 $MgSO_4$–0.4×$7H_2O$ yeast autolysate – 0.25	9.7	[11]
№5	waste oil	refined oil, 0.5	waste oil, 5.0	KH_2PO_4 −6.8 KOH−0.9 NH_4NO_3–0.6 $MgSO_4$–0.4×$7H_2O$ yeast autolysate – 0.25	14.4	[12]

Notes: 1. Mediums according to technologies № 1–5 also contained macro-elements (g/l): $CaCl_2$×$2H_2O$ – 0.1; $FeSO_4$×$7H_2O$ – 0.001, the cost of which was not taken into account because of their insignificant amount.

2. In mediums № 1–4, 0.0006% of pantothenate was used as a growth factor and in medium № 5 – multivitamin preparation "Complevit" (0.00095%, in recount to calcium pantothenate).

3. Hydrolysed molasses were used in mediums № 3 and 4, (20 ml of 1 N H_2SO_4 were added to 100 g of molasses).

4. Quantity of inoculum for technologies № 1, 2 is 5%, for technologies № 3–5 – 10%.

Table 2

Characteristics of xanthan obtaining technologies

Techno-logy	Producer	Medium for		EPS concentration, g/l	References
		inoculum preparation	biosynthesis		
I	*X.campestris* MTCC 2286	molasses, 1%; K_2HPO_4, 2 g/l; Tween 80, 0.3 g/l	molasses, 10 g/l; yeast extract, 10 g/l; K_2HPO_4, 2 g/l; Tween 80, 0.3 g/l; $MgSO_4 \times 7H_2O$, 0.1 g/l	12.3	[6]
II	*X.campestris* 2103	glucose,1.0%; yeast extract, 0.3%; malt extract, 0.3%; pepton, 0.5%	crude glycerin, 2%; urea, 0.01%; KH_2PO_4, 0.1%	7.2	[7]

Notes:

1. Hydrolysed molasses were used in mediums I (10 ml of 5 N H_2SO_4 were added to 200 ml molasses, after which mixture was stirred and sparged with air for 15 minutes).

2. Quantity of inoculum for technology I is 5%, for technology II – 10%.

Results and discussions

Analysis of various technologies of ethapolan obtaining

A number of technologies have been developed for the EPS ethapolan production (see Table 1), each of which has its advantages and disadvantages. Thus, in particular, in *technology № 1* (basic technology) [8] ethanol is used as a carbon source. This technology was developed in the late 80's and early 90's of the XX century, when using of such substrate was expedient, since in the former USSR it was popular to use non-food raw materials (methanol, ethanol, ethylene glycol, etc.) through their low cost. But the situation has changed and every year the cost of ethanol is increasing. Thus, in 2015 state enterprise "Ukrspirt" raised the price of the ethyl alcohol of luxury class for decalitre from 175 to 265 UAH, and since April 2016 the price was increased by another 19% [https: //www.kmu. gov.ua/ua/news/247982137?=print], respectively, such a sharp price change complicates implementation of ethapolan technology production on ethanol.

One of the approaches to intensify synthesis of microbial polysaccharides is using of growth substrates mixture. Under simultaneous consumption of substrates mixture by microorganisms, increasing of biomass and the target product quantities, the growth rate and the reduction of the lag phase length were observed [13]. *Technology №* 2 involves synthesis of 8.3 g/l of ethapolan in a mixture of ethanol and glucose [9]. Compared to the basic technology, the quantity of synthesized ethapolan is 2 times higher, but the disadvantages of this technology are high cost of both substrates, as well as the risk of glucose contamination.

Wastes from sugar production (molasses and sugar syrup) are widely used in the industrial production of polysaccharides [14]. *Technology № 3* [10] envisages using of

ethanol and molasses mixture as a source of carbon and energy. In addition, the salt content in the medium is almost 4 times lower than in the basic one. The advantage of this technology, in comparison with *technologies № 1* and *2*, is the low cost of molasses and no need of an additional source of nitrogen feed, since molasses contain about 1.1% of organic nitrogen [10]. However, on the other hand, this substrate can be a source of contamination, since it contains carbohydrates.

A possible solution of the problem of ethanol high cost is its replacement with sodium acetate (*Technology № 4* [11]). The medium for ethapolan obtaining, which contains a mixture of sodium acetate and molasses, is cheaper compared to the basic one. It should be noted that molasses according to *technologies 3* and *4* require hydrolysis, which requires additional costs and time [10, 11].

Despite the availability and low cost of molasses, this technology has some disadvantages: 1) high risk of contamination; 2) the need for using antifoaming agent (since foaming occurs under molasses mixing); 3) the presence in molasses composition of possible inhibitors of microorganisms growth (betaine, metal cations) [13].

The advantage of *technology № 5* is using waste sunflower oil as a substrate for the EPS synthesis. It should be noted that besides affordability and low cost, this substrate does not require sterilization and may contain additional growth factors that have gone from food during frying [12]. However, depending on the multiplicity of oil using, it may contain toxic impurities, which can be inhibitors of producer's growth and target product synthesis.

Note, that technologies 1–4 envisage using of 0.0006% of pantothenate calcium, according to which the strain IMV B-7005 is auxotrophic. But in Ukraine there is no production of vitamin B_5, therefore there is a need of expensive imported substance. In turn, *technology №5* envisages using the multivitamin complex "Complevit" of Ukrainian production as a source of vitamin B_5 [12].

The final data on the calculation of the ethapolan-containing culture fluid amount, which must be obtained during the fermentation cycle, are shown in Table 3.

Table 3

Data of the *Acinetobacter* sp. IMB B-7005 culture fluid amount calculation for secondary oil extraction

Technology	Concentration of EPS, g/l	Annual quantity of CF (G), m^3	Annual quantity of CF with taking into account losses (G_{an}), m^3	Quantity of CF per fermentation cycle (Gcyc), m^3	Quantity of inoculum production cycles, pcs.
№1	4.25	1849.4	3082.3	17.1	3
№2	8.3	946.4	1577.3	8.8	3
№3	8.35	941.3	1568.7	8.7	4
№4	9.7	810.3	1350.5	7.5	4
№5	14.4	545.8	909.7	5.1	4

Note: CF – culture fluid

Based on the data given in Tables 1 and 3, the cost of various nutrient mediums for the ethapolan preparation was calculated (Table 4).

Table 4

Composition and cost of nutrient mediums for various ethapolan production technologies

Techno-logy	Components of the nutrient medium	Price, UAH/kg	Quantity of components, kg	Cost of the component, UAH	Cost of nutrient medium, UAH
№ 1 Basic	ethanol 96%	70.0	158.3	11081.8	18956
	KH_2PO_4	47.0	122.4	5752.8	
	KOH	36.1	32.3	1166.0	
	KCI	16.2	25.2	408.2	
	NH_4NO_3	12.6	10.8	136.1	
	$MgSO_4 \times 7H_2O$	7.1	7.2	51.1	
	yeast autolysate	80.0	4.5	360.0	
№ 2	ethanol 96%	70.0	60.2	4214.0	10313.9
	glucose	31.2	66.0	2059.2	
	KH_2PO_4	47.0	62.8	2951.6	
	KOH	36.1	16.6	599.3	
	NH_4NO_3	12.6	5.6	70.6	
	KCI	16.2	12.9	208.9	
	$MgSO_4 \times 7H_2O$	7.1	3.7	26.3	
	yeast autolysate	80.0	2.3	184.0	
№ 3	ethanol 96%	70.0	56.1	3927.0	6422.9
	molasses	3.5	130.5	416.8	
	KH_2PO_4	47.0	32.9	1546.3	
	KOH	36.1	8.7	314.1	
	$MgSO_4 \times 7H_2O$	7.1	3.8	26.9	
	yeast autolysate	80.0	2.4	192.0	
№ 4	sodium acetate	56.4	88.3	4980.1	6352.4
	molasses	3.5	112.5	395.8	
	KH_2PO_4	47.0	16.7	784.9	
	$MgSO_4 \times 7H_2O$	7.1	3.3	23.4	
	yeast autolysate	80.0	2.1	168.0	
№ 5	waste sunflower oil	5.38	237.1	1275.0	3535.6
	refined oil	37.4	2.6	97.4	
	KH_2PO_4	47.0	38.5	1809.5	
	KOH	36.1	5.1	184.1	
	NH_4NO_3	12.6	3.4	42.8	
	$MgSO_4 \times 7H_2O$	7.1	2.2	15.6	
	yeast autolysate	80.0	1.4	112.0	

Thus, data of the Table 4 show that the most effective and economically feasible is technology № 5. Costs for nutrient medium according to this technology are 55–80% lower compared to others. In addition, the cost of the selected medium can be reduced by replacing the refined oil with the waste one for inoculum obtaining. Our latest research has demonstrated the ability of using oil of any quality and its mixtures, which makes it possible to develop a universal technology that is independent of the raw materials supplier [11]. Worth to notice that besides the economic benefits, using as a substrate of waste oil also has environmental benefits, since the emissions of oils to the environment are not regulated.

Accordingly, for the comparative evaluation of ethapolan and xanthan polysaccharides using effectiveness, technology №5 was considered as the main one.

Analysis of technologies for xanthan production on industrial waste

Xanthan is one of the most famous polysaccharides, the annual production of which is 30000 tons, which in the monetary equivalent is 408 million dollars USA and every year the need for it increases [14]. Note that, in general, hydrocarbon substrates (glucose, sucrose, starch) are used for xanthan gum obtaining [15, 16]. But among the large number of technologies described in the literature, for the analysis, the technologies for this EPS obtaining on industrial waste were chosen, since the medium for ethapolan obtaining also contains waste oil.

It is worth noting that xanthan, unlike ethapolan, has no ability to increase the viscosity of the solution in the presence of copper salts, respectively, to obtain the required viscosity, culture fluid of xanthan should be used in 10 times more compared to ethapolan.

The generalized data of the *X.campestris* culture fluid needs are given in Table5.

Table 5

Generalized data of calculation of *X.campestris* culture fluid as oil-pressuring agent

Techno-logy	Concentration of EPS, g/l	Annual quantity of CF (G), m^3	Annual quantity of CF with taking into account losses (G_{an}), m^3	Quantity of CF per fermentation cycle (Gcyc), m^3	Quantity of inoculum production cycles, pcs.
I	12.3	6390	10650	59	5
II	7.2	10917	18194	101	5

Note: CF – culture fluid

Based on the data given in Tables 2 and 5, the cost of various nutrient mediums for the xanthan preparation was calculated (Table 6).

Table 6

Composition and cost of mediums for the xanthan production on industrial waste

Techno-logy	Components of the nutrient medium	Price, UAH/kg	Quantity of components, kg	Cost of the component, UAH	Cost of medium, UAH
I	molasses	3.5	621.7	2175.9	58945.4
	yeast extract	80.0	590.0	47200.0	
	K_2HPO_4	47.0	124.3	5842.1	
	Tween 80	195.0	18.9	3685.5	
	$MgSO_4 \times 7H_2O$	7.1	5.9	41.9	
II	crude glycerin	14.2	2020.0	28684.0	44928.0
	glucose	31.2	110.0	3422.0	
	yeast extract	80.0	67.0	5360.0	
	pepton	75.0	35.0	2625.0	
	KH_2PO_4	47.0	101.0	4747.0	
	urea	9.0	10.0	90.0	

Data in Table 6 indicate that technology of xanthan obtaining on crude glycerine is more effective. In addition, to date, the problem of crude glycerine utilization is much sharper than molasses, as annual biofuel production is increasing. It should be noted that for every 100 liters of biodiesel, almost 10 liters of crude glycerol (the so-called glycerol fraction) are forming [17].

Although the technology of xanthan production on glycerol is more effective than on molasses, but compared with technology №5, the cost of nutrient medium preparing for EPS obtaining (for secondary oil extraction) is 13 times higher. It is due to a significantly cheaper carbon source using, higher in twice EPS-synthesizing ability of *Acinetobacter* sp. IMB B-7005 compared to the xanthan's producer, as well as lower costs of EPS-containing culture fluid for wells processing.

Conclusions

Consequently, theoretical calculations of the cost for preparing the nutrient medium for production of the *Acinetobacter* sp. IMB B-7005 culture fluid required for increasing secondary oil production at "Okhtyrkanaftogas" (262 units) is 3535.6 UAH, while for the well-known EPS xanthan (in the amount that will produce equivalent amount of oil) – 44928 UAH.

References

1. Iupov A.H., Sharifullin A.V. (2003), Polimerni ta vuhlevodnevi spoluky dlia pidvyshchennia naftoviddachi plastiv vysokoobvodnennykh, *Naftove hospodarstvo*, 6, pp. 48–51.
2. Li Q., Kang C., Wang H., Liu C., Zhang C. (2002), Application of microbial enhanced oil recovery technique to Daqing Oilfield, *Biochemical Engineering Journal*, 11, pp 197–199.

3. Nazina T.N., Grigoryan A.A., Shestakova N.M., Babich T.L., Ivoilov V.S., Feng Q., et al. (2007), Microbiological investigations of high-temperature horizons of the Kongdian petroleum reservoir in connection with field trial of a biotechnology for enhanced oil recovery, *Microbiology*, 76, pp. 287–96.
4. Sen R. (2008), Biotechnology in petroleum recovery: The microbial EOR, *Progress in Energy and Combustion Science*, 34, pp. 714–724.
5. Pirog T.P., Korzh Yu.V. (2006), Etapolan – mikrobnyi ekzopolisakharyd multyfunktsionalnoho pryznachennia, *Biopolimery i klityna*, 22 (3), pp. 171–183
6. Murugesan A.G., Dhevahi B., Gowdhaman D., Bala Amutha K., Sathesh Prabu C. (2012), Production of xanthan employing *Xanthomonas campestris* using sugarcane molasses, *Journal of Environmental Engineering*, 2(2), pp. 31–34.
7. Brandão L.V., Assis D.J., López J.A., Espiridião M.C.A., Echevarria E.M., Druzian J.I. (2013), Bioconversion from crude glycerin by *Xanthomonas campestris* 2103: xanthan production and characterization, *Brazilian Journal of Chemical Engineering*, 30(4), pp. 737–746, DOI.org/10.1590/S0104–66322013000400006
8. Pirog T.P., Korzh Yu.V. (2006), Vliianie atsetata na sintez ekzopolisakharida etapolana pri kultivirovanii *Acinetobacter* sp. IMV B-7005 na srede s etanolom, *Mikrobiologicheskii zhurnal*, 68(5), pp. 12–20.
9. Pirog T.P., Kovalenko M.A., Kuz'minskaya Yu.V., Krishtab T.P. (2003), Intensification of synthesis of the exopolysaccharide ethapolan by *Acinetobacter* sp. 12S grown on a mixture of substrates, *Microbiology*, 72(1) pp. 18–23. https://doi.org/10.1023/A:1022213703632
10. Pirog T.P., Lashchuk N.V., Zborovska B.M. (2007), Cyntez ekzopolisakharydu etapolanu v umovakh mikotrofnoho rostu *Acinetobacter* sp. IMV B-7005 na sumishi S*2*-spoluk i meliasy. *Kharchova Promyslovist*, 5, pp. 26–29.
11. Pirog T.P., Savchuk O.M., Muchnyk F.V. 2010, Intensyfikatsiia syntezu mikrobnoho polisakharydu etapolanu na sumishi atsetatu i meliasy, *Kharchova promyslovist*, 9, pp. 52–54.
12. Ivakhniuk N.A., Voronenko A.A., Pirog T.P. (2017), Mikrobnyi sintez ekzopolisakharida etapolana na razlichnykh vidakh otrabotannykh rastitelnykh masel, *Izvestiia Natsionalnoi akademii nauk Belarusi. Seriia biologicheskikh nauk*, 2, pp. 87−93
13. Pidhors'kyy V.S., Iutyns'ka H.O., Pirog T.P. (2010), *Intensyfikatsiya tekhnolohiy mikrobnoho syntezu*, Naukova dumka, Kyiv.
14. Kalogiannis S., Iakovidou G., Liakopoulou-Kyriakides M., Kyriakidis D.A., Skaracis G.N. (2003), Optimization of xanthan gum production by *Xanthomonas campestris* grown in molasses, *Process Biochemistry*, 39, pp. 249–256, https://doi.org/10.1016/S0032-9592(03)00067–0
15. Nouha K., Kumar R.S., Balasubramanian S., Tyagi R.D. (2018), Critical review of EPS production, synthesis and composition for sludge flocculation, *Journal Of Environmental Sciences-China*, 66, pp. 225–245, DOI: 10.1016/j.jes.2017.05.020.
16. Felicia Katherine R., Muthukumaran C., Sharmila G., Manoj Kumar N., Tamilarasan K., Jaiganesh R. (2017), Xanthan gum production using jackfruit-seed-powder-based medium: optimization and characterization, 3 Biotech, 7(4), p. 248, DOI: 10.1007/s13205–017–0876–5
17. Pirog T.P., Grytsenko N.A., Sofilkanych A.P., Savenko I.V. (2015), Technologies of synthesis of organic substances by microorganisms using waste biodiesel production, *Biotechnologia Acta*, 8(3), pp. 9−27, DOI: 10.15407/ biotech8.03.009.

Product grinding influence on the drying process of dispersed titanium dioxide paste

Victor Marchevskii, Yaroslav Grobovenko

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Keywords:
Kinetics
Grinding
Dispersant
Coolant
Drying
Paste

Article history:

Received 2.02.2018
Received in revised form 11.06.2018
Accepted 29.06.2018

Corresponding author:

Yaroslav Grobovenko
E-mail: ygrobovenko@gmail.com

DOI:
10.24263/2310-1008-2018-6-1-10

Abstract

Introduction. The research purpose is to determine the effect of the degree of product grinding on the processes of drying titanium dioxide paste and the drying of finely divided particles of titanium dioxide to a low residual moisture content of 0.3%.

Materials and methods. The processes of drying and post drying of fine disperse titanium dioxide paste in vortex fluxes of the heat carrier with the use of continuous grinding of the initial product were carried out in a conical dryer of the vortex type, which includes a special device for shredding the product – dispersant, feeder-dispenser and separation zone.

Results and discussion. The initial moisture content of titanium dioxide was 50–55%. The processes of drying and post drying the paste of titanium dioxide in the vortex flow of the heat-carrier during the application of the original design of the drying apparatus with a knife dispersant and a zone of drying of the material occurred to a low residual moisture content of 0,3%. In this case, the temperature of the coolant at the inlet to the drying chamber was 120 °C, and the volume flow i.e. 50 m^3/hour. During the process, the values of the temperature and humidity of the coolant were automatically measured at the inlet and outlet of the drying chamber and samples of dispersed particles were taken from the grinding zone. Experimentally established dependences for calculating the degree of grinding of z agglomerates of titanium dioxide paste and the value of the drying rate coefficient K_w for titanium dioxide, which is 0,17–2,5 m/s was obtained. In addition, the kinetics of the drying process completely described the drying curve, namely the initial moisture content of the paste was U_0 = 1,17 $kg_w/kg_{a.d.p.}$, U_{1cr} = 0,23 $kg_w/kg_{a.d.p.}$, equilibrium moisture content i.e. U_2 = 0,003 $kg_w/kg_{a.d.p.}$. In the first period, the paste was dried at 37 °C of wet thermometer. The optimum temperature conditions of the coolant for drying the titanium dioxide paste, which are 90–120 °C at the entrance to the drying chamber and 65–90 °C at the outlet was obtained.

The result of calculating the mathematical model is the degree of grinding that is 10–15 conventional units.

Conclusions. The kinetics and methods of intensification of the processes of grinding, drying and drying of agglomerates of titanium dioxide paste were investigated and the parameters necessary for designing industrial drying machines were established.

Introduction

Over the last decade, the world market has seen a sharp increase in demand for titanium dioxide pigment TiO_2 [1–2]. Due to its properties, titanium dioxide is used in the production of a wide range of goods for different purposes. At the present time quite a few scientific data on the kinetics of drying process of fine paste of titanium dioxide and main parameters of drying. Also, the effect of the degree of grinding of TiO_2 agglomerates on the intensity of the process of drying and drying of the product to a low residual moisture content of 0,3% remains insufficiently studied.

The process of drying paste on titanium dioxide is the most energy-intensive and limiting process in TiO_2 production technology [3], which requires a reduction in the cost of heat energy for drying the paste, increasing the drying rate and improving the quality and ensuring a low residual moisture of the finished product [4]. Therefore, the study of the process of drying paste of titanium dioxide and the development of new high-efficient and energy-saving equipment for obtaining a TiO_2 product with high given mechanical and consumer properties is an urgent task.

The purpose of experimental studies is to determine the effect of milling agglomerates of a TiO_2 paste on the processes of drying and drying the titanium dioxide paste in the vortex fluxes of the heat carrier by increasing the contact surface of the product with the coolant and the agglomeration of the agglomerates of the paste by dry powdered titanium dioxide particles.

Select the type of dispersant

In the technology of TiO_2 pigment production, the process of grinding (dispersing) agglomerates of paste is one of the expensive and energy-intensive processes. The cost of production of titanium dioxide is inversely proportional to the size of the fine particle size of the pigment TiO_2 [5], which according to the requirements of state standards should be not more than 15 microns [6]. In this regard, the effective shredding of the titanium dioxide pigment is the most important operation in the production process. Necessary optical properties of fine particles, and in particular e.g. the ability to disperse light (dispersing ability) e.g. the greater the finer the crushed particles of the dispersed phase. The optimum size of the particle size lies in submicron ranges.

In the drying apparatuses of the boiling layer for drying the TiO_2 paste, the following types of dispersants are most commonly used (Figure 1 [7–8]):

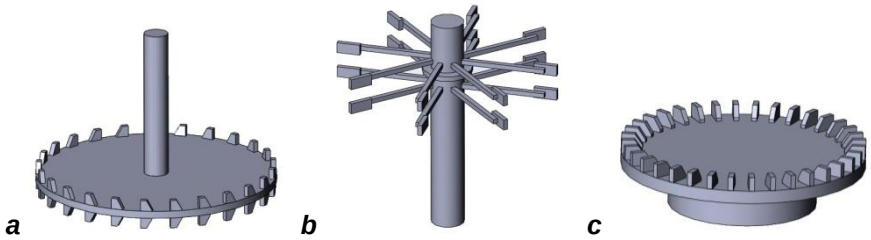


Figure 1. Types of dispersants
a – dissolver; b – knife disperser; c – disk dispersant

The analysis of the designs of the boiling fluid drying apparatuses with the product dispersant [6–9] shows that the most widely used knife dispersers have a number of advantages: prevents sticking the product to the surface of the camera; allows you to work at high speeds; significant speed and degree of shredding.

Therefore, one of the most important aspects for reducing production costs and cost of valuable product, as well as for guaranteeing the necessary decorative and protective properties of the titanium dioxide pigment and coatings on its basis, is the correct selection of dispersing equipment and its efficient work.

Materials and methods

Experimental installation

In order to achieve the set tasks and solve kinetic equations describing the processes of shredding, drying and drying of titanium dioxide paste, a specially designed methodology for carrying out the experiment was used.

Investigation of the processes of grinding, drying and drying of finely divided paste of titanium dioxide in vortex flow of heat carrier was carried out on a pilot drying plant. The composition of the drying unit includes (Figure 2) a drying apparatus of a vortex type equipped with a dispersant for grinding agglomerates of a paste of TiO_2 [Patent of Ukraine No. 108688 of the IPC F26B 17/10 (2006.01)]. Also, the authors of the article developed a method for drying paste-like products, on which the design of a pilot drying apparatus [Patent of Ukraine No. 107089 of the IPC F26B 17/10 (2006.01)].

Measuring complex

The pressure drop in the dispersion zone and the drying zone was continuously measured by two differential pressure sensors D_2 and D_3. The drive power P (Figure 2) of the dispersant was measured by a measuring complex of type K50 №1654, coolant flow rate i.e. difamonometer D_1, the temperature and humidity of the vortex fluxes of the coolant and particles of titanium dioxide by the computerized system when applying moisture and temperature sensors MLX90614 (W/T) with a frequency of 63 measurements per second (63 Hz) connected to the computer through the controller Arduino Pro Mini. Diagram of placement of devices and data transmitters, difemometers and main elements is shown in Figure 2.

Materials

To carry out experimental studies of the processes of grinding and drying the titanium dioxide paste, a thyrotrophic fine titanium dioxide titanium dioxide TiO_2 with an initial moisture content of w = 55% and a density of $\rho = 2173$ kg/m^3 [10] was used which reduced viscosity and increased fluidity under mechanical influence. Thixotropy paste is a very important indicator of the product, due to which it is possible to feed this paste of TiO_2 into a drying chamber at an initial drying rate of 80% using a screw or lobed feeder [11–12], which will not clog.

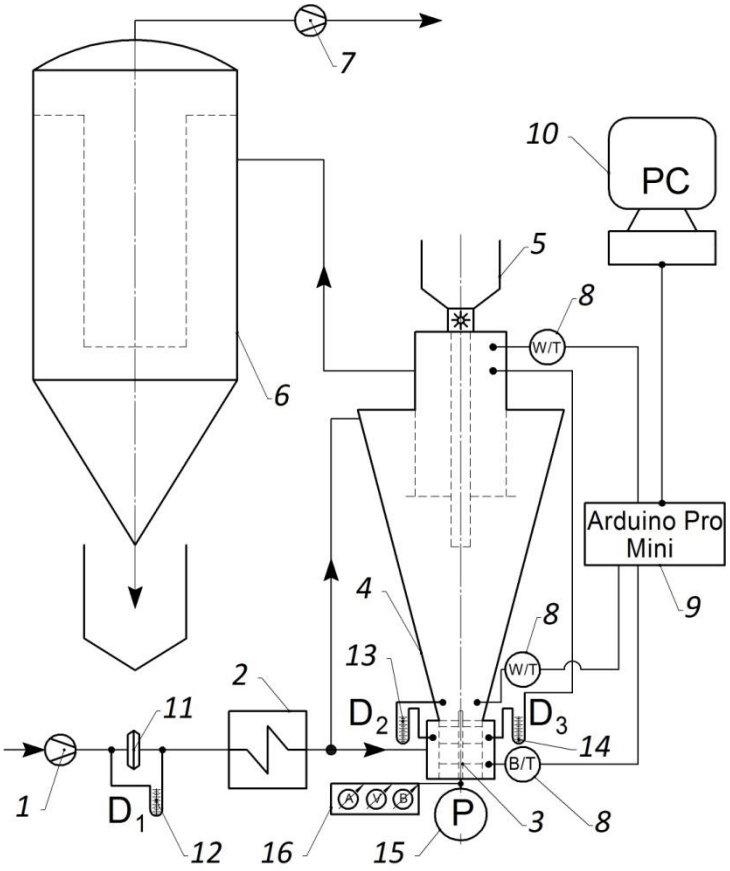
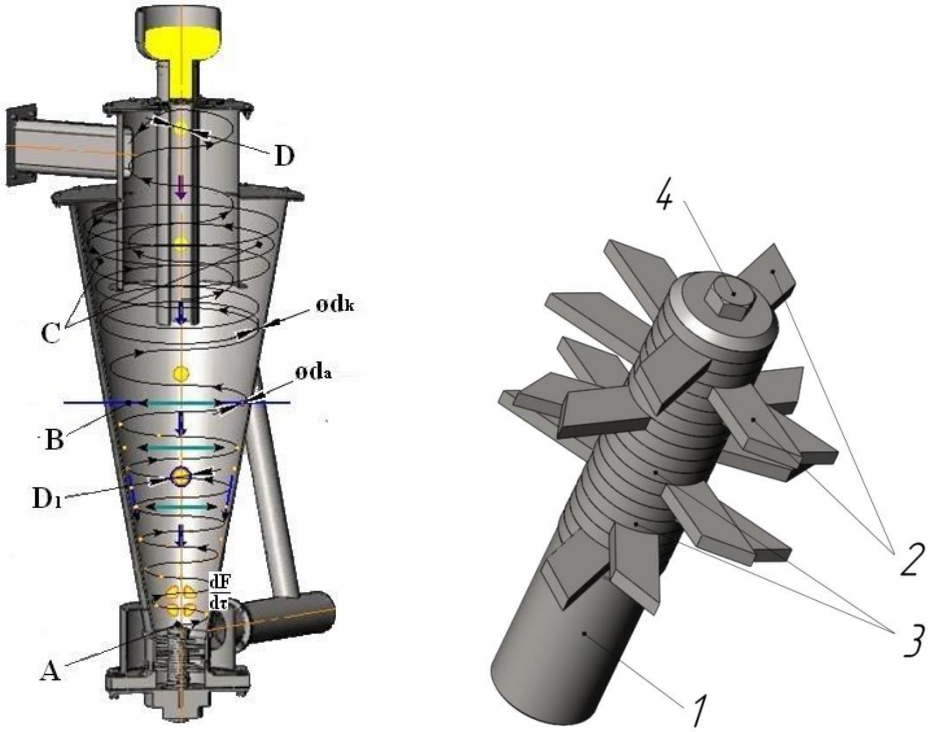


Figure 2. Scheme of a computerized system for measuring the power of a dispersant, fans, temperature and humidity in an experimental drying plant:
1, 7 – booster and exhaust fans; 2 – heater; 3 – dispersant; 4 – drying chamber; 5 – feeder-dispenser; 6 – sleeve filter; 8 – temperature and humidity sensor MLX90614 (W/T); 9 – microcontroller Arduino Pro Mini; 10 – computer for visualization and data storage; 11 – diaphragm; 12, 13, 14 – difemometers; 15 – Electric drive; 16 – measuring complex type K50 №1654

Results and discussion

Physical modeling of the effect of the grinding process of agglomerates of TiO_2 paste on the processes of drying and drying the product in a vortex dryer

Agglomerates of the TiO_2 paste enter the bottom of the drying chamber (Figure 4a) using a feeder feeder on a knife disperser (Figure 4b) rotating at a speed of 2860 1/m. The dispersant continuously shreds the agglomerates of the product and forms a new surface through which the product contacts the coolant.



a ***b***

Figure 4. Diagram of a drying apparatus equipped with a dispersant
a – diagram of the physical model of the processes of grinding and drying paste of TiO_2;
b – knife disperser;
A – dispersion zone; B – separation zone of finely divided TiO_2; C – zone of drying powder TiO_2;
1 – disperser shaft; 2 – knives; 3 – remote washers

Continuous grinding of titanium dioxide in the drying chamber of the device allows significantly increasing the drying speed of the product and reducing the energy consumption of the process.

The physical model includes shredding, drying and drying of the TiO_2 paste includes:

- the supply of a thyrotrophic paste to titanium dioxide in the form of the formed separate clusters of TiO_2 particles, which are interconnected by forces of surface tension in the zone of the vortex layer A;
- contact and powdering the cluster surface with the dried product;
- intensive drying of the surface moisture of the material with simultaneous continuous grinding in zone A with a knife dispersant;
- removal of small particles of product from zone A into separation zone B by a vortex flow of a coolant with reduction of the axial component of speed;
- separation and drying of adsorption-coupled moisture in the zone C of fine particles to low residual moisture content of 0.3%.

