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Editorial office address:

National University of Food Technologies
Volodymyrska str., 68
Kyiv 01601
Ukraine

E-mail:

Ukrfoodscience@meta.ua

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Differences on lipid quality index and amino acid profiles of European Anchovy caught from different area in Turkey

Demet Kocatepe, Mehmet Emin Erdem, Irfan Keskin,
Bayram Köstekli, Yalçın Kaya

Sinop University, Akliman, Sinop, Turkey

Abstract

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Corresponding author:

Demet Kocatepe
E-mail:
demetkocatepe@
hotmail.com

Introduction. European anchovy is a nutritive food preferred by everybody with high omega 3 contents.

Materials and methods. Within the scope of the study, the anchovy which was caught from different seas in Turkey were compared in view of its lipid quality index and amino acid (AA) profile.

Result and discussion. The amount of SFA, MUFA and PUFA's of the Aegean Sea (AS), Black Sea (BS), and the Marmara Sea (MS) anchovy were 41.31, 11.18, 48.10; 32.38, 31.39, 36.24% and 32.92, 32.24, 34.82, respectively. The SFA and PUFA in the AS anchovy were found higher than the others ($p < 0.05$). Similarly, the highest DHA contents were found as 29.51% in the AS anchovy ($p < 0.05$). The oleic acid of BS anchovy were more than 3 times of the AS anchovy. Glutamic acid was the highest essential AAs in the groups. The lysine, aspartic acid, alanine, glycine, glutamic acid, isoleucine, leucine, methionine, phenylalanine, proline in the AS anchovy were higher than the other groups. The histidine of the anchovies was similar ($p > 0.05$). The ratio of EAA with non-EAA of the AS, BS and MS anchovies were found to be 1.21, 1.31 and 1.21 respectively.

Conclusion. It has been found that anchovy contains high amounts of essential fatty acids and EAAs. Especially the AS anchovy was higher quality in view of EPA+DHA and total EAAs compositions.

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Introduction

With increasing demand for quality food throughout the world, the trend towards fish meat has increased. Fish is a nutritive food preferred by young and old people with high protein, mineral matter, water, and unsaturated fat content.

One of the favorite seafoods that can be caught almost all seasons in the territorial waters of our country is the anchovy. European Anchovy (*Engraulis encrasicolus* Linnaeus, 1758) is a pelagic fish species which is preferred by consumers because of its price and taste. Anchovy which is caught during fishing season (September 1- April 15). European anchovy in Turkey is the most important species both in weight and in a value of landings. Annual anchovy caught after the 2000 year in Turkey peaked in the 2001s at over 257000 tons but, since then, landings gave declined, averaging 74304 tons for the last 3 years (2015-2017). In 2017, 322.173 tones fish were caught in Turkey land waters. 49% of all fish caught in our seas were anchovy. 133.766 tons of anchovy were caught from the Black Sea and the others were caught from the Aegean Sea > The Marmara Sea > The Mediterranean Sea. In 2017, the average selling price of 1-kilo anchovy was 5.5TL [1].

In this study, it was investigated the fatty acids, lipid quality index and amino acid contents of the anchovy which were caught from different seas in Turkey.

Material and methods

The study was carried out in December 2017 with the Anchovy (*Engraulis encrasicolus* Linnaeus 1758) caught from the Aegean Sea, Black Sea and the Marmara Sea in Turkey. For sampling, twelve kilos fish were obtained from the fisheries at the same time from different regions. The fish were transported to the laboratory under cold storage conditions. And then the fish were filleted and analyzed.

Amino acid analyzes and fatty acids composition were performed after digestion derivatization method according to HPLC pre-column [2] and IID-19 method [3], respectively. Amino acid profiles of the anchovy were calculated as total essential amino acid (Σ EAA) including Histidine (His), Threonine (Thr), Arginine (Arg), Valine (Val), Methionine (Met), Phenylalanine (Phe), Isoleucine (Ile), Leucine (Leu), Tyrosine (Tyr) and Lysine (Lys); total non-essential amino acid (Σ NEAA) including Aspartic acid (Asp), Glutamic acid (Glu), Serine (Ser), Glycine (Gly), Citrulline (Cit), Alanine (Ala) and Proline (Pro); total sweet amino acids (Σ Sweet AA) including Glu, Ser, Gly and Ala; total bitter amino acids (Σ Bitter AA) including His, Arg, Met, Phe, Lys according to Schiffman [4] and Boisen, et al. [5].

Lipid quality indexes of lipid (Atherogenicity index-AI, Thrombogenicity index-TI [6], flesh lipid quality index (FLQ index [7] and hypocholesterolaemic/hypercholesterolaemic ratio (Hh) [8] following formulas were used;

$$AI = [(C12:0 + (4 * C14:0) + (C16:0))] / [(\Sigma n6 + \Sigma n3 + \Sigma MUFA)]$$

$$TI = [(C14:0 + C16:0 + C18:0)] / [(0.5 * \Sigma MUFA) + (0.5 * \Sigma n6) + (3 * \Sigma n3) / (\Sigma n6)]$$

$$FLQ = 100 * [(EPA\% + DHA\%) / (Total fatty acids\%)]$$

$$Hh = (C18:1n-9 + C18:2n-6 + C20:4n-6 + C18:3n-3 + C20:5n-3 + C22:5n-3 + C22:6n-3) / (C14:0 + C16:0)$$

All analyzes were performed in 2 replicates with 3 parallel. The data obtained at the end of the study were evaluated with one-way ANOVA using Minitab Release 17 package program and Tukey test was used for determination of the significance level of differences in-groups and between groups [9]. Figures and schedules are prepared using MS Office 2010 software.

Results and discussion

The crude protein, crude fat contents of the Aegean, Black Sea and the Marmara Sea anchovies analyzed were 20.16 ± 0.29 , 0.74 ± 0.01 ; 18.75 ± 0.30 , 9.33 ± 0.75 and 18.80 ± 0.12 g/100g – 11.76 ± 0.61 g/100g, respectively.

Fatty acids composition of European anchovy oil

The fatty acid composition results of anchovy oil caught from different seas were in Table 1.

Table 1

Fatty acid composition of Anchovy caught from different seas (%).

	Aegean Sea Anchovy		Black Sea Anchovy		Marmara Sea Anchovy	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Butyric acid (C4:0)	8.28	0.03a	2.87	0.49b	2.89	0.19b
Caproic acid (C6:0)	0.01	0.00a	0.00	0.00b	0.00	0.00b
Caprylic acid (C8:0)	0.00	0.00a	0.00	0.00a	0.00	0.00a
Capric acid (C10:0)	0.03	0.00a	0.01	0.00a	0.04	0.02a
Undecanoic acid (C11:0)	0.01	0.00a	0.01	0.00a	0.01	0.01a
Lauric acid (C12:0)	0.13	0.00b	0.13	0.00b	0.31	0.02a
Tridecanoic acid (C13:0)	0.13	0.00b	0.11	0.00b	0.25	0.01a
Myristic acid C14:0	5.63	0.00b	6.07	0.02a	3.84	0.17c
Penta decanoic acid C15:0	1.59	0.00b	1.84	0.04b	2.95	0.18a
Palmitic acid C16:0	20.24	0.74a	15.41	0.10b	14.91	0.89b
Heptadecanoic acid C17:0	1.89	0.01b	1.85	0.01b	2.68	0.16a
Stearic acid C18:0	0.01	0.00a	0.00	0.00b	0.00	0.00b
Arachidic acid C20:0	0.22	0.00c	0.72	0.00b	1.00	0.06a
Heneicosenoic acid C21:0	0.05	0.00c	0.14	0.00b	0.19	0.01a
Behenic acid C22:0	2.62	0.01ab	2.23	0.04b	2.80	0.20a
Tricosanoic acid C23:0	0.15	0.00b	0.27	0.00a	0.06	0.00c
Lignoserinic acid (C24:0)	0.33	0.01c	0.71	0.01b	1.03	0.07a
SFA	41.31	0.80a	32.38	0.44b	32.92	0.16b
Myristoleic acid (C14:1)	0.36	0.01b	0.55	0.01b	1.40	0.08a
Penta decanoic acid (C15:1)cis-10-	0.20	0.00c	0.29	0.01b	0.55	0.01a
Palmitoleic acid C16:1n7	0.37	0.00c	1.72	0.01a	0.84	0.03b
Heptadecanoic acid C17:1cis -10-	0.42	0.01b	1.19	0.00a	1.21	0.08a
Oleic acid C18:1n9c	4.33	0.02c	14.81	0.16a	10.59	0.71b

<i>Table 1 (continue)</i>						
	Aegean Sea Anchovy		Black Sea Anchovy		Marmara Sea Anchovy	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Elaidic acid (C18:1n9t)	0.22	0.01c	6.04	0.16b	8.90	0.57a
Eicosenoic acid C20:1 cis 11	1.73	0.01c	2.87	0.02b	3.54	0.29a
Erucic acid (C22:1n-9)	0.82	0.03c	1.94	0.04b	2.88	0.18a
Nervonic acid C24:1n-9	2.75	0.00a	1.99	0.00b	2.35	0.16b
MUFA	11.18	0.07b	31.39	0.27a	32.24	2.09a
Linoleadic acid C18:2n6t	0.15	0.00c	2.13	0.02b	3.77	0.27a
Linoleic acid (LA) C18:2n6c	3.19	0.02c	4.12	0.02b	5.09	0.32a
Alpha-Linolenic acid (ALA) C18:3n3	0.68	0.01b	2.10	0.01a	0.00	0.00c
Gamma-Linolenic acid (GLA) C18:3n6	1.07	0.02c	2.78	0.01b	3.68	0.25a
Eicosadienoic acid C20:2 cis 11.14	0.67	0.00b	0.88	0.00b	1.39	0.10a
Arachidonic acid C20:4n6	2.62	0.01ab	2.23	0.04b	2.80	0.20a
Eicosatrienoic acid C20:3n6 cis-8.11.14	0.00	0.00c	1.12	0.01b	1.34	0.09a
Eicosatrienoic acid C20:3n3 cis-11.14.17	0.00	0.00a	0.00	0.00a	0.00	0.00a
Docosapentaenoic acid (DPA) (C22:5n3) cis-7.10.13.16.19	0.00	0.00a	0.00	0.00a	0.00	0.00a
Eicosapentaenoic acid (EPA) C20:5n3 cis 5.8.11.14.17	10.08	0.09a	8.34	0.02a	4.37	4.37a
Docosadienoic acid C22:2 cis13.16	0.15	0.00b	0.27	0.00a	0.30	0.02a
Docosahexanoic acid (DHA) C22:6n-3 cis-.7.10.13.16.19	29.51	0.42a	12.26	0.08b	12.11	0.88b
PUFA	48.10	0.27a	36.24	0.17b	34.82	2.26b
n-3	40.27	0.33a	22.70	0.09b	16.48	3.49b
n-6	5.96	0.04c	9.60	0.08b	12.98	0.86a
TOTAL	100.58	0.59a	100.01	0.00a	99.98	0.00a
Undefined	-0.58	0.59a	-0.01	0.00a	0.03	0.00a
n-3/n-6	6.76		2.37		1.29	

Means with different lowercase letters in the same line are significantly different ($p < 0.05$) from groups. $p < 0.05$

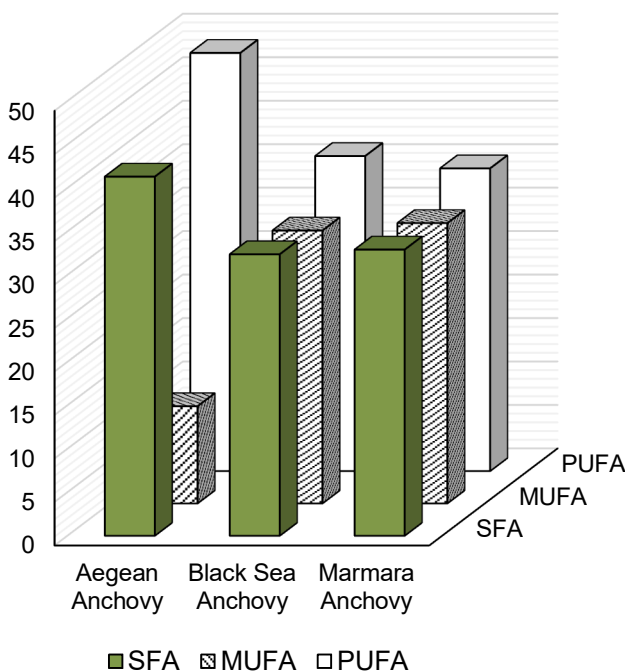


Figure 1. The total fatty acids composition of anchovy (%).

The amount of SFA (saturated fatty acids), MUFA (monounsaturated fatty acids) and PUFA (polyunsaturated fatty acids) of anchovy was max. 41.31% (in the Aegean Sea anchovy), max. 32.24% (in the Marmara Sea anchovy) and max. 48.10% (in the Aegean Sea anchovy), respectively (Figure 1). A large amount of SFA content is composed of palmitic acid (max 20.24% in the Aegean Sea anchovy), butyric acid (max 8.28% in the Aegean Sea anchovy), myristic acid (max 6.07% in Black Sea anchovy) and behenic acid (max 2.80% in the Marmara Sea anchovy). While about 47% of the MUFAs composed of oleic acid in Black Sea anchovy. The predominant n3 fatty acids found in fish meat is especially DHA. Similarly, present study; Özden [10] and Kocatepe and Turan [11] were reported the predominant SFA, MUFA, and PUFA's in the Marmara Sea anchovy were; palmitic acid, oleic acid, and EPA-DHA, respectively.

Fish fats contain 20-30% of saturated fatty acids, 70-80% of unsaturated fatty acids [12, 13]. In the present study the fatty acids content of anchovies was compared, it was seen that the amount of SFA, MUFA and PUFA were changed between 32% - 42%, 11% - 33% and 34% - 49%. respectively.

The SFA contents of the Aegean Sea anchovy was highest ($p > 0.05$). Researchers reported the different SFA ratios were 40.77% [14] in the Marmara Sea anchovy; 38.62, 35.20 and 33.57% in November, December and January in the Black Sea anchovy [15], 37.91 to 34.04% (from October to April) in the Black Sea anchovy [16]; 42.2% in the Black sea and the Marmara Sea [17], 36.23% in the Marmara Sea anchovy [10] and 37.81% [18].

Most of the n-6 fatty acids form was linoleic acid and arachidonic acid in all groups. The n-3/n-6 ratio is the best index for comparing relative nutritional values of fish oils from

different species [19]. In the study, the maximum n-3/n-6 proportional value was determined as 6.76 in the Aegean Sea anchovy, 2.37 in Black sea anchovy and 1.29 in the Marmara Sea anchovy, respectively.