Mathematical description of the processes of grinding, drying and drying of finely divided paste of titanium dioxide

Equation of the energy of the drying process [13–15]:

$$dQ = dQ_1 - dQ_2 \quad (1)$$

Writing the components of equation (1), we obtain:

$$G_{a.d.p.} \cdot (c_{a.d.p.} + c_w \cdot U) \cdot \partial t_{part.} = \alpha \cdot \frac{\partial F_{part.}}{\partial \tau} \cdot (t_{c.} - t_{part.}) \cdot \partial \tau - G_{a.d.p.} \cdot \frac{\partial U}{\partial \tau} \cdot r \cdot \partial \tau, \quad (2)$$

where dQ is heat flow to heat paste, kJ; dQ_1 is convective heat flow from the drying agent, kJ; dQ_2 is heat flux on the evaporation of water from the paste of titanium dioxide, kJ; $G_{a.d.p.}$ is flow of a completely dry powder of titanium dioxide, $\frac{kg}{s}$; w is speed of the drying agent (air), $\frac{m}{s}$; l is equivalent diameter of the particle of titanium dioxide paste, m; $\nu_{c.}$ is kinematic viscosity of the coolant, $\frac{m^2}{s}$; $c_{a.d.p.}$ is specific heat of a titanium dioxide powder, $\frac{J}{kg \cdot K}$; c_w is specific heat of water, $\frac{J}{kg \cdot K}$; U is moisture content of titanium dioxide, $\frac{kg_w}{kg_{a.d.p}}$; α is mass transfer coefficient from the coolant to the particle surface, $\frac{W}{m^2 \cdot K}$; $F_{part.}$ is outer surface of the particle, m^2; $t_{c.}$ is temperature of coolant, ℃; $t_{part.}$ is temperature of particles, ℃; $\frac{dU}{d\tau}$ is drying speed, $\frac{1}{s}$; r is specific heat of steam generation, $\frac{J}{kg}$; $d\tau$ is drying time, s.

The drying rate in the first period is limited by the amount of heat flowing from the coolant [9], and in the second period, the rate of desorption of adsorption-bound moisture. The grinding process does not limit the drying process.

On the basis of the equation of thermal energy (2), the basic equation of mass deducing [15–18] and the law of grinding [1], the mathematical description of the drying process can be represented by the following system of equations:

$$\begin{cases} \frac{\partial t_{part.}}{\partial \tau} = \alpha \cdot \frac{\partial F_{part.}}{\partial \tau} \cdot \frac{t_{c.} - t_{part.}}{G_{a.d.p.} \cdot (c_{a.d.p.} + c_w \cdot U)} - \frac{\frac{\partial U}{\partial \tau} \cdot r}{c_{a.d.p.} + c_w \cdot U} \\ \frac{\partial U}{\partial \tau} = \beta \cdot \frac{\partial F_{part.}}{\partial \tau} \cdot \frac{P_S \cdot (1-\varphi)}{P_{atm.}} - D \cdot \sum F_{part.} \cdot \frac{\partial C}{\partial R} \\ \frac{\partial F_{part.}}{\partial \tau} = kz \end{cases}, \quad (3)$$

where β is mass transfer coefficient from the coolant to the particle surface, $\frac{m}{s}$;
P_s is saturated vapor pressure, Pa; φ is relative humidity of the coolant, %;
D is coefficient of molecular diffusion, m/s; k is grinding factor; z is degree of grinding;
∂C is the driving force of the drying process.

Initial conditions for a given system of equations (3):

$$u|_{\tau=0} = u_0, u_2 = u_{1cr,} \tau_0 = 0, t_0 = t_1, d_0 = 1\ mm, \quad (4)$$

$$\alpha = \frac{Nu \cdot \lambda_{c.}}{D} \quad [1],$$

$$Nu = 0{,}021 \cdot Re^{0{,}8} \cdot Pr^{0{,}43} \cdot \left(\frac{Pr}{Pr_{wall}}\right)^{0{,}25} \cdot \varepsilon \quad [19–20].$$

The dependence $\frac{\partial F_{part.}}{\partial \tau}$ describes the process of dispersing the agglomerates of the TiO_2 paste, taking into account the speed of rotation, the length of the cutting edges and the shape of the disperser knives.

Experimental studies of kinetics of TiO_2 drying

Dependence of moisture content of paste on dioxide $U, \frac{kg_{a.d.p.}}{kg_w}$ from drying time τ, s at volume flows of the coolant 50 m^3/h and initial temperatures of the coolant 90–120 ℃, and the initial humidity of the paste TiO_2 54% is presented as a graphical dependence on figure 5.

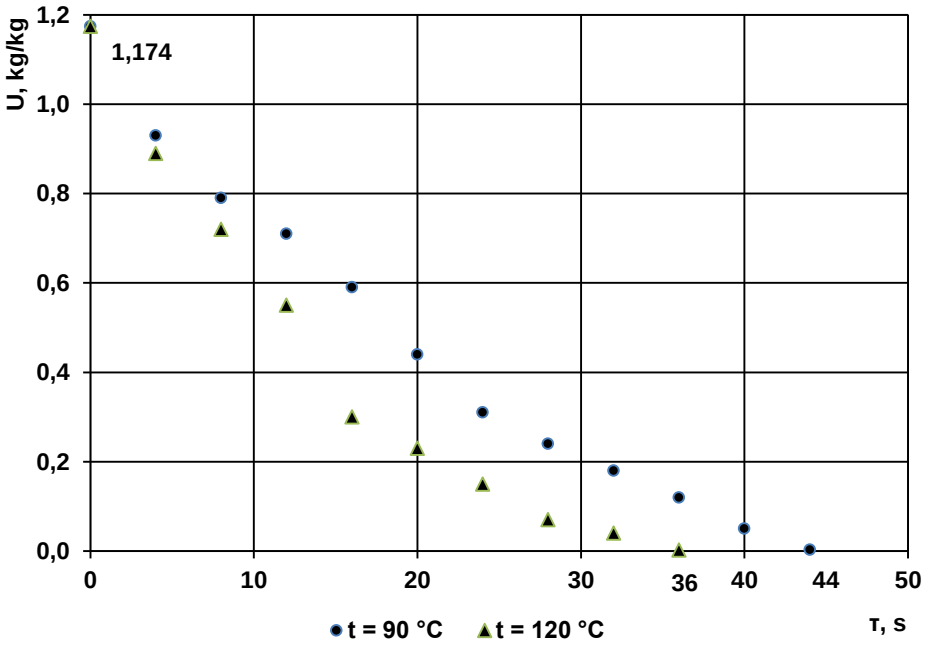


Figure 5. The dependence of the moisture content U of the paste TiO_2 on drying time τ

Figure 5 shows that the same amount of paste of titanium dioxide at an initial temperature of the coolant temperature of 120 ℃ acquires equilibrium moisture content 36 seconds after the start of drying, and at 90 ℃ i.e. after 44 seconds. The graphs clearly show the first and second periods of drying, and the value $U_{1cr} = 0{,}22 \frac{kg_{a.d.p.}}{kg_w}$.

The thermal curves describing the experimental dependence of the temperature of the product on drying time are presented in Figure 6.

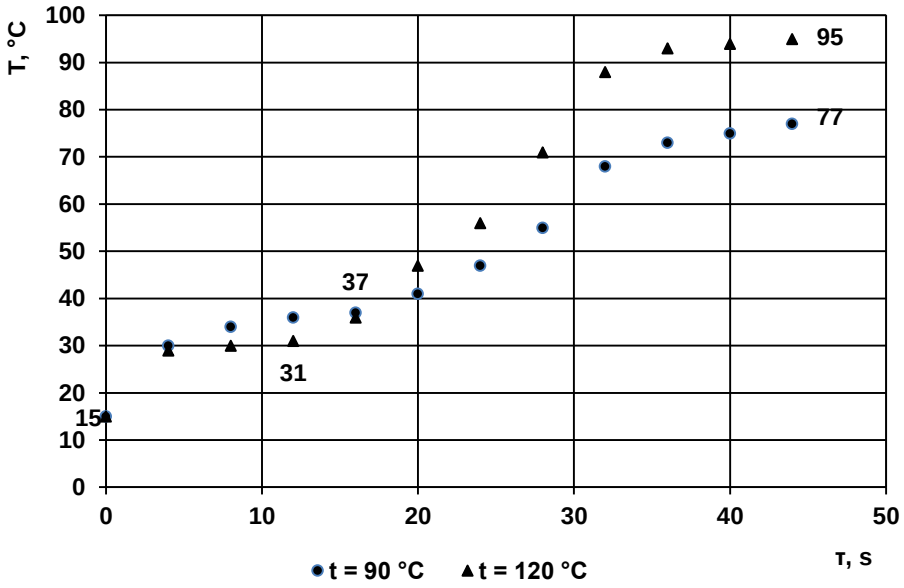


Figure 6. Dependence of temperature t on drying time τ

Figure 6 shows that the temperature of the wet thermometer of the product is 31 ℃ and 37 ℃ at an initial temperature of the coolant 90 ℃ and 120 ℃, respectively. From the graphs a constant temperature (temperature of the wet thermometer) is observed, which corresponds to the area of the first drying period, when the drying rate is constant.

Experimental studies of the process of grinding agglomerates of paste

The grinding process was investigated on a knife disperser (Figure 7). The dependence of the current strength on the time of dispersion is depicted in Figure 7.

The data of current strength was obtained by video recording of ammeter displays, and the time of dispersion was measured by a stopwatch. For grinding, dried in an electric oven at t = 105 ℃, titanium dioxide was used, since the hardness of the dry product would be much greater than the hardness of the wet paste of TiO_2. Three experiments were carried out for samples of dried product 0.3 kg, 0.6 kg and 1 kg. The force of the idle speed of the knife disperser was 3.5 A.

As can be seen from Figure 7, the maximum jump in current on the dispersant drive reached 5.32 A when loaded with 1 kg of product. The grinding fine particles of the product were deposited with a coolant in the unit filter bag.

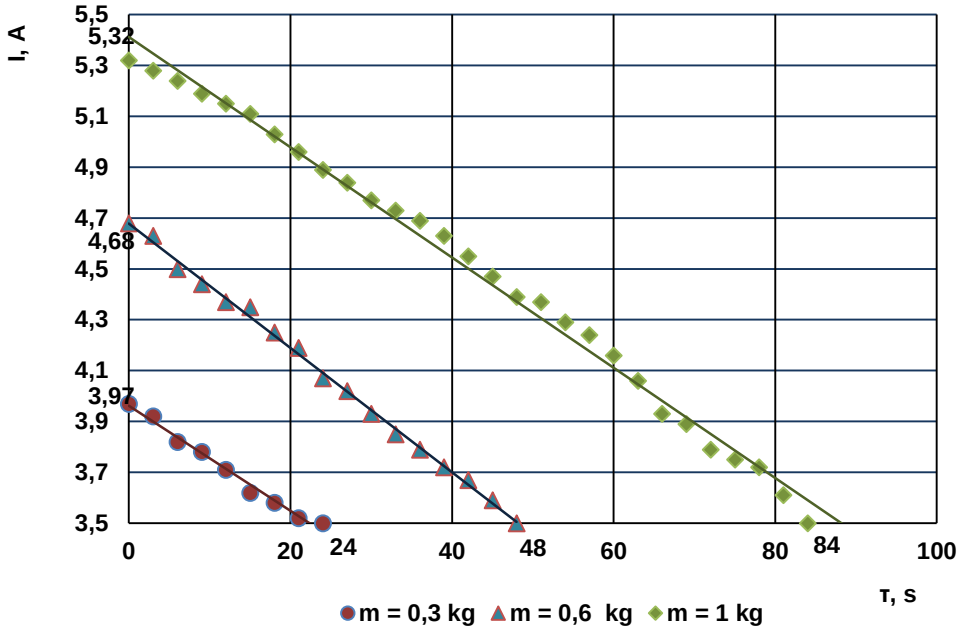


Figure 7. The dependence of the current I of the dispersant on the time of shredding τ

Conclusions

It was found that the grinding process of agglomerates of TiO_2 paste significantly intensifies the process of drying and drying the titanium dioxide product, which in turn increases the drying rate $\frac{\partial U}{\partial \tau}$ by continuously increasing the value $\frac{\partial F_{part.}}{\partial \tau}$.

It was established that the process of grinding agglomerates of paste of TiO_2 significantly intensifies the process of drying and drying the product of titanium dioxide, namely increasing the drying rate, by increase the value $\frac{\partial F_{part.}}{\partial \tau}$. Simultaneous grinding of agglomerates of a product helps to reduce energy costs for further grinding of the product after the drying stage. The initial coolant temperature can be increased to 300 ℃, and volume flow reduced to 30$\frac{m^3}{hour}$. The resulting design of the dryer provides a combination of grinding, drying and drying of fine titanium dioxide paste.

The result of this work is to find ways to increase the drying rate of fine titanium dioxide paste and obtain TiO2 product with high specified mechanical and consumer properties.

References

1. (2014), *Podbor dispergiruyushchego oborudovaniya dlya proizvodstva pigmentirovannyh lakokrasochnyh materialov*, available at: https://www.himtek-yar.ru/useful/lkm_technology/1669/.

2. Marcus R., Leung L., Klinzing G., Rizk F. (1990), *Pneumatic Conveying of Solids: A Theoretical and Practical Approach, 1st Ed*, Powder Technology Series, Great Britain.
3. Pecora A., Goldstein L., Lombardi G., Pagliuso J. (1994), New *particulate solids pneumatic feeding device with mass flowrate control,* Powder Technology, Great Britain.
4. Pugsley T., Milne B., Berruti F. (1996), An innovative non-mechanical solids feeder for high solids mass fluxes in circulating fluidized beds, *Powder Technology Journal*, 2, pp. 123–131.
5. Ferreira M., Freire, J. (1992), Fluid dynamics characterization of a pneumatic bed with a spouted bed type solid feeding system, *The Canadian Journal of Chemical Engineering*, 7, pp. 905–909.
6. Littman H., Morgan M., Paccione J., Jovanovic S., Grbavic Z. (1993), Modeling and measurement of the effective drag coefficient in decelerating and non-accelerating turbulent gas-solids dilute phase flow of large particles in a vertical transport pipe, *Powder Technology Journal*, 5, pp. 267–283.
7. Grobovenko Y., Marchevskii V. (2018), Kinetics of drying the titanium dioxide paste in the vortex dryer, Ukrainian Food Journal, 7(2), pp. 311–323.
8. Costa I., Ferreira M., Freire, J. (2004), Analysis of regime transitions and flow instabilities in vertical conveying if coarse particles using different solids feeding systems, *The Canadian Journal of Chemical Engineering*, 3, pp. 48–59.
9. Markowski A. (1992), Drying Characteristics in a Jet spouted Bed Dryer, *Can. J. Chem. Eng.*, 5, pp. 156–163.
10. Barret N., Fane A. (1990), Drying Liquid Materials in a Spouted Bed, *New York Hemisphere Publ,* 8, pp. 278–286.
11. Jong J., Hoffmann A., Finkers H. (1999), Properly Determine Powder Flowability to Maximize Plant Output, *Chem. Eng. Prog.*, 4, pp. 135–142.
12. Grobovenko Y., Marchevskii V. (2017), Modeliuvannia protsesu sushinnia dribnodyspersnykh chastynok TiO_2 v pototsi sushylnoho ahentu, *Visnyk Natsionalnoho tekhnichnoho universytetu Ukrainy "KPI", Khimichna inzheneriia ekolohiia ta resursozberezhennia*, 1, pp. 78–81.
13. Grobovenko Y., Marchevskii V. (2018), Aerodynamika vykhrovykh potokiv sushylnoho ahentu u sushylnii kameri. *Visnyk Zhytomyrskoho derzhavnoho tekhnolohichnoho universytetu, seriia "Tekhnichni nauky"*, (1), pp. 22–25.
14. Grobovenko Y., Marchevskii V. (2016), Protses sushinnia pasty dioksydu tytanu u vykhrovomu sushylnomu aparati, *Naukovyi zhurnal "Smart and young"*, 11–12, pp. 55–58.
15. Dmitriev V. (2013), Konvektivnaya sushka polidispersnykh materialov v apparatakh zakruchennogo vzveshennogo sloya, *Vestnik Tambovskogo gosudarstvennogo tekhnicheskogo universiteta*, 3, pp. 602–606.
16. Adamiec J. (2002), Drying of waste sludges in a fluidized bed dryer with a mixer, *Drying Technology*, 20, p. 839.
17. Bait R., Pawar S., Banerjee A., Mujumdar A., Thorat B. (2011), Mechanically agitated fluidized bed drying of cohesive particles at low air velocity, *Drying Technology*, 29, p. 808.
18. Puspasari I., Talib M., Daud W., Tasirin S. (2012), Drying kinetics of palm oil frond particles in an agitated fluidized bed dryer, *Drying Technology*, 30, p. 619.
19. Chongdian S., Wu J., Wang Y., Zhang Y., Shang X. (2015), Drying of low rank coals: A review of fluidized bed technologies, *Drying Technology*, 33, p. 277.
20. Kim J., Han G. (2006), Effect of agitation on fluidization characteristics of fine particles in a fluidized bed, *Powder Technology*, 166, p. 113.

Comparative analysis of equipment and research the superfine grinding process of titanium dioxide and quinacridone red suspensions in the bead mill

Kateryna Hrininh, Ruslan Hordeichuk, Oleksii Gubenia

National University of Food Technologies, Kyiv, Ukraine

Keywords:

Grinding
Beads
Mill
Pharmacy
Cosmetics
Suspension

Article history:

Received 25.01.2018
Received in revised form 27.05.2018
Accepted 29.06.2018

Corresponding author:

Kateryna Hrininh
E-mail: neackriss@gmail.com

DOI:
10.24263/2310-1008-2018-6-1-11

Abstract

Introduction. Analytical and experimental research was conducted to improve the process and equipment for the superfine grinding of medicinal and cosmetic preparations.

Materials and methods. On the basis of modern scientific literature and own experience was given a comparative analysis of modern equipment for ultra-fine grinding. In the investigation are used suspensions of titanium dioxide and quinacridone red 122 with the vaseline oil.

Results and discussion. Among the recommended installations, the most versatile, productive, compact, energy saving, with high degree for grinding (up to 1 microns), effective in the process of dispersion and homogenization, have a simple constructive solution are bead mills.

When grinding titanium dioxide over a period of 0 to 30 minutes, the power increases from 205 to 209 W. The temperature of the suspension is from 21.9 to 23.4 °C, the density increases from 889 to 1176 kg/m^3, and the particle size decreases from more than 100 μm to 10 μm. The most intensive grinding in the first 5 minutes of the process. When the quinacridone red 122 is grinded, the power is increased from 205 to 210 W, the temperature of the suspension is from 22.4 to 24.3 °C, the density increases from 870 to 952 kg/m3, and the particle size decreases from more than 60 μm to 2 μm, while the most intensive grinding occurs in the first 5 minutes of the process.

Conclusions. Among the recommended installations, the most optimal and productive are bead mills. It is recommended to carry out the grinding process on the bead mills periodically with the circulation of the suspension with the obligatory cooling.

Introduction

In the modern production of pharmaceuticals and cosmetics, a high degree of grinding of the raw material for further use is of great importance. When the technological process of the produce of the soft dosage forms is implemented, it is necessary to distribute and grind fine dispersed solids in a liquid medium, because during storage and transport of the starting material, the particles stick together forming the conglomerates, and the powder particles have an irregular shape and a non-uniform particle size distribution [12] and such raw materials can`t give the product the necessary efficiency and quality. Therefore, the obligatory stage in the production of ointments, liniments, gels and pastes is dispersing [2]. This task perfectly solve the bead mills, which are used for grinding a wide range of different products, including pharmaceutical and cosmetic industries.

Exposition

Comparative analysis of existing equipment for superfine grinding

For today, there are such type of machines for superfine grinding: bead mills, three-roller mills, colloid mills, jet mills, vibrating mills, planetary mills.

Three-roll mills. Rolls that are rotated toward at different speeds ensure the product moves from a roll to a roll and increases friction between them. Rolls are made of porcelain, basalt or metal [3]. To maintain the optimum temperature of the product rolls are make hollow for serving the coolant inside. Degree of material grinding is to 3 μm (index taken from industrial working equipment). In the cosmetic industry it is used for grinding of the pigmentary pastes, creams. In the pharmaceutical industry – for the production of the ointments, liniments, gels, pastes [3, 13].

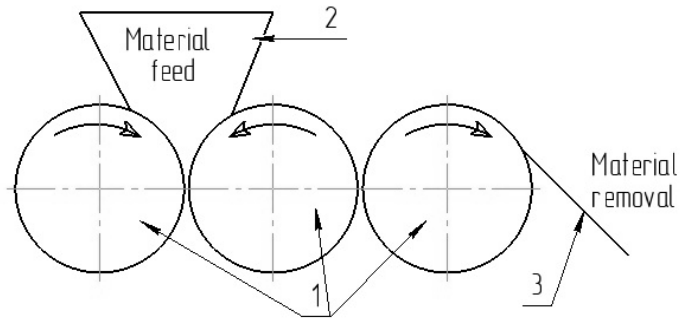


Figure 2. Three-roll mill:
1-rolls; 2 – bunker; 3 – shooting knife

Advantages: magnet-based safety devices; possibility of embedding into an industrial continuous production line; suitable for the processing of very common materials that are prone to sticking or containing sticky inclusions; compactness.

Disadvantages: not intended for grinding dry ingredients; intensive and uneven wear of working surfaces of rolls and a knife; relatively low specific productivity; the probability of bias shaft due to uneven tightening springs; when the maximum fineness is reached, the productivity decreases [13].

Bead mill. The bead mill consists of two parts: a grinding chamber, in which the beads are loaded together with the components of the mixture, and the rotor, which rotates the entire system. The grinding process proceeds between the individual bead particles which are in contact with each other, as well as between the beads and the rotor or the walls of the container. The size of the crushed product can reach less than 1 microns. In the cosmetic industry they are used for grinding of the pigmentary pastes, creams. In the pharmaceutical industry – for the production of the ointments, pastes, gels, liniments [10, 11, 13].

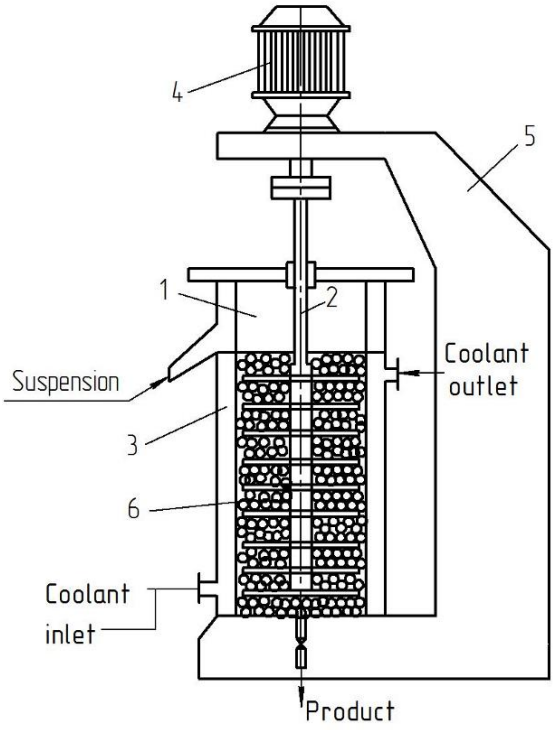


Figure 1. Bead mill:
1 – cylinder, 2 – disk rotor, 3 – shirt, 4 – engine, 5 – bedplate, 6 – beads.

Advantages: easy maintenance; reliability and safety of work; versatility; high performance; invariably quality of grinding; simplicity of construction; possibility of embedding into an industrial continuous production line; effective in the process of dispersing, homogenizing and grinding simultaneously.

Disadvantages: great power consumption; a small coefficient of useful action – 15%; not economical consumption of water and detergent to prepare the equipment for work; burning and "burning out" of the suspension in case of insufficient cooling. [9, 10, 13].

Vibration mills. The grinding is carried out using a special vibrating device, which is on the same axis with the electric motor, the ball drum vibrates. The balls are made from a porcelain, hard alloys or steel. The drum is full with balls for 80-90%. The size of the crushed product is 1-5 microns. They are used for fine-grained crushing of materials of low strength [6, 10].

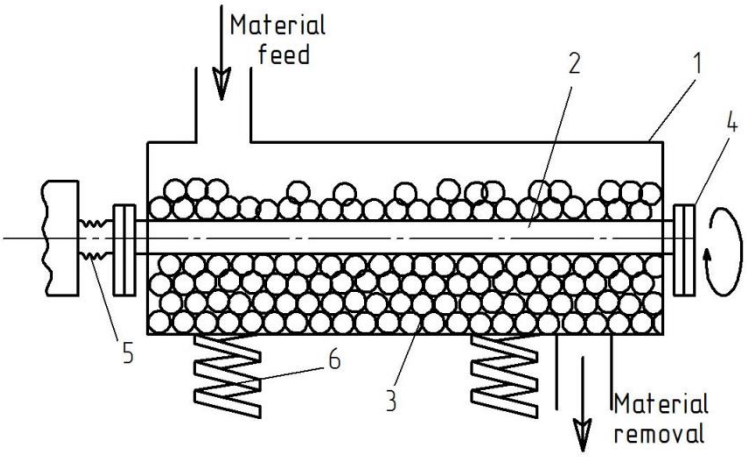


Figure 3. Vibration mill:
1 – housing, 2- vibrator, 3 – milling balls, 4 – out of balance weight,
5 – flexible coupling to drive motor, 6 – spring mounting.

Advantages: high dispersion and homogeneity of the particle size of the product are achieved very quickly.

Disadvantages: not suitable for grinding powders sticky and viscous pastes and thermolabile materials; low productivity (up to 1 t/h); rapid wear of grinding bodies; hard working conditions [6, 10].

Colloidal mills. A lot of designs of the mills are offered. For preventing the adhesion of particles, the milling is done in the presence of a dispersing medium. The size of the crushed product is less than 0.4 microns. In the pharmaceutical industry they are used for the produce of liniments, ointments, pastes. In the chemical industry – for the crushing of some mineral pigment [12].

Advantages: effective emulsification and dispersion process.

Disadvantages: high wear of working elements; little knowledge of the process [13].

Jet mills. An energy source (a compressed gas or a steam) at expansion in the nozzles acquires a high speed, which sometimes reaches several hundred meters per second. The material particles are crushed as a result of a collision between themselves when streams jets intersect, as well as strokes and abrasion on the wall of the chamber [6, 11]. The size of the crushed product is 2-5 microns. In the pharmaceutical industry are used to obtain superfine powders from expensive components [12, 13]

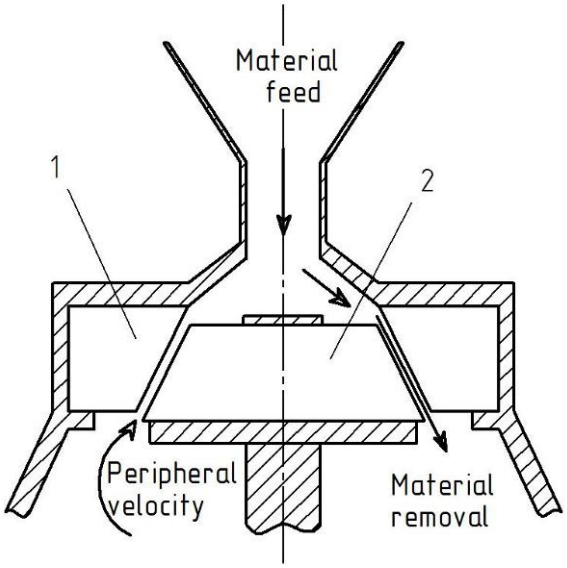


Figure 4. Colloidal mill:
1- stator, 2 – rotor.

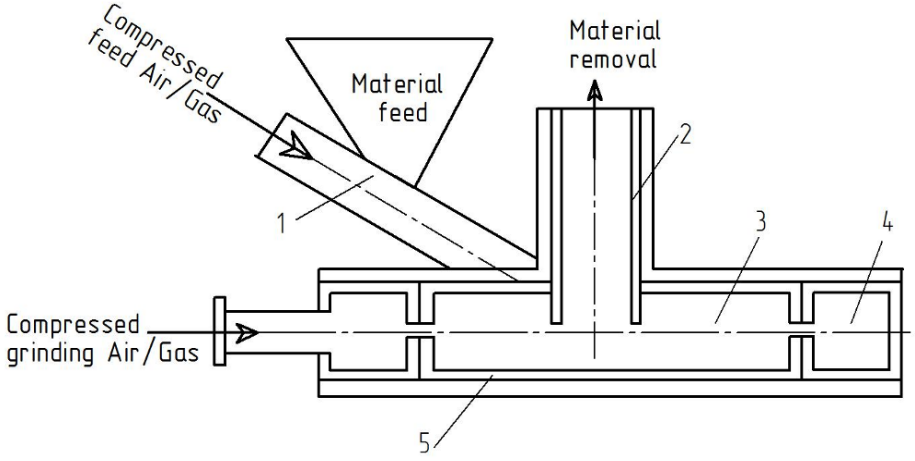


Figure 5. Jet mill:
1 – Venturi eductor, 2 – vortex finder, 3 – grinding chamber,
4 – grinding Air/Gas manifold, 5 – replaceable liners.

Advantages of the jet mill: the grinding elements of the mill practically do not wear out, and therefore don`t add impurities to the finished product; longevity of equipment; provides high purity powders with a predominantly oval form of particles; the material in the process of grinding doesn't change its initial temperature, which allows processing of thermolabile; minimal product loss.

Disadvantages of the jet mill: high energy consumption resulting in high energy consumption of the process; necessary to uniform supply of material and maintenance of constant aerodynamic mode of operation; necessary provision of additional equipment (air separator); danger of work [6, 12]

Planetary mills. The principle of the work is to rotate 3–4 drum around to the central axis and around its own axis in the opposite direction of rotation of the rotor (central axis) of the mill. The size of the crushed product is less than 4–6 microns. Used mainly in laboratories for scientific research, as well as in industries where small amounts of fine powders are required [1, 12].

Advantages: high specific productivity.

Disadvantages: high wear of working elements; difficulty with continuous loading and unloading of material [1, 4, 12].

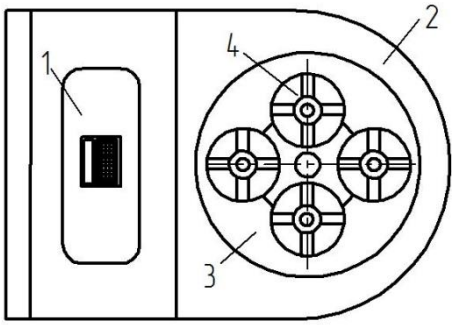


Figure 5. Planetary mill:
1 – control panel, 2 – safety switch, 3 – planetary disk, 4 – ball mill jar.

Among the recommended mills, the most versatile, compact, energy saving, capacity, with the possibility of embedding to an industrial continuous production line, with high grinding rates (up to 1 μm), effective in the process of dispersion and homogenization, have a simple constructive solution, are bead mills. Despite its disadvantages, the bead mill is one of the most popular mill using in the cosmetic industry to grind pigment pastes and creams, and in the pharmaceutical industry – for the production of ointments, gels, pastes, liniments.

Materials and method

Materials

The following materials were used for the research: Vaseline oil perliquidum pharmaceutical, white pigment titanium dioxide (food additive E171) pharmaceutical, pigment quinacridone red Red 122.

Vaseline oil perliquidum pharmaceutical – mineral oil, a mixture of liquid hydrocarbons of petroleum distillate. The quality of Vaseline oil is characterized by its color. It is determined by the Saybolt scale. The dark one is "- 16", the light one is 30 [5,6].

Vaseline oil in pharmaceutics is used as a basis for creating multi-component ointments and creams, injectable suspensions, as a solvent for some medicines, and as a separate medicinal product. In the cosmetic industry, oil is used as a base for the preparation of a wide range of creams, but only if it has been multistage cleaned and completely cleared of foreign smell and impurities. Also, it is used in the production of decorative cosmetics [5,6].