The minimum value of the PUFA/SFA ratio recommended is 0.45 [20]. PUFA/SFA ratio of anchovy was higher than the limit value in all groups (Table 2).

Table 2
PUFA/SFA ratio, lipid quality indices, crude lipid and EPA+DHA value (to meet the EPA and DHA recommendation) of whiting meat and roe (%).

	Aegean Sea Anchovy	Black Sea Anchovy	Marmara Sea Anchovy
PUFA/SFA	1.17	1.13	1.06
AI	0.75	0.62	0.49
TI	0.19	0.24	0.26
FLQ	39.37	16.48	19.01
h/H	1.98	2.51	2.81
Crude lipid%	0.74	11.76	9.33
EPA+DHA	0.29	2.42	1.54

Flesh Lipid Quality Indices (FLQ) indicate the global dietetic quality of lipids and their potential effects on the development of coronary disease [21]. The FLQ values of the Aegean Sea anchovy was highest. AI and IT indexes should be low to prevent cardiovascular diseases related with lipid intake [6] and the high value of h/H ratio represents high-quality lipids. In this study, AI and IT indexes were measured to be lower than 1.0 but high in h/H in all groups. Ouraji *et al.* [22] and Stancheva *et al.* [23] determined that higher values of AI and IT (>1.0) are detrimental to human health. Especially the h/H ratio of the Marmara Sea anchovy was higher than the others. It was showed that the lipids quality of the Aegean Sea anchovy had the highest quality in view of the lipid quality.

The ratio of n-3/n-6 fatty acid is commonly used as an index for assessing the nutritional quality of fishery products [24]. The ratio of n-3/n-6 of the Aegean Sea anchovy was the highest (6.76). The maximum amount of n3 and n6 were detected in the Aegean Sea anchovy and the Marmara Sea anchovy, respectively. Several studies report that a high n-6/n-3 FA ratio is associated with an increased risk of CRC (colorectal cancer), PC (Pancreatic cancer) and BC (breast cancer). Since a risk associated with n-6 has not been demonstrated, it can be concluded that a low n-3 PUFA intake is responsible for the observation [25]. The difference in the fatty and fatty acid composition of seafood depends on different factors such as nutritional pattern, geographical conditions, environmental temperature, season, hunting area, fish size, sex and species [13, 26].

For adult pregnant and lactating females, the minimum intake for optimal adult health and fetal and infant development is 0.3 g/d EPA+DHA, of which at least 0.2 g/d should be DHA [25]. Similarly, the British Nutrition Foundation [27] has emphasized that people who care for balanced and healthy nutrition should get 0.2 g of EPA + DHA every day. Daily intake of 100 g anchovy consumption (caught from all sea studied in this study) is meet the EPA + DHA requirement. This study was indicating that the very oily Black sea anchovy has more EPA+DHA than the others. Especially the crude fat value of the Aegean Sea anchovy was very low, for this reason to meet the EPA and DHA recommendation was lowest according to the BNF.

Amino acids composition of European anchovy

The results of the amino acid compositions of the anchovies caught from different seas were shown in Table 3. Total nine essential amino acids except from tryptophan and nine non-essential amino acids were identified in the anchovy. The maximum amount of glutamic acid detected in the Aegean Sea anchovy ($p < 0.05$). The content of aspartic acid in the Black Sea and the Marmara Sea anchovies were found to be similar ($p > 0.05$).

The highest amount of essential amino acids was detected for lysine in all groups. The amount of lysine was lowest in the Marmara Sea anchovy. The ratio of essential amino acids to non-essential amino acids (EA/non-EA) in fish meat was found to be 1.21 in the Aegean and Marmara Sea anchovy and 1.31 in Black Sea anchovy.

Table 3

Amino acid composition of anchovy caught from different Sea (mg/kg).

	Aegean Sea Anchovy		Black Sea Anchovy		Marmara Sea Anchovy	
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
Alanine	1.68	0.02a	1.35	0.04b	1.24	0.01b
Arginine*	1.53	0.01a	1.37	0.05a	1.17	0.02b
Aspartic Acid	2.39	0.07a	1.88	0.03b	1.85	0.04b
Cysteine	0.32	0.00a	0.31	0.01a	0.24	0.00b
Glutamic Acid	3.35	0.04a	2.92	0.02b	2.47	0.02c
Glycine	1.05	0.01a	0.59	0.01b	0.83	0.03c
Histidine*	1.11	0.01a	0.93	0.09a	0.83	0.06a
Isoleucine*	0.93	0.02a	0.78	0.02b	0.70	0.03b
Leucine*	1.88	0.01a	1.56	0.05b	1.43	0.00b
Lysine*	2.95	0.15a	2.80	0.12ab	2.24	0.04b
Methionine*	0.80	0.03a	0.58	0.01b	0.62	0.02b
Ornithine	0.06	0.01a	0.07	0.01s	0.06	0.01a
Phenylalanine*	1.16	0.00a	0.98	0.02b	0.91	0.00c
Proline	0.99	0.01a	0.81	0.00b	0.77	0.01b
Serine	1.19	0.03a	1.03	0.07s	0.94	0.06a
Threonine*	1.27	0.04a	1.13	0.06sb	0.97	0.00b
Tyrosine	0.93	0.04a	0.76	0.04s	0.75	0.03a
Valine*	1.30	0.03a	1.31	0.02s	1.03	0.01b
Taurine	0.38	0.02a	0.32	0.00s	0.35	0.01a
Total amino acids	25.26	0.31a	21.46	0.25b	19.39	0.15c
Total Essential amino acids (EA)	13.86	0.15a	12.18	0.14b	10.64	0.14c
Total non-essential amino acids(NEA)	11.41	0.15a	9.27	0.11b	8.75	0.01b
Sweet amino acids	7.28	0.10a	5.88	0.07b	5.48	0.02b
Bitter amino acids	7.55	0.13a	6.66	0.18b	5.76	0.12c
EA/NEA	1.21		1.31		1.21	

Fish meat is a protein source with high nutritive value. In fish meat containing all essential amino acid as aspartic acid, glutamic acid and lysine [28]; aspartic acid and glutamic acid are important amino acids that play a role in enzyme activation, preservation of the solubility and ionic character of proteins. One of the most important sources (50-85%) of non-protein nitrogen in fish meat is free amino acids. Free amino acids give the fish meat a characteristic taste.

The level of total sweet AA components was higher in the Aegean Sea anchovy ($p < 0.05$) than the other anchovies, total bitter AA was also higher than when compared the other groups. Proteins are composed of 20 different amino acids. Most proteins contain glutamate in high content. For example, glutamate contents of casein in milk, gluten in wheat, glycine in soybean, and myosin in muscle are 21–35%. Although free glutamate has umami taste, glutamate in proteins has no taste. Proteolysis during fermentation produces free glutamate in high content [29]. Umami taste is found in foods rich in glutamates such as fish, meat, milk, tomatoes, and some vegetables. In addition, the umami flavor is enriched with certain ribonucleotides (inosine and guanosine nucleotides) found in some meats and fish [29-31]. Foods rich in glutamate content, when combined with ribonucleotides, have a higher taste intensity than the sum of both contents [30, 31]. An important component of umami taste is glutamic acid. Glutamate is an amino acid that is very common in foods [32]. The glutamic acid contents of the Aegean Sea anchovy were highest. It can be said that; the umami taste of the Aegean Sea anchovy is more dominant.

The World Health Organization's [33] on protein and amino acid requirements for human nutrition reports an adult daily protein intake of 0.83g/kg, with essential amino acids; leucine 59 mg/g, lysine 45 mg/g, isoleucine 30 mg/g, threonine 23 mg/g and methionine 16 mg/g. In the present study, about 80 g anchovy meat daily consumption meets the leucine, lysine, isoleucine, threonine and methionine requirements. In addition, 320 g anchovy consumption enough for daily protein requirements (Table 4).

Table 4

Anchovy amounts to meet the recommended daily intake (g).

	Recommended Daily Intake*	Aegean Sea Anchovy	Black Sea Sea Anchovy	Marmara Sea Anchovy
Protein	60 g **	291 g	319 g	320g
Leucine	59 mg/g	64.5g	77.7g	71.3g
Lysine	45 mg/g	31.05g	37.8g	30.2g
Isoleucine	30 mg/g	66.3g	80.7g	72.4g
Threonine	23 mg/g	37.3g	44.5g	38.2g
Methionine	16 mg/g	41.1g	48.6	51.7g

Conclusion

Fatty acid and amino acid composition of anchovy caught from different seas in Turkey are different from each other. In generally the European anchovy is a good source of n-3 PUFA. Especially the maximum amount of n3 and n6 have detected in the Aegean Sea anchovy and the lipids quality of the Aegean Sea anchovy had the highest quality in view of the lipid quality index. But the crude lipid composition of Black Sea anchovy was highest, for this reason, Black sea anchovy has more EPA+DHA than the others. Especially the crude fat value of the Aegean Sea anchovy was very low, and to meet the EPA and DHA recommendation was lowest according to the BNF. The amino acid composition of anchovies was different from each other, about 80 g European anchovy meet the daily consumption requirements of the leucine, lysine, isoleucine, threonine, and methionine.

References

1. TUIK (2018), Turkish Statistical Institute, *Fisheries Statistics*, Available at: http://www.tuik.gov.tr/PreTablo.do?alt_id=1005.
2. Anonymous (1998), Amino acid analyzer LC 3000 operation manual (AAAOM) sample preparation for physiological fluids (Tissue Extract), In: Manual version 4.1. of Eppendorf Biotronik Co., pp. 65–81.
3. IUPAC (1979), *Standard methods for analysis of oils, fats and derivatives*, 6th edn. (5th edn. Method II.D.19), Pergamon Press Oxford, Oxford.
4. Boisen S., Hvelplund T., Weisbjerg MR. (2000), Ideal amino acid profiles as a basis for feed protein evaluation, *Livestock Production Science*, 64(2-3), pp. 239–251, DOI: 10.1016/S0301-6226(99)00146-3.
5. Schiffman S.S. (1975), Taste of nutrients: Amino acids, vitamins, and fatty acids. *Perception & Psychophysics*, 17(2), pp. 140-146, DOI: 10.3758/BF03203878.
6. Ulbricht T., Southgate D. (1991), Coronary heart disease: seven dietary factors, *The Lancet*, 338, pp. 985–992, DOI: 10.1016/0140-6736(91)91846-M.
7. Abrami G., Natiello F., Bronzi P., McKenzie D.J., Bolis L., Agradi E. (1992), A comparison of highly unsaturated fatty acid levels in wild and farmed eels (*Anguilla anguilla*), *Comparative biochemistry and physiology. B. Comparative biochemistry*, 101(1-2), pp. 79–81, DOI: 10.1016/0305-0491(92)90161-J.
8. Santos-Silva J., Bessa R.J.B., Santos-Silva F. (2002), Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II Fatty acid composition of meat. *Livestock Production Science*, 77, pp. 187–194, DOI: 10.1016/S0301-6226(02)00059-3
9. Sümbüloğlu K., Sümbüloğlu V. (2007), Biyoistatistik. Hatipoğlu Yayınları.
10. Özden Ö. (2005), Changes in amino acid and fatty acid composition during shelf-life of marinated fish, *Journal of the science of Food and Agriculture*, 85, pp. 2015–2020. DOI: 10.1002/jsfa.2207
11. Kocatepe D., Turan H. (2012), Proximate and fatty acid composition of some commercially important fish species from the Sinop region of the Black Sea. *Lipids*, 47(6), pp. 635–41, DOI: 10.1007/s11745-012-3658-1.
12. Gökoğlu N. (2002), Su Ürünleri İşleme Teknolojisi. Su Vakfı Yayınları. Haziran 2002.
13. Çaklı Ş., (2007), Su Ürünleri İşleme Teknolojisi -1 (Su Ürünleri İşleme Teknolojisinde Temel Konular), Ege Üniversitesi Yayınları. Su Ürünleri Fakültesi Yayın no: 76. İzmir.
14. Güner S., Dincer B., Alemdag N., Colak A., Tüfekci M. (1998), Proximate composition and selected mineral content of commercially important fish species from the Black Sea. *Journal of the Science of Food Agriculture*, 78, 337–342. DOI: 10.1002/(SICI)1097-0010(199811)78:3<337::AID-JSFA122>3.0.CO;2-A
15. Kaya Y., Turan H. (2008), Comparison of protein, lipid and fatty acids composition of anchovy (*Engraulis encrasicolus* L. 1758) during the commercial catching season, *Journal of Muscle Foods*, 21, pp. 474–483. DOI: 10.1111/j.1745-4573.2009.00196.x
16. Öksüz A., Özyılmaz A. (2010), Changes in fatty acid compositions of Black Sea Anchovy (*Engraulis encrasicolus* L.1758) during catching season. *Turkish Journal of Fisheries and Aquatic Science*, 10, pp. 381–385, DOI: 10.4194/trjfas.2010.0311
17. Tanakol R., Yazıcı Z., Sener E., Sencer E. (1999), Fatty acid composition of 19 species of fish from the Black Sea and the Marmara Sea, *Lipids*, 34(3), pp. 291–297. DOI: 10.1007/s11745-999-0366-8
18. Bayır A., Haliloglu H.I., Sirkecioglu A.N., Aras N.M. (2006), Fatty acid composition in some selected marine fish species living in Turkish waters, *Journal of the Science of Food and Agriculture*, 86, pp. 163–168. DOI: 10.1002/jsfa.2295.
19. Piggott G.M., Tucker B.W. (1990), *Seafood effects of Technology on Nutrition*, Marcel Dekker. New York.