Appearance: colorless, clear, oily liquid. Virtually insoluble in water, slightly soluble in ethanol 96%, mixed with carbohydrates. Color (Saybolt) – +30. The kinematic viscosity at 40 °C is 11–15 CST. Dynamic viscosity at 20 °C is 33–45 MPa·s. The relative density at 20 °C is 818–880 kg/m^3 [5, 6].

Titanium dioxide (titanium white, E171) is a white pigment. In the pharmaceutical industry, titanium dioxide is used for high chemical cleanliness to provide a high whitening and crusting effect. It is used for cosmetic products for giving white color and light tightness. In addition, it is used for the preparation of concentrated pigment pastes for various types of lipsticks, lip glosses, nail polishes, powders, tonal creams and other decorative products [5, 6].

Appearance: powder from white to slightly colored. The residue on the sieve with a mesh of 45 μm is 0.08%. Bulk density of 82 kg/m^3; Specific density 4 000 kg/m^3. Insoluble in water and organic solvents [5, 6].

Quinacridone red Red 122. Universal dry pigment, which has a stable purple hue among the violet-red pigments. It also has an increased stability of flocculation, good flowability. Used in the cosmetic industry for the preparation of concentrated pigment pastes for various types of lipsticks, lip glosses, nail polish [5, 6].

Appearance: powder of bright red color with a blue hue. Specific density is 1460 kg/m^3; bulk density 540 kg/m^3; The residue on the sieve with a mesh of 320 μm is 23,4%; the average particle size is 0,09 μm; specific surface area of 59 m^2/g. Resistant to acids, alkalis, water, organic solvents [5,6].

Methods

Expiremental instalations were used:

Bead laboratory mill. Equipped with three capasity (glasses) with a shirt for water cooling and a sampler on the lid of a glass with a sieve cartridge. The rotor consists of a shaft on which 4 guide discs with 4 symmetrically located holes with a diameter of 1 cm are fixed. The working members are a glass bead that has a diameter of 2 mm. The motor operates at 380 V with a current of 1.0 A with a rotor speed of 1350 rpm [7, 13, 14].

Pyrometer is a non-contact digital thermometer. Infrared principle of action. The temperature range is from -50 °C to + 330 °C (from -58 °F to 626 °F). The accuracy is ±1.5% [9, 12].

Grindometer "Klin" is intended for the analysis of the particle size and agglomerates in determining the degree of grinding when testing pigmented suspension materials in different measuring ranges. The measuring range is from 0 to 100 μm. The scale division is 10 μm. The limit of the permissible absolute error is ±10 μm. Dimensions: measuring plate – 175×35×20; the scraper is 60×40×6 mm [9, 12].

The current clamps is a model of a multimeter with clamps, which opens up to a width of 5 cm. Clamps work on the principle of electromagnetic induction.

With it, you can measure AC and DC voltage, resistance, temperature, test diodes, ring connections, measure frequency. Equipped with a liquid crystal display with a resolution of 3½, which displays the results of all measurements [9, 14].

The scheme of the experimental setup is shown in Figure1 [7, 8, 14].

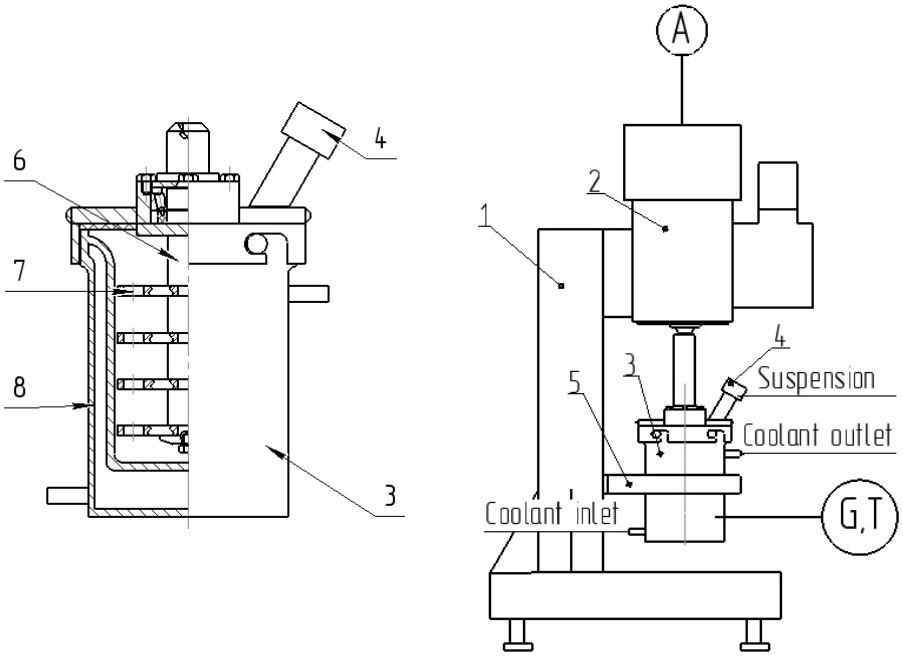


Figure 6. The scheme of the experimental instalation:
1 – bedplate; 2 – motor; 3 – glass; 4 – sampler; 5 – clamp.

The preparation of the samples was as follows: in three clean glasses with a volume of 250 ml hung pigments and Vaseline oil according to the following recipe [9, 12]:

Composition A: Vaseline oil – 250 g;

Composition B: titanium dioxide 50 g, Vaseline oil 200 g;

Composition C: Red 122 – 30 g, Vaseline oil – 200 g.

There were weighed on an analytical scale with a precision of 0.01 g. The compositions B and B were mixed on a agitator.

Composition A was tested for temperature only. Compositions B and C were tested for the temperature of the suspension by means of a pyrometer, the particle size with a "Klin" grindometer.

After testing, the compositions took turns taking part in the experiment [9, 12].

The bead mill operated in a batch mode with cooling, after each experiment the installation was washed. The samples were analyzed and the instruments readings were taken every 5 minutes for 30 minutes. The obtained samples were analyzed for the degree of grinding by a grindometer, the pyrometer measured the temperature of the suspension, and the amperage at three phases was measured with a current clamps [2, 13].

Results and discussion

The results of the research are shown in the graphs below (Figures 7–11).

Consequently, with increasing grinding time for both components, power, temperature and density increase. The greatest growth is observed in the site from 0 to 15 minutes.

When grinding titanium dioxide over a period of time from 0 to 30 minutes, power increases from 205 to 209 W (Figure 7), that is, from 20.5 to 33.2 W (Figure 8) is consumed relatively the power that is consumed to drive the grinding bodies (beads). At the beginning of the experiment, the particle size and agglomerate were at an average of 100 μm, and at the end of the experiment, 10 μm (Figure 9). The most intense reduction in the size of the particles occurred in the first 5 minutes of the experiment (the particles were grinding from 100 μm to 50 μm). During the process, the temperature rises to an average of 21.9 ºC to 23.4 ºC for 30 minutes of the experiment (Figure 10). The greatest increase in temperature occurred in the interval from 15 to 20 minutes, where the temperature increase from 22.3 to 22.8 ºC, and also where the suspension particles were grinded from 25 to 20 μm. This can be explained by the fact that the suspension has the highest density after grinding – 1176 kg/m^3 (Figure 11), as well as the largest size of agglomerates at the beginning of the experiment (more than 100 μm) [5, 6, 8].

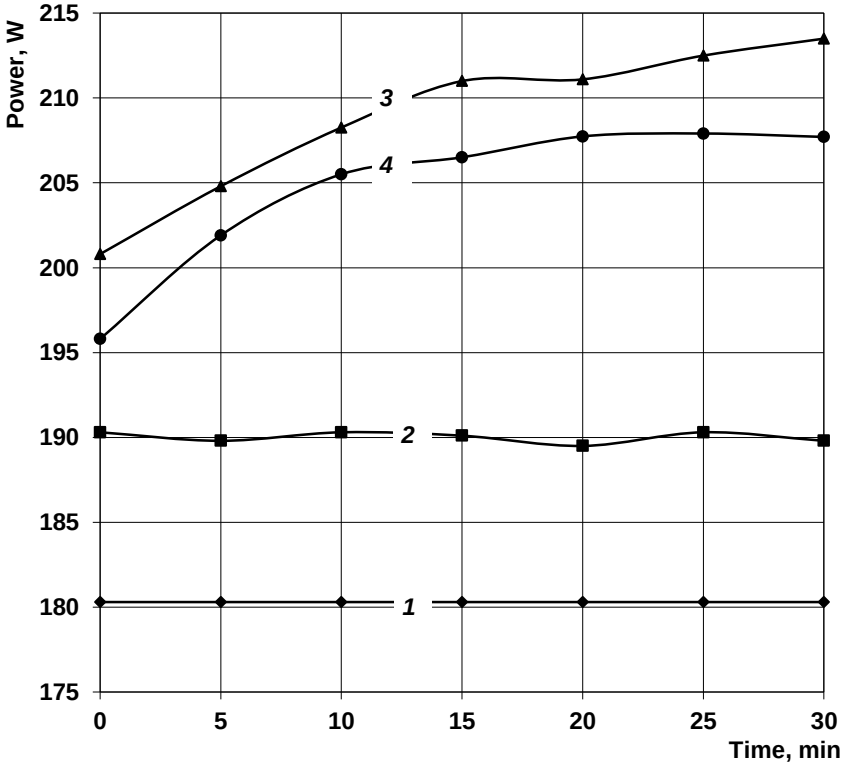


Figure 7. Effect of grinding time in power:
1 – Without glass; 2 – Vaseline oil; 3 – Titanium dioxide; 4 – Red 122

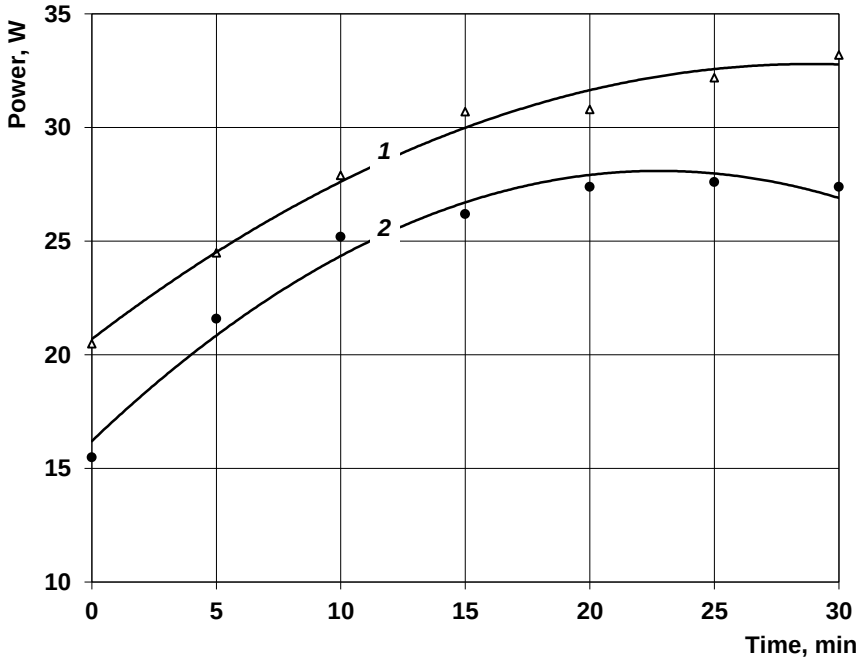


Figure 8. Total amount of power for mixing and grinding:
1 – Titanium dioxide; 2 – Red 122

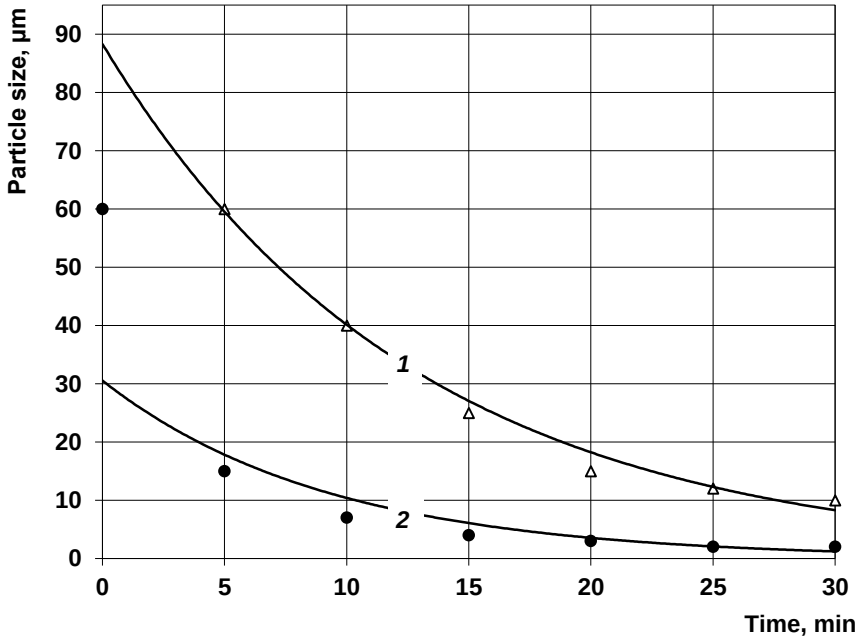


Figure 9. Change in particle size, µm:
1 – Titanium dioxide; 2 – Red 122

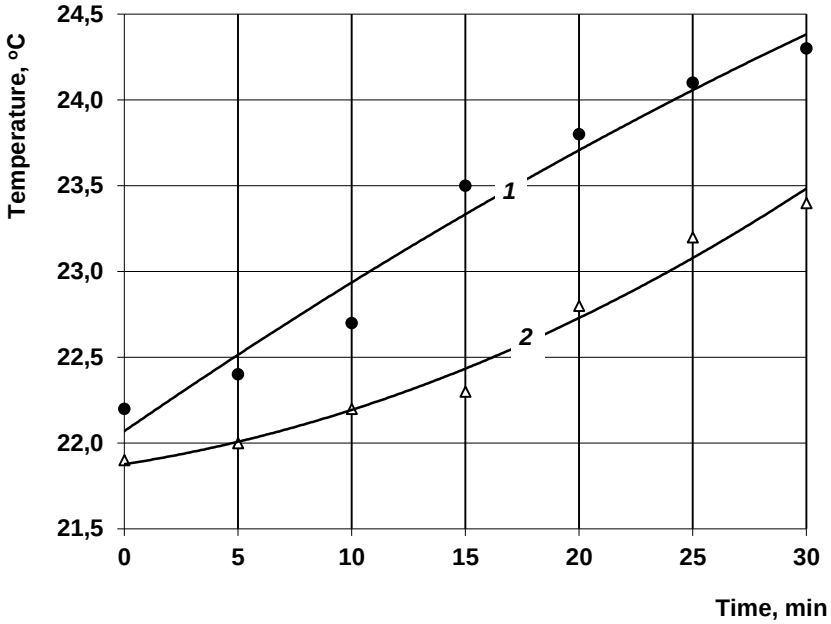


Figure10. Change in temperature of the suspension, °C:
1 – Titanium dioxide; 2 – Red 122

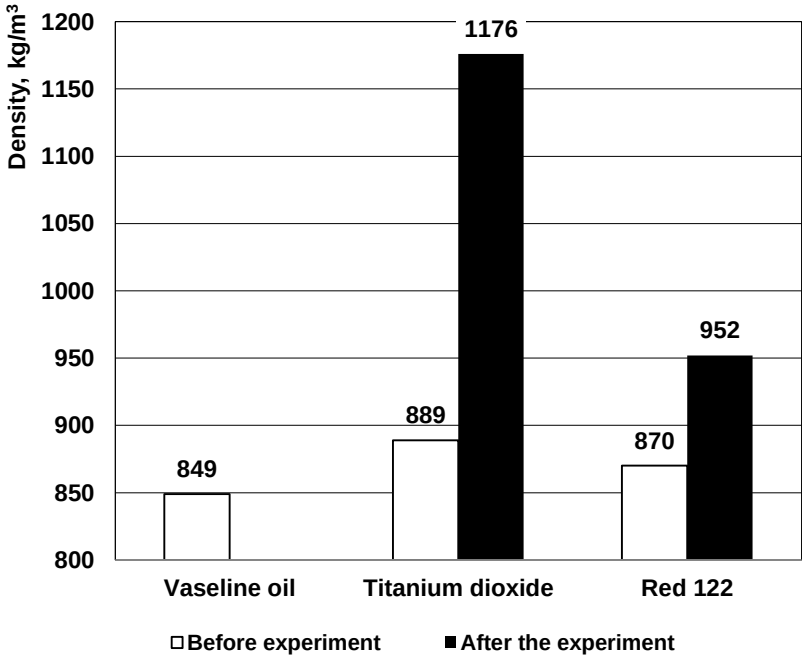


Figure 11. Change in suspension density, kg/m^3

When grinding a suspension of quinacridone red Red 122 over a period of time from 0 to 30 minutes, power increases from 195.8 to 207.9 W (Figure 7), that is, from 15.5 to 27.6 W (Figure 8) is consumed relatively the power that is consumed to drive the grinding bodies (beads). The particle size was 60 μm on average and 2 μm at the end of the experiment (Figure 9). At the end of the experiment, there was almost no grinding (from 4 to 2 μm in 15 minutes). The temperature increased on average from 22.2 ºC to 24.3 ºC, which is much higher than the data when grinding a suspension of titanium dioxide (Figure 10). The highest temperature increase occurred over a period of 10 to 15 minutes, when the temperature increase from 22.7 to 23.5 ºC, where the size of the suspension particles decreased from 7 to 4 μm. This can be explained by the fact that Red 122 has a greater bulk density (540 kg/m^3) than titanium dioxide (82 kg/m^3) and crystal lattice strength due to a different chemical formula, which may also be due to the density of the suspension [5,6,8].

During the experiment, the density of the suspension changed (Figure 11). Thus, the average density of Vaseline oil (according to the manufacturer) is 849 kg/m^3. The density of the titanium dioxide suspension to the experiment is an average of 889 kg/m^3, and the density of the quinacridone red Red 122 before the experiment was an average of 870 kg/m^3 (Figure 11). After the experiment, the density of the titanium dioxide suspension amounted to 1176 kg/m^3, and the average density of the suspension of quinacridone red was 952 kg/m^3. The density of the titanium dioxide suspension increased during the experiment by 287 kg/m^3, and the quinacridone red – 82 kg/m^3 (Figure 11) [5, 6, 8].

For the job of a bead mill with Vaseline oil, which is used in this case as a lubricant to avoid wear of the plant, it consumes from 188.9 to 190.3 W.

Conclusion

Consequently, with increasing time of grinding, both suspensions increase power, temperature, and density and decrease the size of particles. Basically, the most intense changes occur during the first 15–20 minutes of the experiment, where there is an intense reduction of particles of solid material.

This is due to the fact that initially in the suspension are not only individual particles of solids, but also agglomerates that are grinding quite easily. When the size of the particles of the material decreases, the strength of the particles increases, so the more power is consumed and therefore more energy is consumed to overcome the forces of mutual adhesion of solid particles with external forces. In addition, reducing the size of the particles leads to the dissipation of energy in the form of heat and goes to the movement of particles inside the body, without causing its destruction. Also, the smaller the size of the particles that can be achieved, the larger the area of the newly formed surface and, accordingly, increasing the density of the suspension. Accordingly, the amount of energy that needs to be applied before grinding the solids suspension and stirring the suspension increases, and energy dissipation in the form of heat increases [4].

In results, the smaller the particle size and the higher density of the suspension that needs to be ground, the more energy is needed to conduct the process and the more heat will be released.

Acknowledgements. *The authors would like thanks the perfumery and cosmetics firm "Astra Cosmetic" (Kyiv, Ukraine) for its practice help and transmitted experience.*

References

1. Chen Y., Lian X., Zheng S. (2015), Research on superfine grinding process and kinetics of calcined black talc in planetary mill, *Procedia Ingineering*, 102, pp. 379–387.
2. Drögemeier R., Leschonski K. (1994), *Comminution*, Elsevier.
3. EXAKT Technologies, Inc., Available at: https://www.exakt.de/de/startseite.html.
4. Hrininh K., Gubenia, O., Dimitrov TS. (2018), Osobennosti sverkhtonkogo izmel'cheniya mokrym sposobom v bisernykh mel'nitsakh, *16 International Scientific and Technical Conference «Science for education, production, economics», January 25–27, 2018*, Best Sprint, Minsk, pp. 303–307.
5. Loh Z.H., Samanta A. K., Heng P.W.S. (2015), Overview of milling technigues for improving the solubility of poorly water-soluble drugs, *Asian Journal of Pharmaceutical Science*, 10, pp. 255–274.
6. Kanda Y., Kotake N. (2007), *Handbook of Powder Technology*. Elsevier.
7. Mende S., Rappl M. (2014), Mill performance matched to the task. Throughput enhanced by optimising cooling and disc configuration, *European Coatings Journal*, 12, pp. 88–91.
8. Mende S., Stenger F., Peukert W., Schwedes J. (2013), Mechanical production and stabilization of submicron particles in stirred media mills, *Powder technology*, 132, pp. 64–73.
9. Nakach M., Authelin J., Agut C. (2017), New Approach and Practical Modelling of Bead Milling Process for the Manufacturing of Nanocrystalline Suspensions, *Journal of Pharmaceutical Sciences*, 106(7), pp. 1889–1904.
10. Ohnishi O., Suzuki H., Uhlmann E., Schröer N. (2015), *Handbook of Ceramics Grinding and Polishing*, William Andrew Applied Science Publishers.
11. Postma P.R., Suarez-Garcia E., Safi C., Yonathan K., Oliveiri G., Barbosa M.J., Wijffels R.H., Eppink M.H.M. (2017), Energy efficient bead milling of microalgae: Effect of bead size on disintegration and release of proteins and carbohydrates, *Bioresource Technology*, 224, pp. 670–679.
12. Rowe W.B. (2014), *Principles of Modern Grinding Technology*, William Andrew Applied Science Publisher.
13. Salenko YU. (2008), *Obladnannya dlya podribnennya materialiv: drobarki ta mlini*. Kremenchuk: KDPU.
14. Stephen Miranda (2011), Using an agitator bead mill for nanoparticle dispersion and comminution, *Nanotechnology*, 11.

Determination of energy losses on switchgears of pneumatic transport of meat products

Sergei Beseda, Igor Litovchenko

National University of Food Technologies, Kyiv, Ukraine

Keywords:

Meat
Pneumatic
Transporting
Pressure
Energy

Article history:

Received 24.11.2018
Received in revised form 11.02.2018
Accepted 29.06.2018

Corresponding author:

Igor Litovchenko
E-mail: postman300000@gmail.com

DOI:
10.24263/2310-1008-2018-6-1-12

Abstract

Introduction. Researches of various variants of connection of pipelines for transportation of food intermediate products are carried out. The purpose of the study is to determine energy losses depending on the geometric parameters of the connection.

Materials and methods. Computer simulation was used as a research tool. The software CAE complex FlowVision uses the finite element method to predict the movement of viscous liquids in the case of a drop in air pressure at the entrance and exit from the geometric model.

Results and Discussion. The combination of structures allows to determine their resistance to the motion of the product to select the optimal branching method, as well as to obtain a comparative characteristic of the local resistance, depending on the angle of rotation. In our case, the angles of rotation are significant: option 2 – 45°, option 1 – 30°, option 4 – 22,5°, option 3 – 15°. At another position of the valve, when the movement of the product is straightforward, energy losses practically do not occur.

The novelty of the used method of computer modeling for this work is to determine the values of the dissipation of the kinetic energy of the moving product. In the course of research, the method of visualization – "isolines" – was used, which allows a clear definition of the limits of gradation of values. When calculating the area occupying one or another range of values of isolines of energy dissipation, it is possible to compare the intensity of energy losses if they are attributed to the total area of branching. If you evaluate the area that is limited by isolines of a certain intensity of the factor, you can obtain an integral characteristic of the action of dynamic parameters. Significant areas, which are limited by large values of dissipation, show the origin of turbulence, which is the main source of loss of transporting pressure. The mathematical processing of each curve gives the best description of the behavior of graphs when using polynomials of the third degree.

Conclusions. When designing the piping laying options, you can combine straight sections, pipe turns, switches in such a way as to minimize pressure loss. That is, it is expedient to use symmetrical branching variants and minor turns of pipes even in simple areas (depending on their length).

Introduction

The means of pneumatic transportation of raw materials, intermediate products and waste products at meat processing plants are a complex three-dimensional branched system. It includes sets of refueling tanks, pipelines of different diameters and lengths, branching with switches [2, 7].

In the case of the design [7] of a general system of pneumatic transport within the workshop or the whole enterprise, there are a number of options for constructive solutions for laying pipelines and connecting them to the general communications system [1, 5]. By combining different variants of pipelines, branches (dampers) it is possible to determine the optimal variants of their gaskets for different production situations [8, 9, 11]. The criterion of optimality (target function) is the lowest energy consumption (compressed air) to provide the desired performance of the transport system [18, 19].

The purpose of this scientific study is to determine the effect of the design of various variants of branching pipelines that occur in production, on energy losses when passing through them a moving product.

Materials and methods

Materials. Table 1 shows variants of branches, which differ in structure – symmetric or asymmetric branching. For each of the options, different angles under which the pipes are directed are studied.

Table 1

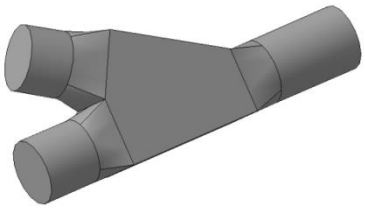
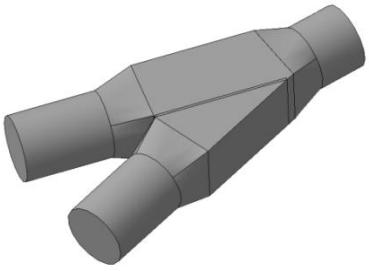
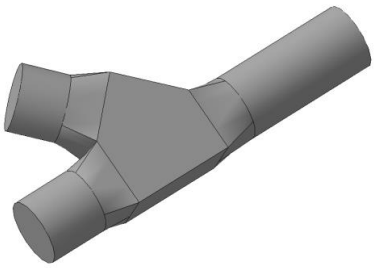
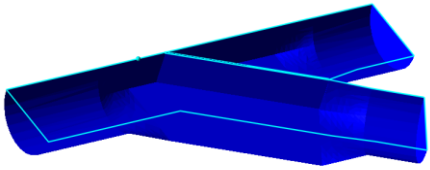
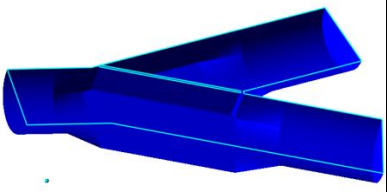
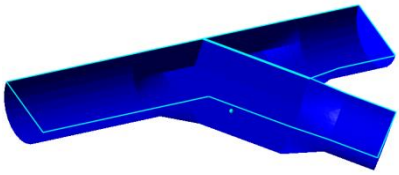
Turn angle, degrees	Asymmetrical pipe separation	Symmetrical pipe separation
30	Option 1 	Option 2 
45	Option 3 	Option 4 

Table 2 shows in the section the structure of each branch in a situation where the damper changes the direction of movement of the product.

Table 2

	Asymmetrical pipe separation	**Symmetrical pipe separation**
Turn angle 30 degrees		
Turn angle 45 degrees		

The combination of structures allows to determine their resistance to the motion of the product to select the optimal branching method, as well as to obtain a comparative characteristic of the local resistance, depending on the angle of rotation.

In our case, the angles of rotation are significant: option 2 – 45°, option 1 – 30°, option 4 – 22,5°, option 3 – 15°.

At another position of the valve, when the movement of the product is straightforward, energy losses practically do not occur.

The geometric and rheological conditions of the study are as follows:

- the diameter of the cylindrical part – 150 mm;
- section of rectangular part – 150x150 mm;
- Product Density – 1050 kg/m^3;
- Product Viscosity – 0,01 Pa;
- air pressure in the pipeline system – 4x10^5 Pa/

Methods

Computer simulation was used as a research tool.

The software CAE complex FlowVision uses the finite element method to predict the movement of viscous liquids in the case of a drop in air pressure at the entrance and exit from the geometric model. The boundary conditions of the "wall" with a given roughness determine slip and local pressure losses.

The basic ones in FlowVision are: the Navier-Stokes equation, the flow indeterminacy equation, and the equation for turbulent viscosity. In addition, the model includes equations for turbulent energy k and dissipation rates of turbulent energy ε. During the simulation a k-ε model of the turbulent flow of viscous fluid with small changes in density was used with large changes in the Reynolds number. The use of this program allows you to get unique scientific information in various fields of the food industry [6, 10].

The novelty of the used method of computer modeling for this work is to determine the values of the dissipation of the kinetic energy of the moving product. In the course of research, the method of visualization – "isolines" – was used, which allows a clear definition of the limits of gradation of values. When calculating the area occupying one or another range of values of isolines of energy dissipation, it is possible to compare the intensity of energy losses if they are attributed to the total area of branching.

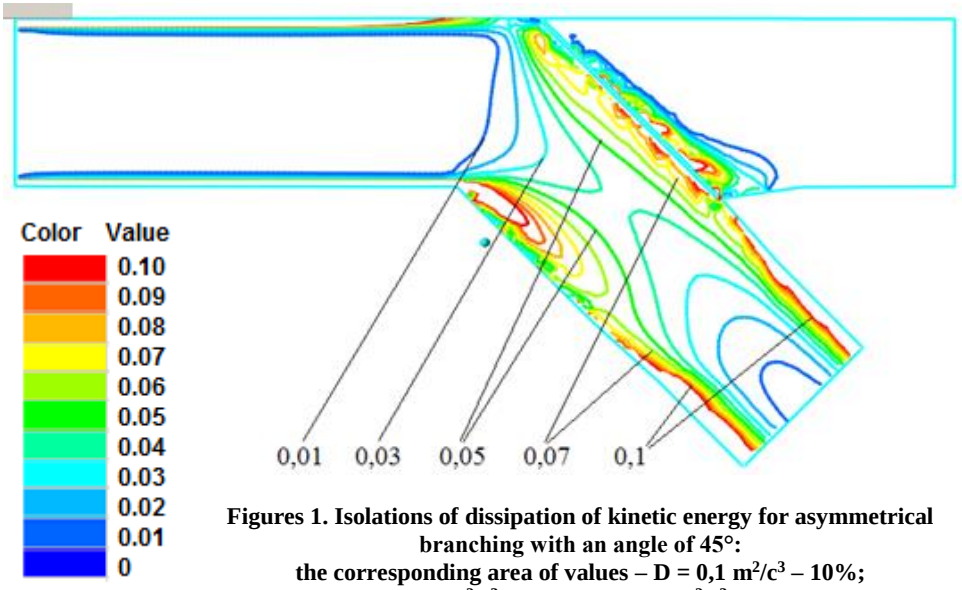
If you evaluate the area that is limited by isolines of a certain intensity of the factor, you can obtain an integral characteristic of the action of dynamic parameters.

Significant areas, which are limited by large values of dissipation, show the origin of turbulence, which is the main source of loss of transporting pressure.