20. HMSO UK. (1994), *Nutritional aspects of cardiovascular disease (report on health and social subjects No.46)*, London.
21. Senso L., Suarez M.D., Ruiz-Cara T., Garcira-Gallego M. (2007), On the possible effects of harvesting season and chilled storage on the fatty acid profile of the fillet of farmed gilthead sea bream (*Sparus aurata*), *Food Chemistry*, 101, pp. 298-307. DOI: 10.1016/j.foodchem.2006.01.036.
22. Ouraji H., Shabanpur B., Abediankenari A., Shabani A., Nezami A., Sudagar M., Faghani S. (2009), Total lipid, fatty acid composition and lipid oxidation of Indian white shrimp (*Fenneropenaeus indicus*) fed diets containing different lipid sources. *Journal of the Science of Food and Agriculture*, 89(6), pp. 993–997, DOI: 10.1002/jsfa.3545.
23. Stancheva M., Merdzhanova A., Dobрева D.A., Makedonski L. (2014), Common carp (*Cyprinus carpio*) and European catfish (*Silurus glanis*) from Danube River as sources of fat soluble vitamins and fatty acids, *Czech Journal of Food Sciences*, 32, pp. 16–24, DOI: 10.17221/31/2013-CJFS.
24. Chen D.W., Zhang M. (2007), Non-volatile taste active compounds in the meat of Chinese mitten crab (*Eriocheir sinensis*), *Food Chemistry*, 104, pp. 1200–1205, DOI: 10.1016/j.foodchem.2007.01.042
25. FAO (2008), FAO Food and Nutrition Paper 91. Fats and fatty acids in human nutrition. Report of an expert consultation. 10-14 November 2008. Geneva. Available at: <http://www.fao.org/3/a-i1953e.pdf>
26. Alasalvar C., Taylor K.D.A., Zubcov E., Shahidi F., Alexis M. (2002), Differentiation of cultured and wild sea bass (*Dicentrarchus labrax*), pp. total lipid content, fatty acid and trace mineral composition. *Food Chemistry*, 79, pp. 145-150, DOI: 10.1016/S0308-8146(02)00122-X
27. British Nutrition Foundation (BNF) (1992), Unsaturated Fatty Acids. Nutritional and Physiological Significance. Report of British Nutrition Foundation. Chapman and Hall. London, pp. 152–163.
28. Oladapo A.A., Omosola A.A., Olusegun L.O. (1984), Quality changes of Nigerian traditionally processed freshwater fish species, nutritive and drgnoleptic changes, *J Food Sci*, 9, pp. 333–340.
29. Kurihara K. (2015), Umami the Fifth Basic Taste: History of Studies on Receptor Mechanisms and Role as a Food. Flavor, *Biomed Research International*, 4(13), pp. 1–5, <http://dx.doi.org/10.1155/2015/189402>.
30. Yamaguchi S. (1967), The Synergistic Taste Effect of Monosodium Glutamate and Disodium 5-Inosinate. *Journal Food Science*, 32, pp. 473–478, DOI: 10.1111/j.1365-2621.1967.tb09715.x
31. Rifkin B., Bartoshuk L.M. (1980), Taste Synergism Between Monosodium Glutamate and Disodium 5- Guanylate. *Physiology Behavior*, 24, pp. 1169–1172, DOI: 10.1016/0031-9384(80)90066-9
32. Cömert M., Güdek M. (2017), Fifth taste: Umami. *Journal of Tourism and Gastronomy*, 5(3), pp. 397–408, DOI: 10.21325/jotags.2017.101.
33. World Health Organization (WHO) (2007), *Protein and amino acid requirements in human nutrition (Vol. 935)*, World Health Organization.

Microscopic examination of chops with content of lentil flour

Iryna Simonova¹, Liudmyla Peshuk², Oleg Galenko²

1 – Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, Lviv, Ukraine

2 – National University of Food Technologies, Kyiv, Ukraine

Abstract

Keywords:

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Introduction. Histological examination of truncated semi-finished products including poultry meat and sprouted lentil flour was performed in order to determine ingredients of formula and their characteristics for further identification of these components.

Materials and methods. In order to perform histological examination proper samples of truncated semi-finished products were fixed in 10% neutral buffered formalin. Subsequently material was dehumidified in series of alcohol solutions with ascendent concentration 70, 80, 90, 96°, condensed in two portion of chloroforme and embedded in paraffin. Slices with thickness of from 5 to 15 µm were prepared using sliding microtome; thereafter they were stained with hematoxylin and eosin. Light microscopy and microphotographing were performed using microscope.

Results and discussion. During the soaking of lentils for germination, the initial humidity was 15%, and after 8 hours it reached a degree of soaking 35%, which affects the processes of growth and metabolism of the grain, formation of enzymes. To minimize the loss of nutrients during germination, control of the duration of germination and germination temperature is performed; on average it lasts for 72 to 88 hours at a temperature of 17±2 °C.

A histological study of the investigated truncated semi-finished products showed polygonal and round muscular fibers with pronounced nuclei under sarcolemma, which corresponds to highquality meat raw material, it means that chilled meat is used. Adding to the products of sprouted lentil flour leads to an improvement in the degree of swelling of fibers and more active accumulation of particles of minced meat finely-grainular protein mass, which improves the conditions for the formation of products and their structure. Cells of lentil seedcoat are stained in pink color, forming dense translucent structures that are similar to cell lines with a noticeable violet colored cellulose shell. The mincemeat is even and homogeneous, the components are well mixed, resulting in loosening of the fibers.

Conclusions. The method of obtaining flour of germinated lentils has been characterized and the components of truncated semi-finished products has been identified. Sprouted lentil flour look like purple lines of cells, cells of pepper and onion have brown colour.

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Corresponding author:

Oleg Galenko
E-mail:
galen@i.ua

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Introduction

In the era of modern technologies in manufacturing of truncated semi-finished products, the adaptation of recipes using meat and vegetable raw materials is important. [1] Most food producers refuse to manufacture products in accordance with State standards, but develop and approve their assortment in accordance with the specifications of requirement [2]. Lack of supply of farm animals meat and the import of frozen meat prompts the development of technologies for truncated semi-finished products with a combined composition of meat and vegetable raw materials [3].

Literature review

Current issues of the present remain the use of poultry meat as sources of valuable protein and in comparison with other types of meat, less valuable raw materials. There are known technologies of production of truncated semi-finished products with poultry meat mechanical deboning. It also receives protein-mineral nutritional supplements that are used in cooking potatoes and schnitzels [4,5].

The composition of the recipes of many meat products includes soy. The content of protein in soybean seeds, which yields soy flour, ranges from 30 to 45% on average. However, there is a lot of information on the harm to human health of genetically modified organisms, which include soy [6, 7, 8, 9].

An alternative to soya is lentil. By its content, lentil protein is also ahead of peas and beans. Protein lentils, like other leguminous cultures, is rich in the most important essential amino acids that are necessary for the human body, lysine, tryptophan, valine, arginine, and others. In almost all grain legumes contain various anti-nutrients (enzyme inhibitors, in particular trypsin, alkaloids, etc.). Most of these substances have protein origin, they can be inactivated by thermal treatment [10].

It should also be noted that during heat treatment the beneficial properties of lentils are completely preserved. In addition to high protein content (25 ... 50%), different varieties of lentils contain about 50% of carbohydrates, 2-4% of minerals, 1-3% of fat. In comparison with lentil, soya contains up to 26% fat. It should be emphasized that lentil is a source of vitamins B (thiamine, riboflavin, niacin), β -carotene, minerals such as sodium, potassium, calcium, magnesium, phosphorus, iron, amino acids and protein which are easily digestible by the human body [11].

The use of lentil flour in combination with meat makes it possible to form a stable system that can withstand weakly bound water and fat during heat treatment, and thus obtain the finished products of a dense and elastic consistency [12].

The use of plant material in the production of meat semi-finished products does not require additional complex processes, ensures compliance with traditional technological schemes of production and cheapening finished products [13].

As a result, the quality control of meat products remains topical. In order to detect various components that are part of meat products, methods of histological analysis are widely used [14,15]. These methods are based on the microstructure and chemical properties of the components. This allows using a special differential coloring to detect all components of the recipe during a microscopic study [16, 17].

Abdel Hafeez H.H., Zaki R.S. Abd El-Magiud DS have done a research on the purpose of revealing the components that are included in the recipes of meat products by means of histological analysis. They found that in the composition of many sausages and chops used

for hot dogs and hamburgers is also place for meat with a large amount of connective tissue, tendons, byproducts, soy and other vegetable raw materials [18].

R. Latorre, J. Sadeghinezhad, B. Hajimohammadi, F. Izadi, M.T. Sheibani during histological studies found components of the meat products not mentioned on the marking, namely, connective tissue and fat tissue, stomach and cartilage tissues [19].

In the writings of Guelmamene R. Bennoune O. Elgroud R. special attention is paid to the histological study of meat and meat products with the discovery of their mechanical deboned meat, twice frozen meat, and the presence of meat with signs of damage. This allows us to conclude that the effectiveness of using this method is not only to identify signs of falsification, but also to confirm the quality and safety of the product [20].

On the basis of morphological peculiarities of structures, it is possible to quantify the available components in truncated semifinished products. This prevents possible falsification of these products [21].

When conducting research, important attention should be paid to the peculiarities of the technological process of truncated semifinished products, as the technological process consists of the preparation of raw materials, preparation of minced meat. All components are weighed or dispensed with dispensers. Weighed raw materials and spices are loaded into a continuous-action mixer or continuous-action aggregates, in which the minced meat is prepared, and stirred for 4 to 6 minutes, cutlery machines are used for the formation of semifinished products [22]. Then they carry out packaging, marking and storage of finished products. Therefore, working with biological tissues in food products has certain specifics compared with native tissues, because in this case the material is subject to research after mechanical, thermal and other treatments [22].

The scientific value of the research results is the identification of quality meat, lentil flour, spices in chops by the histological method, which is effective for qualitative and quantitative analysis of minced meat and the detection of possible falsification of the data of the recipe components.

The aim of the work is to determine the microstructure of the branched semi-finished products, to identify the individual components of the recipe, give their characteristics for further identification of these components.

The main task is to characterize the method of obtaining flour sprouted lentils; identify the components of cut semi-finished products.

Materials and methods

Materials

Recipes have been developed for researches of semi-finished products, namely, chops, which are chilled or frozen semi-finished product containing meat raw materials in accordance with a recipe of not less than 50%, an oval, oval-flattened form having a mass of 50 g to 100 g in breadcrumbs.

In the recipe of the half-finished semifinished products, beef meat was replaced by pork meat, goose, chicken, wheat flour bread on lentil flour, and instead of breading with wheat breads, corn grits were used. From the experimental recipes, melange and unsalted fat have not been removed. Number of onions has been increased from 2 to 4 kg per 100 kg, in order to improve the organoleptic characteristics of semifinished products. The amount of added salt and black pepper has not changed.

Chops with the recipes of which include first-class beef, semi-lean pork, wheat flour bread, wheat bread for panning have been taken for a control sample. Preparation of semi-finished products is carried out in accordance with the general technology.

Getting lentil flour

Getting the flour of germinated lentils is to wash the grains with running water, soaking the grains in a water reservoir at a temperature of 18 ± 2 °C for 8 hours, re-washing, sprouting lentil grains in a reservoir without water at a temperature of 17 ± 2 °C for 3 days to the length of the 1 cm stem, drying the raw material to a moisture content of 16% and chopping up to a particle size of 0.2 mm - 0.4 mm. The size of the particles of the flour is determined by sifting it through a sieve with a passage of 0.2 mm to 0.4 mm grating openings [12].

The moisture content of lentils was determined using the SuperPoint grain moisture meter, which is used for rapid analysis of grain moisture in laboratory and field conditions. To measure the grain humidity, the appliance is switched on, the name of the scale of the corresponding measuring crop or product is selected on the LCD screen, the necessary sample is selected, which falls into the device, the pressure cover of the pressurizes to the level until the pressure indicator is set to the level with the upper surface of the lid. After tightening the button "TEST" is pressed and after 10 seconds the result of the measurements of humidity in% is received. Measurement is carried out with an accuracy of 0.5% with a range of humidity measurement from 8 to 45%.

Research methodology

For histological examination in samples with uniform distribution of components, fragments from different sites were taken - a cube or a plate 1-1.5 cm thick was cut out. Prepared samples of the chops were fixed in a 10% neutral solution of formalin. For this purpose, an ordinary method of making slices is used, which begins with the fixation of the material. All investigated semi-finished products were fixed for 24-48 hours at room temperature ($15-20$ °C) in a 10% solution of formalin. After a certain period of time, the material was taken out of formalin, washed with running water, dehydrated, using the traditional method using alcohols of ascending concentration [14,16].

The next step was paraffin filling. After that, the fixed material was dehydrated in a number of solutions of alcohol at concentrations of 70, 80, 90, 96 %, densified in two portions of chloroform and poured into paraffin. Depending on the type of meat product, the filling time of the material may be different. The production of paraffin blocks from semi-finished products lasted up to 48 hours [14,16].

After receiving paraffin blocks, the histological sections were made on the sled the microtome, from 5 microns to 15 microns thick, they were fixed on a specimen glass and stained with hematoxylin and eosin for 10 to 15 minutes. Light microscopy and microphotography of histoparticles were performed using an OLYMPUS CX 41 microscope and a OLYMPUS C-5050 camera [14,16].

Results and discussion

Characteristics of lentil during germination and flour production

Since lentil contains oligosaccharides and high-polymeric protein structures that affect the digestion and absorption of the product, their negative effects can be reduced by germination. When lentils are soaked, water penetrates into the embryo of the grain, and then through the side shells in the grain. Water absorption capacity depends on the duration of soaking, temperature, grain size.

During the soaking of lentils, absorption of moisture does not occur exactly as the rapid and even moisture of the floury body, as the distribution of water is uneven. The initial moisture content of lentils was 15%, and after 8 hours it reached a degree of soaking 35%, which affects the processes of growth and metabolism in the grain, as well as the formation of enzymes. Excessive water absorption of the grain leads to the death of the embryo.

To minimize the loss of nutrients during germination, the duration of germination and germination temperature must be controlled, which is 17 ± 2 °C. The duration of germination is achieved when the length of the sprout reaches 1 cm, which on average lasts from 72 hours to 88 hours. According to the scientific literature [23], under such conditions, the maximum accumulation of extractives is up to 29.9 mg / 100, the maximum yield of sprouted grains of lentils at given technological parameters is 92%, and the loss of germinated sprouts is reduced.

The germination is completed by removing drying water, which prevents further growth of the embryonic roots. As a result of heat exposure during drying, most embryos die, so drying was carried out in the dryer at a temperature not exceeding 30 °C. Simultaneously with the termination of germination, the dissolution ends and further processes of splitting cease.

The grinding of lentil grain was carried out using laboratory mills LMT 2, OS 124, where all the components of the grain are ground evenly to obtain a homogeneous mixture. The size of the flour particles passing through sieve is 0.2 mm - 0.4 mm. When adding lentil flour to the minced meat, its interaction with water and hydration occurs, swelling and peptization of high-molecular organic compounds of flour occurs too. By absorbing water osmotically, the protein molecule of flour is significantly increased in volume. During the addition of minced meat as a result of the mechanical action, the swollen particles of proteins stick together and form a structure that provides minerals of plasticity.

Histological studies of truncated semi-finished products

The histological study of experimental samples revealed polygonal and round muscular fibers with pronounced sarcoma nuclei. This is due to the fact that meat raw materials are of high quality, obtained from chilled meat (Figure 1). Compared with the data of Sadeghinezhad J., in which the histological method was mainly used to detect fresh and defrosted pork meat, ice crystals and changes in muscle fiber were not detected in experimental samples of the chops [24].