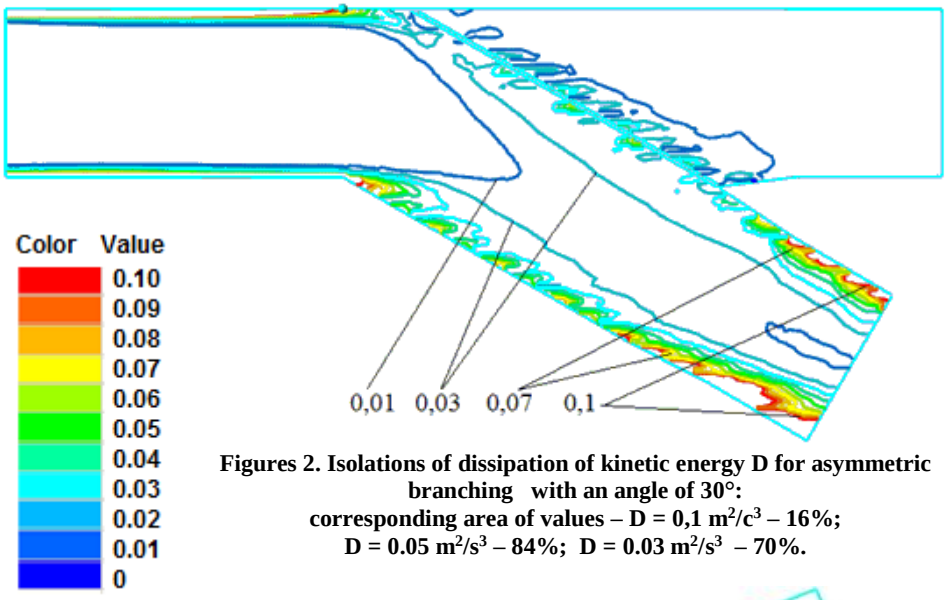
Results and discussion

Figures 1–4 show the simulation results of energy losses. The sequence of the layout of the figures is shown in the direction of decreasing the turning angle of the flow.

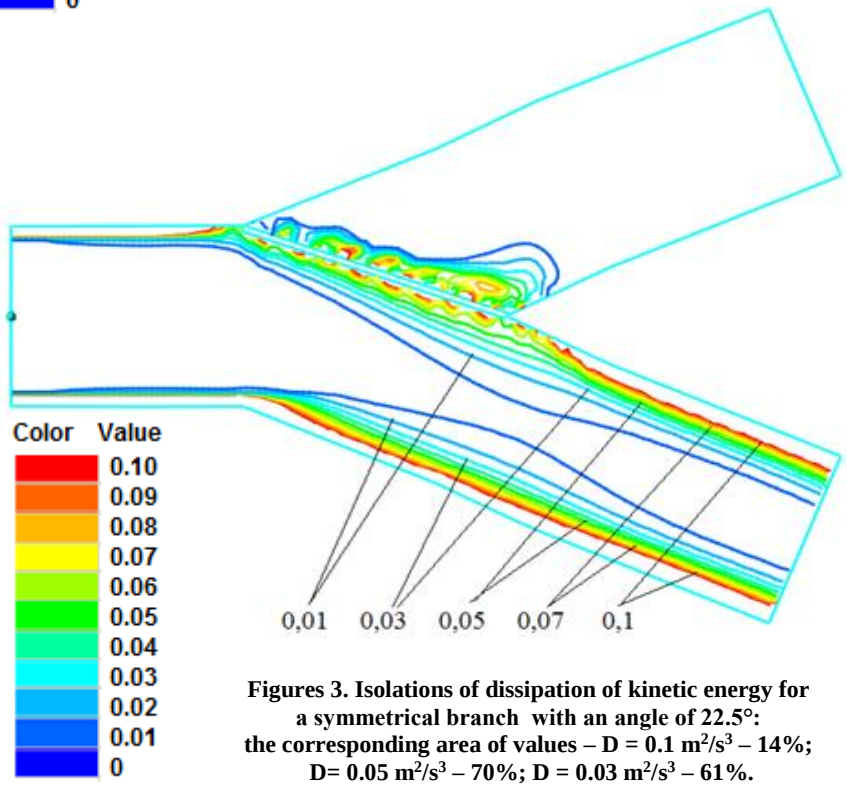
In order to generalize the results of the study, let's compare the results of measurements in the drawings of areas of dissipation of the same intensity (Figures 5).



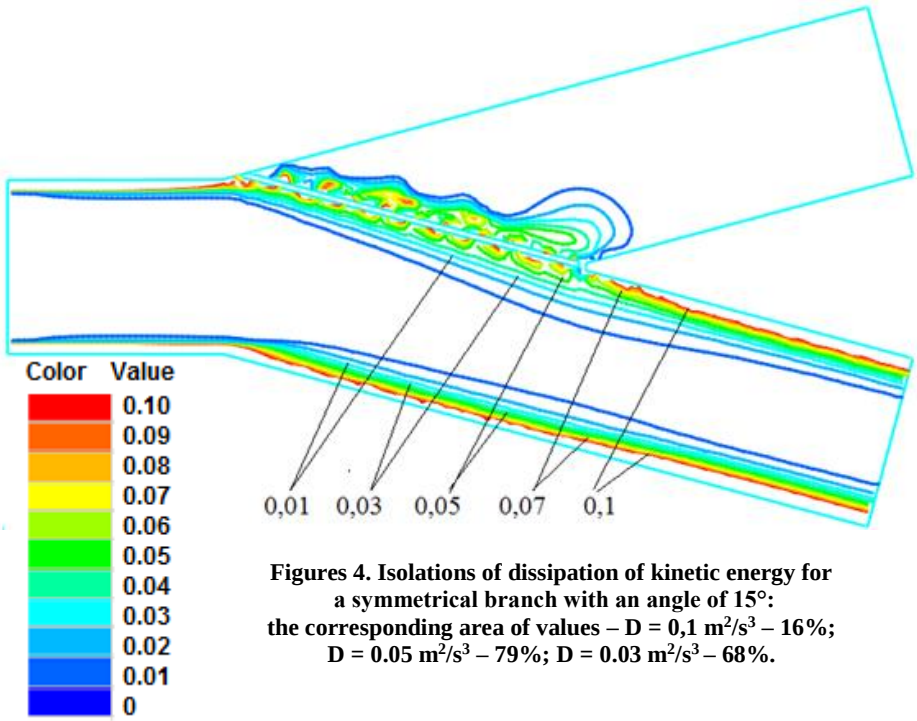
Figures 1. Isolations of dissipation of kinetic energy for asymmetrical branching with an angle of 45°:
the corresponding area of values – D = 0,1 m^2/c^3 – 10%;
D = 0.05 m^2/s^3 – 47%; D = 0.03 m^2/s^3 – 18%.



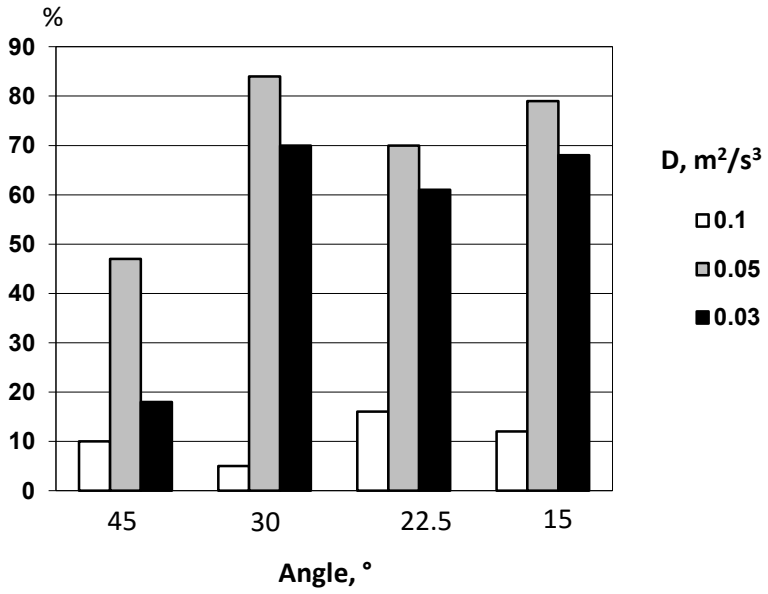
Figures 2. Isolations of dissipation of kinetic energy D for asymmetric branching with an angle of 30°: corresponding area of values – D = 0,1 m^2/c^3 – 16%; D = 0.05 m^2/s^3 – 84%; D = 0.03 m^2/s^3 – 70%.



Figures 3. Isolations of dissipation of kinetic energy for a symmetrical branch with an angle of 22.5°: the corresponding area of values – D = 0.1 m^2/s^3 – 14%; D= 0.05 m^2/s^3 – 70%; D = 0.03 m^2/s^3 – 61%.



Figures 4. Isolations of dissipation of kinetic energy for a symmetrical branch with an angle of 15°: the corresponding area of values – D = 0,1 m^2/s^3 – 16%; D = 0.05 m^2/s^3 – 79%; D = 0.03 m^2/s^3 – 68%.



Figures 5. Percentage of the areas of areas of dissipation D of a certain intensity as a percentage of the total area of the branching, depending on the angles of the flow of the stream

The mathematical processing of each curve gives the best description of the behavior of graphs when using polynomials of the third degree. Accordingly, the following equations represent the intensity of the course of dissipative processes depending on the type of branching and the numerical value of the angle of rotation.

Dissipation, m^2/s^3	Equation
0,1	$y = 12x^3 – 99x^2 + 249x – 115$
0,05	$y = 13x^3 – 108x^2 + 285x – 172$
0,03	$y = 2x^3 – 16x^2 + 40x – 16$

Distortion occurs on the plate of the switch – the minimum gap between the wall and the plate is in reality and in the model about 1 mm. It is important to note that a certain breakthrough in flow at these speeds and pressures is still happening.

Analyzing the obtained results, it can be noted that the dependence of energy losses on the geometry of the pipeline connection is rather complicated and is described by nonlinear dependencies.

This can be explained by the fact that changing the modeling parameters changes the criterial nature of the product motion [17, 23].

Conclusions

The length of rectilinear pipelines affects the cost of transportation energy much less than the local supports: turns of pipes and switches.

When designing the piping laying options, you can combine straight sections, pipe turns, switches in such a way as to minimize pressure loss. That is, it is expedient to use symmetrical branching variants and minor turns of pipes even in simple areas (depending on their length).

References

1. Beseda S.D., Shtefan Ye.V., Taran V.M. (2006), Vyznachennia ratsionalnykh konstruktyvnykh ta ekspluatatsiinykh kharakterystyk obladnannia dlia transportuvannia nekharchovoi miasnoi syrovyny, *Miasnoe delo*, 11, pp. 66–68.
2. Purnell G. (203), Robotics and automation in meat processing, *Robotics and Automation in the Food Industry*, Grimsby Institute of Further & Higher Education (Gifhe), pp. 304–328.
3. Longdell G.R. (1994), Advanced technologies in the meat industry, *Meat Science*, 36(1–2), pp. 277–291.
4. Toledo R.T. (2007), Fundamentals of Food Process Engineering. Third Edition, Springer.
5. Beseda S.D., Lytovchenko I.M. (2014), Doslidzhennia parametriv rukhu miasnoi syrovyny v kruhlykh truboprovodakh pry pnevmotransportuvanni, *Novi idei v kharchovii nautsi – novi produkty kharchovii promyslovosti: mizhnarodna naukova konferentsiia, prysviachena 130-richchiu Natsionalnoho universytetu kharchovykh tekhnolohii*, Kyiv, pp. 412.

6. Shpak M.S., Litovchenko I.N. (2011), Modelirovanie osnovnykh protsessov v oborudovanii pishchevoi promyshlennosti, *Inzhenernye sistemy: tezisy dokladov, mezhdunarodnaia nauchno-prakticheskaia konferentsiia*, p. 4.
7. Lelieveld H., Holah J., Gabrić D. (2016), Handbook of Hygiene Control in the Food Industry (Second Edition), Elsevier.
8. Luchian M.I., Litovchenko I., Stefanov S., Csatlos C. (2012), Numerical simulation of energy dissipation in mixing process of bread dough, *Journal of EcoAgriTourism*, 25, pp. 67–70.
9. Stefanov S., Hadjiiski W., Litovchenko I. (2012) Use of computer modeling for modernization of final proofers of preparation of dough, *12th International Conference "Research an d Development in Mechanical Industry" RaDMI 2012, 13–17 September 2012, Vrnjacka Banja, Serbia*, P. 791–796.
10. Litovchenko I., Stefanov S., Hadzhiyski V. (2015), Investigation work proofers by computer simulation, *Ukrainian Food Journal*, 4(2), pp. 119–126.
11. Beseda S.D., Lytovchenko I.M. (2012), Modeliuvannia parametriv rukhu miasnoi syrovyny v systemakh pnevmatychnoho transportu, *Naukovi pratsi Natsionalnoho universytetu kharchovykh tekhnolohii*, 47, pp. 50–54.
12. Steven M. Lonergan, David G. Topel, Dennis N. Marple (2019), Chapter 15: Packaging for meat and meat products, *The Science of Animal Growth and Meat Technology (Second Edition)*, pp. 255–269
13. James S.J., James C. (2014), MEAT MARKETING. Transport of Meat and Meat Products, *Encyclopedia of Meat Sciences (Second Edition)*, 2014, pp. 236–243
14. Telychkun V.I., Gavva O.M., Telychkun Yu.S., Gubenia O.O., Desyk M.H., Chepeliuk O.M. (2017), *Tekhnolohichni kompleksy kharchovykh vyrobnytstv*, Stal, Kyiv.
15. Brennan J. G., Alistair S.G. (2011), *Food Processing Handbook, 2nd Edition*, Wiley-VCH Verlag GmbH & Co.
16. Litovchenko I., Taran V., Beseda S., Hadjiiski W. M., Stefanov S.V. (2011), Computer modelling of movement of meat raw material on pipelines, *The 7th International Conference «Integrated systems for agri-food production»*, Nyiregyhaza, Hungary, pp. 211–214.
17. Fellows P. (2013), *Food processing technology. Principles and Practice. Second Edition*, CRC Press.
18. Holah J., Lelieveld H.L.M. (2011), *Hygienic Design of Food Factories*, Elsevier
19. Kennedy S. (2017), *Food Protection and Security. Preventing and Mitigating Contamination during Food Processing and Production*, Woodhead Publishing.
20. Litovchenko I. (2013), The study of the baking ovens by computer simulation, *Food technology*, XVII, pp. 107–115.
21. Ralko O. (2012), *The* restructuring and organisational development in the food industry in Ukraine, in: Tetyana Mostenska, Iryna Fedulova, Virginija Jurėnienė (2012), *Restructuring: theory and practice: [monograph]*, Kyiv: Kondor, pp. 171–195.
22. Beseda S. D., Lytovchenko I.M. (2016), Enerehetychni pokaznyky protsesu pereduvky miasnoi syrovyny, *Naukovi pratsi Natsionalnoho universytetu kharchovykh tekhnolohii*, pp. 120–125.
23. Yiu H. Hui. (2006), *Handbook of Food Science, Technology, and Engineering*, CRC Press.

Scenarios of intellectual fuzzy automated control of bread production

Vasyl Kishenko[1], Borys Goncharenko[1], Oleksii Lobok[1], Viacheslav Ivashchuk[1], Maryna Sych[2]

1 – National University of Food Technologies, Kyiv, Ukraine
2 – National University of Bioresources and Natural Uses of Ukraine, Kyiv

Keywords:

Bread
Backing
Automation
Intellectual
Control
technology

Article history:

Received 31.01.2018
Received in revised form 20.06.2018
Accepted 29.06.2018

Corresponding author:

Borys Goncharenko
E-mail: goncharenkobn@i.ua

DOI:
10.24263/2310-1008-2018-6-1-13

Abstract

Introduction. The research of the scenario approach in the automation of the control of the processes of baking bakery products [3, 4] has been carried out in order to increase the efficiency of production and improve the quality of products.

Research methods. Are analysis of the characteristics and criteria of the chosen problem, compilation of qualitative assessments and previous scenarios of process management, estimation of the realistic solutions (expert, cross-influence, Saati method [1]), rules and sequence of their application in the writing of generalized scenarios.

Result and discussion. The article deals with the main components of the stages and operations of bread production and various possible schemes for their regulation. The disadvantage of the typical scheme of automatic humidity control on dough machines of continuous action is its orientation to the stable quality of flour. To regulate the duration of fermentation, the mass of the semifinished product in the fermentation vessel fixes the weighing mechanism, and the consumption takes into account the flow meter, these data are processed according to the corresponding formula. At the stage of mechanical treatment of the dough, it is necessary to control the mass of the dough and its degree of readiness for baking. The controlled parameters are the temperature and humidity of the air in the cabinet, as well as the durability of the stand.

It is proposed to develop an automated multi-purpose control system based on a scenario approach and intelligent technologies [5, 8, 10] in order to increase productivity, reduce specific losses and cost of resources while improving product quality. The essence of the situational approach to the management of technological processes of baking bread is outlined. The abstract (A-) and structural (C-) scenarios of bread production are offered, which can be used in the quotient-purpose analysis of bread production. C-scenario details the A-script based on the evolution of the object when performing operations and transferring objects from one operation to another [6, 7]. Each class C- scenario runs autonomously and interacts with other classes and the environment to make new objects in the input queues and to remove from the output queues "worked out".

Conclusions. The analysis of the state of the problem of control of technological processes of bread production and the examples of control scenarios are given.

Introduction

As a result of the study and analysis of baking processes as objects of control, it was found that, firstly, dynamic models of objects of control are characterized by considerable dimensionality, lag, uncertainty and parametric instability; and secondly, with a limited number of regulated parameters and adjusting actions [3,4], the requirements for stabilization of regulated parameters increase with the transition to more complex control; thirdly, the set of functional management tasks is limited, but the requirements for the effectiveness of their solution are increasing; and fourth, the analysis of production, which is characterized by multi-stage, allows to allocate a technological subsystem of a number of subsystems. All this allows you to move from estimates to the ratio to the estimates of the situation. In this case, first of all, two guiding approaches are used: program-target and network (scenario).

The program-oriented approach in control is oriented towards the achievement of the final result: the formation of a goal tree, the development of an executive program and its implementation. The scenario approach is associated with prediction. There are not only one, but several possible strategies, respectively, which builds the system of mathematical models and does not set rigid goals. The main elements in the scenario approach lie not in linear, but in network logic. The scenario approach is not necessarily focused on solving a global problem and it is a continuation of simulation without the use of formal methods of analysis [9].

Studies have been conducted on the creation of automated systems for managing baking production processes based on a scenario (network) forecasting approach, and not only on the achievement of the final result according to the logic of phased actions, as in the program-target approach, in order to increase the efficiency of production and quality products. The purpose of the article is to increase the technical and economic indicators of baking production by creating an automated system of multi – purpose management using scenarios of production situations and intellectual mechanisms.

Materials and methods

Modern methods, means and forms of organization of information management processes (materials), which should include and automate the processes of production of bread [3, 4, 5], do not allow to effectively solve the tasks of automated control. There are problems of a fundamental nature, connected with the absence, firstly, of theoretical studies of production processes (the theory of the development of information-logical models of subject areas), and secondly, the structure and functioning of the corresponding automated system [4, 5]. The combination of the processes of modernization of equipment and production technologies will provide the theoretical basis for implementation in the process of production management of methods and means of information technology.

Research methods in the complex of technological prediction implementation in the control scenarios were used at different stages of the different:

- preliminary study of the problem – analyzed its characteristic features, determined directions of research, formed important criteria for the chosen problem;
- qualitative analysis of the problem – qualitative assessments or previous scenarios were prepared for the next stage of the prediction, which summarized the scenarios, analyzed and evaluated their realism for final decisions (Delphi method – expert assessments, cross-impact, Saati method [1]);
- Writing scenarios – for a set of rules and their sequential use in writing generalized scenarios.

Result and discussion

Considering the main problems hampering further effective development of the baking industry, we can say that one of the most important problems is yearly reduction in of bread consumption of in Ukraine. Reduction caused by as decreasing of production as well as by the needs of the internal market. In recent years the population has decreased by millions of people, also blur has decreased purchasing power, increased prices for bread products. In the Table 1 is presented production dynamics and consumption of bread in Ukraine over recent years [2].

Table 1

Indicator	2003	2004	2005	2006	2007	2008	2009	2010	2011	Jan.-Dec. 2012
Production of bread and bakery products, thousand tons	2335	2307	2264	2160	2032	1978	1828	1808	1769	1607
Consumption of bakery, kg/person	125	125	123,5	120	115,9	115,4	111,7	111,3	110,4	-

Recently, the situation has only intensified. To ensure production efficiency is possible only by improving the quality of products under these conditions.

In the baking industry the main raw material may be different by its quality characteristics. A wide range of changes in raw material quality significantly influences the course of technological processes and carries out the constant disturbing influences which complicate the production process control of quality products.

To prevent shortages of products and receipt of satisfactory quality of bakery products from flour with low baking properties can be regulated the run of technological processes with help of using different technological methods. Parameters of technological process as the storage of raw materials, the duration of kneading, the dough temperature, temperature, humidity and length of proofing, baking temperature and duration also have influence upon the quality of the finished product (Figure 1).

Making bread sponge method has several advantages over spongeless method: reducing of yeast costs and significant technological flexibility to select the most efficient regime for processing flour depending on its technological features. However, the sponge method also has disadvantages: during the preparation of dough is necessary twice dosing and mixing of raw sponge and dough more overall duration of fermentation. Therefore, the loses of dry matter of raw materials to fermentation increases, and the output of bread decreases by 0.5% compared to spongeless method.

It is believed that products made by the sponge method have better flavor and aroma, porosity, physical properties of the crumb, due to the degree of swelling and peptization of flour colloids. Sponge method also gives better result in the processing of weak and defective flour with low-quality grain.

In order to develop an effective system of automation there is conducted a detailed analysis of technological process of bread production. So, let`s consider the main the stages and operations, highlighting tasks problems and problems of each stage [3, 4].

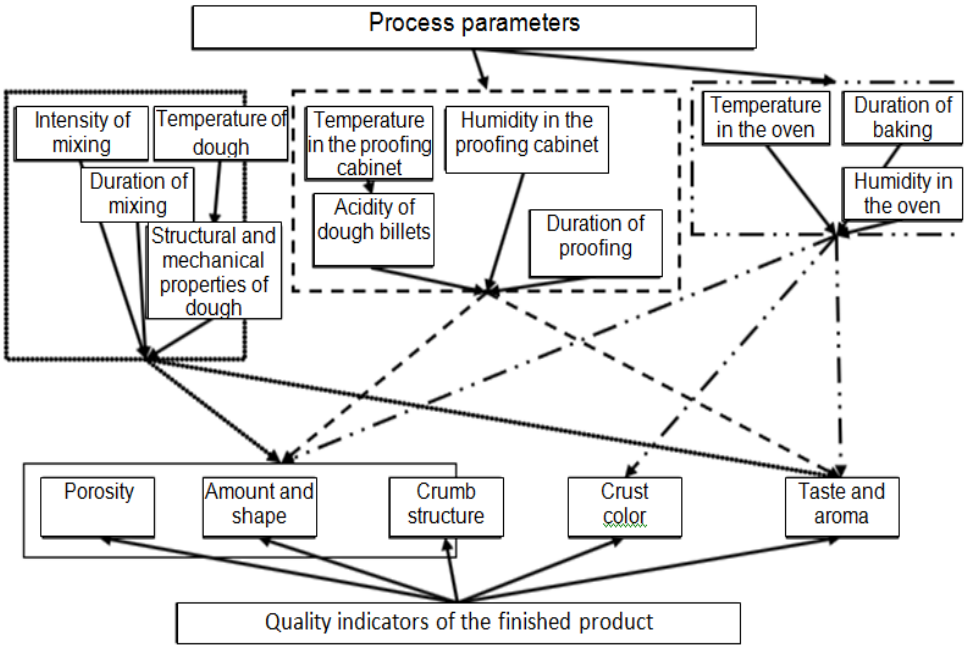


Figure 1. Indicators of baking quality finished product

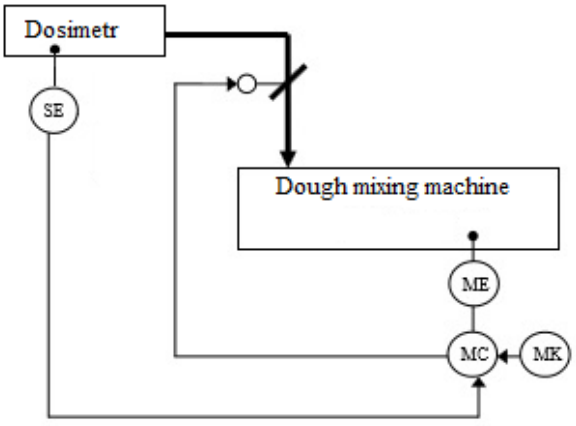


Figure 2. The typical scheme of automatic control and regulation of humidity of semi-finished products and dough

A typical scheme of automatic control of humidity on dough mixing machines of continuous action is shown in Figure2. The disadvantage of this scheme is that it is designed for consistent quality of flour. Therefore rational will be add a decision support system, will be rational approach and using of it will contribute to the effective recycling of different flour quality. Duration of semi fermentation is a basic parameters of dough [3]. For the weighting mechanism fixes the mass of semifinished product in the fermentation tank for its regulation and the consumption is taken into account by flowmeter, these data is processed by the corresponding formula (Figure 3).

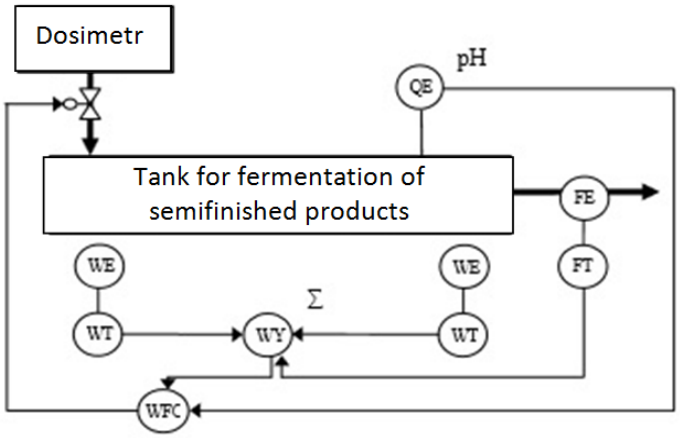


Figure 3. The typical scheme of regulation the duration of fermentation.

If you change the duration of fermentation (due to malfunction of batcher dosimeter or when you change the performance of the aggregate unit (WFC) gives a command to change the performance for batcher dosimeter calculating device to establish a new weight.

The degree of mechanical processing of dough during mixing is characterized by the expended energy. Following the scheme in Figure 4 torque by sensor that sends a signal to the control device, which according to the rheological properties of dough for this type of flour controls the frequency rotation, slope of mixing blades or kneading duration.

At this stage it is necessary to control the mass of dough billets and degree of readiness for baking. Controlled parameters are temperature and humidity in the proofing cabinet and the duration of proofing. Typical scheme of the section of processing dough, with contours of regulation is shown in Figure 4.

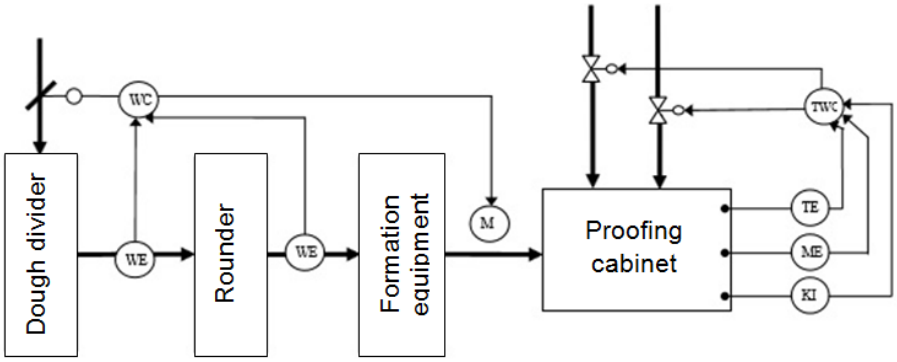


Figure 4. A typical scheme of automatic control processing dough

The regulation the weight of the dough billet by stabilizing the level of the dough above divider with level sensors doesn`t give the required accuracy, so it is advisable to stabilize the temperature and humidity in the proofing cabinet and regulate only the duration proofing.

Formed dough proofing billet has porous less structure. So for, the stress relaxation, for loosening dough billets, and providing her forms of bread the future it is used to conduct a final proofing process. To proceeding this process in quite rapidly and without drying the surface of the dough blanks, the parameters of air in proofing cabinet must comply with certain values of temperature and relative humidity (35–45 °C, 75–85%). During the proofing biochemical, microbiological, physical and colloid processes are occurred. Then bread baking starts.

Baked bread is placed in trays that are placed on trolleys and then happens the selecting of products that do not comply with standard documentation. Quality of finished products is evaluated according to the analysis of overage samples taken from the batch bakery products, according to state Standard.

Bakery industry is characterized by a high degree of uncertainty, for which you can eliminate some of the controls at various stages of the process. For example, intensive dough reduces the duration of fermentation. Insufficient degree of fermentation dough can be compensated by increasing the duration of proofing and baking under appropriate modes, they are: increasing the relative humidity in the proofing cabinet and the environment in the baking chamber, and increasing the temperature of proofing and decreasing the temperature of baking [4]. Thus, the same end results of functioning of technological process are available in various different operational parameters and different structure of the technological scheme that provides a wide range of control.

Action at designing of the technological scheme and attached to its analysis, in order to improve control systems. But enumerate all possible structures and choose the best of them is almost impossible.

To improve the situation may be through the use of scenarios of bakery production management (control) that based on cognitive – scenario models of technological processes and control algorithms using intellectual mechanisms. That why, the development of systems for multipurpose control (management) of technological processes of bakery production, based on scenario approach and intellectual technologies will increase productivity, decreasing losses of resources and raw materials, improving product quality [4,5].

Methodology of approaches to control of complex organizational and technical (technological) systems contain goals, laws, principles, methods, features, technology and practice in management of decisions. There are allocated different approaches of controlling organizational and technical (technological) systems, they are: system, process, situational.

The situational approach concentrates on situational differences, it determines which changeable situant and how they influence on the effectiveness of controls. The situational approach to management explores which of models and algorithms are effective and on the basis of this analysis is offered the decision to build control systems for specific conditions.

The technological situation *S(t)* as the image is described by feature vectors that characterize the corresponding object, and determined by some relation on the set of parameters {Y}, which is characterized by multiple classes of situations *{Ks}*, which are reflected in the control scenario, by multiple classification algorithms $\{K_A\}$ and rules of selection of classification algorithms $\{P_K\}$:

$$\{Y\} = \{KS, KA, P_K\}.$$

The sequence of specific actions in the scenario has a property of causality and provides connection preliminary steps with the following. Implementation of scenarios of process control carried on fuzzy model of knowledge representation. This method is quite flexible and convenient to represent logical connections between elements of scenarios [6,7].

For effective production quality management model it is necessary to have models of quality, that are based on expert surveys and qualimetry.

Quality rating by methods of multidimensional scaling allows to analyze initial data of any type and receive final models with a minimum value that confirms the possibility of their using for making decision on management (control) [6].

The scenario approach allows a multivariate situational analysis of simulated system. Scenario is a way of achieving goals, considering factors affecting the environment in which the system is, which is characterized by objectives, factors of influence, operations, interoperation connections. Operation as a step of scenario is determined differently as in the abstract A- and structural C-scenarios. In case A- scenario the operation ignores the internal structure of the object while transformation input values into output ("black box"). C-scenario details the internal structure of objects that are described by a set of properties attributes. Attributes take on values in some areas. These values may vary according to the specified rules. Operation C- scenario is a block, which contains objects with the same set of attributes. The scenario has the following components: objectives, factors of influence operations, interoperable connections.

C-scenario details A-scenario considering the evolution of the object while performing operations and transfer of object from one operation to another. Evolution of the objects appears in the change attribute values, during transition "mutations" occurres – the appearance of new signs and the loss of signs that became unnecessary. Each class C-scenario opperates autonomously and interacts with other classes and with environment to bring input queue in new objects and remove output queue from "worked out " objects.

The sequence of control actions defined on the set of input and output variables represented as fuzzy value [7]. Each scenario connects changes in external conditions of the resulting output. C-scenario determines, as noted, the internal structure of the object and its set of properties describing attributes. Operation is a unit which contains objects with the same set of attributes and is treated as a class, whose elements belong to some space [8].

Lets form graphical representation of A – scenario system (Figure5). Object flows A – scenarios of a process of making bread is presented in Table 2.

Table 2

Designation of object data streams

Designation	Content
P1	Flour feeding
P2	Water feeding
P3	Salt feeding
P4	Feeding yeast grout
P5	Feeding supplementary raw materials
P6	Output of finished goods to distribution network
P7	Feeding of prepared flour
P8	Water feeding
P9	Spouge feeding
P10	Feeding supplementary raw materials (by the recipe)
P11	Dough feeding
P12	Dough pieces feeding
P13	Feeding dough pieces after proofing
P14	Output of finished goods (products)

We will differentiate between modeling the functioning of the existing system and the simulation system development. The scenario approach is more effective applying to the development of the system.

The scenario should include the prediction of development of a system at different chosen strategies, choosing (based on the results of prediction) the best strategy, and operation to implement the chosen strategy.

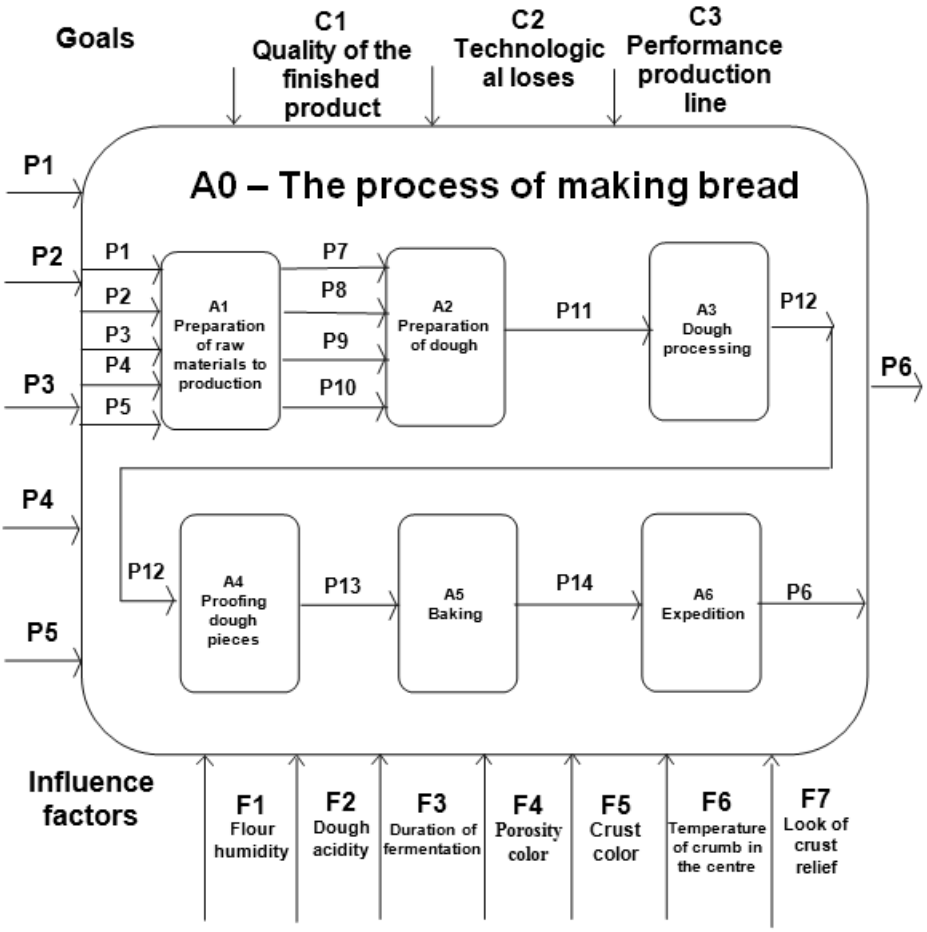


Figure 5. Graphical representation A-scenario system.

Attributes objects listed in Table 3.

A – scenario turns into a the C- scenario in such way [9]:

- structuring of objects;
- object classes and transitions between them are descripted of life cycles within each class is forming;
- tet of integrated indicators of system`s functioning is determined(values of these parameters are established during the simulation modeling of C-scenario);
- then the expression of dependency of level of goal achieving from integrated indicators and factors of impacts is requested.

Table 3

Attributes objects C-scenario

Designation	Marking an attribute	The content attribute
A1	a 1.1	Flour power
	a 1.2	Flour Color
	a 1.3	Content of random impurities
	a 1.4	The ability to form gas
	a 1.5	Flour humidity
	a 1.6	Size of flour
	a 1.7	Flour acidity
	a 1.8	Water color
	a 1.9	Turbidity of water
	a 1.10	% Content of insoluble substances in brine
	a 1.11	Rising speed of dough
A2	a 2.1	Humidity of flour
	a 2.2	Acidity of flour
	a 2.3	Spange humidity
	a 2.4	Spange temperature
	a 2.5	Time of the ripening
	a 2.6	Maturation of dough
	a 2.7	Dough humidity
	a 2.8	Dough temperature
A3	a 3.1	Dough density
	a 3.2	Humidity of dough billets
	a 3.3	Duration of proofing
A4	a 4.1	The temperature in the proofing cabinet
	a 4.2	Relative air humidity
	a 4.3	Duration of proofing
A5	a 5.1	crumb temperature
	a 5.2	Crust color
	a 5.3	Crumb stickiness
	a 5.4	The mass of dough billets
	a 5.5	The temperature of the oven (furnace)
	a 5.6	Baking duration
	a 5.7	Humidity in the baking chamber
	a 5.8	Amount of dough billets
A6	a 6.1	Organoleptic indicators
	a 6.2	Weight of production

An important step of predictions is evaluating of realism of developed scenarios according to the previous definition of conditional probabilities of events that shape these scenarios. The main feature of conditional probabilities is that in this case they actually acts as psychological assessment of the probability of this or that event.

Figure6 shows a fragment of C- scenario based on scenario A1-preparation of raw materials to production.

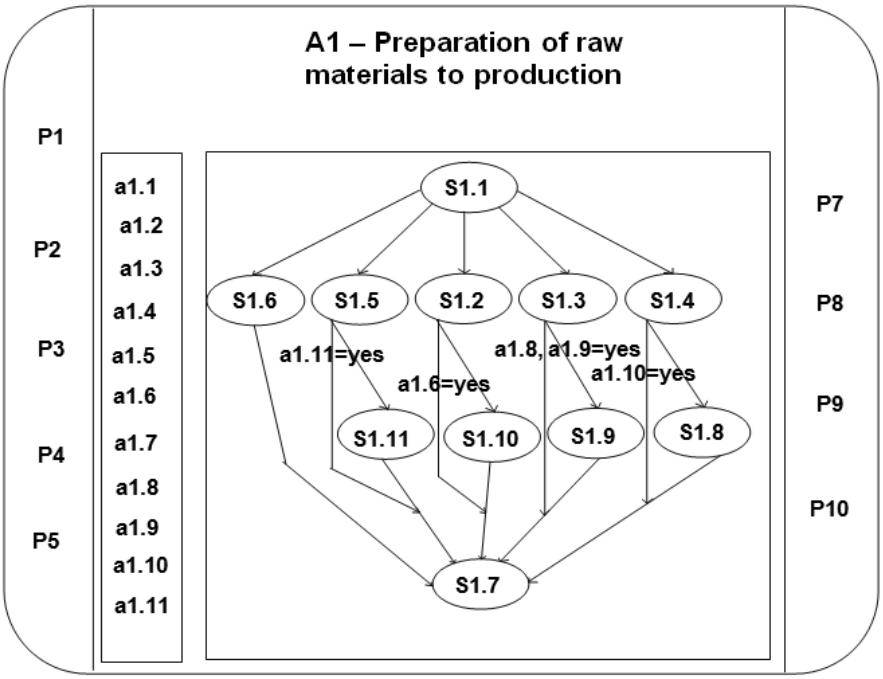


Figure 6. Fragment C scenario, class A1.

Conclusions

The use of scenarios and control algorithms using intellectual mechanisms will increase productivity, reduce specific costs and losses of resources and raw materials, improve product quality. These are presented contents and sample scenarios of abstract (A-) and structural (C-) controls and their implementation. Carried out representing the input and output variables of processes in the form of fuzzy variables. These is formed graphic representation of A- and C-management (control) scenarios.

References

1. Peter S. Pande, Robert P. Neuman, and Roland R. Cavanagh (2014), *The six sigma way: How to Maximize the Impact of Your Change and Improvement Efforts*, McGraw-Hill Education, New York McGraw-Hill Education.
2. Wixon B., Roth R., Dennis A. (2014), *System analysis and design*, San Jose.
3. Kyshenko V. (2016), *Categorical-functorial analysis of bakery production, Scientific enquiry in the contemporary world: theoretical basics and innovative approach*, B&M Publishing, San Francisco.
4. Pankov D., Kyshenko V. (2017), Features introduction of automated quality control system bakery products, *Slovak international scientific journal*, 6, pp. 83–86.
5. Pankov D., Kyshenko V. (2018), Informational support of the automated control system for baking production, International science project, 12, pp. 37–41.

6. Schultz V.L., Kulba V.V., Zaikin O.A., Shelkov A.B., Chernov I.V. (2017), Regional Security: Analysis of the Emergency Management Effectiveness Based on the Scenario Approach, Advances in Systems Science and Applications, 17(1), pp. 9–24.
7. Schultz V.L., Kulba V.V., Andreeva Z.K., Zaikin O.A., Shelkov A.B., Chernov I.V. (2018), Decision support system on social stability governance based on scenario approach, *International Journal of Engineering and Technology (UAE)*, 7(2), pp. 240–242.
8. Kononov D.A., Kosyachenko S.A., Kulba V.V. (2007), Design and analysis of development scenarios of social economic systems with the application of the operator graph apparatus, *Automation and Remote Control*, 68(1), pp. 109–123.
9. Hierons R.M., Ural H. (2003), Concerning the ordering of adaptive test sequences, *Proc. 23rd IFIP Int. Conf. on Formal Techniques for Networked and Distributed Systems, Berlin, Sept. 2003*, Springer, Berlin.
10. Alfonso A., Braberman V., Kicillof N., Olivero A. (2004), Visual timed event scenarios, *Proc. 26th Int. Conf. on Software Engineering*, ACM Press, pp. 168–177.

System analysis and approaches to the developement of the automated electrical energy consumption and supply system of the food industry enterprise

Lyudmila Kopylova, Sergii Baliuta, Oleg Mashchenko

National University of Food Technologies, Kyiv, Ukraine

Keywords:

Electrical
Control
Consumption
Supply
Algorithm

Article history:

Received
29.01.2018
Received in revised
form 26.05.2018
Accepted
29.06.2018

Corresponding author:

Oleg Mashchenko
E-mail:
oll973@ukr.net.

DOI:
10.24263/2310-1008-2018-6-1-14

Abstract

Introduction. The conducted researches of the food industry enterprise (FIE) electrical energy consumption and supply control process with the aim of electrical resources transmission and use efficiency increase by electricity consumption.

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

Results and discussion. The main stages of the electrical energy supply and consumption control process: the basic control functions – electrical energy (EE) consumption registration, forecasting of EE consumption, calculation of EE consumption norms, conducting of FIE electrical energy supply system (EESS) regimes analysis as well as electrical energy quality indices (EEQI) and FIE EESS reliability analysis, consumers – regulators (CRs) list formation; control functions support conditions – EE consumption information, restrictions and rates, electricity consumption forecasting accuracy requirements;decision-making about configuration change and FIE EESS regimes optimization as well as EEQI normalization;organizational and technical mechanisms of control functions fulfillment – information and computing system, electric power dispatcher, technological process operator, electrical supervisor; automated power sector control system of the FIE data base, which is used for decisions preparation;basic information flows which provide electrical energy consumption control. The functional scheme is represented and the separate FIE EE consumption and supply control units requirements with use of CRs. FIE EE consumption and supply is implemented using decision-making support subsystem what includes interconnection of technological process and EE consumption process.

Conclusion. Developing on the base of the system analysis and interconnection methods provides the high EE consumption and supply efficiency.

Glossary

ACS – automated control system;
CR – consumer-regulator;
DB – database;
DMSS – decision-making support subsystem;
EE – electrical energy;
EECACSS – electrical energy consumption automated control and supply system;
EEQI – electrical energy quality indices;
EESS – electrical energy supply system;
FIE – food industry enterprise;
RPA – relay protection and automatic;
UES – united electrical energy system.

Introduction

The electric energy (EE) consumption reducing problem, the EE supply reliability and normative EEQI ensuring is relevant for the food industry, since it allows to increase the generating capacities use efficiency and to reduce EE consumption during its transmission and the energy intensity of production outputted by enterprises.

For ensuring of rational EE consumption and wastes levels for food industry enterprise (FIE) EE supply systems, it is necessary to forecast its consumption and use consumers – regulators (CRs) as well as to optimize regimes of these systems.

Let us look at the works, devoted to FIE EE consumption and supply control questions. some of them. In the article [1] the technical facilities complex and the software of commercial EE accounting systems of "Energomira" company is represented. It is represented by the software modules set for the commercial EE accounting organization on energy sites. As such objects can be used energy companies, electricity grid areas, substations and other EE consumers.

The technical facilities complex "Energomira" software includes realization of following function:

- automation of dispatcher workplace, which realizes the data processing from the data collection device and from data collection and transmission device, their representation in form of charts and tables;
- report generator for creating various documents forms;
- software data collection and database (DB) forming;
- technical facilities complex administering programs for the EE consumption accounting system devices parameters determining.

As a result of works analysis [1, 2] was ascertained that the software which is presented in these works is developed by various organizations, which during its developing do not interact with each other. This fact causes essential complications by common use of the mentioned software.

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

dispatcher workplaces. However, the mentioned system, solves only the EE accounting problems.

Recently, by developing of new generation automated control and accounting EE systems the modern industrial controllers are extensively used [4]. These systems except the problems solving of commercial EE accounting and capacity consumption ensure also the technical accounting and monitoring of industrial enterprises electrical loads in real time mode, what is the base for FIE EE consumption and supply control tasks solving.

The works analysis [4–6] shows that the presented in these works automated systems are performing functions of electric capacity and EE consumption control. But these systems do not realize the EE normalization, planning, forecasting and optimal FIE EE consumption and supply control functions of industrial enterprises, which allow to obtain the main economic effect.

Aim of the research consists in the synthesis of FIE EE consumption automated control and supply system (EECACSS) on the base of the systematic analysis of EE transmission, dividing and consumption control process with ensuring of integration and compatibility sequence of separate parts.

Materials and methods

Research materials

In this work the FIE EE consumption and supply control process are studied [7] as well as the automated system developing principles are formulated [4, 8] and the functional scheme of automated control system (ACS) is developed [9].

Research methods

Researches were conducted in the following order:

- there were formulated FIE EE consumption and supply control tasks [6, 10];
- it was made a systematic analysis of the FIE EE consumption and supply control process [9];
- there were formulated FIE EE consumption and supply control criteria [11, 12];
- it was developed the FIE EE consumption and supply control functional scheme [13, 14];
- it was developed the algorithm of compatibility and integration ensuring method when construction of FIE EECACSS [5, 15];

Here is used the method of sequence modeling [10, 16], which is based on the simple, the most abstract description and makes possible to include the objects of various type [17] and get connections of different character and content [18].

Results and discussion

EE consumption and supply control task consist in minimization of technical and economical criteria set on following grounds:

FIE damages from CR active load disconnection (changing to the reduced work mode):

$$F_1 = \sum_{j=1}^{M} \sum_{i=1}^{I_j} y_{ij} k_{ij} \ ; \tag{1}$$

CR disconnection amount (electrical grid commutation):

$$F_{21} = \sum_{j=1}^{M} \sum_{i=1}^{I_j} k_{ij} \ ; \tag{2}$$

capacity (energy) wastes of FIE electrical grid, which appear as a result of reactive energy flows:

$$F_3(X) = \sum_{j=1}^{M} \sum_{i=1}^{I_j} \{[Q^2(t) - \sum_{g_{ij}=1}^{G_{ij}} Q_{g_{ij}}(t) h_{g_{ij}}]\} R_{ij} \Big/ U_{ij}^2(t) \ ; \tag{3}$$

by restrictions: on FIE active load :

$$\sum_{i=1}^{I_1} P_{extr}^{C}(t+t^*) - \sum_{j=1}^{J} \sum_{i=1}^{I_j} P_{extr_{ij}}^{C}(t+t^*) k_{ij} \le P_{rest} \ ; \tag{4}$$

on FIE reactive load:

$$Q_{\min}(t) \le \sum_{i=1}^{I_1} [Q_{extr}^{C}(t+t^*) - \sum_{g_{j1}=1}^{G_{i1}} Q_{gi_1}(t) h_{g_{i1}}] \le Q_{\max}(t) \ ; \tag{5}$$

on the EE receiver voltage:

$$U_{ij\min} \le U_{ij}(t) \le U_{ij\max} \tag{6}$$

on EEQI:

$$\delta U_y \le \delta U_y^{(NORM)}; \tag{7}$$

$$\delta U_t \le \delta U_t^{(NORM)}; \tag{8}$$

$$k_{U2} \le k_{U2}^{(NORM)}; \tag{9}$$

$$k_{U0} \le k_{U0}^{(NORM)}; \ k_U \le k_U^{(NORM)}; \tag{10}$$

$$k_{U(n)} \le k_{U(n)}^{(NORM)}; \tag{11}$$

where $\delta U_y, \delta U_t$ is standard deviation and voltage change variation; k_{U2}, k_{U0} – null and inverted sequence coefficients; $k_U, k_{U(n)}$ - harmonicity distortion and n - harmonious waveform voltage part; (with upper index (norm) are marked standard indices values).

EECACSS of FIE is impossible to describe with the help of the present mathematical apparatus. Thus occurs the necessity for their division into separate subsystems, for formalization of which can be used mathematical methods. However even at that still leaves the wide horizon of experience, that can not be described with the necessary completeness on the base of mathematical tools.

There was proposed the approach to the decomposition of FIE EECACSS, which ensures the independence and completeness of decomposition criteria.

This approach stipulates:

- the control system structure formalization at the theoretical-multiple level;
- as part of the unified conception the subsystems development conception, which ensure its functioning;
- the ensuring of the common functioning of these subsystems.

System analysis of FIE EE supply and consumption control process

The EE consumption and supply control is the most important FIE ACS subsystem, what causes the FIE EE supply efficiency.

At the theoretical-multiple level the control process of organizational-technical objects is presented in the form of representation of separate actions

$$F_n : \{L \times K \times Z \times P_{inc}\} \to P_{outc}, n = \overline{1, N} \quad , (12)$$

where: L means actions of basic control functions forming; K and Z mean actions of possible main conditions combinations forming and fulfillment mechanism of control function accordingly; $P = P_{inc} \cup P_{outc}$ are actions of possible combinations forming of main information flows; P_{inc} and P_{outc} mean sets of incoming and outcoming information flows. By FIE EE supply and consume control are implemented following actions:

A**ctions of main control functions forming:**

L_1 is EE consume, electric grid mode and conditions as well as EEQI meterage and measuring data adequacy validation; L_2 means the model choose as well as production units and enterprise EE wastes (consume) forecasting; L_3 is EE wastes rates estimation as well as EE wastes planning and EE balances forming according; L_4 means EEQI and *FIE EESS* parameters estimation, electric grid configuration analysis; L_5 is CRs list and their optimal composition forming; L_6 means FIE EE wastes control DB forming and its maintenance in actual mode and status. L_7 means production subunits and FIE EE wastes decision-making as well as maximal capacity consumption ; L_8 is decision-making for electric grid configuration, EEQI improvement, FIE EESS mode optimization;

Actions of control functions main fulfillment conditions forming:

K_1 means FIE EE consumption information інформація (normative acts); K_2 is restriction and rates information, which contains in FIE EE supply contract; K_3 are metrological forecasts accuracy requirements; K_4 are EE consumption forecast accuracy requirements;

K_5 means the interaction order with the DB control system; K_6 are EEQI and EE supply reliability requirements. K_7 are FIE EESS parameters requirements.

For actions of control ensuring are used the following main parts and mechanisms, which implement control functions:

Z_1 means is an information and computing complex of electrical supervisor service, who gives information about FIE EESS conditions and work mode; Z_2 is is an electric power dispatcher, who forms restrictions for EE consumption standards fulfillment; FIE EESS functioning mode as well as EEQI and electric grid configuration. Z_3 means the technological process operator, who forms restrictions concerning CRs; Z_4 is the electrical supervisor, who forms restrictions for unified energy system (UES) requirements fulfillment; EE supply reliability Z_5 are EE consumption, EEQI, FIE EESS parts conditions accounting sensors and electrical apparatuses for consumers commutation and FIE EESS configuration change; Z_6 means DB of ACS of FIE EE, that is used for decision-making.

For control functions ensuring are used the following information flows:

P_1 mean forecasted values of environmental temperature and air humidity, received with the help of the weather station; P_2 are current data on production subunits and FIE EE consumption; P_3 mean data on production volumes produced by subunits and FIE; P_4 are current data on connected CRs and damages, caused by their disconnection; P_5 mean FIE EE consumption limit; P_6 are EE consumption current data; P_7 are current data on current environmental temperature; P_8 are forecasted values of subunits and FIE EE consumption; P_9 is FIE EE consumption plan; P_{10} mean EE consumption decision-making; P_{11} are actions of control for EE consumption regulation; P_{12} is CRs optimal composition; P_{13} mean EEQI current data; P_{14} are FIE EESS parameters current data; P_{15} are FIE EESS configuration current data; P_{16} mean actions of control for EEQI control; P_{17} are actions of control for FIE EESS configuration change; P_{18} mean actions of control for FIE EESS modes optimization.

System analysis results of FIE EE consumption control process are presented in form of representations for separate actions:

– EE consumption registration, electric grid conditions and EEQI estimation as well as measuring information reliability check:

$$F_1 : \{L_1, (P_1, P_2), K_3, (Z_1, Z_2, Z_5)\} \to (P_6, P_7); \quad (13)$$

– model choose and EE consumption forecasting conducting:

$$F_2 : \{L_2, (P_3, P_6, P_7), (K_1, K_4), Z_1\} \to P_8; \quad (14)$$

– separate subunits and FIE balances normalization, planning and forming:

$$F_3 : \{L_3, (P_3, P_8), K_1, (Z_1, Z_2)\} \to P_9; \quad (15)$$

– FIE EESS and EEQI modes analysis conducting as well as FIE EESS reliability analysis conducting:

$$F_4 : \{L_4, (P_3, P_4, P_5), (K_6, K_7), (Z_1, Z_2, Z_4, Z_5)\} \to P_3, P_4, P_5; \quad (16)$$

– CRs list and their optimal composition forming:

$$F_5 : \{L_5, (P_2, P_3, P_5, P_8), (K_1, K_2), (Z_1, Z_2, Z_3, Z_4)\} \to P_4, P_2; \quad (17)$$

– EE consumption decision-making:

$$F_6 : \{L_7, (P_5, P_6, P_9, P_{12}), (K_1, K_2), (Z_1, Z_2, Z_3, Z_4)\} \to P_{10}, P_{11}; \quad (18)$$

– FIE EESS configuration change and modes optimization decision-making as well as EEQI normalization decision-making:

$$F_7 : \{L_8, (P_{13}, P_{14}, P_{15}), (K_6, K_7), (Z_1, Z_2, Z_4, Z_5, Z_6)\} \to P_{16}, P_{17}, P_{18}; \quad (19)$$

– FIE EE consumption control DB forming and updating:

$$F_8 : \{L_6, (P_3, P_4, P_5, P_6, P_7, P_8, P_9, P_{10}, P_{12},), K_5, (Z_1, Z_3, Z_6)\} \to P_3, P_4, P_5, P_6, P_8, P_9. \quad (20)$$

The decomposition of the EE supply and saving control system, which has ensured its representation wholeness and represents informational interaction, conditions and mechanisms was conducted.

Approaches to the development of the FIE EECACSS

The aim of the FIE EE supply and consumption control is effective (reliable and economical) FIE EE supply and consumption.

The control criterion under existent relations with the EE supply organization could be given in following form

$$J = \lambda_W W + \lambda_W^{'} \Delta W + \lambda_R P_S + \lambda_R^{'} \Delta P_S + \lambda_Q Q + k_W \lambda_W W + \\ + Y_R\left(\Delta P, t_{rest}\right) + Y_{\mathrm{TR}}\left(y_{pc}, 3\right) \to \min. \quad (21)$$

where: λ_W and W are EE rate and its consumption volume by FIE (including conumption in electric grid) accordingly; $\lambda_W^{'}$ and ΔW are consumed over the contract EE rate and its wastes correspondingly; λ_R are P_S contracted (stated, subscribed) capacity rate, that takes part in maximal UES load, and this capacity value correspondingly; $\lambda_R^{'}$ and ΔP_S are active capacity rate, that was consumed over than was stated and its value accordingly; λ_Q and Q are UES peak hours maximal load reactive capacity rates and maximal value of this capacity correspondingly; $k_W = k_W^{''''}$ (or $k_W = k_W^{''''}$) means the charge coefficient for consumed (or generated) reactive EE over the contract (confirmed by rates regulation authority) accordingly; Y_R are FIE consumption of UES peak hours maximal load active capacity regulation; Y_{TR} mean damages from unreliable work of electrical equipment y_{pc} and its tardy out of service for repair.

Electrical energy consumption automated control and supply system of food industry enterprise

On the base of main control tasks and using control criterion the functional scheme of FIE EECACSS is developed (Figure 1).

On the base of the conducted system analysis let us formulate requirements for FIE EE consumption and supply separate automated control functional subsystems (blocks).

Functional block of EE supply and consumption monitoring: in this block the automatic data transmission form EE accounting devices and information reliability control are implemented. Data registering time interval is determined, starting from parameters accounting accuracy, that describe EE supply and consumption process.

The FIE EE supply and consumption efficiency control to a considerable degree depends on the initial information quality, that is metering from measuring devices with the aim of subsequent processing.

At the initial stage this information reliability control is implemented via EESS modes and FIE EE consume parameters prior data analysis, such as permissible limits and character of their temporal change, consistency etc. The additional control based on the use of different dependence between EE supply and consume parameters.

Functional block of EE consumption: the FIE and its subunits EE consume forecast (daily, monthly and annual) is conducted. For the forecasting are used both statistical model and artificial neuronal network, what allows to take into account factors variety, which have an influence on EE consumption norms and limits by FIE energy facilities.

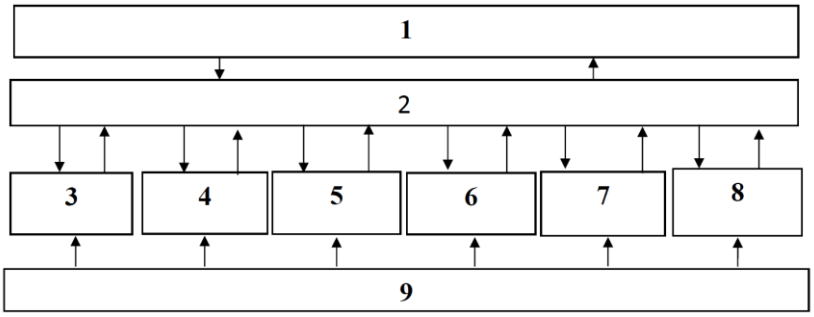


Figure 1. Functional scheme of FIE EE consumption and supply control:
1 – DB of FIE power sector ACS;
2 – DB of FIE EE supply and consume; 3 is monitoring block of EE consumption: here is implemented the automatic data transmission from EE accounting devices and information reliability control;
4 – forecasting block of EE consumption: here is implemented the FIE EE forecast (daily, monthly and annual);
5 – analysis and optimization block of EE consumption: here is efficient comparison and annual, quarterly and monthly EE balances optimization for FIE and its subunits;
6 – control block of EE consumption specific rates and efficient EE supply implementation, that ensures the decision-making process of EE supply control;
7 – optimization block of EE supply modes on the base of measured voltage values, active and reactive capacity;
8 – control block of EEQI based on the measuring devices values and normative EEQI ensuring methods choose;
9 – organizational-technical FIE EE supply and consumption control methods.

Functional block of EE consumption analysis and optimization: on the base of the FIE EE consumption collection and processing information automation the effective comparison and optimization of annual, quarterly and monthly EE balances for FIE and separate production subunits (shops) is conducted, as well as their accuracy and reliability due to exception with erroneous data of erroneous devices recordings is ensured.

On the base of EE balances:

- the EE consumption analysis is conducted;
- EE saving tendencies are defined;
- EE consumption reduction possibilities are determined;
- EE consumption improvement measures are planned;
- EE consumption optimal scheduling strategy is chosen.

The electrical balance presents the base for EE consumption normalization improvement, which essence brings to its implementation during the scheduling of economically and scientifically justified EE consumption rates.

Functional block of EE consumption specific rates and efficient EE supply implementation control ensures the act of control forming process and need to be conducted by an expert or a group of experts on the base of the professional-logical analysis with the use of decision-making support subsystems (DMSS) for EE industry.

The DMSS use ensures:

- more accurate and effective decision-makings for FIE and its production subunits EE control;
- improves the decision-makings quality in incompleteness and uncertainty condition of outcoming information;
- reduces time and labor intensity of decision-makings.

Daily is given the summary list of FIE production subunits EE consumption indices, such as current and scheduled absolute and specific EE consumption, specified limits use coefficients and rate indices. As the need arises, the summary list can be given on staff request by electrical supervisor service at any time. Especially it is necessary during FIE EE supply failures and UES capacity deficiency.

According to this information the electrical supervisor service on the base of DMSS use makes a justified decision on FIE and its subunits EE consumption parameters. DMSS consist of the operating-supervisory control system, that ensures the prompt and efficient decision-making, including alarm conditions in FIE EE supply system and by UES capacity deficiency.

The managerial decision-makings is also supported by visualization tools, that realize graphical models. On the base of EE consumption normalization principles [8] EE consumption control decision are made.

Functional block of EE supply modes optimization on the base of measured in EESS branch points capacity values, active and reactive capacity with the use of mathematical models ensures forming of efficient capacity and EE consumption levels in FIE distribution electric grids.

In functional block of EEQI control with the help of measuring devices set at various EESS hierarchy levels are defined EEQI and with the help of mathematical models are defined technical facilities control methods for normative EEQI ensuring.

For functioning ensuring of functional blocks are developed corresponding control algorithms.

FIE EECACSS integration is implemented via: unification of various functions (EE accounting, capacity regulation, EE resources supply and consumption modes control, EEQI control) in hardware and software tools with the use of data exchange unified protocols and communication channels; effect estimation, received as a result of common and coordinated ACS functioning as well as wastes for their compatibility and interaction ensuring.