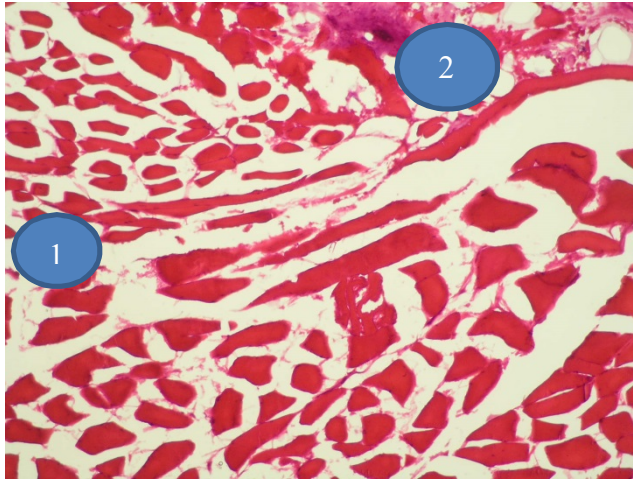


Figure 1. Chops control sample
(Hematoxylin and eosin, Eyepiece 10, lens 20 × 100)

Hajimohammadi B, Izadi F found animal and vegetable components, namely, transverse sections of the striped skeleton, dense connective tissue and smooth stomach muscles, cotyledonous soybean cells, soy extrudate in the studies of minced meat [25]. In contrast, experimental samples are made without the use of soy, and beef meat is replaced by poultry meat.

The conformity of components of the recipe of their composition is established. In the control sample, oval cells of adipose tissue (1), visible onions, black pepper, painted in brown (2) are observed.

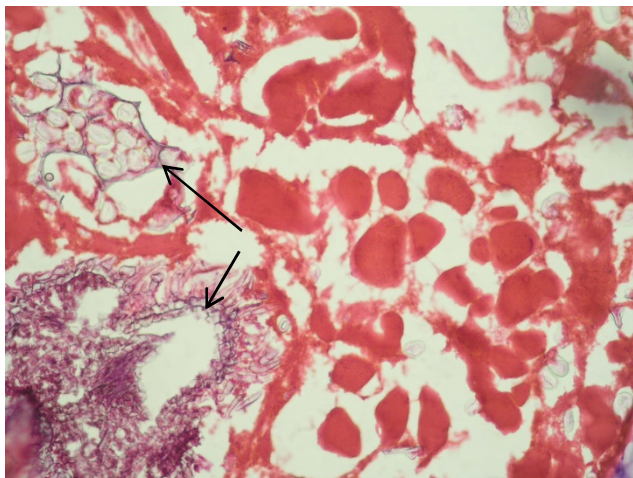


Figure 2. Chops control sample
(Hematoxylin and eosin, Eyepiece 10, lens 20 × 100)

The recipe of the control sample includes bread made from wheat flour, shown in Figure 2 with brown fibers (shown with arrows).

Cells shell flour lentils are painted in pink color, forming dense translucent structures that resemble a thread of cells with a noticeable purple shell of cellulose. Picture 3 shows the arrows.

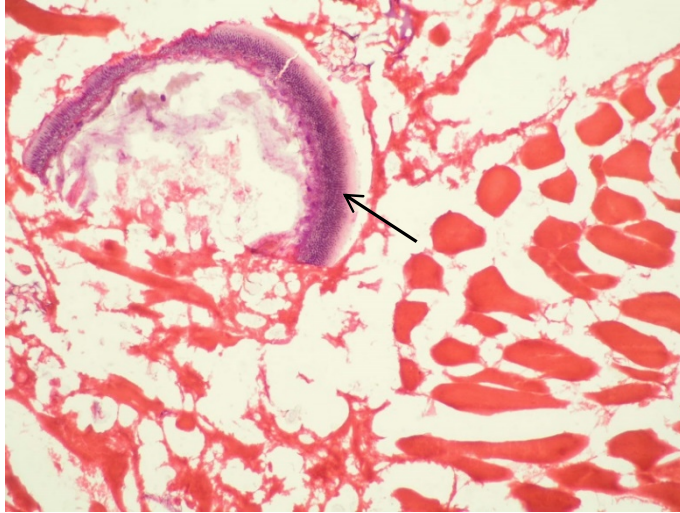


Figure 3. Chops sample with the usage of lentil flour sprouted (Hematoxylin and eosin, Eyepiece 10, lens 20 × 100)

Meat products with the usage of soy flour are identified as a group of cells with a pronounced eosinophilic cytoplasm, and the cells themselves are separated by non-painted layers of cellulose (Figure 4) [14].

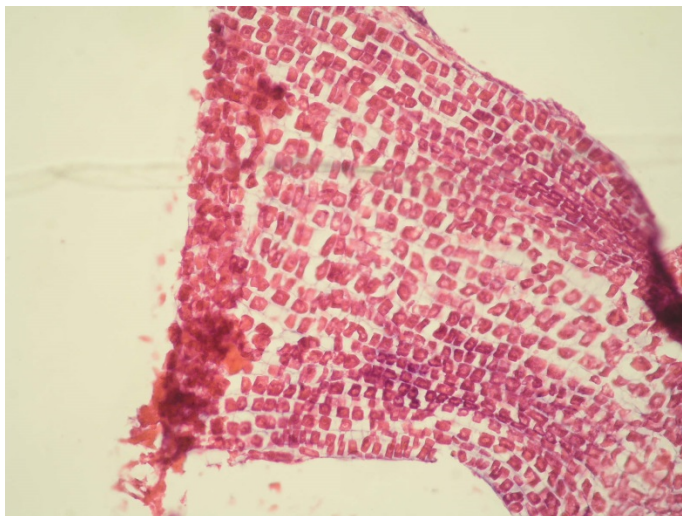


Figure 4. Sample of meat products using soy flour (Hematoxylin and eosin, ocular 10, lens 40 × 50) [14]

Jahed-Khaniki GR was involved in the identification of frozen raw materials and soybeans in hamburgers by the histological method [26]. In contrast to these studies, the difference between the cells of lentil flour in experimental chops and soy flour cells is in the size, shape and number of constituents of soy flour cells. This is due to the fact that the accumulation of its cells can count cells as the same type, and with different morphological structure (rounded, oval-cylindrical).

Adding to the products of lentil flour, germinated, leads to an improvement in the degree of swelling of fibers and more active accumulation of fine particles of fine-grained protein mass, which improves the conditions for the formation of products and their structure (Figures 5-6).

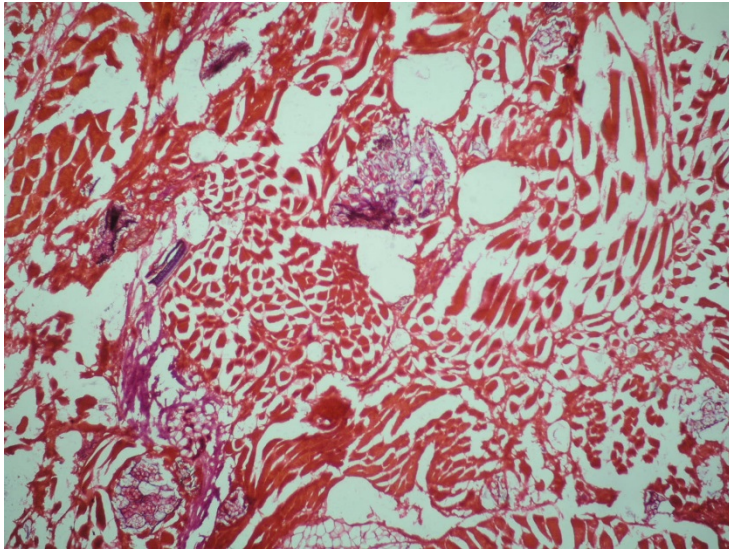


Figure 5. Sample number 2 using flour sprouted lentil, added in the amount of 10 kg per 100 kg (Hematoxylin and eosin, Eyepiece 10, lens 20 × 100)

There is the inclusion of particles of lentil flour in all new experimental samples of the chops. Minced meat structure is even and homogeneous, the components are well mixed, resulting in loosening of the fibers. Unlike research on hamburgers, Abbasy-Fasarani M, containing 30 and 60% of meat [27], experimental samples of the chops are produced without deviations from the recipe. Histological studies confirm the meat content of the product not less than 50%.

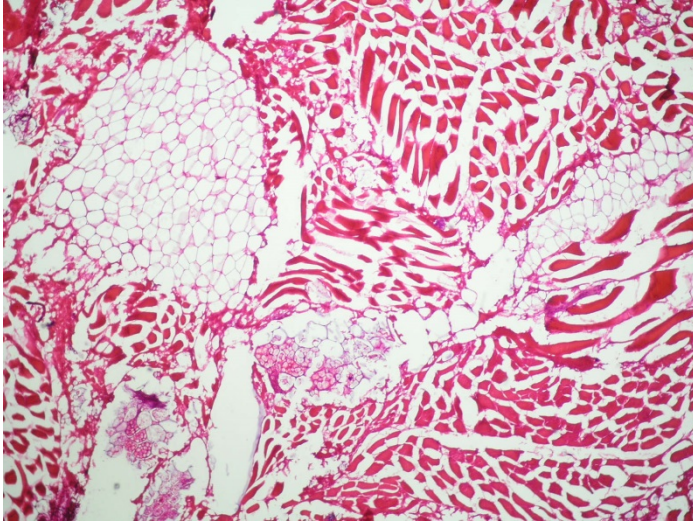


Figure 6. Sample number 3 using flour of germinated lentils added in the amount of 12 kg per 100 kg (Hematoxylin and eosin, Eyepiece 10, lens 20 × 100)

Figure 6 shows the fraction of the test sample with the presence of acute muscle fibers, mesh cells of adipose tissue, brown colored cells, confirming the presence of black pepper. This is due to the use of poultry meat, semi-fat pork and lentil flour in a recipe amounting to 12 kg per 100 kg of raw meat material.

Conclusion

1. Lentil sprouting provides a reduction in the negative effects of oligosaccharides and high-polymer protein structures on the digestion and assimilation of the product. The germination time is from 72 to 88 hours.
2. During the histological studies, it was established that the amount of meat in the experimental samples of truncated semifinished products (cjops) is not less than 50%. The ingredients of the recipe are evenly mixed, the lentil flour of germinated has the form of filament of purple-colored cells, pepper and onion seeds are painted in brown color.

References

1. Markovych I.I. (2015), Vplyv priano–aromatychnoi syrovyny na yakist tvarynnykh zhyriv, *Skhidnoevropeyskyi zhurnal peredovykh tekhnolohii*, 2/10(74), pp. 31–36.
2. Taran T.V., Ushakov O.F. (2016), Mikrostrukturnyi analiz kovbasnykh vyrobiv, *Scientific reserches and their practical application. Modern state and ways of development*, 10, pp. 47–55.
3. Peshuk L.V., Galenko O.O., Budnik N.V. (2014), Use of collagenase in technology gerodietetic products, *Journal of food and packing science, technique and technologies*, 2(3), pp. 8–11.

4. Topchii O.A., Peshuk L.V. (2007), Vykorystannia netradytsiinoi syrovyny v kombinovanykh miasnykh napivfabrykatakakh, *Naukovi pratsi NUKhT*, 2, pp. 51–57.
5. Peshuk L.V., Hashchuk O.I., Moskaliuk O.I. (2015), Innovatsiyni miasnyi produkt, *Kharchova promyslovist*, 17, pp. 64–67.
6. Mao L., Wang W., Tai K., Yuan F., Gao Y. (2017), Development of a soy protein isolate–carrageenan–quercetagetin non–covalent complex for the stabilization of β –carotene emulsions, *Food Funct.*, 25, pp. 40–45, DOI:10.1039/c7fo01238a.
7. Sumczynski D., Bubelova Z., Sneyd J., Erb–Weber S., Mlcek J. (2015), Total phenolics, flavonoids, antioxidant activity, crude fibre and digestibility in non–traditional wheat flakes and muesli, *Food Chem.*, 174, pp. 319–25, DOI:10.1016/j.foodchem.2014.11.065.
8. Caparros, Megido R., Alabi T., Nieuw C. et al. (2016), Optimisation of a cheap and residential small–scale production of edible crickets with local by–products as an alternative protein–rich human food source in Ratanakiri Province, *Cambodia. J. Sci. Food Agric*, 96(2), pp. 627–32, DOI:10.1002/jsfa.7133.
9. Souza P.M., Bittencourt M.L., Caprara C.C., et al. (2015), A biotechnology perspective of fungal proteases, *Braz J Microbiol*, 46(2), pp. 337–46, DOI:10.1590/S1517–838246220140359.
10. Markovych I.I. (2014), Doslidzhennia amino kyslotnoho skladu napivkopchenykh kovbas z vykorystanniam sochevytsi yalivtsiu ta chebretsiiu, *Skhidnoievropeiskyi zhurnal peredovykh tekhnolohii*, 6/10(72), pp. 38–44, DOI: 10.15587/1729–4061.2014.28725.
11. Drachuk U., Simonova I., Halukh B., Basarab I., Romashko I. (2018), The study of lentil flour as a raw material for production of semi–smoked sausages, *Eastern–european journal of enterprise technologies*, 6/11(96), pp. 44–50, DOI:10.15587/1729–4061.2018.148319.
12. Markovych I. I. (2015), Doslidzhennia zhyrnokyslotnoho skladu napivkopchenykh kovbas z vykorystanniam sochevytsi, yalivtsiu ta chebretsiiu, *Kharchovanauka i tekhnolohiia*, 1(30), s. 37–42.
13. Hrehircha N.M., Peshuk L.V., Zusko K.V. (2017), Doslidzhennia sosysok z vkluchenniam kvartetsetynu i natyvnoi kvartetsetynvmisnoi syrovyny podovzhenoho terminu zberihannia, *Naukovi pratsi NUKhT*, 23(4), pp. 223–230.
14. Shchebentovska O.M. (2014), Suchasni metody vyjavlennia ta identyfikatsii bilkivsoi u miasnykh vyrobakh, *Naukovo–tekhnichniyi biuletyn Instytutu biologii tvaryn i Derzhavnoho naukovo–doslidnoho kontrolnoho instytutu vetpreparativ ta kormovykh dobavok*, 15(1), pp. 239–245.
15. Ince E., Özfiliz N. (2018), Detection of adulterations in fermented and heat–treated Turkish type sau–sages by histological examination. *Ankara Üniversitesi Veteriner Fakültesi Dergisi*, 65(1), pp. 99–107, DOI:10.1501/vetfak_0000002834.
16. Iesina E.V., Martseniuk I.V. (2010), Osoblyvosti provedennia mikrostrukturnoho doslidzhennia vyrobiv, *Visnyk Dnipropetrovskoho Derzhavnoho Ahrarnohouniversytetu*, 1, pp.114–119.
17. Peshuk L.V., Galenko O.O., Budnik N.V. (2011), Gerodietic meat products technology enriched with calcium and phosphorus, *Journal of Faculty of Food Engineering, Ștefancel Mare University–Suceava*, pp. 1–8.
18. Abdel Hafeez H.H., Zaki R.S., Abd El–Magiud D.S. (2016), Applying light, histochemical and scanning histological methods for the detection of unauthorized animal and herbal content in street meat sandwich: what is in the sandwich we eat,

Journal of Food Processing & Technology, 7, pp. 12–17, DOI: 10.4172/2157–7110.1000643.

19. Latorre R., Sadeghinezhad J., Hajimohammadi B., Izadi F., Sheibani M.T. (2015), Application of morphological method for detection of unauthorized tissues in processed meat products, *Journal of Food Quality and Hazards Control*, 2, pp. 71–74.
20. Guelmamene R., Bennoune O., Elgroud R. (2018), Histological techniques for quality control of meat and meat products – A mini–review, *J Nutr Hum Health*, 2, 2, pp. 24–29.
21. Vanha G., Kvasnicka F. (2011), Methods of detecting plant raw materials in meat products – a review, *Czech J. Food Sci*, 29, pp. 471–479.
22. Peshuk L.V., Salov K.M., Halenko O.O. (2011), Tekhnolohiia nutrientno–adekvatnykh produktiv z vykorystanniam netradytsiinoi syrovyny u herodiietychnomu kharchuvanni, *Kharchova nauka i tekhnolohiia*, 2, pp. 8–12.
23. Telezhenko L.M., Atanasov V.V. (2013), Obhruntuvannia tekhnolohichnykh pidkhodiv kompleksnoi pererobky sochevytsi, *Kharchova nauka i tekhnolohiia*, 4 (25), pp. 77–80.
24. Radzievska I., Melnyk O., Galenko O., Peshuk L. (2018), Two–stage technology for palm oil fractionation for production of cocoa butter substitutes, *Nauka innov.* 2018, 14(1), pp. 40–49.
25. Sadeghinezhad J., Izadi F., Latorre R. (2016), Application of histomorphological method to assess meat products: A Case Study, *Anatomical Sciences*, 13(2), pp. 79–84.
26. Jahed–Khaniki GR, Rokni N. (2004), Histological detection of soya in freezing raw hamburger of Iran (Persian), *Animal Sciences (Pajouhesh&Sazandegi)*, 62(1), pp. 71–75.
27. Abbasy–Fasarani M., Hosseini H., Jahed–Khaniki GR, Adibmoradi M., Eskandari S. (2012), Histological study of industrial hamburgers containing 30 and 60 percent meat for presence of unpermitted edible tissues and correlation of this factor to meat connective tissue chemical indices (Persian), *Iranian Journal of Nutrition Sciences&Food Technology*, 7(5), pp. 311–318.

Mini review on Keto-Enol ratio of curcuminoids

Sameera A. Rege, Megha Arya, Shamim A. Momin

Institute of Chemical Technology, Matunga (East), Mumbai, India

Abstract

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Corresponding author:

Rege A. Sameera
E-mail:
sameerarege@
gmail.com

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Introduction. Curcumin, demethoxycurcumin and bisdemethoxycurcumin collectively constitute curcuminoids, exhibit different rates of degradation as well as therapeutic properties. Their remarkable dissimilar behaviour is affiliated to their tendency to undergo keto-enol tautomerism whereas their rates of degrading and imparting therapeutic properties depend on the ratio of keto and enol tautomers of individual curcuminoid.

Materials and Methods. The aim of the current review is to focus on the ratio of keto and enol tautomers and to explain how the ratio of the two tautomers affects the rate of activities of the curcuminoids. The papers regarding variations in the rate of activities of curcuminoids were scrutinized. The factors affecting the ratio of keto-enol tautomerism were studied.

Results and discussion. Structurally, curcuminoids are the compounds possessing β -diketone moiety. The characteristic property of compounds containing β -diketone moiety is to exhibit keto-enol tautomerism. Hence, each curcuminoid is a mixture of keto and enol tautomers. The keto tautomer of curcuminoids is responsible for their therapeutic activities. On the other hand, enol tautomer of curcuminoids has tendency to undergo degradation. Hence, the ratio of keto and enol tautomer needs to be considered while studying the activities of curcuminoids.

Nevertheless, the ratio of keto and enol tautomer depends on the existence of other functional groups. Because of the presence of electron donating hydroxyl group, the proportion of enol tautomer predominates in curcuminoids. Further, due to the presence of two more electron donating methoxy groups in curcumin, the ratio of the enol tautomer is higher and hence, the susceptibility to undergo degradation is greater than demethoxycurcumin, which contains only one methoxy group. The ratio of the enol tautomer is minimum in bisdemethoxycurcumin amongst all the curcuminoids, which is devoid of methoxy group. Consequently, bisdemethoxycurcumin has the least rate of degradation amongst curcuminoids. Methoxy group enhances the activity of the functional sites in curcuminoids in keto form. Therefore, curcumin shows maximum beneficial activities in keto form amongst all the curcuminoids, followed by demethoxycurcumin and bisdemethoxycurcumin. Thus, the rate of the activities displayed by curcuminoids is governed by their keto and enol proportion.

Conclusion. It can be concluded from this review article that besides β -diketone moiety, responsible for keto-enol tautomerism, other groups also play an important role in determining the ratio of keto and enol tautomers.

Introduction

Turmeric (*Curcuma longa* L.) is one of the herbs, which is extensively used as a spice. It is mainly cultivated for its rhizome. Curcumin, demethoxycurcumin and bisdemethoxycurcumin constitute curcuminoids, which are the polyphenolic compounds present in the turmeric rhizome [1]. The composition of curcuminoids was found to be curcumin 60-80%, demethoxycurcumin 15-30%, bisdemethoxycurcumin 2-6% [2]. Curcuminoids are the natural colouring agents used in food industry. The three curcuminoids are proven to have various therapeutic properties such as antioxidant [3], anti-inflammatory, wound healing [4, 5], anticancer [6, 7] and anti-depressant [8, 9]. They are used to prevent Alzheimer's disease [10].

However, the overall activity of the mixture of curcuminoids is attributed to the three individual curcuminoids and each shows a different rate of activity [10]. The three curcuminoids display different rates of degradation as well [11]. In this review, our main focus is to evaluate the root cause of the different rates of activities of each curcuminoid.

Materials and methods

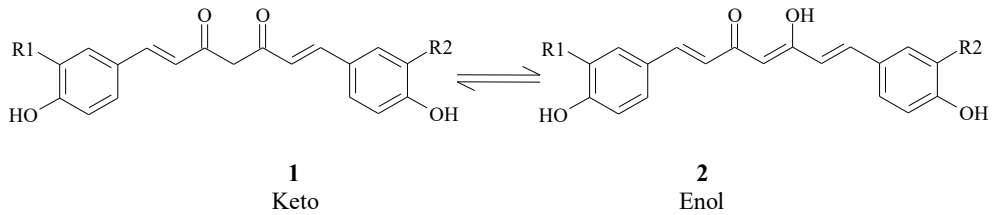
Phenolic hydroxyl groups and the heptadienone moiety are responsible for the beneficial activities of curcuminoids. The dienone moiety is accountable for keto-enol tautomerism. The enol tautomer is liable to degradation. The difference in the keto-enol ratio of each curcuminoid is the key parameter for the different rates of beneficial activities as well as degradation shown by curcuminoids. The ratio of keto-enol tautomers is influenced by the other groups present on phenolic rings. The objective of our study is to show how the overall structure of each curcuminoid contributes to the keto-enol ratio and hence, the rate of activity.

Review is constructed on the basis of previously available research articles.

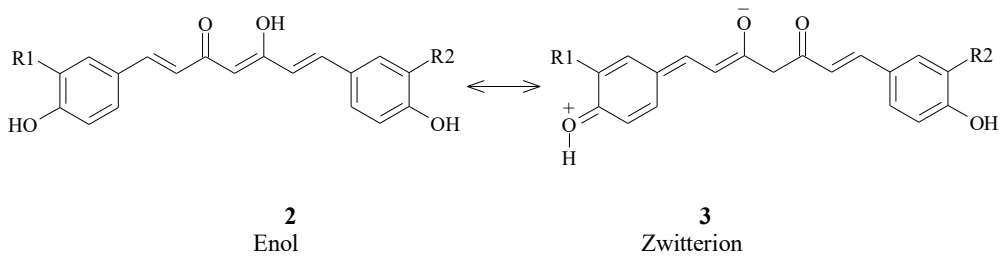
Results and discussion

Proportion of keto and enol tautomers of curcuminoids

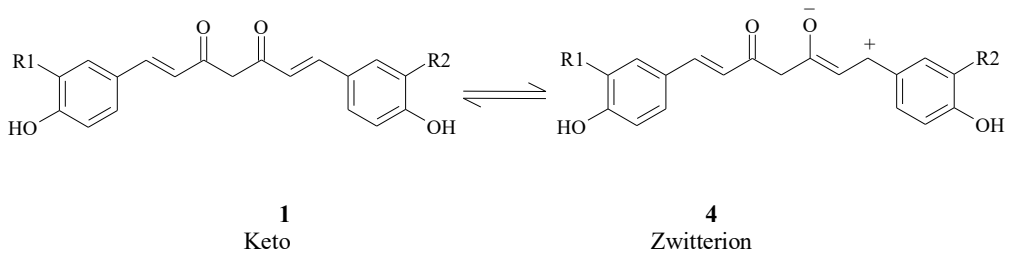
The curcuminoids exhibit keto-enol tautomerism, structures (1) and (2) (Figure 1), a typical property of the compound having β -diketone moiety [12]. The enol tautomer is certainly more stable than keto tautomer due to resonance of conjugated pi system and intramolecular hydrogen bonding [13]. Also, since they possess electron donating hydroxyl group in the aromatic ring and electron withdrawing carbonyl group in heptadienone moiety, structures (3) and (4) can be drawn respectively. The existence of structures (3) and (4) has already been proven by NMR data [14]. Structures 3 and 4 resemble the enol tautomer (Figure 1).



(i) Tautomerism due to β -diketone moiety



(ii) Formation of zwitterion (3) due to hydroxyl group

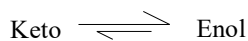


(iii) Formation of zwitterion (4) due to carbonyl group

Figure 1. Tautomerism of curcuminoids:

- (i) R1 = R2 = -OCH₃; Curcumin
- (ii) R1 = -OCH₃, R2 = -H; Demethoxycurcumin
- (iii) R1 = R2 = -H; Bisdemethoxycurcumin

Thus, it can be represented as,



Moreover, due to the presence of two additional electron donating methoxy groups in curcumin, the proportion of enol tautomer is maximum amongst all the curcuminoids. In case of demethoxycurcumin, which contains only one additional electron donating methoxy

group, the proportion of enol tautomer is higher compared to bisdemethoxycurcumin which is devoid of additional electron donating group. Thus, the different ratios of keto and enol tautomers of the curcuminoids are dependent on the number of the methoxy groups present. Even though the electron donating group prefers the enol tautomer, it does not shift the equilibrium completely to the enol form [15].

Based on the above discussions, we are proposing the following resonating structures of demethoxycurcumin and curcumin (Figure 2).

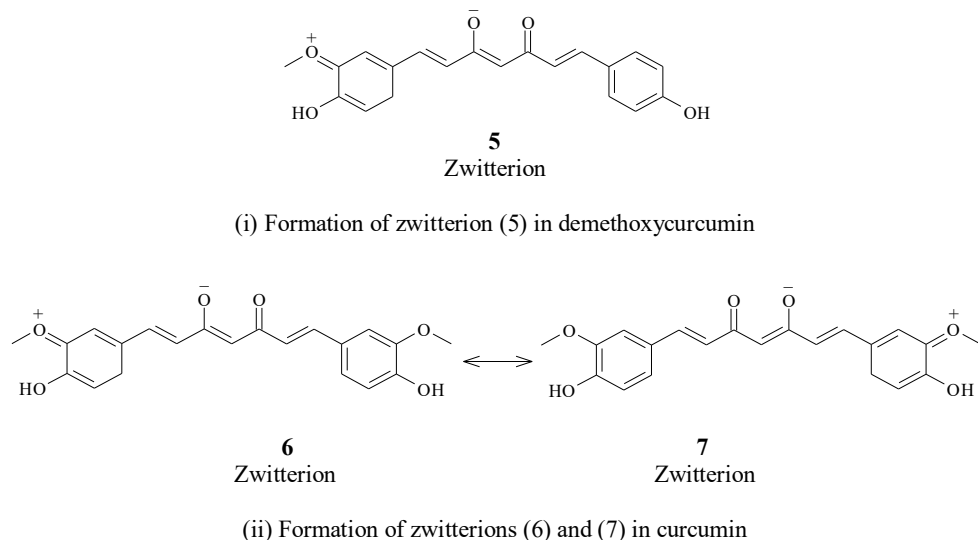


Figure 2. Formation of zwitterions due to methoxy groups

Because of the presence of a single methoxy group in demethoxycurcumin, an additional resonating structure (5) is formed, which resembles the enol tautomer. Hence, the proportion of enolic form of demethoxycurcumin is higher than bisdemethoxycurcumin. Similar explanation can be given for the maximum enolic content of curcumin amongst curcuminoids, which contains two methoxy groups thereby forming two additional resonating structures (6 and 7).

Effect of different ratios of keto-enol tautomers of curcuminoids on their individual rate of activity

Under alkaline and non-polar medium, since the enol tautomer of curcuminoids undergoes degradation [16, 17], curcumin degrades at the highest rate followed by demethoxycurcumin and bisdemethoxycurcumin. The beneficial effects of all the curcuminoids can only be achieved when they do not undergo degradation, i.e., when the activity of keto tautomer predominates that of enol in acidic or polar medium. Though the proportion of keto tautomer is same in all the three curcuminoids, they differ in the rate of

activity depending on the number of methoxy groups present in them. Methoxy group, being an electron donating group, increases electron density on hydroxyl groups and diketone moiety, which are the functional sites of the curcuminoids [18]. Hence, the rate of activities associated with hydroxyl groups and diketone moiety also enhances due to presence of methoxy group. As curcumin has two methoxy groups, the rate of activities linked with hydroxyl group and diketone moiety is higher than demethoxycurcumin, which contains only one methoxy group. Bisdemethoxycurcumin does not contain a methoxy group, hence shows the least rate of activities amongst all the curcuminoids.

Exclusive activity of curcuminoids as keto or enol tautomer depending on the medium

Both, keto and enol tautomers of curcuminoids are present in varied ratio in any medium. Nevertheless, the equilibrium ratio of the two tautomers in a medium is constant. The activity of one tautomer leads the other depending on the polarity of the medium [19]. If any one of the keto or enol tautomers is removed, more of the same tautomer will be formed to retain the equilibrium. Hence, in an acidic or polar medium, when the activity of keto tautomer of any of the curcuminoids predominates, the keto tautomer gets utilized thereby decreasing its quantity; the enol tautomer gets converted to the keto tautomer to maintain the equilibrium. Hence, the molecule as a whole displays the activity of keto tautomer.