As a basis of a method is taken following principles of:

- **systemacy** – the integrated ACS creates the open dynamic system and corresponds to wholeness, statefulness and purposefulness requirements;
- **hierarchy**. ACS hierarchy levels are defined by control processes division levels. The determination of efficient modes organization of the same hierarchy level parts and various levels parts intercommunication and interaction;
- **technological information unity**. The technological facilities monitoring results serve as the base both for technical-economical tasks solving for technological control of the production cycle as a whole and for technological control (regulation processes parametric optimization, EE balances and technical-economical equipment work indices accountings etc.);
- **integrated ACS efficiency increase**. The increase in comparison with overall effectiveness of free-running ACS.

For principle maintenance it is necessary to ensure the compatibility of integrated ACS hardware, software and informational ensuring. The essence of the method of EE ACS compatibility and integration ensuring is in subsequent implementation of following stages.

At the first stage the functional integration is conducted and following characteristics are ensured:

- **system functioning local aims unity ensuring** via FIE EECACSS functioning aim determination is EE transmission effectiveness, division and consumption improvement due to electric grid and EE consumers work modes optimization, EEQI normalization, reliability ensuring of EE supply in emergency mode with the help of relay protection and automation (RPA) and measuring reliability;
- **generic functional structure synthesis of the whole system, its decomposition into components** via control system hierarchical structure development for FIE EE supply and consumption automation including its structure and topology, power sources amount, shop transforming substations amount, transforming substations automation degree, information transmission channel-forming apparatuses use. Separation in the structure of following subsystems: EE accounting and consumption control subsystem, EE supply control subsystem, EEQI control subsystem, RPA subsystem;
- **setting for each component the effectiveness criterion as well as functioning model, data processing procedure, also functional and informational connections between components** with the help of efficiency criterion determination: for EE consumption accounting and control subsystem it is measuring reliability, EE consumers optimal composition and work modes; for EE supply control subsystem it is optimal configuration and optimal working configuration levels of distribution and shop grids; EEQI control subsystem it is optimal amount of EEQI improvement facilities; for RPA subsystem it is EE supply ensuring in emergency modes. The communication channels and communication grid choose. Functions and criteria effectiveness concordance of all components.

At the second stage the informational integration is conducted and following characteristics are ensured:

unified approach development to the information collection, transmission, saving and use of the EE consumption, supply and EEQI control object at all hierarchical levels of FIE EECACSS, what is ensured via system development of effective central DB organization and, which unify functioning of following subsystems: EE accounting and consumption control subsystem, EE supply control subsystem, EEQI control subsystem, RPA subsystem. The ensuring of interdependent information circulation between system components.

At the third stage the software integration is conducted and following characteristics are ensured:

software tools common functioning ensuring, that are used for tasks solving of EE resources monitoring and control as well as EE supply in standard and emergency modes, what is ensured via program development for automated work place:

a – EE supply automation program module in standard modes;
b – EEQI monitoring module;
c – EE consumption monitoring module;
d – EE supply automation module in emergency modes;
e – EE supply system configuration change module.

At the fourth stage the technical integration is conducted and following characteristics are ensured:

computing techniques tools, sensors, basic automation and local computing grids tools unify, that allows to conduct the automated implementation of all integration kinds under conditions of devided information processing, which is ensured via: communication channels, informational grids of all subsystems and local EE supply automation systems unify; unified exchange protocols use; software development, that are based on the identification and adaptation of EE consumption, supply and EEQI control systems simulated models to their originals with the subsequent determination of optimal regulators settings parameters.

At the fifth stage the experimental method effectiveness estimation according to common criteria is conducted and following characteristics are ensured:

effect determination, that is gained as a result of ACSs common and coordinated functioning, what is reached via determination at the economical effectiveness integration development stage by dint of rate per one FIE shop transforming substation unit. According to main FIE EE transmission, distribution and consume parameters of integration comparison results for the same period last year: EE consumption and wastes determination, capacity wastes, consumed EE costs and fines.

Organizational-technical ensuring of FIE EE consumption and supply control

For FIE EECACSS development let us implement modern information technology. The analysis of ACSs development has shown, that FIE EE consumption control is advisable to implement on the base of common operational system and not on the base of real-time operating system, because FIE EECACSS includes the big amount of «background» tasks, that are not combined hard with the decision-making time: EE balance accounting tasks, FIE EE consumption normalization and scheduling tasks and other tasks. Function, which are combined with information collection and its primary processing, as a rule, are implemented by programmed logical controllers. They are programmatically compatible with the MS Windows platform and are situated on the control centers. Information received from them is inserted into PC.

For FIE EECACSS development is used informational data model, which is developed according to object directed principle, that means that all EE consumption and supply objects, which are control objects, are described by sever objects in the model.

Control objects description in the model is implemented in three stages:

- type development, which determines the object description structure;
- hierarchy element development, correspondingly the object type; the hierarchy element determines the object place of this type in the control objects common structure;
- the object copy of this type is developed, what determines the description elements meaning of the certain object. For the same object type can be create optional hierarchy elements amount and copies.

As the base for data model development is used CIM (Common Information Model), the common informational model, IEC standard 61968, 61970).

Advantages of CIM-model use:

- objects description unification;
- software integration of various producers within the bounds of FIE;
- CIM-scheme portability between the applications.

Let us examine the data model at the level of applied and calculated tasks. At the level of applied and calculated tasks are presented aggregated, processed according to special algorithms data and information. During this information analyzing, it can driven a conclusion about EE supply system work reliability and efficiency. This level has to unify following programs:

- EE resources programs;
- FIE EE supply and consumption modes optimal control programs;
- FIE EEQI control programs.

Thus the offered approach to FIE EECACSS development, which consist of multilevel control system organization taking into account the EE supply hierarchal system structure, local and centralized control systems and energy efficient intellectual control algorithms use and ensures the reach of high efficiency functioning of EE supply system and EE consumption modes.

Conclusion

The FIE EE consumption and supply system analysis on the base of the control process decomposition allows to determine the main control process stages; control functions conditions ensuring; basic informational flows, that ensure EE consumption and supply control as well as organizational-technical control function implementation mechanisms. The FIE EECACSS synthesis is conducted with the use of the compatibility and integration method, what allows to ensure functional, informational, program hardware technical integration, experimental method effectiveness estimation according to common criteria. For the FIE EECACSS development is used the informational data model, which is developed according to the object directed principle with the use of informational CIM-model.

References

1. Mirzoian Iu. T. (2000), Programmnoe obespechenie KTS «Energomera», *Energetik*, 8, pp. 42–44.
2. Kapitonova B. Tuganov V. Satarov L. (1996), Territorialno-raspredelennaia avtomatizirovannaia sistema ucheta i kontrolia elektropotrebleniia, *Sovremennye tekhnologii avtomatizatsii*, 1, pp. 78–80.
3. Bulaev Iu.V., Tabakov V.A., Eskin V.V. (2001), Kompleksnaia avtomatizatsiia energosnabzheniia predpriiatiia, *Promyshlennaia energetika*, 2, pp. 11–15.
4. Egorov V.A. (2001), ASKUE sovremennogo predpriiatiia, *Energetik*, 12, pp. 41.
5. Kovezev S. N., Urazov B.V., Chumakov V.V. (2001), Sozdanie ASKUE na baze IVK «Sprut», *Energetik*, 2, pp. 11–13.
6. Molokan E. (1996), Avtomatizatsiia ucheta energopotrebleniia, *Sovremennye tekhnologii avtomatizatsii*, 1, pp. 74–76.

7. Cheremisin M. M., Kholod A. V. (2012), Kompleksna avtomatyzatsiia enerhoobiektiv na bazi suchasnykh SCADA system, *Visnyk Vinnytskoho politekhnichnoho instytutu*, 3, pp. 128–131.
8. Prakhovnik A.V., Rozen V.P., Degtiarev V.V. (1985), *Energosberegaiushchie rezhimy elektrosnabzheniia gornodobyvaiushchikh predpriiatii*, Nedra, Moscow.
9. Rezchikov A.F., Ivashchenko V.A. (2008), Upravlenie eeektropotrebleniem promyshlennykh predpriiatii, Saratov.
10. Zamulko Anatoly, Veremiichuk Yurii (2014), Methods of controlling power consumption in terms of reforming market conditions, *Scientific Journal of Riga Technical University Power and Electrical Engineering*, 32, pp. 41–45.
11. Auffhammer M., Blumstein C. (2007), *Demand-Side management and Energy Efficiency revisited*, Berkeley.
12. Steimle W., W. Thoma, Wille-Haussmann B. (2006), Intelligent Energy Management in Low Voltage Grids with Distributed Resources, *IEEE Transactions on Power Systems*, pp.125–135.
13. Choi J.H., Kim J.C. (2001), Advanced voltage regulation method of power distribution systems interconnected with dispersed storage and generation systems (revised); *IEEE Transactions on Power Delivery*, 16(2), pp. 329–334.
14. Liu Y., Zhang P., Qiu X. (2000), Optimal reactive power and voltage control for radial distribution systems, *IEEE Power Engineering Society Summer Meeting*, pp. 85–90.
15. Wasiak M., Thoma C., Foote R., Mienski R., Pawelek P., Gburczyk G., Burt A., Morini (2006), *A Power Quality Management Algorithm for Low Voltage Grids with Distributed Resources*, IEEE Transactions on Power Delivery.
16. Lopes M.A.R., Antunes C.H., Martins N. (2012), Energy behaviours as promoters of energy efficiency: A 21st century review, *Renewable and Sustainable Energy Reviews*, 16(6), pp. 4095–4104.
17. Ralf Martin, Mirabelle Muûls, Laure B. de Preux, Ulrich J. Wagner (2012), Anatomy of a paradox: Management practices, organizational structure and energy efficiency, *Journal of Environmental Economics and Management*, 63(2), pp. 208–223
18. Lässig J., Riesner W. (2012), Energy efficiency benchmark for industrial SME, *Smart Grid Technology, Economics and Policies (SG-TEP), 2012 International Conference*, pp. 1–4.

Optimization of external power delivering system of object by mechanical influence on the work of power line wires

Volodymyr Shesterenko, Oleg Mashchenko, Volodymyr Romaniuk

National University of Food Technologies, Kyiv, Ukraine

Keywords:

Overhead
Power
Line
Wire
Sag
Voltage

Article history:

Received 10.12.2017
Received in revised form 04.03.2018
Accepted 29.06.2018

Corresponding author:

Volodymyr Shesterenko
E-mail: shest.iren.co@ukr.net

Abstract

Introduction. The work is devoted to the research of methods of decreasing the sag of the power lines wires using thermo-compensating devices. In this work will be reviewed types and structure of active thermal compensating devices.

Research and methods. Mathematical models that characterize the work of power line wires were used.

Results and discussion. Proven, that compensation of power line wires sag by using active thermal compensation devices, that are made of alloy with "shape memory effect" (SMA) creates conditions under which it is possible either to increase spans, or to reduce the height of the transmission towers, while preserving the existing estimated spans.

In the industrial applications, it is necessary not only to calculate the mechanical response of the actuator in terms of recovery force or deformation, but also to evaluate its temporal characteristics, i.e., the actuation and reset times.

Compensation devices in the most general form are elements of force action mechanically connected with wires and they have a force influence on wires.

The advantage of active thermal compensation devices of power line arc of sagging over existing inventions was shown.

Conclusions. Scientific novelty of this work consists in research of influence of active thermal compensation devices on work of overhead power line wire.

DOI:
10.24263/2310-1008-2018-6-1-15

Introduction

An analysis of structural costs for the construction of power lines shows that the cost of installation and assembling them is 20–35% and the remaining 80–65% are spent on towers, towers bases, insulation, grounding [1]. Therefore, one of the promising directions for solving the problem is compensation of the temperature sagging of wires and wire ropes of overhead power lines, which allows to increase spans without changing the height of the hanging wire[6].

It is known that the main limitation in choosing the maximum spans is the permissible approach distance of the wires to the ground or to the engineering structure which is intersected. Spans are determined for the case of maximum ambient temperatures. The permissible approach distance of the wires should be less than the difference between the height of the suspension of the lower wires of the power lines and their extreme sagging in the span. With existing fastening of wires on towers, there is a reverse dependence [3] between temperature extension and tension in wires. It follows that in the presence of devices that increase the tension in the wires at maximum temperatures, the compensation of the temperature sagging of power lines wires is realized. Compensation of power line sag creates conditions under which it is possible either to increase spans, or to reduce the height of the transmission towers, while preserving the existing estimated spans. As a result, the specific consumption of the towers, linear fittings, insulation is reduced, and the time for construction of the power lines is reduced also [6].

Materials and methods

It should be noted that the main function of such methods and devices is to reduce tension in the wires of power lines in the event of an overload (hoarfrost) for the purpose of preventing wires from breaking, reducing the probability of crossing the wires in strong winds, fighting hoarfrost, fighting vibration of wires [9].

Shape memory alloys (SMA), because of their unique mechanical characteristics and shape memory effect (SME), have been widely used as force and displacement actuators in many fields. In the industrial applications, it is necessary not only to calculate the mechanical response of the actuator in terms of recovery force or deformation, but also to evaluate its temporal characteristics, i.e., the actuation and reset times [9].

Compensation devices in the most general form are elements of force action mechanically connected with wires and they have a force influence [7] on wires. However, to some extent compensation of the temperature arc of sagging can also be achieved by optimizing the location of towers and wires on towers.

Ways of wires sag compensation can be divided by the duration of influence to the wire on power line: continuous; periodic; one-time impact.

By the nature of the working element, the compensation devices can be divided into: load type, spring type (with compression springs, stretching springs); hydropneumatic; jumper compensators; combined [6].

By the way of connecting a working element with a power line wire, the compensation devices can be divided into those that have a connection to the power line through the insulating element and those that have a direct connection to the conductor. This paper presents the fundamental characteristics of SMA and a complete design mathematical model of an active thermal compensator. It is shown, that compensation devices can react not only to tension in the wire, but also to the temperature of the conductors of the power lines (Patent of Ukraine for invention № 92091, H01R 11/00. – Patent of Ukraine № 10389, F 03G 7/06. Termopryvod/ Shesterenko V. Ye., Shesterenko O. V., Patent of Ukraine №14520, H01H 33/70).

Results and discussion

The purpose of this work is the development and research of multifunctional devices for compensating temperature arcs of sagging of power lines wires, optimization of their parameters, research of combined work of wires in spans with similar devices. The results of these studies can be applied to power lines of any voltage ratings [4].

The calculation and operation of such nodes of the directed load, which are the stretching and compression springs, are well studied. When reducing the tension in the wire, the spring is pulling the wire by reducing its length. With increasing tension in the wire, the spring increases [6]. This automatically adjusts the tension in the wire and the sag. This is how the node of the directed load which is located parallel to the wire of power line is functioning.

The analysis shows that, as a rule, for all the wires in the the estimated span is determined by the sagging of the wire (arc of sagging) at maximum temperatures.

When using identical transmission towers, the specific cost of construction of a power line depends on the number of towers per 1 km of the length of the line []. On the other hand, an increase in spans without replacement of wires is possible only to a certain magnitude, which can be increased by using the new designs of towers. Increasing the height of the towers causes disproportionate using of materials (metal, reinforced concrete, wood, etc.), which leads to an increase in specific value.

Given the fact that there is a reverse dependence between the temperature extension of the wires and the tension in the wires, compensation of the temperature arcs of sagging of the wires can be accomplished by increasing the tension in the wires at the maximum temperature.

At the same time, without breaking the restrictions, you can reduce the sag of wires, which allows either to increase the span, or to lower the height of the towers with existing spans [5].

Load type compensators are widely used in electric transport power lines. Because of them it is possible to minimize the arc of sagging of the contact wire [2].

The spring and hydropneumatic thermo-compensators are nodes of directed loads, which are mechanically connected to the power line wire.

Mechanical properties of nitinol. The thermal compensation of the arcs of sagging is implemented by the elements of force action, which are fastened to the wire and affect on it. Due to the fact that the material with a "shape memory effect" has a significant impact strength, a high endurance limit, easy to bend, dampens vibration, does not corrode even in seawater, does not oxidize when heated to a temperature of 880°K, does not crack under stress and is non-magnetic [1], from this material it is possible to make a power element in the form of a thread in the length of 1–8 m and to set it parallel to the segment of the wire in each span.

When the air temperature increases, the length of the wire increases. When the ambient temperature reaches the temperature of the start of the reverse martensitic transformation of the thermal compensator, it begins to pull the wire by changing its own length. With further increase in temperature, the wire continues to increase its length, and the thermal compensator – to decrease [6].

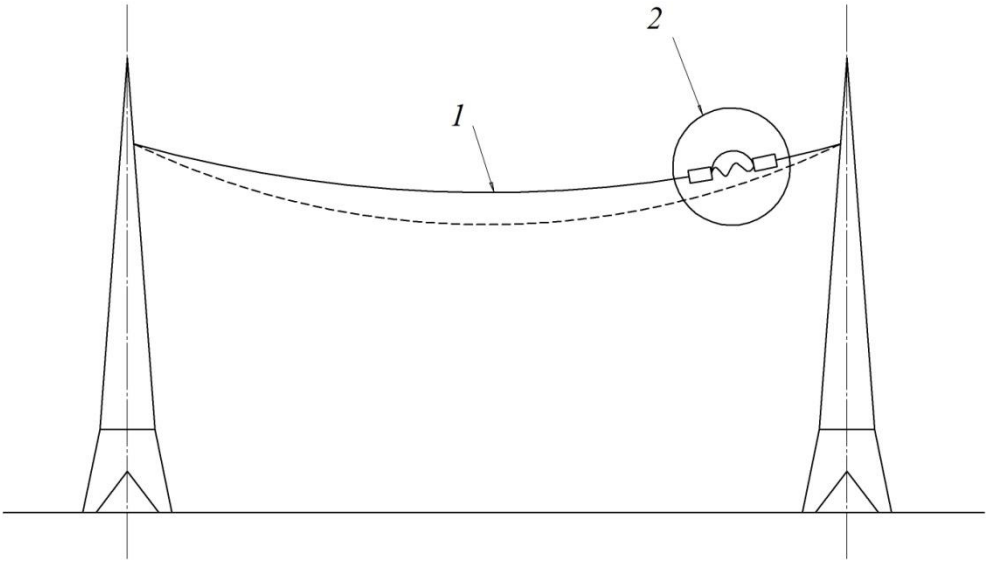


Figure 1. Principle of implementation of thermal compensation of wire sag on overhead power line

Using the unique properties of a material with a "shape memory effect", it is possible to have a zero or negative extension of the power line wire while temperature increases.

Figure1 schematically shows the span of the overhead power line with the thermal compensator that is made from the material with "shape memory effect".

Wire 1, secured in the span on the towers, has a temperature compensation unit 2 which consists of a thermosensitive element.

Work of thermal compensator on power line

The thermosensitive element at maximum temperature is compressed, the tension in the wire 1 increases and the sagging arc decreases (solid line of Figure1) in comparison to the arc without compensation (dashed line). If the temperature of the wire drops below the martensitic point (about 288°K), the thermosensitive element loses its rigidity and under the action of stretching aligns along the wire. With the next increase in temperature, the thermal compensator restores its shape.

The main requirement for the operation of the thermal compensator with "shape memory effect" is: the length of the section of the wire, parallel to which the thermal compensator attaches, shall be equal to the length of the thermal compensator in the unloaded state, increased by the magnitude of the maximum permissible deformation of the compensator in the area parallel to the wire, and the value of the maximum possible deformation of the thermal compensator shall be equal to the absolute elongation of the wire in the given temperature range [8].

The thermal compensator can connect two spans of the wire. The force which it perceives, is limited only by the horizontal component of tension in the wire, which allows to significantly reduce the cost of materials on the thermal compensator. In addition, such fastening of thermal compensator thanks to the flexible coupling of two adjacent spans of the wire, gives an opportunity to regulate the vibration of the wires. In this case, the energy of the fluctuation of a wire in one span is transmitted to adjacent spans and summed there with

the energy of oscillations of these spans. Since the energy transfer is carried out through a flexible compensator, the amplitude, frequency and phase of the oscillations change, and the summation of such oscillations leads to their weakening. Thus, the damping effect of the thermal compensators is similar to the action of vibration dampers [7].

Making wires or springs with zero or negative temperature extensions for a certain temperature range has become possible after the discovery of the unique property of some alloys to "memorize the shape" [6]. Most clearly this property is expressed in the alloy of nickel with titanium – nitinol. The alloy is heated to transition to a high-temperature modification and in this state it is given a certain shape. Then the alloy is transfered to another, low temperature phase. This phenomenon reminds the thermoelastic transformation. If after this the product from the alloy in the martensitic state is subjected to repeated plastic deformation and then heated back to the high-temperature modification, it will receive its original form, which was given to it at the first deformation in the state of high-temperature modification [1] due to the reverse martensitic transformation.

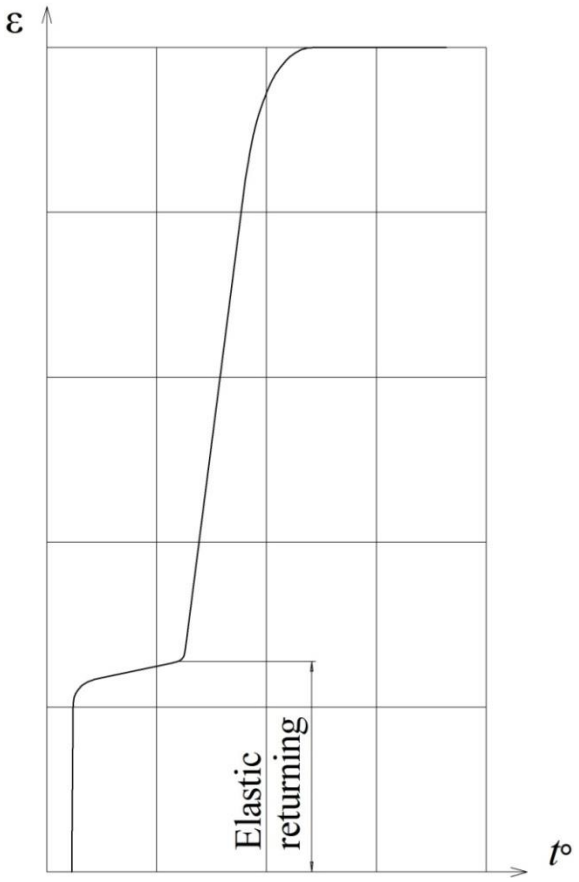


Figure 2. Stages of shape memory alloy returning to its original form

In order to reduce the arc of sagging of the wires at maximum temperatures and increase the estimated span in the overhead power line, which contains wires, fixed in the spans, at least part of the wire is made using a material with "shape memory effect".

Characteristic of the deformations of the thermal compensator that is made from the material with "shape memory effect" are shown in Figure2. The temperature of the start and end of the martensitic transformation, respectively $M_s \approx 282^{\circ}K$, $M_f \approx 278^{\circ}K$ and the start and end of the reverse martensitic transform, respectively $A_s \approx 285^{\circ}K$, $A_f \approx 306^{\circ}K$. The shape of the curve of dependence $\Delta l_к = f(t)$ is determined by the rate of heating and cooling.

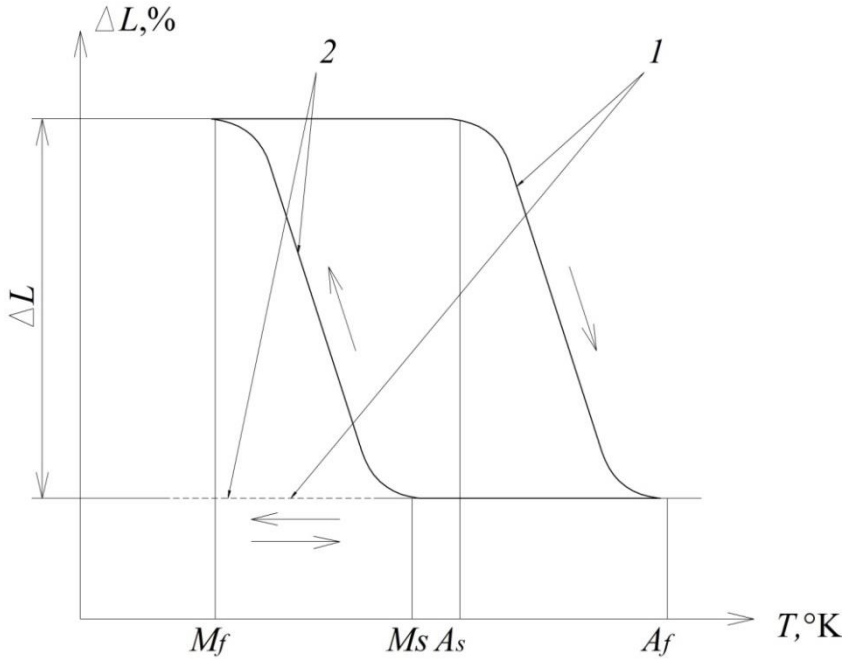


Figure 3. Dependence of deformation of an element with "shape memory effect" from its temperature:
1 – reverse transformation; 2 – direct transformation.

Hysteresis of shape memory alloys. On the magnitude of the hysteresis affects the composition of the material with "shape memory effect". Thermal compensator activation temperature depends on the load, i.e. working points of the same material are not stable and can move a few degrees [7].

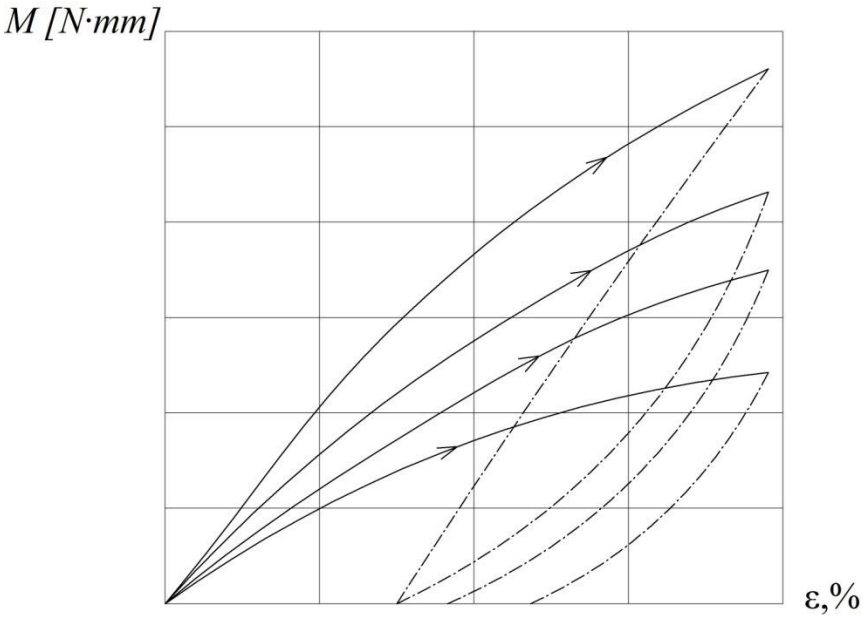


Figure 4. Dependence of deformation from applied load

When examining the joint operation of the wire and the thermal compensator, made of material with "shape memory effect", we will take into account the piecewise-linear approximation of the performance characteristics of the thermal compensator.

At the point A_f the thermal compensator completely restores its shape. The position of the wire with the thermal compensator is indicated by a solid line in Figure1.

With a decrease in temperature, the thermal compensator, due to the presence of hysteresis, continues to keep its shape (A_f-M_s).

Lowering the temperature to the start of a direct martensitic transformation (point M_s) causes deformation of the thermal compensator. Tension in the wire in the temperature range from the direct martensitic transformation (point M_s) to its end (point M_f) varies along the curve M_s – M_f. With further lowering of the temperature, the thermal compensator did not participate in the work of the wire, and the tension changes according to the natural characteristic.

In electrical grids, the dependence of the stresses in the wire that came from the load and the temperature is expressed by the equation of the state of the wire.

Analysis of mathematical models that characterize work of a wire with thermal compensator

Because of the fact that the characteristics of the thermal compensator are unambiguous, several equations are required to describe the operation of the wire with the thermo-compensator.

For a section of a characteristic of a material with "shape memory effect" $M_f \leq t \leq A_s$, where the thermal compensator does not significantly affect on the work of the wire, the

equation of the state of the wire does not differ from the equation without the thermal compensator:

$$\sigma - \frac{\nu^2 \cdot E \cdot l^2}{24 \cdot \sigma^2} = \sigma - \frac{\nu^2 \cdot E \cdot l^2}{24 \cdot \sigma_0^2} - \alpha \cdot E \cdot (t - t_0),$$

where ν_0 – the specific load of the wire in its initial state;
t_0 – the temperature in the initial state;
σ_0 – tension at the lower point in the initial state;
E – modulus of elasticity;
α – temperature coefficient of linear elongation of the wire material;
l – the length of the span;
ν,σ,t – Specific load, tension, and temperature in the final state.

At the section of the characteristic $A_s \leq t \leq A_f$ (Figure3) the thermal compensator activates and restores its shape.

The magnitude of the direct and reverse action of the shape memory alloy elements depends on the load (Figure 4).

This increases the tension in the wire and decreases the arc of sagging. Mathematical model of the state of the wire for the given range:

$$\sigma - \frac{\nu^2 \cdot E \cdot l^2}{24 \cdot \sigma^2} = \sigma_0 - \frac{\nu_0^2 \cdot E \cdot l^2}{24 \cdot \sigma_0^2} - \alpha \cdot E \cdot (t - t_0) - \frac{l_k \cdot \alpha_k \cdot E}{l} \cdot (t - A_s),$$

where α_k – temperature coefficient of elongation of the thermal compensator.

$$\alpha_k = \frac{\varepsilon}{100 \cdot \Delta t_\phi},$$

where ε – maximal elongation (compression) of the material with “shape memory effect”, %;

Δt_ϕ- temperature range of phase transformation.

Conclusions

1. Results of research data can be applied for power lines of any voltage ratings, with any transmission towers.
2. A material with “shape memory effect” can be used to optimize the power lines.
3. One of the promising directions for solving the problem of optimization of power lines is compensation of temperature sagging of overhead power line wires, which allows to increase spans without changing the height of the suspension of the wire.

References

1. Duerig T.W., Pelton A.R. (1994) "Ti-Ni shape memory alloys", in: *Materials Properties Handbook: Titanium Alloys*, Gerhard Welsch, Rodney Boyer, E.W. Collings (eds.), American Society for Metals, pp. 1035–1048.