Likewise, in basic or non-polar medium, when the enol tautomer takes up the activity, the keto tautomer gets converted to enol tautomer and the molecule gets degraded.

Conclusion

The two factors that influence the activity of curcuminoids are medium and structure. The mode of activity of curcuminoids (viz. keto or enol) is determined by the nature of the medium while the rate of activity of curcuminoids is determined by the structure. Though the β -diketone moiety present in the three curcuminoids is responsible for keto-enol tautomerism of the curcuminoids, the equilibrium shift towards enol tautomer depends on the other groups present in the molecule. Hence, the variation in the amount of keto and enol tautomers of the three curcuminoids is observed. The rate of activity of keto tautomer and the proportion of enol tautomer are directly dependent on the number of methoxy groups present. The number of methoxy groups is in the order of curcumin > demethoxycurcumin > bisdemethoxycurcumin. Hence, the rate of valuable activities of keto tautomer and degradation of enol tautomer is also in the same order. Further research needs to be carried out to find out the exact ratio of keto and enol tautomers of curcuminoids.

References

1. Jayaprakasha G.K., Rao L.J, Sakariah K.K. (2005), Chemistry and biological activities of *Curcuma longa*, *Trends in Food Science and Technology*, 16(12), pp. 533–548.
2. Wichitnithad W., Jongaroonngamsang N., Pummangura S., Rojsitthisak P. (2009), A simple isocratic HPLC method for the simultaneous determination of curcuminoids in commercial turmeric extracts, *Phytochemical Analysis*, 20(4), pp. 314–319.

3. Jayaprakasha G.K., Rao L.J., Sakariah K.K. (2006), Antioxidant activities of curcumin, demethoxycurcumin and bisdemethoxycurcumin, *Food Chemistry*, 98(4), pp. 720–724.
4. Kant V., Gopal A., Pathak N.N., Kumar P., Tandan S.K., Kumar D. (2014), Antioxidant and anti-inflammatory potential of curcumin accelerated the cutaneous wound healing in streptozotocin-induced diabetic rats, *International Immunopharmacology*, 20(2), pp. 322–330.
5. Somchit M., Changtam C., Kimseng R., Utaipan T., Lertcanawanichakul M., Suksamrarn A., Chunglok W. (2014), Demethoxycurcumin from *Curcuma longa* rhizome suppresses iNOS induction in an in vitro inflamed human intestinal mucosa model, *Asian Pacific Journal of Cancer Prevention*, 15(4), pp. 1807–1810.
6. Aggarwal B.B., Kumar A., Bharti A.C. (2003), Anticancer potential of curcumin: Preclinical and clinical studies, *Anticancer Research*, 23(1A), pp. 363–398.
7. Ko Y.C., Hsu S.C., Liu H.C., Hsiao Y.T., Hsia T.C., Yang S.T., Hsu W.H., Chung J.G. (2015), Demethoxycurcumin alters gene expression associated with DNA damage, cell cycle and apoptosis in human lung cancer NCI-H460 cells in vitro, *In Vivo*, 29(1), pp. 83–94.
8. Panahi Y., Badeli R., Karami G.R., Sahebkar A. (2015), Investigation of the efficacy of adjunctive therapy with bioavailability-boosted curcuminoids in major depressive disorder, *Phytotherapy Research*, 29(1), pp. 17–21.
9. Shao Y., Zhu W., Da J., Xu M., Wang Y., Zhou J., Wang Z. (2017), Bisdemethoxycurcumin in combination with α -PD-L1 antibody boosts immune response against bladder cancer, *OncoTargets and Therapy*, 10, pp. 2675–2683.
10. Ahmed T., Gilani A.H. (2014), Therapeutic potential of turmeric in Alzheimer's disease: curcumin or curcuminoids, *Phytotherapy Research*, 28(4), pp. 517–525.
11. Price L.C., Buescher R.W. (1997), Kinetics of alkaline degradation of the food pigments curcumin and curcuminoids, *Journal of Food Science*, 62(2), pp. 267–269.
12. (2004), *Curcumin, Chemical and Technical Assessment*, 61st JECFA. pp. 1-8. Available at: ftp://ftp.fao.org/esn/jecfa/cta/CTA_61_Curcumin.pdf.
13. Kalsi P.S. (2006), Chapter 2: Delocalized Chemical Bonding, *Organic Reactions and Their Mechanisms (Second Edition)*, New Delhi, India: New Age International (P) Limited, pp. 37–80.
14. Rege S.A., Momin S.A., Wadekar S.D., Bhowmick D.N., Pratap A.P. (2014), Effect of demethoxycurcumin and bisdemethoxycurcumin on antioxidant activity of curcumin in refined sunflower oil, *Journal of Food Processing and Preservation*, 38(1), pp. 296–303.
15. Antonov L., Deneva V., Simeonov S., Kurteva V., Crochet A., Fromm K.M., Shivachev B., Nikolova R., Savarese M., Adamo C. (2015), Controlled tautomeric switching in azonaphthols tuned by substituents on the phenyl ring, *ChemPhysChem*, 16(3), pp. 649–657.
16. Tonnesen H.H., Karlsen J. (1985), Studies of curcumin and curcuminoids: V. Alkaline degradation of curcumin, *Zeitschrift für Lebensmittel-Untersuchung und –Forschung*, 180(2), pp. 132–134.
17. Rege S.A., Momin S.A., Bhowmick D.N., Pratap A.P. (2012), Stabilization of emulsion and butter like products containing essential fatty acids using kalonji seeds extract and curcuminoids, *Journal of Oleo Science*, 61(1), pp. 11–16.
18. Priyadarsini K.I. (2013), Chemical and structural features influencing the biological activity of curcumin, *Current Pharmaceutical Design*, 19(11), pp. 2093–2100.
19. Rege S.A., Arya M., Momin S.A. (2019), Structure activity relationship of tautomers of curcumin: a review, *Ukrainian Food Journal*, 8(1), pp. 45–60.

Correlation between the quality indicators of activated coal in vodka technology

Tatiana Shendrik¹, Leonid Levandovskiy²,
Anatolii Kuts³, Vitalii Prybylskiy³, Margarita Karputina³

1 – L.M. Litvinenko Institute of Physical–Organic Chemistry and Coal Chemistry of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

2 – Kyiv National University of Trade and Economics, Kyiv, Ukraine

3 – National University of Food Technologies, Kyiv, Ukraine

Abstract

Keywords:

Active coal
Sorption
Alcohol
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Correlations

Introduction. The purpose of the publication is to establish correlation relations between the quality indicators of active coal (AC) used in the distillery production in vodka technology.

Materials and methods. AC of natural origin, which is used for distillery production. Standard methods of determination and quantitative characteristics of AC quality indicators. Mathematical-statistical methods of research are linear correlation analysis based on the Pearson correlation coefficient.

Results and discussion. It was found that the correlation coefficient (r) between iodine adsorption activity (A_i), which characterizes the amount and volume of micropore AC with diameter $D_m < 2$ nm, including nanopore with diameter $D_m < 1$ nm, and methylene blue ($A_{m.b.}$), which depends on the mesopore volume with a diameter $D_{m\bar{e}} = 2 \dots 50$ nm, is equal to 0.93. The total volume of the micro- and mesoporous space determines the total sorption capacity of AC relative to the organic impurities present in the water-alcohol mixtures. AC's sorption activity also depends on its fractional composition. The correlation (reverse dependence) between adsorption activity on acetic acid ($A_{a.a.}$) and the mass fraction of the sorbent residue on a screen with a cloth №10 ($F_{№10}$) with a coefficient $r = -0.94$ was established. Reducing the mass fraction of the residual on a screen with a cloth from 97...98% to 62...64% leads to an increase in adsorption activity of AC by acetic acid to 117 ml versus 62 ml. This is directly due to the fact that the residual sorbent on the sieve № 10 has a large area of the surface of the microporous and mesoporous space due to the reduced size of the grains. The total volume of sorbents in water ($T_{p.v.}$) is directly proportional to the mass fraction of water soluble ash ($M_{w.a.}$) $r = 0.92$ and the mass fraction of moisture (M_m) at $r = 0.99$. In order to release AC from water soluble ashes and increase the volume of pore space, it will be logical to wash the prepared AC with water and then dry it to the water content in the coal to 2%. It was established that the fractional composition, the mass of the residue on the sieve with canvas № 36 ($F_{№36}$) is directly dependent on the mass fraction of ash (M_a) ($r = 0.91$) and the mass fraction of water soluble ash ($M_{w.a.}$) ($r = 0.91$), which indirectly indicates the influence of inorganic components AC on its mechanical strength. It is assumed that in the largest fractions of AC with a mass of the residue on the sieve with canvas № 36 ($F_{№36} = 2.1\%$) contains more ash in the macropore space ($M_a = 5.12\%$), including water soluble ash ($M_{w.a.} = 1.95\%$).

Conclusions. As a result of the analysis of standard quality indicators AB and the study of their mutual dependencies using the mathematical-statistical method using the Pearson correlation coefficients, it has been found that 92% (12 out of 13) indicators have strong internal relationships that are characterized by a "very high" correlation force with coefficients $r = 0.90 - 0.99$.

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Corresponding author:

Tatiana Shendrik
E-mail:
shendriktg@
gmail.com

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Introduction

Today, one of the topical problems of alcoholic beverage production is the improvement of alcohol production technologies at the main stages of production, the development of technical means and the search for optimal conditions for technological processes for their implementation. The *purpose* of the publication is to establish correlation relations between the quality indicators of active coal used in the distillery production in vodka technology.

Analysis of recent researchs and publications

The most important stages in the production of vodka (Oliinyk et al, 2016, 2014; Kuzmin et al, 2014, 2015, 2017) [1-7] are the creation of water-alcohol mixtures (Kuzmin et al, 2013, 2014, 2017, 2018) [8-14] and processing them with activated carbon (Oliinyk et al, 2014; Mukhin et al, 2003, 2004) [2, 15, 16]. The quality of the activated carbon depends on the quality of the finished product (Mukhin et al, 2003, 2004; Petrov et al, 2004, 2005) [15-18]. Often, the main raw material for activated carbon is a wide range of precursors (natural coal, wood, carbonaceous wastes of various origin, etc.) (Marsh, Rodriguez-Reinoso, 2006; Rivera-Utrilla et al, 2011; Bansal, Goyal, 2005) [19-21].

There are several methods for producing activated coal, the most common of which is the activation of gases and water vapor at temperatures of 800-900 °C (the so-called "physical" activation) (Marsh, Rodriguez-Reinoso, 2006; Kong et al, 2013; Matos et al, 2011) [19, 22, 23] and thermochemical activation, involving reagents of various nature (Marsh, Rodriguez-Reinoso, 2006; Kong et al, 2013; Kuzmin et al, 2017; Kwiatkowski et al, 2017; Kumar, Jena, 2017; Zubkova, 2011) [19, 22, 24-28]. Advantages of chemical activation: one-stage process; lower activation temperature; shorter activation time; large exits; more developed surface; more controlled microporosity (Lillo-Ródenas et al, 2007) [29]. However, chemical activation involves the use of an activating agent ($ZnCl_2$, H_3PO_4 , $NaOH$, KOH , etc.) (Kuzmin et al, 2017; Kwiatkowski et al, 2017; Kumar, Jena, 2017) [24-27], which is introduced by impregnation or stirring, after which the raw material is heated (activated) in an atmosphere of inert (or intrinsic) gases to a certain degree roasting (as a rule, up to 50-70%).

Activated charcoal is classified (Kinle, Bader, 1984; Roshchina, 1998) [30, 31]:

- for the predominant form of pores: spherical; slit-shaped (Figure 1); bottle-shaped;
- by pore size: macropores; mesopores; micropores (Figure 2);
- for porosity: large porosity; fine porosity; active coke; carbon molecular sieve (Table 1).

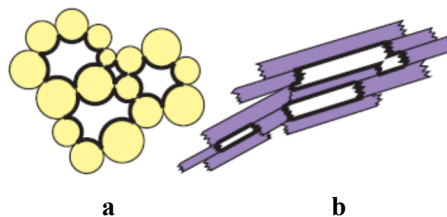


Figure 1. Characteristics of pores in the form:
a - spherical; b - slit-shaped

Table 1

Characteristics of activated carbon for porosity (Kinle, Bader, 1984) [30]

The name of the coal	Macropores $D_{ma} > 50$ nm	Mesopores $D_{me} = 2 \dots 50$ nm	Micropores $D_m < 2$ nm
Volume of pores of broadly porous coal, cm^3/g	0,4	0,6...0,8	0,1...0,2
Volume of pores of finely porous coal, cm^3/g	0,3	0,1	0,6...0,8
Volume of active coke pore, cm^3/g	0,1	0,1	0,1
Volume of pore carbon molecular sieves, cm^3/g	0,1	0,05	0,25

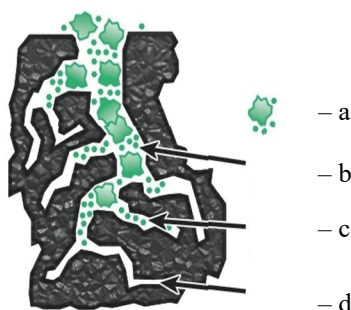


Figure 2. Matrix of pore space in activated charcoal:

a – adsorbed molecules in size of particles (large, small); b – macropores $D_{ma} > 50$ nm; c – mesopores $D_{me} = 2 \dots 50$ nm; d – micropores $D_m < 2$ nm

Characteristics of macropores: diameter $D_{ma} > 50$ nm; volume $V_{ma} = 0,2 \dots 0,8$ cm^3/g ; surface $S_{ma} = 0,5 \dots 2,0$ m^2/g . Macropores are channels for penetration of substances deep into the sorbent, on the surface of which it is impossible to capillary condensation of steam (Kinle, Bader, 1984) [30].

Characteristic mesopores: $D_{me} = 2 \dots 50$ nm; $V_{me} = 0,02 \dots 0,10$ cm^3/g ; $S_{me} = 20 \dots 70$ m^2/g . Filling the mesoporous volume occurs when capillary condensation of steam, adsorption – at pressures, lower boundaries of capillary condensation (Kinle, Bader, 1984) [30].

Characteristics of the micropores: $D_{mi} < 2$ nm; $V_{mi} = 0,20 \dots 0,60$ cm^3/g . Micropores represent the space in which the adsorption field appears at low partial pressure, even before capillary condensation (Kinle, Bader, 1984) [30].

For the solution of special problems of the liquor industry, the production of activated coal with certain properties is relevant. Thus, the adsorption activity of activated charcoal by acetic acid characterizes the catalytic characteristics of activated charcoal, with the decrease of activity, regeneration of active coal or replacement is recommended, with increase – an increase in the content of aldehydes in the water-alcohol mixture (Petrov et al, 2004) [17].