2. Shesterenko V.Ye. (2011), *Systemy elektrospozhyvannia ta elektropostachannia promyslovykh pidpryiemstv*, Nova knyha, Vinnytsia.
3. Otsuka K., Wayman C.M. (1999), *Shape Memory Materials*, Cambridge University Press, p. 27.
4. Wilkes K.E., Liaw P.K. (2000), *The fatigue behavior of shape-memory alloys*, p.45.
5. Duerig T.W., Melton K.N., Stökel D., Wayman C.M. (1990), *Engineering aspects of shape memory alloys*, Butterworth-Heinemann Ltd, p. 207
6. Lihachev V.A., Kuzmin S.L., Kamentseva Z.P.(1987), Effekt pamyati formyi, LGU, Kyiv, p. 216.
7. Ootsuka K., Simidzu K., Sudzuki Yu. (1990), Splavyi s effektom pamyati formy, Metallurgiya, Moscow.
8. Kornilov I.I., Belousov O.V., Kachur E.V. (1977), Nikelid titana i drugie splavyi s effektom pamyati formyi, Nauka, Moscow.
9. István Mihalcz (2001), Fundamental characteristics and design method for nickel-titanium shape memory alloy**,** *Periodyka Polytechnic, Ser. Mech. Eng*., 45, 1, pp. 75–86.
10. Siryi O.M., Shesterenko V.Ye. (2003), *Rozrakhunky pry proektuvanni ta rekonstruktsii system elektropostachannia promyslovykh pidpryiemstv*, Kyiv.
11. Arrillaga J., Neville R.W. (2003), *Power System Harmonics*, Hoboken, Wiley.
12. Dulce Fernão Pires, Carlos Henggeler Antunes, António Gomes Martins (2012), NSGA-II with local search for a multi-objective reactive power compensation problem Original Research Article, *International Journal of Electrical Power & Energy Systems*, 43(1), pp. 313–324.
13. Shamtsyan M., Klepikov A. (2014), Some prospects of pulsed electric field treatment in food processing, *Journal of Food and Packaging Science, Technique and Technologies*, 2(1), pp. 60–64.
14. Shesterenko V., Izvolensky I., Mashchenko O., Shesterenko O. (2014), Optimization of power supply system at food production enterprises, *Ukrainian Journal of Food Science*, 2(1), pp. 97–105.
15. Shesterenko V., Mashchenko O., Shesterenko O. (2015), Problem of increasing the power factor in industrial enterprises, *Ukrainian food journal*, 4(1), pp.134–144.

Improving of informative and operating system of the power industry of food enterprises based on intellectualization the process of the decision making

Alina Siryk, Olga Yevtushenko

National University of Food Technologies, Kyiv, Ukraine

Keywords:
Labor
Intellectualization
Safety
Power

Article history:

Received 24.04.2018
Received in revised form 02.05.2018
Accepted 29.06.2018

Corresponding author:

Alina Siryk
E-mail: alsok3030@gmail.com

DOI:
10.24263/2310-1008-2018-6-1-16

Abstract

Introduction. The improving of information and management system of the modern power enterprises of the food industry through the introduction of multiagent technologies that will allow to leader of power enterprise effectively use different sets of events within the total set of legal documents to improve the level of safety of labor.

Materials and methods. The research was conducted based on general system approach, grounded on interconnection of elements intelligent agent, information object, method of mathematical modeling.

Results and discussion. The process of intellectualization is proposed carry out based on introduction of multi-agent technologies that will allow to the leader of power enterprises effectively use different sets of events within the overall set of legal and regulatory documents to increase the level the safety of work. In addition, the increased efficiency of functioning the information and operating system of management the safety of work in the food industry, to allow determine the optimal set of events for labor safety, and this makes it possible to achieve improving the labor safety. It is showing the curtailment of time on solve the tasks of management the level of labor safety in a changing information environment, especially during the peak of load in the energy sector of the food industry. The results of mathematical modeling which based on using of multi-agent technologies in information and operating system of management the labor safety achieved improving labor safety in the energy sector of the food industry on 12–18%.

Conclusion. The main research results are recommended for use on enterprises of the food industry to reduce the risk of an offensive extraordinary situation in the energy industry of food enterprises industry to a level that meets acceptable risk, at the expense of choice the optimal set of measures for ensuring labor safety.

Introduction

In modern conditions of market business in Ukraine creating, reconstructing and operating a large number of enterprises of food industry that operate industrial power installs. Among the objects that operated, occupy a significant amount those installs, that were built and began to work in the last century with the consideration of requirements and technologies of that time. This is one of the factors that degrade the state of labor protection on enterprises.

Analysis of the modern economic situation in the food industry, including the energy sector, allow to make a conclusion about the presence of a crisis, primarily due to the presence of the investment deficit is practically blocked the process of renewal of the primary funds. The result of this is the abrupt fall of technological, production, labor discipline, which in turn significantly effect on the level of the safety of work.

Production in the food industry associated with the consumption of large amounts of electricity, fuel and other energy (steam, compressed air, hot water) and providing of communication systems. In the food industry the part of consumed energy in the production cost is about 30%. Normal functioning of industrial system of the enterprise depends on timely supply of energy resources by their types and in a certain amount.

At the enterprises of food industry, a large number of factors that are interconnected and conditionality effect on the level of injury. Therefore, organizational structure of the providing the labor protection should be enough to prompt and consider all production factors, timely detection, do accounting of their, analysis and estimation and shut out traumatic situations. However, the system of energy sector is to expanded. Therefore, timely communication between the leader and departments is rather difficult.

In the modern conditions of business, that characterized by an extremely difficult situation in the country, the question of safety of the production processes in the field of labor protection take on particular topicality as in the conditions of a low funding it promotes the searching and rational use the ways of decrease the level of production injuries. Great contribution to the solution of these problems made domestic and foreign scientists: O.I. Amosha, R. Anderson, P. V. Beresnyevych, B.O. Bilinsky, Y.F. Bulgakov, G. Vylde, A.O. Vodyanyk, A.R.Hale, V. A. Glyva, H.H.Gogytashvili, V.I. Holinko, A.O. Gurin, O.I. Zaporozhets, W. Kelen, F.S. Klebanov, V.I. Kozlov, O. E. Kruzhylko, O.E. Lapshyn, O.G. Levchenko, G.V. Lesenko, M.O. Lysyuk, I.A. Luchko, N.A. Prahovnik, I. M. Podobed, A. Rayf, N.V. Stupnytska, K.N. Tkachuk, A.M. Feber, M.I. Shvydkyi. In particular, in [1] proposed a new system of the creation documentations for management systems of information security, that display features, that characteristic the system of management of information safety of the organization. In [2] improved the evaluating of effectiveness of management decisions under conditions of operation information-analytical systems based on uses the indicators of executive discipline, quality and effectiveness of realization of management decisions. The problems of perfection the system of management by labor protection on enterprises explored in the works of such authors as Shulga Y.I. Sukach S.V. [3], G.G. Gogitashvili G.G. [4], Lesenko G.G. [5], Sergienko M.I. [6], Romanchuk A.A. [7].

However, in the presents of a large number of scientific sources that consider the questions of the organization of safety and prevention injury in various industries today all these events are planning and implementing based on subjective opinion of leader considering on the economic opportunities (not decrease profits) and considering requirements of the regulatory framework. Considering the state of labor protection [8] carried out on the results of the consequences of injuries [9, 10] and occupational diseases of workers. In the background stays the task of neutralization the dangerous and harmful factors.

One of the promising areas of research is the introduction of intellectualization of the process the decisions making based on the total amount of information. Only such decisions allow to produce the optimal set of events to providing the labor protection.

The process of improving the functioning the system of management the labor protection (SMLP) requires the rational organization and a coherent interaction between the leader of power manage and heads of all structural units, and effective interaction with industry, accordingly to state agencies and the implementation of all regulations.

Today on the forefront of science researches put the task of raising the level of intelligence of specialized control systems, which stems from the limitations of traditional informational approach. Within the general concept of construction, the information and management system of the power enterprise of food industry formulated agent-oriented approach to intellectual interaction of components.

Intelligent Agent (IA) – a program or hardware object that operates autonomously to achieve the aims set in front of it by the owner or the user that has certain intellectual abilities.

Materials and methods

Despite of number important works [8, 9, 10] in the field of building integrated intellectual systems, the task of creating methods of designing intellectual information and management systems for such complex objects, the energy sector is not resolved. Require further research and development such questions as: the development object of the model of information and control system the energy sector of the food industry, which would include the base of a framework regulations in the field of safety of work; build a model intelligent agent for information and control system the energy sector of the food industry; build a model of finding a solution on the selection of total events [11] to raise the level of safety of the work in the energy sector of the food industry. Development of the methods for storage and search of regulatory and legal framework in the information and management system the energy sector of the food industry.

The mathematical model of the information object of intellectual information-analytical management system of the energy divisions for the food industry plants was developed that also includes an ability to update the database of labor laws.

The mathematical model of intellectual agent was created, as part of intellectual information-analytical management system of labor protection of the energy divisions for the food industry plants, which also includes parameters of harmful and dangerous factors of production flows.

In the work the topology and methodology of constructing an intellectual information and analytical system management of labor protection of the energy divisions for the food industry plants was developed and brought to practical implementation of architecture.

Results and discussions

In general, the model of information and control system the energy sector of the food industry can be represented as follows (Figure 1).

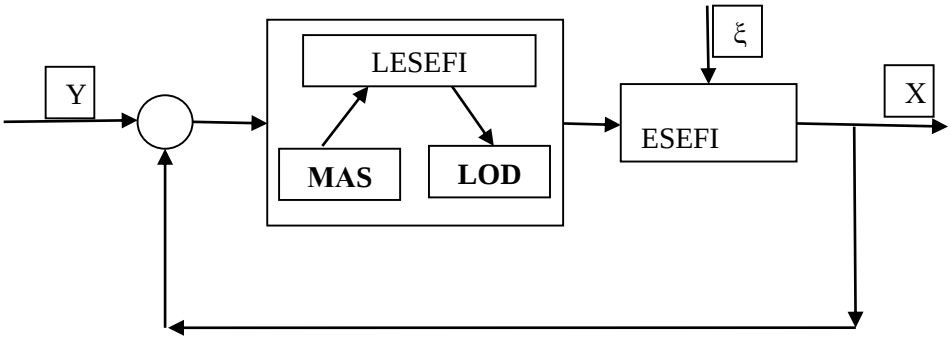


Figure 1. The general model of the information and control system the energy sector of the food industry:
Y – the vector of the regulatory and legal base; LESEFI –the leader of energy sector of the enterprises food industry; MAS – the multi-agent system; LOD – the leaders of official departments; ξ – the destabilizing factors; X – the vector of the state the safety of work in the energy sector of food industry.

The task of rise the safety of work in the energy sector of the food industry using multi-agent technologies in a formalized form it can be defined as

$$L(SW) \rightarrow \max,$$

where L(SW) – the level of the safety of work in the energy sector of the food industry, the imposition of limitation on value of the events

$$C \leq C_h.$$

An essential basis for formalization intelligent components of the information and control systems the energy sector, shown in Figure 1, is a model of information object (IO)

Information object propose to define as follows:

$$O: = <N_O,\{A\},\{O\},\{F\},\{L\}>$$

where N_O – the name of object; $\{A\}$ – *the* set of object attributes $(A_0,...,A_n)$, A_i – i-th attribute IO; $\{O\}$ – the set of objects, which structurally include in the object, ($O_{NO_1}, O_{NO_2},...,O_{NO_m}$), де O_{NO_i} i-th subordinated object, the object with name N_O; {F} – set of functions which implement this IO, {L} –the set of regulations, from which select the optimum set of recommendations.

The attribute of IO defined as:

$$\boldsymbol{A} = <\boldsymbol{N}_A, S_A, V_A>$$

where N_A – the name of attribute, S_A – the set, in which define the meaning of attribute, V_A – the meaning of attribute, namely $\alpha \in S_A$ at this time t.

Based on analysis of the characteristics and imperfections of the known models of intelligent agents (IA) IA proposes that the structure of IA look like:

$$IA = <N_{IA}, S_A, V_{IA}, M_{VB}, V_O>,$$

where, N_{IA} –the name of intelligent agent; S_A –the structure of attributes, which defined similar to structure of attributes for information objects (IO); $V_{IA} = \{IA\}$ – the sets of invested IA; M_{VB} –the mechanism of choice the model of operation the regulatory and legal base $VO = \{O\}$ – the set of information objects that implement the screenplays of work the IA.

The intelligent agent based on criterions the choice of model the functioning, founded in the M_{VB}, make a decision about the realization at this time some of the screenplay of work and initializes the appropriate IO. The information space of intelligent agent is defined as a set of IO and IA that surround IA_i and interact with it, where

$$AR^i_{IA} = (N_{IAj}, A^{\xi}_{IA_j}, ..., A^{\psi}_{IA_j}, N_{IAI}, A^{\xi}_{IA_I}, ..., A^{\psi}_{IA_I}),$$
$$AR^i_{IO} = (N_{IOj}, A^{\xi}_{IO_j}, ..., A^{\psi}_{IO_j}, N_{IOI}, A^{\xi}_{IO_I}, ..., A^{\psi}_{IO_I}).$$

The model of choice the behavior of AI may be present: M_{VB} = (MIS, MG, MSR, MA), where MIS – the model of information environment, MG – the model of defining the aim, MSR – model of finding a solution considering the regulatory and legal framework, MA – the model of active action.

The model of defining the aim is constructed so:

$$MG_{IA_i} = (SS_{IA_i}, FSS_{IA_i}, GS_{IA_i}, G^{top}_{IA_i}, G^{down}_{IA_i}, FG^{D}_{IA_i}, FG^{S}_{IA_i}, FAG_{IA_i}, SMA_{IA_i}(t)).$$

Here SS – the set of strategies, that understand as methods for selecting aims $SS = (S_i \,|\, i = 1, ..., n)$, FSS – the function of choice the strategy; GS – the set of static aims, . G^{top}. –the set aims that get from this IA from agents a higher level of hierarchy, G^{down} – the set of the aims that can be transferred to IA of lower levels; FG^D – the function of forming the dynamic aims FG^S – the function of choice the static aims; FAG –the function of choice the active aims, scilicet aims that accept to realization; SMA – the state of the multi-agent environment.

Under the search decisions should understand the finding of way to achieving the aim or aims given from IA in the current state of MA-environment (Figure2). Because different structural departments of the energy sector of the food industry has its own specific including at making a decision, it is hardly possible to use some universal method of searching a decision for all subsystems of IOS.

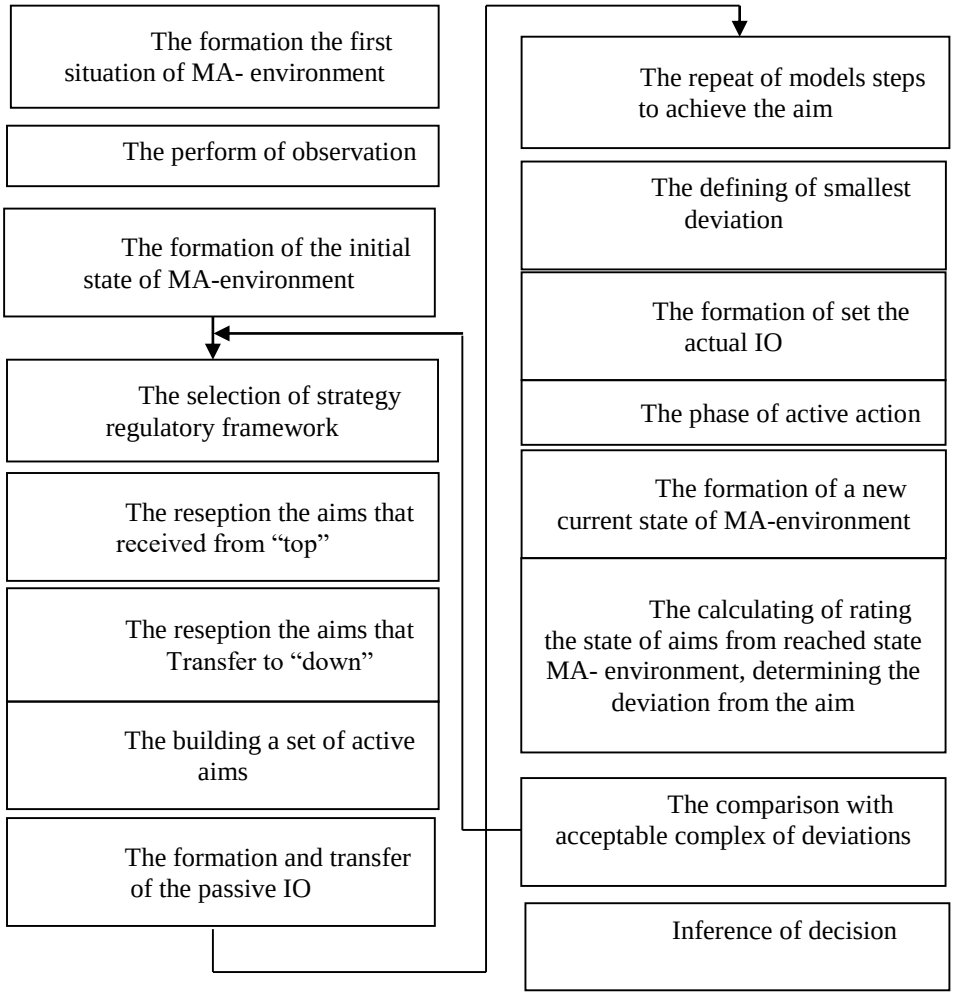


Figure 2. Algorithm for finding a solution by intelligent agent

In the proposed model IA, the following type of search solution. We think that the IA has a certain set of static aims $GS = \{gs^i \,|\, i = 1,...,n\}$. Here each IO cover some plan. Known ways to achieve the aims scilicet are built information objects . $(IO^i \,|\, i = 1,...,n)$., the operation of which should lead to gs^i . Here each IO cover some plan. Inside this plan, that is in behavior IO, can be formed arbitrary messages and arbitrary sequences of actions.

Then the model of finding a solution given the function of finding a solution $SR : GS \to VO$, where VO – a set of invested IO of i-th IA. This image is synonymous, but not mutually, because maybe, that some aims are achieved by the same IO. The model of active actions determined by image $AD : GA \to VO$, which chose necessary for launching in the current time of IO.

The constructed model of finding a solution in a model of IA allows to describe such known classes models of realization behavior as a model with conditioned ending set of elementary actions; model with the set of plans; model with random messages and actions. On the base of this model can be created the new models of behavior the IA, that combine the mechanisms of different classes.

Based on designed methodology of searching a solution about the choice of totality of events to increase the level of safety the work [14], implemented the estimation of using of IOS on the example of the work the leader of the energy sector of the food industry.

The evaluation of the efficiency of work the information and management systems of energy sector the enterprises of the food industry considered on the example of the analysis of the algorithm of the head's activity of the energy sector in relation to the task of selecting the totality of events to increase the safety of work. The essence of the task is consist in choice the optimal set of tools to increase the level of the safety of work. For this task were divided into elementary operations (total 12 operations) and logical terms (3 conditions). Quantitative

characteristics (number of detected violations from safety of work per year, the number of staff's injuries per year, the number of days of sick leaves per year, the time of basic operation, time dispersion of basic operation and the probability of error-free implementation) are taken from statistical data [12, 13].

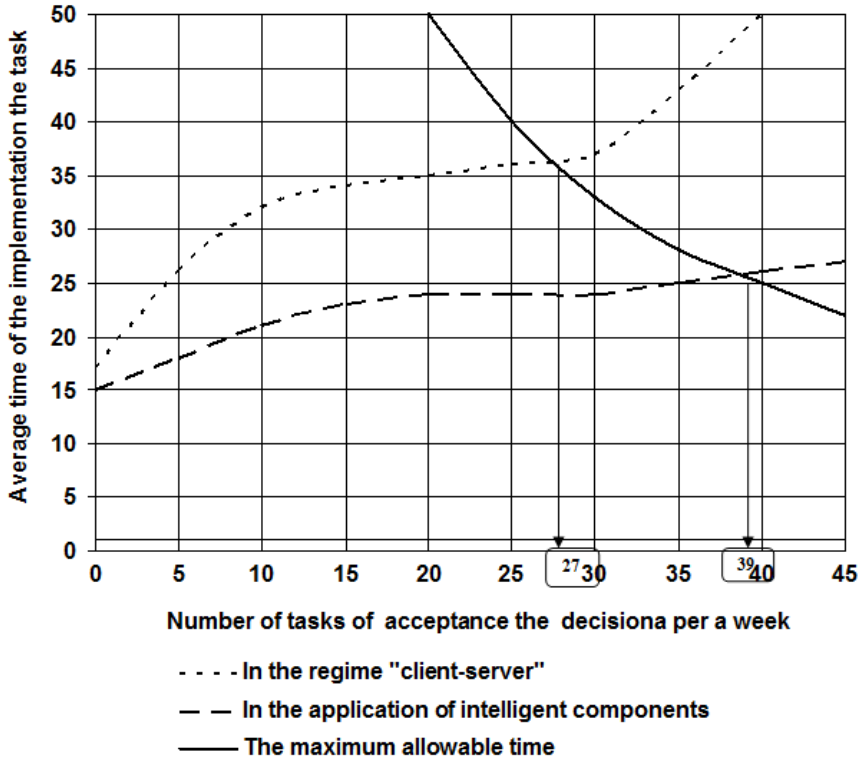


Figure 3. The dependence of the average time to make a decision from the number of tasks decision-making tasks per week

On the graph (Figure 3) shows the average time for decisions by leader of the energy sector based on around-the-clock character of activity providing staff. As can be seen from the graphs, using intellectual IOS gives a essential advantage in solution the tasks of the choice the set of events to increase the level the safety of work, however, due that the average time on perform one solution in intellectualization system is less, the total number of decisions per week increases.

Solving the converse task about to definition the probability of faultless decision-making at a fixed time to solve management problems can also determine the effectiveness and feasibility of the introduction of intellectualization of information and operating system of the energy sector of the food industry. Thus, the rise of efficiency when using the same initial data will be 12 – 18%.

Conclusions

In this work it is shown as possible to improve the information and operating system of the modern energy enterprises of the food industry by intellectualization of the process of the decision-making based on the received amount of information. This process of intellectualization is proposed carry out based on introduction of multi-agent technologies that will allow to the leader of power enterprises effectively use different sets of events within the overall set of legal and regulatory documents to increase the level the safety of work. In addition, the increased efficiency of functioning the information and operating system of management the safety of work in the food industry, to allow determine the optimal set of events for labor safety, and this makes it possible to achieve improving the labor safety. It is showing the curtailment of time on solve the tasks of management the level of labor safety in a changing information environment, especially during the peak of load in the energy sector of the food industry. The results of mathematical modeling which based on using of multi-agent technologies in information and operating system of management the labor safety achieved improving labor safety in the energy sector of the food industry on 12–18%.

References

1. Kozhedub Yu.V. (2015), Stvorennia dokumentatsii dlia system upravlinnia informatsiinoiu bezpekoiu, *Information Technology and Security*, 3(5), pp. 95–100.
2. Kruzhylko O.Ye., Maistrenko V.V., Demchuk H.V. (2015), Otsinka efektyvnosti upravlinskykh rishen u sferi okhorony pratsi, *Problemy okhorony pratsi v Ukraini*, 29, pp. 3–9.
3. Shulha Yu.I., Sukach S.V., Kobylianskyi M.A., Velychko O.L., Mozghovoi O.V. (2012), Avtomatyzovanyi kontrol system bezpeky pratsi ta zhyttiezabezpechennia, *Problemy okhorony pratsi v Ukraini*, 22, pp. 16–26.
4. Hohitashvili H.H. (2002), Systemy upravlinnia okhoronoiu pratsi, *Afisha*, p. 320.
5. Lesenko H.H. (2003), Rozrobka ta vprovadzhennia SUOP na pidpryiemstvi, *Okhorona pratsi*, 6, pp. 36–38.
6. Serhiienko M.I., Bakhtina Ye.A. (2012), Pidvyshchennia okhorony pratsi tkatskoho vyrobnytstva za rakhunok vprovadzhennia novykh system kondytsiiuvannia zi zvo-lozhenym povitriam, *Problemy okhorony pratsi v Ukraini*, 23, pp. 109–115.
7. Romanchuk A.A. (2010), Sistemnyi menedzhment okhrany truda na predpriiatii. *Modeli upravleniia*. *Chast 1*., Ilichevsk.

8. Kruzhilko Oleg, Bogdanova Olga (2016), Method of human factor minimization in expert judgement for occupational risk assessment and decision making, *Ukrainian Journal of Food Science*, 4(1), pp. 138–150.
9. Volodchenkova Nataliya, Hivrich Olexandr, Labzhynska Marharyta (2016), Evaluation of the working items of hotel-restaurant complex stability structures, *Ukrainian Journal of Food Science*, 4(1), pp. 151–158.
10. Kruzhylko O.Ye., Bohdanova O.V. (2016), Alhorytm pidhotovky upravlinskykh rishen na osnovi kombinovanoho metodu otsinky ryzyku vyrobnychoho travmatyzmu, *Naukovi pratsi Natsionalnoho universytetu kharchovykh tekhnolohii*, 3(22), pp.140–149.
11. Horlova T.M. (2017), Pryiniattia upravlinskykh rishen u korporatyvnykh systemakh, *Naukovi pratsi Natsionalnoho universytetu kharchovykh tekhnolohii*, 23(2), pp.16–22.
12. Karmazina O.O. (2016), *Statystychnyi biuleten. Travmatyzm na vyrobnytstvi u 2015 rotsi*, Derzhkomstat Ukrainy, p. 124.
13. Karmazina O.O. (2015), *Statystychnyi biuleten. Travmatyzm na vyrobnytstvi u 2014 rotsi*, Derzhkomstat Ukrainy, p. 123.
14. Anderson W. E. (2005), Risk Analysis Methodology Applied to Industrial Machine Development. *Industry Applications, IEEE Transactions on*, 41(1), pp. 180–187.

Анотації

Харчові технології

Удосконалення технології варених ковбас з використанням білково-мінерально-вуглеводної добавки

Людмила Пешук, Олександр Горбач, Олег Галенко
Національний університет харчових технологій, Київ, Україна

Вступ. Проведені дослідження з метою визначення впливу додавання хітозану до м'ясного продукту з механічно відокремленим м'ясом птиці.

Матеріали і методи. Досліджується технологія ковбас із додаванням до складу м'яса птиці механічного обвалювання, концентрату сироваткового білка, білка соєвого гідратованого, тваринного білка, сироваткового білка і білково-мінерально-вуглеводної добавки. Визначення амінокислотного складу проводили відповідно до методу іонообмінної хроматографії.

Результати і обговорення. Варена ковбаса з білково-мінерально-вуглеводною добавкою має вищі споживчі властивості у порівнянні з контрольними зразками.

Вологоутримувальна здатність фаршевих систем, до складу яких було внесено хітозан, білок соєвий, білок тваринний, білок сироватковий, білково-мінерально-вуглеводну добавку, зростає на 10–15%, що збільшує вихід готового продукту та спланувати його властивості після завершення технологічних процесів.

Введення білково-мінерально-вуглеводної добавки в кількості 10% у гідратованому стані позитивно впливає на технологічні властивості фаршу утримувати вологу, жир у процесі термообробки, що важливо при використанні в технології саме варених ковбасних виробів.

Готові ковбаси мають збалансований амінокислотний склад, якщо порівняти з контролем. У варених сосисках спостерігаються більш високі рівні валіну (0,8%), лізину (на 0,91%), метіоніну (на 0,10%), треоніну (на 0,54%), аланіну (на 0,54%), аспарагінової кислоти (до 0,65%) тагліцину (на 0,59%), якщопорівняти з контрольною пробою.

Висновки. Хітозан при взаємодії з будь-яким тваринним білком підвищує вологість готового продукту на 10–15%. Варена ковбаса з м'ясом птиці механічного дообвалювання та білково-мінерально-вуглеводною добавкою має добре збалансований склад, характеризується високими споживчими властивостями та може бути віднесена до повноцінних продуктів харчування за вмістом незамінних амінокислот.

Ключові слова: *білок, вуглеводи, м'ясо, ковбаси, хітозан.*

Фізичні характеристики функціонального печива, збагаченого пластівцями ейнкорну

Іван Дімов[1], Вікторія Стомановска[2]
1 – Тракійський університет, Стара Загора, Болгрaрія
2 – Бітольський університет «Св. Климент Охридський», Бітола, Македонія

Вступ. Сучасні дослідження, пов'язані із споживанням функціональних продуктів, підверджують, що продукти із зерна ейнкорну мають фунціональні властивості та відіграють важливу роль у харчуванні людини.

Матеріали і методи. Для виготовлення печива були використані такі матеріали: зерно ейнкорну (Triticum monoccocum L.) та ейнкорнові пластівці. Виробництво печива, а також визначення їх фізичних властивостей (упікання та об'єм) проводили згідно з методами AACC 10-50D. Колір печива визначали спектральним методом із застосуванням тонометра, Livibont Tintometer RT 100 Colour.

Результати і обговорення. Під час випікання вода, присутня в утвореному тесті, випаровується, що надає печиву характерну структуру. Найбільші втрати під час випікання мало печиво, виготовлене із 100% борошна (15,16±1,01%), а найменші – з 100% пластівців (9,54±1,22%), з різницею між двома зразками – 5,62%.

Результати, отримані для упікання печива, виготовленого із 100% ейнкорнових пластів, є статистично значущими ($p < 0,05$).

Найбільший об'єм мало печиво, виготовлене із 100% ейнкорнового борошна (79,00±0,50 $см^3$).

Всі зразки печива мали кольори в зеленому та жовтому спектрах, а найсвітлішими були зразки, випечені із 100% ейнкорнових пластівців. Відмінності між окремими зразками були незначними.

Висновки. Збільшення кількості ейнкорнових пластівців, доданих до ейнкорнового борошна, призводить до незначного зниження втрат на упікання та об'єму випеченого печива, а також освітлює колір печива.

Ключові слова: *ейнкорн, пластівці, печиво, функціональність.*

Вплив цукрів на структурно-механічні характеристики гелів агарових полісахаридів

Антонелла Дорохович[1], Олена Гончарук[2], Дарія Матяс[1], Юлія Камбулова[1]
1 – Національний університет харчових технологій, Київ, Україна
2 – Інститут хімії поверхні ім. О.О. Чуйка НАН України, Київ, Україна

Вступ. Актуальним науковим завданням є встановлення відмінностей структурно-механічних характеристик гелів агару і к-каррагінану з різними видами цукрів (сахарозою, глюкозою, фруктозою, лактулозою).

Матеріали і методи. Структурно-механічні характеристики гелів агарових полісахаридів (агару, k-каррагінану) – модуль миттєвої пружності, модуль еластичності, пружну, еластичну та пластичну деформацію – досліджували методом тангенціального зміщення пластинки. У дослідженнях використані модельні системи гелів на агарі і k-каррагінані із сахарозою, глюкозою, фруктозою та лактулозою.

Результати і обговорення. Гелі агарових полісахаридів можуть витримувати різні максимальні навантаження залежно від виду цукру. Модуль миттєвої пружності має

найбільші значення в гелях із сахарозою як на агарі, так і на k-каррагінані, а значення модуля еластичності були вищими для гелів з моносахаридами. На нашу думку, відмінності пояснюються різницею в просторовій будові і молекулярній масі цукрів,що накладає відбиток на здатність зв'язувати ними воду, тобто гідратаційну здатність. Значення загальної деформації залежать від виду гелю: для агарових і k-каррагінанових гелів залежності з цукрами різні. Найбільше значення загальної деформації агарового гелю має зразок із сахарозою – 42,38 ум.од. Для к-каррагінанових гелів найбільше значення загальної деформації з моносахаридами. При цьому як на агарі, так і на k-каррагінані зразки з дисахаридом сахарозою мають більші значення показника пружної деформації, ніж сумарна кількість еластичної та пластичної деформацій. Проте, незалежно від полісахариду, використання глюкози й фруктози надає гелям еластичності і пластичності. Додавання лактулози в системи з агаровими полісахаридами призводить до зміцнення структури сформованого гелю, про що свідчать більші значення сили максимального навантаження на кожну систему.

Висновки. Встановлений індивідуальний вплив сахарози, глюкози, фруктози, лактулози на структурно-механічні характеристики гелів агару і k-каррагінану. Дисахариди в цілому обумовлюють більший модуль пружності, а моносахариди – модуль еластичності систем і збільшення сумарної частки еластичної та пластичної деформацій.