The adsorption activity of activated charcoal by iodine depends on the amount and volume of micropores and determines the sorption capacity of activated charcoal relative to the impurities of organic substances present in water-alcohol mixtures (Petrov, Limonov, 2005) [18].

The oxidation of water-alcohol mixtures by the Lang method is an indicator of the effectiveness of the action of activated charcoal, which is determined in water-alcohol mixtures before and after treatment with activated charcoal. The difference in oxidation for high-grade vodka should be ≥ 2.5 minutes, for low-grade vodka – 2 minutes. If the difference is less indicated – active coal is

regenerated or replaced (Petrov, Limonov, 2005; Lovyahin et al. 2008) [18, 32].

The hardness of active coal – characterizes the ability of active coal to withstand the pressure of the liquid and not crushed by rubbing the particles one by one (Mukhin et al, 2003, 2004; Petrov et al, 2004; Roshchina, 1998) [15-17, 31].

The fractional composition of activated carbon must also meet certain criteria. The high content of small particles of activated carbon leads to increased removal of activated carbon from coal columns, as well as to "loosening" the layer of activated carbon in a column, which leads to additional abrasion of activated carbon (Petrov et al, 2004) [17].

The mass fraction of active coal ash characterizes the amount of mineral impurities in activated charcoal. Low ash content and low content of water soluble ash reduce the ability of water-alcoholic raw materials to aldehyde formation (Mukhin et al, 2003, 2004; Petrov et al, 2004; Roshchina, 1998) [15-17, 31].

The cost of activated charcoal is also an important technical and economic factor, but it is not analyzed in this paper.

Traditionally, the BAU-A grade of activated charcoal, obtained by the method of physical activation with water vapor at $T \geq 800$ °C, is used in the distillery production, which has the following characteristics: $\rho = 200$ g/dm³, $V_{\Sigma} = 1.50$ cm³/g; $V_{ma} = 1.19$ cm³/g; $V_{me} = 0.08$ cm³/g; $V_{mi} = 0.23$ cm³/g; $S_{me} = 57$ m²/g [17].

The main advantages of BAU-A type activated coal (Petrov et al, 2004) [17]: high specific surface area ($S = 500 \dots 800$ m²/g), which provides good organoleptic characteristics of vodkas.

The main disadvantages of activated charcoal BAU-A brand (Mukhin et al, 2003, 2004) [15, 16]: high alkalinity of the surface (pH 9...11); low mechanical hardness (37...42%); presence of water soluble ash 0,5...0,7%; uneven fractional composition, which leads to an independent sorting of activated charcoal in the adsorber, with large-sized fractions located in the middle of the column, smaller – in the periphery, which changes the velocity of the water-alcohol mixture in the adsorber.

The spent activated charcoal BAU-A grades are regenerated at a temperature of 700–900 °C by pyrolysis and activated at a temperature of 110...115 °C with water vapor (Mukhin et al, 2003, 2004) [15, 16].

Based on the critical analysis of literary sources, it is concluded that the active charcoal of BAU-A brand does not fully meet the requirements of alcoholic beverage production, which is why the search for alternative active coal is needed and the development of additional requirements for activated carbon in terms of: hardness; adsorption activity (Shulman-Babkova's method); adsorption activity by acetic acid (Oshmyan method).

In the distillery production prospects are active charcoal from fruit stones, shells of coconut, walnuts, etc., which have: a higher bulk density; higher adsorption activity by acetic acid (UAK – 130 units, BAU-A - 60 units); a significant difference in oxidation between vodka and aqueous-alcoholic mixture (UAK – 3.8 minutes, BAU-A – 3.0 minutes); less amount of water soluble ash; greater intergenerational resource of activated carbon; higher hardness than activated charcoal of BAU-A mark (Mukhin et al, 2003, 2004; Petrov et al, 2004) [15-17].

One of the promising areas for the creation of new adsorbents is the production of activated charcoal with particles of colloidal-dispersed silver deposited on its surface. As a result of the electrochemical potential difference between silver and activated carbon there are positive changes in the surface of activated carbon: the intensification of oxidation-reduction reactions and reactions of esterification; increase of hardness of activated carbon; increase of the active coal activity resource; reduction of the aldehyde formation process; increase of organoleptic parameters of vodkas (Tarasov et al, 2003) [33].

The main disadvantages of activated carbon impregnated with silver are: the reduction of the efficiency of treatment of water-alcohol mixtures as a result of the gradual washing out of the surface of activated carbon silver (Tarasov et al, 2003; Zhabkina et al, 2005) [33, 34].

Materials and methods

Materials. The object of the study was active carbons of various types: crushed activated wood charcoal BAU-A; charcoal activated wood crushed BAU-A-LVZ; BAU-A silver impregnated active carbon BAU-A-Ag; active stone coal MeKS; coconut activated carbon KAU-2; anthracite active coal KDS-A (Table 2).

Characteristics of active carbons

Table 2

Symbol	Name of the indicator	Brand of active coal					
		BAU-A	BAU-A-LVZ	BAU-A-Ag	MeKS	KAU-2	KDS-A
A_i	Adsorption activity by iodine, %	62	69	73	94	82	51
$A_{a.a}$	Adsorption activity by acetic acid, ml	64	73	82	117	67	62
$A_{m.b.}$	Adsorption activity by methylene blue, mg/g	129	141	169	273	265	117
$T_{p.v.}$	Total pore volume of water, cm ³ /g	1,72	1,91	2,00	1,57	1,23	1,43
B_d	Bulk density, g/dm ³	215	221	228	572	524	691
$F_{\text{№}36}$	Fractional composition, mass of the residue on the sieve with canvas: № 36, %	1,6	1,4	2,1	0,1	0,2	0,1
$F_{\text{№}10}$	Fractional composition, mass of the residue on the sieve with canvas: № 10, %	98,0	97,6	96,6	90,4	96,3	97,2
F_p	Fractional composition, the mass of the residue on the sieve with canvas: on the pallet, %	0,4	1	1,3	9,5	3,5	2,7
M_a	Mass part of ash, %	4,70	4,95	5,12	3,61	3,26	2,40
$M_{w.a.}$	Mass part of water-soluble ash, %	1,64	1,87	1,95	1,27	1,04	0,78
M_i	Mass part of iron, %	0,12	0,13	0,15	0,19	0,13	0,10
M_m	Mass part of moisture, %	3,8	4,1	4,5	3,2	2,1	2,9
A_r	Abrasion resistance, %	52,8	59,6	63,1	90,1	86,7	79,3

The research methods are based on the research methods of active carbons by physicochemical parameters: adsorption activity by iodine; adsorption activity by acetic acid; adsorption activity by methylene blue; total pore volume of water; bulk density; fractional composition; mass part of ash; mass part of water-soluble ash; mass part of iron; mass part of moisture; abrasion resistance.

Linear correlation (Pearson). Pearson correlation coefficient measures the strength of the linear association between variables. Each variable should be continuous, random sample and approximately normally distributed (Hinkle et al, 2003) [35].

The correlation coefficient can take a range of values from +1 to -1. Positive correlation

coefficient means that if one variable gets bigger, the other variable also gets bigger, so they tend to move in the same direction. Negative correlation coefficient means that the variables tend to move in the opposite directions: If one variable increases, the other variable decreases, and vice-versa. When correlation coefficient is close to zero two variables have no linear relationship (Hinkle et al, 2003) [35].

There are many rules of thumb on how to interpret a correlation coefficient, but all of them are domain specific. For example, here is correlation coefficient (Table 3) interpretation for behavioral sciences offered by Hinkle et al, 2003 [35].

Table 3

Correlation coefficient interpretation by Hinkle et al, 2003 [35]

Absolute value of coefficient (<i>r</i>)	Strength of correlation
0,90...1,00	Very high
0,70...0,90	High
0,50...0,70	Moderate
0,30...0,50	Low
0,00...0,30	Little, if any

Results and discussions

Table 4 presents the correlation matrix for the coals studied.

Table 4

Marked correlations (*r*) are significant at $p < 0,05$; $N=6$

	<i>A_i</i>	<i>A_{aa}</i>	<i>A_{mb}</i>	<i>T_{p.v.}</i>	<i>B_d</i>	<i>F_{N236}</i>	<i>F_{N210}</i>	<i>F_p</i>	<i>M_a</i>	<i>M_{w.a.}</i>	<i>M_i</i>	<i>M_m</i>	<i>A_r</i>
<i>A_i</i>	1,00	0,80	0,93	-0,11	0,07	-0,23	-0,80	0,73	0,11	0,09	0,90	-0,18	0,52
<i>A_{aa}</i>	0,80	1,00	0,64	0,14	0,16	-0,20	-0,94	0,84	0,08	0,11	0,96	0,11	0,45
<i>A_{mb}</i>	0,93	0,64	1,00	-0,46	0,36	-0,49	-0,76	0,77	-0,22	-0,25	0,72	-0,52	0,75
<i>T_{p.v.}</i>	-0,11	0,14	-0,46	1,00	-0,80	0,87	0,20	-0,40	0,87	0,92	0,19	0,99	-0,75
<i>B_d</i>	0,07	0,16	0,36	-0,80	1,00	-0,94	-0,45	0,62	-0,97	-0,94	-0,01	-0,79	0,87
<i>F_{N236}</i>	-0,23	-0,20	-0,49	0,87	-0,94	1,00	0,50	-0,68	0,91	0,91	-0,06	0,88	-0,89
<i>F_{N210}</i>	-0,80	-0,94	-0,76	0,20	-0,45	0,50	1,00	-0,97	0,24	0,22	-0,88	0,22	-0,69
<i>F_p</i>	0,73	0,84	0,77	-0,40	0,62	-0,68	-0,97	1,00	-0,44	-0,42	0,75	-0,42	0,82
<i>M_a</i>	0,11	0,08	-0,22	0,87	-0,97	0,91	0,24	-0,44	1,00	0,99	0,24	0,84	-0,77
<i>M_{w.a.}</i>	0,09	0,11	-0,25	0,92	-0,94	0,91	0,22	-0,42	0,99	1,00	0,25	0,89	-0,75
<i>M_i</i>	0,90	0,96	0,72	0,19	-0,01	-0,06	-0,88	0,75	0,24	0,25	1,00	0,15	0,37
<i>M_m</i>	-0,18	0,11	-0,52	0,99	-0,79	0,88	0,22	-0,42	0,84	0,89	0,15	1,00	-0,77
<i>A_r</i>	0,52	0,45	0,75	-0,75	0,87	-0,89	-0,69	0,82	-0,77	-0,75	0,37	-0,77	1,00

The volume of iodine adsorbed by coal (A_i) is in the range of 51–94%. Iodine adsorption activity (Figure 3) is directly related to the adsorption activity of the sorbent for methylene blue ($A_{m.b.}$). Methylene blue adsorption activity is in the range of 117–273 mg/g. The coefficient of pair correlation (r) between the indices of the adsorption activity on iodine and methylene blue was $r=0.93$, which is characterized by “very high” correlation strength, since the value is in the range of 0.90–1.00. The adsorption activity of active carbon in iodine depends on the number and volume of micropores, which are characterized by a diameter of $D_{mi}<2$ nm, including nanopores with a diameter of $D_n<1$ nm. The adsorption activity of the sorbent for methylene blue depends on the number and volume of mesopores, which are characterized by a diameter of $D_{me}=2–50$ nm. The internal correlation between the adsorption activity of active carbon in iodine and methylene blue determines their total effect of the micropore and mesoporous space on the adsorption process. It determines the sorption capacity of activated carbon relative to the impurities of organic substances present in water-alcohol mixtures.

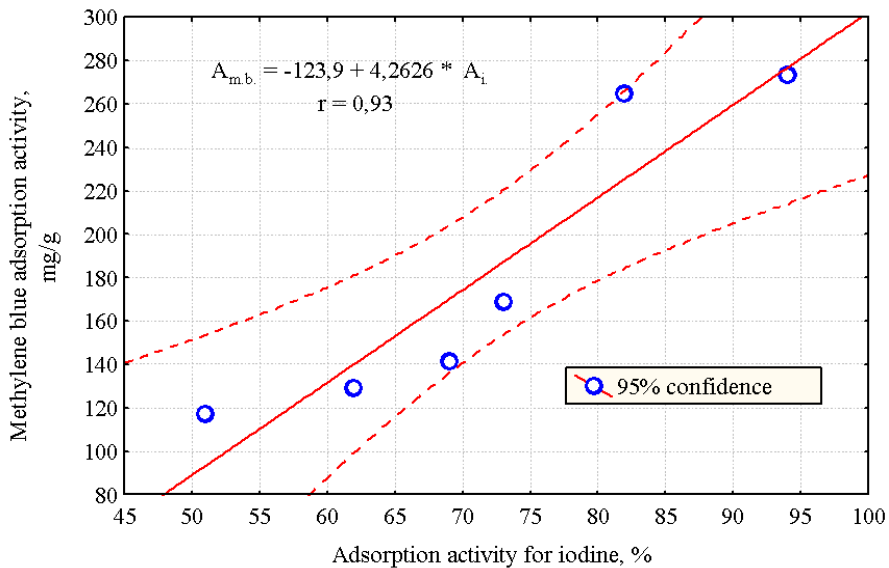


Figure 3. Dependence of adsorption activity for iodine on methylene blue adsorption activity

From the data of table 2 it can be seen that the active carbon of MeKS brand, which has the highest values of adsorption activity for iodine – 94% and adsorption activity for methylene blue – 273 mg/g, has the most developed micropore and mesoporous space. The least developed total pore space is inherent in the structure of active carbon KDS-A, made of fossil coal – anthracite. It is characterized by the lowest values of adsorption activity for iodine – 51% and adsorption activity for methylene blue – 117 mg/g. Interrelation of $A_{m.b.}$ and A_i shown in Figure 3. These qualities of sorbents are characterized by a “very high” correlation force ($r=0.93$).

The sorption properties of porous materials are inextricably linked with their fractional composition. This relationship was considered by us on the example of the adsorption activity of the samples with respect to acetic acid ($A_{a.a.}$) and the fractional composition of activated carbons. So, $A_{a.a.}$ the studied sorbents lie in the range of 62–117 ml. The coefficient of pair correlation (r) between

the indicators of the adsorption activity of acetic acid ($A_{a.a.}$) and the fractional composition of activated carbon, characterized by weight (%) of the residue on the sieve with cloth № 10 ($F_{№10}$), was $r=-0,94$ (Figure 4). This is characterized by a "very high" force of inverse (negative) correlation.