Ключові слова: *гель, агар, k-каррагінан, міцність.*

Копрова олія: хімічний склад, виробництво. Широкий огляд індійських характеристик та функціональних аспектів.

Г.В Паван Кумар, Н.В.В.С.С. Лаксхмі, Ч. Деена, В. Паван Кумар, П. Радженра Кумар
Корангський коледж фармації, Корангі, Індія

Вступ. Проведено аналітичний огляд з метою оцінити хімічні та терапевтичні переваги кокосової (також відомої як копрової) олії.

Матеріали і методи. Огляд базується на аналізі сучасної наукової літератури.

Результати і обговорення. «Чиста» кокосова олія (найчистіша форма кокосової олії) – безбарвна і вільна від гіркоти. Вона під час екстрагування відділяється від натуральної кокосової олії, яка відділяється шляхом холодного пресування копри (висушеного ендосперму кокосових горіхів), який відділяється із «молока» свіжих кокосових горіхів. Для отримання олії використовуються натуральні або механічні засоби, із застосуванням нагрівання і без нього. Олія не підлягає хімічному збагаченню, освітленню або дегідруванню. Подальші процеси, такі як ферментація та відцентрове розділення, замороження, піддавання дії ферментів дозволяють відокремити олію від води. У деяких випадках використовують мікродистиляцію, тобто кипіння свіжої кокосової олії з подальшим випарюванням води, або пряме холодне стиснення свіжосушеної м'якоті кокосового горіха. Аромат свіжого кокосового горіха може варіюватися від легкого до інтенсивного в залежності від методу екстрагування олії.

Загальне виробництво харчової кокосової олії в Індії складає близько 400000 тонн. Для виробництва кокосової олії в Індії шляхом подрібнення копри використовуються роторні та шнекові преси.

В основному «чиста» кокосова олія складається з тригліцеридів середнього ланцюга, стійких до перекисного окислення. Вона відрізняються від тваринного жирів,

які складаються з довгих ланцюгових насичених жирних кислот і є одним з основних факторів ризику серцевого ускладнення. Жирні кислоти середнього ланцюга відрізняються від довгих жирних кислот, оскільки вони знижують ризик атеросклерозу і серцево-судинних захворювань.

Висновок. «Чиста» кокосова олія має ряд переваг для здоров'я, зокрема, у догляді за шкірою, волоссям, полегшенням стресу, зниженні ваги та підтримуванні рівня холестерину, володіє імуномодулюючими ефектами, знижує ризик серцево-судинних захворювань та хвороби Альцгеймера. Вона має тривалий термін зберігання і використовується під час виробництва хліба, дитячих сумішей, лікарських препаратах і косметики.

Ключові слова: *кокос, копра, олія, функціональність, Індія.*

Нутрієнтні властивостей м'ясних паштетів з використанням рослинної сировини

Оксана Москалюк[1], Олександра Гащук[1], Людмила Пешук[1],
Людмила Синєок[2], Олег Галенко[1]
1 – Національний університет харчових технологій, Київ, Україна
2 – ДУ «Інститут геронтології ім. Д. Ф. Чеботарьова НАМН України», Київ, Україна

Вступ. Досліджені м'ясні паштети для оздоровчо-профілактичного харчування з використанням грибної сировини та фітокомплексу пророщених зерен злакових культур. Наведено результати досліджень жирнокислотного складу, перетравлюваності в середовищі in vitro і клінічних досліджень безпечності паштетів.

Матеріали і методи. Дослідження жирнокислотного складу досліджених паштетів здійснювали методом хроматографії високороздільної здатності. Для підтвердження нутрієнтної адекватності рецептур паштету «Грибного» і паштету з фітокомплексом «CHOICE» досліджено перетравлюваність в середовищі *in vitro* із застосуванням війчастої інфузорії *Tetrahymena pyriformis* в камері Фукс-Розенталя. Клінічні дослідження паштетів з грибною сировиною проводили за участю людей літнього віку у загальнотерапевтичному відділенні клінік.

Результати і обговорення. Методом хроматографії високороздільної здатності встановлено груповий жирнокислотний склад паштетів з використанням грибної сировини та фітокомплексу пророщених зерен злакових культур і виявлено, що вміст мононенасичених кислот в досліджених паштетах становить близько 35%, а насичених – лише 23% в усіх досліджуваних зразках. Аналізуючи вміст ПНЖК, слід відмітити їх стабільно високий вміст в усіх чотирьох рецептурах незалежно від виду внесених компонентів. Проте рецептура з грибною сировиною відрізняється найвищим загальним вмістом ПНЖК – 41,92% та одночасно найвищим вмістом есенціальної ліноленової кислоти – 1,55%.

Результати дослідження засвоюваності в умовах *in vitro* свідчать про те, що паштет «Грибний» має більшу відносну біологічну цінність і кращу засвоюваність, якщо порівняти з контрольним зразком, на 3,5%, а паштет з фітокомплексом «CHOICE» – на 2,1%.

За результатами досліджень встановлено ефективність і безпечність паштету «Грибного» та з'ясовано можливість усунення дефіциту вітаміну B_{12} при вживанні.

Висновки. Аналіз результатів досліджень свідчить про нутрієнтну адекватність досліджених паштетів з використанням грибної сировини та фітокомплексу пророщених зерен злакових культур оздоровчо-профілактичного харчуванню

Ключові слова: *м'ясо, паштет, жирна кислотна, рослинна сировина, перетравлюваність.*

Формування якості та безпечності субпродуктових ковбас

Ліна Білик, Наталія Попова
Національний університет харчових технологій, Київ, Україна

Вступ. У статті досліджується питання виготовляння якісної та безпечної продукції на м'ясопереробних підприємствах на прикладі субпродуктової ковбаси. Проведені дослідження з метою встановлення впливу способу пакування ковбас на термін їх зберігання.

Матеріали і методи. Дослідження проводили на зразках ковбаси субпродуктової, виготовлених у виробничих умовах. Досліджували pH ковбаси та вміст вологи. Рівень pH було досліджено потенціометричним методом, методом висушування було досліджено вміст вологи в ковбасі.

Результати і обговорення. З вмістом води тісно пов'язана стійкість продукту під час зберігання та його транспортабельність, а також придатність до подальшої переробки, тому що надлишок вологи сприяє перебігу ферментативних і хімічних реакцій, активізує діяльність мікроорганізмів, в тому числі таких, які призводять до псування продукту, зокрема його пліснявіння. У зв'язку з цим вміст вологи в продукті визначає умови та строки його зберігання.

Оптимальним вмістом вологи у субпродуктовій ковбасі вважається 52%. На вміст вологи у ковбасі можуть впливати різні фактори, наприклад? температура та умови зберігання, обраний для ковбасних виробів тип пакування та терміни її зберігання.

У ході виконаних досліджень даний показник змінювався таким чином: у контрольному зразку не виходив за межі норми, у свіжій ковбасі, без пакування на 6 добу зберігання показник зменшився до 44% , у замороженій – до 50. У ковбасі, яка зберігалась у поліетиленовому пакеті, масова частка вологи збільшилась до 55%, а у ковбасі в пергаменті – до 53%.

pH є показником, який свідчить про ступінь свіжості ковбасних виробів. Значення активної кислотності відіграє важливу роль у процесі зберігання ковбасних виробів. Лужність середовища свідчить про розвиток мікроорганізмів і початок псування ковбаси.

Оптимальним значенням pH для субпродуктової ковбаси вважається 6–7.

При аналізі досліджуваних зразків були отримані такі результати: свіжа ковбаса без пакування (на 6 добу дослідження) – 7, ковбаса заморожена – 6,5, ковбаса в поліетиленовому пакеті – 7,5, ковбаса у пергаменті – 7,2.

Висновки. На формування якісного та безпечного продукту впливають такі показники, як вміст вологи та pH продукту. При цьому важливим є питання підбору якісного й ефективного пакування. Згідно з проведеними дослідженнями найкращим способом пакування є пакування в пергамент.

Ключові слова: *м'ясо, сировина, субпродукт, ковбаса, якість, безпека.*

Мікробіологія, біотехнологія

Порівняльна характеристика екзополісахаридів етаполану та ксантану як агентів для підвищення вторинного нафтовидобутку

Микола Івахнюк, Тетяна Пирог
Національний університет харчових технологій, Київ, Україна

Вступ. Мета дослідження полягала у порівнянні вартості поживних середовищ для отримання необхідної для вторинного нафтовидобутку культуральної рідини *Acinetobacter* sp. IMB B-7005 і штамів *Xanthomonas campestris* − продуцентів ксантану.

Матеріали і методи. Розрахунок кількості культуральної рідини та вартості поживних середовищ для отримання екзополісахаридів етаполану (продуцент *Acinetobacter* sp. IMB B-7005) та ксантану (продуценти штами *Xanthomonas campestris*) як нафтовитиснювальних агентів для 262 свердловин НВГУ «Охтирконафтогаз» проводили з урахуванням таких параметрів: 4–разове оброблення в рік свердловин розчином ЕПС у кількості 15 $м^3$ та концентрацією 0,05%.

Результати і обговорення. На основі даних по концентрації синтезованих полісахаридів штамами-продуцентами розраховано річну потребу культуральної рідини (545–1849 $м^3$) для обробки свердловин НВГУ «Охтирконафтогаз» і кількість продукту за цикл ферментації згідно з обраними технологіями.

Теоретичні розрахунки показали, що витрати на приготування поживного середовища для отримання культуральної рідини *Acinetobacter* sp. IMB B-7005 на відпрацьованій після смаження м'яса соняшниковій олії, необхідної для підвищення вторинного нафтовидобутку на свердловинах «Охтирканафтогаз», в 1,8–5,4 раза менші, якщо порівняти з отриманням етаполану на C_2-C_6 субстратах, мелясі чи їх суміші.

Проведено порівняння вартості поживних середовищ для отримання етаполану та найвідомішого полісахариду ксантану, отриманого на мелясі або технічному гліцерині. Затрати на отримання полісахариду ксантану (в кількості, що забезпечить видобуток еквівалентної використанню етаполану нафти) в 12,7 – 16,7 раза вищі, якщо порівняти з отриманням етаполану.

Висновок. Одержані результати доводять економічну доцільність синтезу етаполану на відпрацьованій олії для використання полісахариду у вторинному нафтовидобуванні порівнян з технологіями отримання ксантану.

Ключові слова: *Acinetobacter* sp. IMB B-7005, *Xanthomonas campestris, екзополісахарид, культивування, нафта.*

Процеси і обладнання

Вплив ступеня подрібнення продукту на процес сушіння тонкодисперсної пасти діоксину титану

Віктор Марчевський, Ярослав Гробовенко
Національний технічний університет України "Київський політехнічний інститут імені Ігоря Сікорського"

Вступ. Мета дослідження полягає у визначенні впливу ступеня подрібнення продукту на процеси сушіння пасти TiO_2 і досушування тонкодисперсних частинок діоксиду титану до низької залишкової вологості 0,3%.

Матеріали і методи. Процеси сушіння і досушування тонкодисперсної пасти TiO_2 у вихрових потоках теплоносія із застосуванням безперервного подрібнення вихідного продукту проводилися у конічному сушильному апараті вихрового типу, до складу якого входить спеціальний пристрій для подрібнення продукту – диспергатор, живильник-дозатор і сепараційна зона.

Результати і обговорення. Початкова вологість пасти діоксиду титану складала 50–55%. Процеси сушіння та досушування пасти діоксиду титану у вихровому потоці теплоносія при застосуванні оригінальної конструкції сушильного апарата з ножовим диспергатором і зоною досушування матеріалу відбувалися до низької залишкової вологості продукту 0,3%. При цьому температура теплоносія на вході в сушильну камеру становила 120°С, а об'ємні витрати – 50 м^3/год. У процесі дослідження автоматично замірялися значення температури і вологості теплоносія на вході та виході із сушильної камери та бралися зразки дисперсних частинок із зони подрібнення. Експериментально встановлені залежності для розрахунку ступеня подрібнення z агломератів пасти діоксиду титану та отримані значення коефіцієнта швидкості сушіння K_w пасти діоксиду титану, що становлять 0,17–2,5 м/с. Крім цього, кінетика процесу сушіння повністю описувала криву сушіння. Так, початковий вологовміст пасти становив $U_0 = 1{,}17 кг_в/кг_{а.с.п.}$, $U_{1кр} = 0{,}23 кг_в/кг_{а.с.п.}$, рівноважний вологовміст – $U_з = 0{,}003 кг_в/кг_{а.с.п.}$. У першому періоді паста TiO_2 сушилась при температурі мокрого термометра 37°С. Отримані оптимальні температурні режими теплоносія для сушіння пасти діоксиду титану, що становлять 90–120°С на вході в сушильну камеру та 65–90°С на виході.

Результатом розрахунку математичної моделі є ступінь подрібнення, який складає 10–15 умовних одиниць.

Висновки. Досліджено кінетику та способи інтенсифікації процесів подрібнення, сушіння та досушування агломератів пасти TiO_2 і встановлено параметри, необхідні для проектування промислових сушильних апаратів.

Ключові слова: *подрібнення, диспергатор, сушіння, паста*, *діоксин титану.*

Визначення втрат енергії на розподільчих пристроях пневматичного транспорту м'ясних продуктів

Сергій Беседа, Ігор Литовченко
Національний університет харчових технологій, Київ, Україна

Вступ. Проведені дослідження різних варіантів з'єднання трубопроводів для транспортування харчових продуктів. Метою дослідження є визначення втрат енергії залежно від геометричних параметрів з'єднання.

Матеріали і методи. Комп'ютерне моделювання було використане як інструмент дослідження. Комп'ютерне програмне забезпечення CAE FlowVision здійснюється на основі методу кінцевих елементів для прогнозування руху в'язких рідин при перепаді тиску повітря на вході та виході з геометричної моделі.

Результати і обговорення. Комбінація геометричних параметрів трубопроводів дає змогу визначити їх опір руху продукту для вибору оптимального методу розгалуження, а також для отримання порівняльної характеристики локального опору залежно від кута повороту. У нашому випадку кути повороту є значними: варіант 2 – 45°, варіант 1 – 30°, варіант 4 – 22,5°, варіант 3 – 15°. В іншому положенні заслінки, коли рух продукту є прямим, втрати енергії практично не відбуваються.

Новизна використаного методу комп'ютерного моделювання полягає у визначенні значень дисипації кінетичної енергії рухомого продукту. В ході дослідження використовувався метод візуалізації – "ізолінії", що дає змогу чітко визначити межі градації значень. При обчисленні площі, що займає той чи інший діапазон значень ізоліній розсіювання енергії, можна порівняти інтенсивність втрат енергії, якщо віднести їх до загальної площі розгалуження. Якщо оцінювати область, яка обмежена ізолініями певної інтенсивності фактора, можна отримати інтегральну характеристику дії динамічних параметрів. Значні області, обмежені великими значеннями дисипації, показують початок турбулентності, що є основним джерелом втрат транспортуючого тиску. Математична обробка кожної кривої дає опис поведінки графів при використанні многочленів третього ступеня.

Висновки. При проектуванні варіантів встановлення трубопроводів можна комбінувати прямі ділянки, труби, перемикачі так, щоб мінімізувати втрати тиску. За результатами дослідження доцільно використовувати симетричні варіанти розгалуження та незначні повороти труб навіть у простих областях (залежно від їх довжини).

Ключові слова: *м'ясо, пневматика, транспортування, тиск, енергія.*

Автоматизація

Сценарії інтелектуального нечіткого автоматизованого керування виробництвом хліба

Василь Кишенько[1], Борис Гончаренко[1], Олексій Лобок[1],
Вячеслав Іващук[1], Марина Сич[2]
1 – Національний університет харчових технологій, Київ, Україна
2 – Національний університет біоресурсів і природокористування України, Київ

Вступ. Проведено дослідження застосування сценарного підходу до автоматизації керування процесами випічки хлібних виробів з метою підвищення ефективності виробництва та покращення якості продукції.

Методи дослідження. Методи дослідження – аналіз характеристик і критеріїв обраної проблеми, складання якісних оцінок і попередніх сценаріїв керування процесами, оцінка реалістичних рішень (експертна, перехресний вплив, метод Сааті), правила та послідовність їх застосування у написанні узагальнених сценаріїв.

Результати і обговорення. В статті розглянуті основні складові етапи та операції виробництва хліба та різні можливі схеми їх регулювання. Недоліком типової схеми автоматичного регулювання вологості на тістомісильних апаратах неперервної дії є її спрямування на стабільну якість борошна. Для регулювання тривалості бродіння масу напівфабрикату в ємності для бродіння фіксує зважувальний механізм, а витрату враховує витратомір. Ці дані опрацьовуються за відповідною формулою. На етапі механічного оброблення тіста необхідно контролювати масу тістової заготівки та ступінь її готовності до випікання. Керованими параметрами є температура та вологість повітря в шафі вистоювання, а також тривалість вистоювання.

Розроблено автоматизовану систему багатоцільового керування на основі сценарного підходу та інтелектуальних технологій з метою підвищення продуктивності, зменшення питомих втрат і витрат ресурсів при підвищенні якості продукції. Викладена суть ситуаційного підходу до керування технологічними процесами випікання хліба. Запропоновані абстрактні (А-) та структурні (С-) сценарії виробництва хліба, які можна використати при виконанні факторно-цільового аналізу виробництва хліба. С-сценарій деталізує А-сценарій з урахуванням еволюції об’єкта при виконанні операцій і передачі об’єктів від одних операцій до інших. Кожен клас С-сценарію працює автономно і взаємодіє з іншими класами та зовнішнім середовищем, щоб внести у вхідні черги нові об’єкти та видалити з вихідних черг «відпрацьовані».

Висновки. Проведений аналіз стану проблеми керування технологічними процесами виробництва хліба та наведені приклади сценаріїв керування.

Ключові слова: *хліб, випікання, керування, технологія, автоматизація.*

Системний аналіз і підходи до побудови автоматизованої системи керування електроспоживанням та електропостачанням підприємства харчової промисловості

Людмила Копилова, Сергей Балюта, Олег Мащенко
Національний університет харчових технологій, Київ, Україна

Вступ. Проведені дослідження процесу керування електроспоживанням та електропостачанням підприємства харчової промисловості (ПХП) з метою підвищення ефективності передавання та використання електроресурсів.

Матеріали і методи. Дослідження виконані на основі методів системного аналізу процесів керування та сучасної теорії автоматичного керування.

Результати і обговорення. Визначені основні етапи процесу керування електропостачанням та електроспоживанням: **базові функції керування** – реєстрація споживання електричної енергії (ЕЕ), прогнозування витрат ЕЕ, розрахунок норм витрат ЕЕ, проведення аналізу режимів системи електропостачання підприємства (СЕП), показників якості ЕЕ (ПЯЕЕ) та надійності СЕП, формування переліку споживачів-регуляторів (СР); умови забезпечення функцій керування – інформація про витрати ЕЕ, обмеження й тарифи, вимоги до точності прогнозу електроспоживання; прийняття рішення щодо зміни конфігурації й оптимізації режимів СЕП; нормалізації ПЯЕЕ; організаційно-технічні механізми реалізації функцій керування – інформаційно-обчислювальний комплекс, енергодиспетчер, оператор технологічного процесу, головний енергетик; база даних автоматизованої системи управління енергетикою підприємства, яка використовується для підготовки рішень; базові інформаційні потоки, які забезпечують керування електроспоживанням. Представлена функціональна схема і сформульовані вимоги до окремих блоків керування електроспоживанням та електропостачанням ПХП з використанням СР. Керування електроспоживанням та електропостачанням ПХП реалізується з використанням підсистеми підтримки прийняття рішень, що враховує взаємний зв'язок технологічного процесу і процесу електроспоживання.

Висновок. Розробка на основі методів системного аналізу та сумісності забезпечує високу ефективність енерговикористання та електропостачання.

Ключові слова: *електроенергія, керування, електроспоживання, електропостачання, алгоритм.*

Безпека життєдіяльності

Удосконалення інформаційно-керуючої системи енергетичного господарства харчових підприємств на основі інтелектуалізації процесу прийняття рішень

Аліна Сірик, Ольга Євтушенко
Національний університет харчових технологій, Київ, Україна

Вступ. Покращення інформаційно-управлінської системи сучасних енергетичних підприємств харчової промисловості шляхом впровадження мультиагентних технологій, що дають змогу керівнику енергетичного господарства ефективно використовувати різні набори подій у рамках всього комплекту правових документів для підвищення рівня безпека праці.

Матеріали і методи. Дослідження проводилося на основі загальносистемного підходу, заснованого на взаємозв'язку елементів інтелектуального агента, інформаційного об'єкта, методу математичного моделювання.

Результати і обговорення. Процес інтелектуалізації пропонується проводити на основі впровадження мультиагентних технологій, що дасть змогу керівнику енергетичного господарства ефективно використовувати різні сукупності заходів у рамках загальної множини нормативно-правових документів для підвищення рівня безпеки праці. Крім того, підвищено ефективність функціонування інформаційно-керуючої системи управління охороною праці підприємств харчової промисловості, що забезпечить визначення оптимальної сукупності заходів з охорони праці, а це дає можливість досягти підвищення рівня безпеки праці. Показано скорочення часу на вирішення завдань управління рівнем безпеки праці у змінному інформаційному середовищі, особливо в період пікових навантажень у роботі енергетичного господарства підприємств харчової промисловості. За результатами математичного моделювання на основі використання мультиагентних технологій в інформаційно-керуючій системі управління охороною праці досягнуто підвищення рівня безпеки праці в енергетичному господарстві підприємств харчової промисловості на 12–18%.

Висновки. Основні результати досліджень рекомендується використовувати на підприємствах харчової промисловості для зниження ризику настання позаштатної ситуації в енергетичному господарстві підприємств харчової промисловості до рівня, що відповідає прийнятному ризику, за рахунок вибору оптимальної сукупності заходів забезпечення безпеки праці.

Ключові слова: *праця, інтелектуалізація, безпека.*

Instructions for Authors

Dear colleagues!

The Editorial Board of scientific periodical «**Ukrainian Journal of Food Science**» invites you to publication of your scientific research.

Requirements for article:

Language – English

Size of the article 8 – 15 pages in Microsoft Word 2003 and earlier versions with filename extension *.doc

All article elements should be in Times New Roman, font size 14, 1 line intervals, margins on both sides 2 cm.

The structure of the article:

1. The title of the article
2. Authors (full name and surname)
3. Institution, where the work performed.
4. Abstract. The structure of the Abstract should correspond to the structure of the article (Introduction, Materials and methods, Results and discussion, Conclusion)
5. Key words.
6. The main body of the article should contain the following obligatory parts:
   - Introduction
   - Materials and methods
   - Results and discussion
   - Conclusion
   - References

   If you need you can add another parts and divide them into subparts.
7. The information about the author (Name, surname, scientific degree, place of work, email and contact phone number).

All Figure s should be made in graphic editor, the font size 14.

The background of the graphs and charts should be only in white colour. The colour of the Figure elements (lines, grid, text) – in black colour.

Figure s and EXCEL format files with graphs additionally should submit in separate files.

Photos are not appropriate to use.

Extended articles should be sent by email to:
ukrfoodscience@meta.ua

Ukrainian Journal of Food Science публікує оригінальні наукові статті, короткі повідомлення, оглядові статті, новини та огляди літератури.

Тематика публікацій в **Ukrainian Journal of Food Science:**

Харчова інженерія
Харчова хімія
Мікробіологія
Властивості харчових продуктів
Якість та безпека харчових продуктів
Нанотехнології
Процеси та обладнання
Економіка та управління
Автоматизація процесів
Упаковка для харчових продуктів
Здоров'я

Періодичність журналу 2 номери на рік (червень, грудень).

Результати досліджень, представлені в журналі, повинні бути новими, мати зв'язок з харчовою наукою і представляти інтерес для міжнародного наукового співтовариства.

Ukrainian Journal of Food Science індексується наукометричними базами**:**

EBSCO (2013)
Google Scholar (2013)
Index Copernicus (2014)
Universal Impact Factor (2014)
Directory of Open Access scholarly Resources (ROAD) (2014)
CAS Source Index (CASSI) (2016)
FSTA (Food Science and Technology Abstracts) (2018)

Ukrainian Journal of Food Science включено у перелік наукових фахових видань України з технічних наук, в якому можуть публікуватися результати дисертаційних робіт на здобуття наукових ступенів доктора і кандидата наук (Наказ Міністерства освіти і науки України № 793 від 04.07.2014)

Рецензія рукопису статті. Наукові статті, представлені для публікації в «**Ukrainian Journal of Food Science**» проходять «подвійне сліпе рецензування» (рецензент не знає, чию статтю рецензує, і, відповідно, автор не знає рецензента) двома вченими, призначеними редакційною колегією: один є членом редколегії, інший – незалежний учений.

Авторське право. Автори статей гарантують, що робота не є порушенням будь-яких існуючих авторських прав, і відшкодовують видавцю порушення даної гарантії. Опубліковані матеріали є правовою власністю видавця «Ukrainian Journal of Food Science», якщо не узгоджено інше.

Політика академічної етики. Редакція «**Ukrainian Journal of Food Science**» користується правилами академічної етики, викладеними в праці Miguel Roig (2003, 2006) "Avoiding plagiarism, self-plagiarism, and other questionable writing practices. A guide to ethical writing". Редакція пропонує авторам, рецензентам і читачам дотримуватися вимог, викладених у цьому посібнику, щоб уникнути помилок в оформленні наукових праць.

Редакційна колегія

Вимоги до оформлення статей

Мова статті – англійська.

Рекомендований обсяг статті – **8–15 сторінок** (для оглядових статей – 20–30 сторінок) формату А4.

Стаття виконується в редакторі Microsoft Word 2003 в форматі ***.doc**.

Для всіх (!) елементів статті шрифт – **Times New Roman**, кегль – **14**, інтервал – 1, абзац – 1 см.

Структура статті:

1. **Назва статті.**
2. Автори статті (ім'я та прізвище повністю, приклад: Денис Озерянко).
3. *Установа, в якій виконана робота*.
4. Анотація. Рекомендований обсяг анотації – пів сторінки. Анотація повинна відповідати структурі статті та містити розділи Вступ (2–3 рядки), Матеріали і методи (до 5 рядків), Результати та обговорення (пів сторінки), Висновки (2–3 рядки).
5. Ключові слова, 3–5 слів, **але не** словосполучень (!).

Пункти 1–5 виконати англійською і українською мовами.

6. Основний текст статті. Має включати такі обов'язкові розділи:
   - Вступ
   - Матеріали та методи
   - Результати та обговорення
   - Висновки
   - Література.

За необхідності можна додавати інші розділи та розбивати їх на підрозділи.

7. Авторська довідка (Прізвище, ім'я та по батькові, вчений ступінь та звання, місце роботи, електронна адреса або телефон).
8. Контактні дані автора, до якого за необхідності буде звертатись редакція журналу (телефон та електронна адреса).

Розмір тексту на рисунках повинен бути **співрозмірним** (!) основному тексту статті. Скановані рисунки не приймаються.

Фон графіків, діаграм – лише білий (!). Колір елементів рисунку (лінії, сітка, текст) – лише чорний (не сірий).

Оригінали рисунків (файли графічних редакторів), а також файли формату EXCEL з графіками обовязково подаються в окремих файлах.

Фотографії та кольорові зображення бажано не використовувати.

Скорочені назви фізичних величин в тексті та на графіках позначаються латинськими літерами відповідно до системи СІ.

В списку літератури повинні переважати статті та монографії іноземних авторів, які опубліковані після 2000 року.

Детальні інструкції для авторів розміщені на сайті

http://ukrfoodscience.ho.ua

Стаття надсилається за електронною адресою:
ukrfoodscience@meta.ua

Оформлення списку літератури

Посилання на статтю

Автори (рік видання), Назва статті, *Назва журналу (курсивом)*, том (номер), сторінки.

Всі елементи після року видання розділяються **комами**.

Приклади:

1. Yannick Fayolle, Sylvie Gillot, Arnaud Cockx, Laetitia Bensimhon, Michel Roustan, Alain Heduit (2010), In situ characterization of local hydrodynamic parameters in closed-loop aeration tanks, *Chemical Engineering Journal*, 158(2), pp. 207–212.
2. Carlo Tocchi, Ermanno Federici, Laura Fidati, Rodolfo Manzi, Vittorio Vincigurerra, Maurizio Petruccioli (2012), Aerobic treatment of dairy wastewater in an industrial three-reactor plant: Effect of aeration regime on performances and on protozoan and bacterial communities, *Water Research*, 46(10), pp. 3334–3344.

Приклад оформлення статті, оригінал якої українською мовою:

1. Pyroh T.P., Konon A.D., Skochko A.B. (2011), Vykorystannia mikrobnykh poverkhnevo-aktyvnykh rechovyn u biolohii ta medytsyni, *Biotekhnolohiia*, 4(2), pp. 24–38.

За бажання після транслітерованої назви статті або журналу в {фігурних дужках можна дати переклад англійською мовою}.

Посилання на книгу

Автори (рік), *Назва книги (курсивом)*, Видавництво, Місто.

Всі елементи після року видання розділяються комами.

Приклади:

1. Harris L. (1991), *Money theory*, McGraw-Hill Companies, Hardcover
2. Rob Steele (2004), *Understanding and measuring the shelf-life of food*, CRC Press.

Приклад оформлення статті, оригінал якої українською або російською мовою:

1. Donchenko L.V. (2000), Tekhnologiya pektina i pektinoproduktov, Deli, Moscow
2. Kirianova H.A. (2008), Udoskonalennia tekhnolohii termostabilnykh zheleinykh nachynok shliakhom ratsionalnoho vykorystannia hidrokoloidiv roslynnoho ta mikrobnoho pokhodzhennia: PhD tethis, NUHT, Kyiv.
3. Zalutskyi I.R., Tsymbaliuk V.M., Shevchenko C. H. (2009), Planuvannia i diahnostyka diialnosti pidpryiemstva, Novyi svit, Lviv.

За бажання після транслітерованої назви книги в {фігурних дужках можна дати переклад англійською мовою}.

Посилання на електронний ресурс

Виконується аналогічно посиланню на книгу або статтю. Після оформлення даних про публікацію пишуться слова **available at:** та вказується електронна адреса.

Приклад посилання на статтю із електронного видання:

1. Barbara Chmielewska. (2012), Differentiation of the standard of living of families in countries of the European Union, *Ukrainian Food Journal*, 2(2), pp. 230–241, available at: http://ufj.ho.ua/Archiv/UKRAINIAN%20FOOD%20JOURNAL%202013%20V.2%20Is.2.pdf
2. (2013), *Svitovi naukovometrychni bazy*, available at: http://www1.nas.gov.ua/publications/q_a/Pages/scopus.aspx

Наукове видання

Ukrainian Journal of Food Science

Volume 6, Issue 1
2018

Том 6, № 1
2018

Рекомендовано Вченою радою
Національного університету
харчових технологій
Протокол № 12 від 21.06.2018 р.

Адреса редакції:

Національний університет
харчових технологій
Вул. Володимирська, 68
Київ
01601
Україна

E-mail:

Ukrfoodscience@meta.ua

Підп. до друку 29.06.2018 р. Формат 70x100/16.
Обл.-вид. арк. 13.35. Ум. друк. арк. 13.96.
Гарнітура Times New Roman. Друк офсетний.
Наклад 100 прим. Вид. № 08н/18.

НУХТ 01601 Київ–33, вул. Володимирська, 68

Свідоцтво про державну реєстрацію
друкованого засобу масової інформації
КВ 19324–9124Р
видане 23 липня 2012 року.