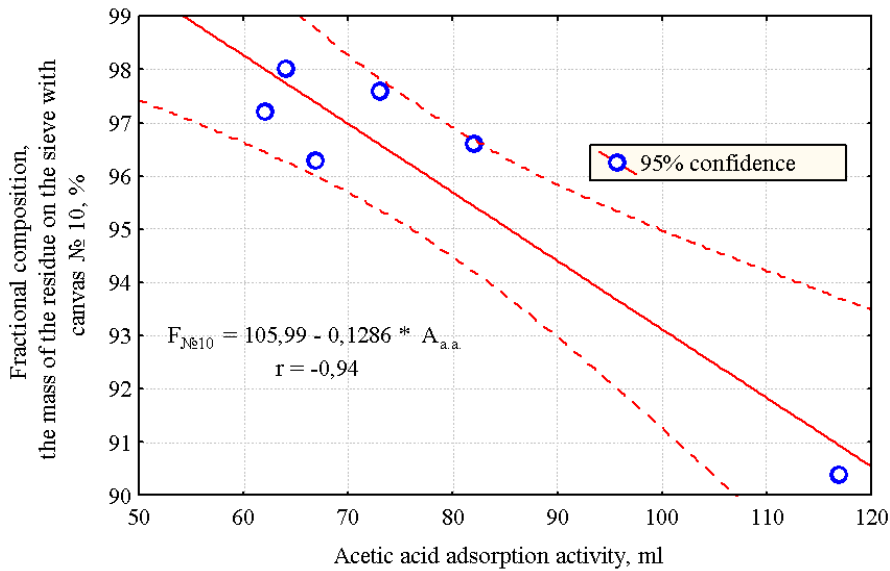


Figure 4. Dependence of acetic acid adsorption activity for fractional composition, the mass of the residue on the sieve with canvas № 10

Interpretation of the results. A decrease in the fraction of active carbon fractions on a sieve with canvas № 10 from 98.0% to 90.4% leads to an increase in the adsorption activity of active carbon on acetic acid from 62 to 117 ml. This characterizes the presence of a smaller amount of the fine fraction on the sieve with the canvas number 10, which has a greater surface area due to the developed micropore and mesoporous space, and, accordingly, increased adsorption activity on acetic acid.

It is known that the presence of iron in active carbon determines the catalytic properties of active carbon. At the same time, the mass fraction of iron (M_i) also affects for the adsorption activity of active carbon for acetic acid ($A_{a.a.}$). The coefficient of pair correlation (r) between the indicators for adsorption activity for acetic acid ($A_{a.a.}$) and the mass fraction of iron (M_i) was $r=0.96$ (Figure 5). This indicates a "very high" strength of direct (positive) correlation. An increase in the mass of iron in active carbon from 0.10% to 0.19% leads to an increase in the adsorption activity of active carbon on acetic acid from 62 ml to 117 ml. At the same time, a decrease in the mass of iron in active carbon to 0.10% reduces the adsorption activity of active carbon on acetic acid to 62 ml.

The total pore volume of water ($T_{p.v.}$) is in the range of 1.23–2.00 cm^3/g . This parameter (Figure 6-7) is in direct relationship with the mass portion of water soluble ash ($M_{w.a.}$) and the mass portion of moisture (M_m). The coefficient of pair correlation (r) between the indicators of the total pore volume of water and the mass fraction of water-soluble ash was $r=0.92$. The relationship between the total pore volume of water and the mass fraction of moisture turned out to be even closer. The coefficient of pair correlation (r) in this case was $r=0.99$, which means "very high" correlation force. Note that all three indicators are related to moisture, which is in the active carbon, and water absorbed in the process of determining

the total pore volume. That is, the larger the pore volume of water ($T_{p.v.}=2.00 \text{ cm}^3/\text{g}$), determined by the standard method in active carbon, the more active carbon retains moisture ($M_m=4.5\%$) and the more water-soluble ash is in the volume of active carbon ($M_{w.a.}=1.95\%$). Therefore, to release the sorbent from water-soluble ash and increase the pore volume, it is necessary to wash the activated carbon with water and then dry it to a mass of water of 2%.

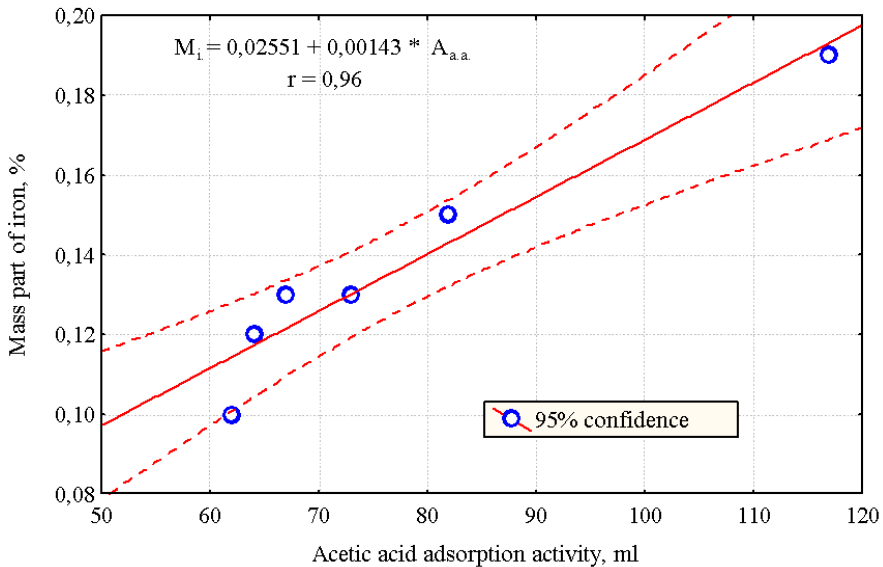


Figure 5. Dependence of acetic acid adsorption activity for mass part of iron

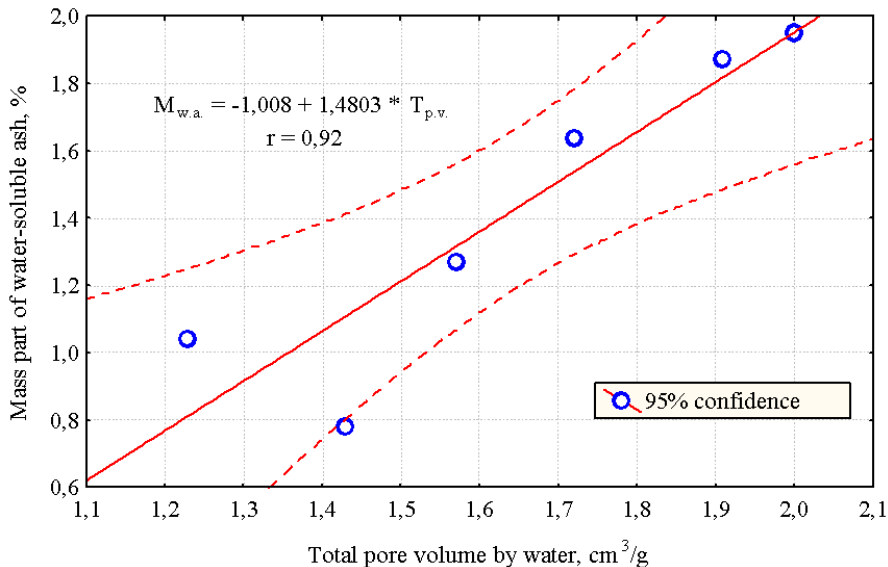


Figure 6. Dependence of total pore volume by water for mass part of water-soluble ash

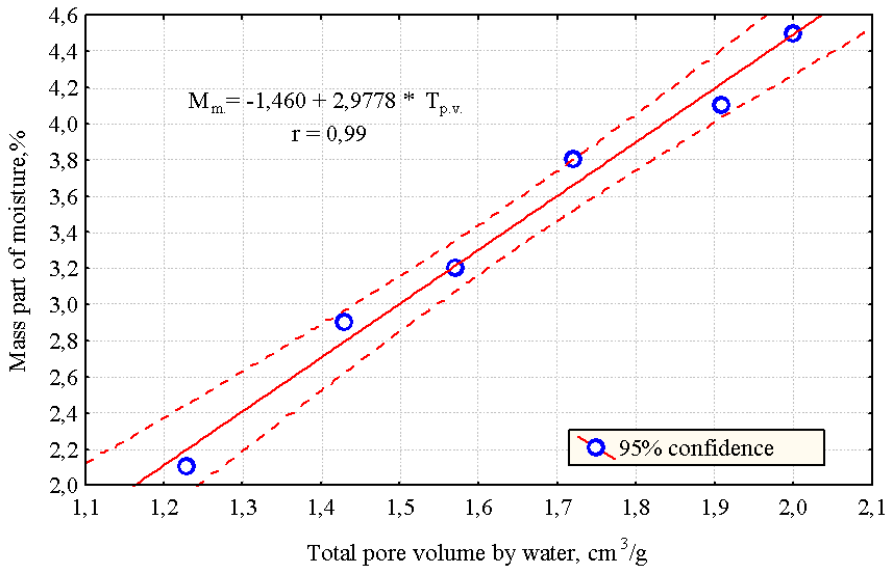


Figure 7. Dependence of total pore volume by water for mass part of moisture

One of the indicators characterizing the operational properties of active carbons is bulk density. The bulk density (B_d) of the coals studied is in the range of 215–691 g/dm³. At the same time, the bulk density (B_d) (Figure 8-10) is inversely related to the fractional composition of the sorbent, namely, to the mass portion of the residue on the sieve with web № 36 ($F_{№36}$), mass portion of ash (M_a), mass part of water soluble ash ($M_{w.a}$).

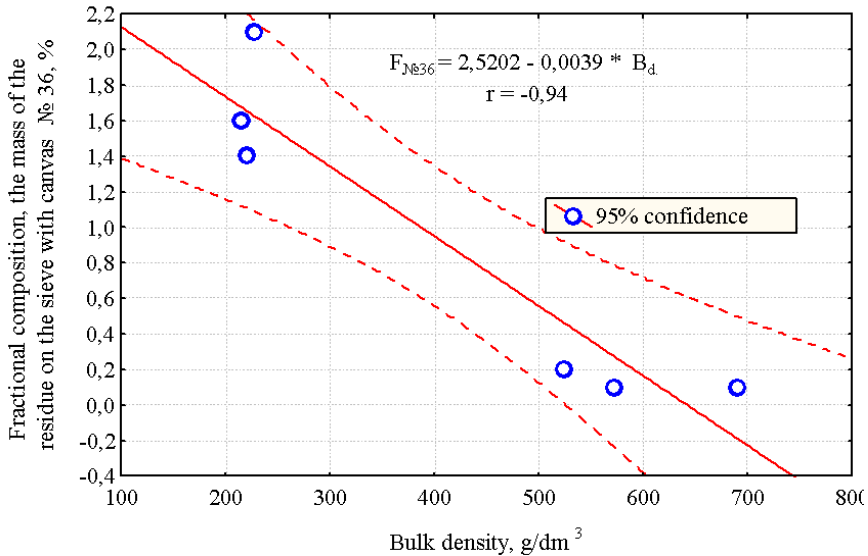


Figure 8. Dependence of bulk density for fractional composition, the mass of the residue on the sieve with canvas № 36

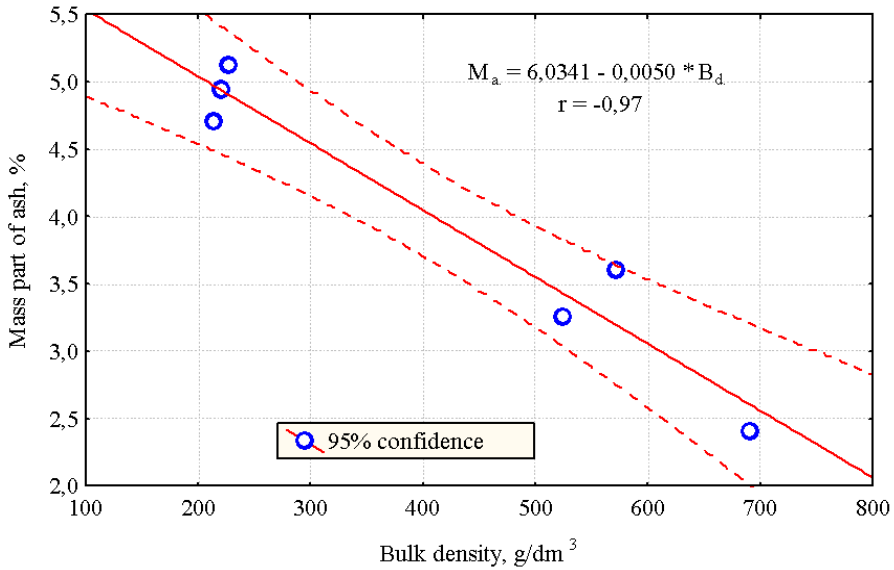


Figure 9. Dependence of bulk density for mass part of ash

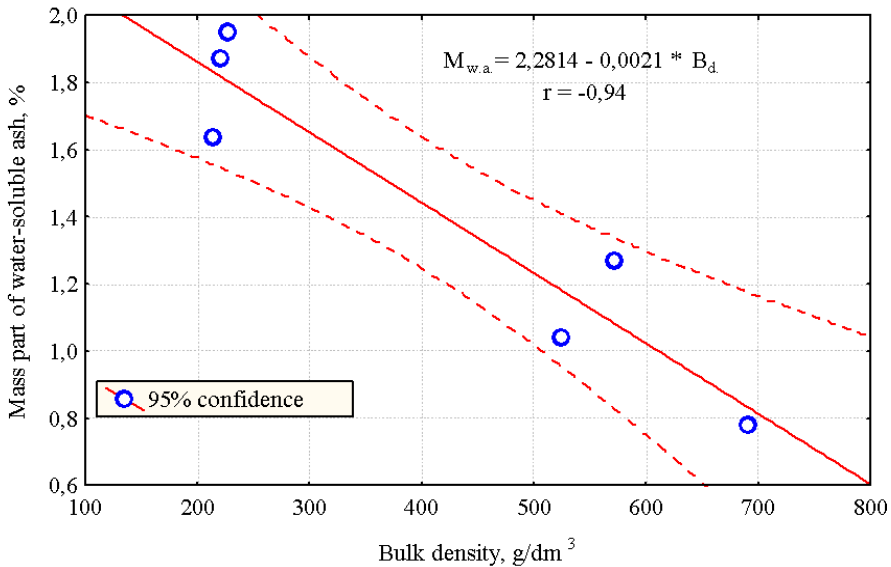


Figure 10. Dependence of bulk density for mass part of water-soluble ash

The coefficient of pair correlation (r) between the indicators bulk density (B_d) and the mass part of the residue on the sieve with the web № 36 ($F_{N\#36}$) was $r=-0.94$. The coefficient of pair correlation (r) between the indicators bulk density (B_d), The mass part of ash (M_a) and the mass part of water-soluble ash ($M_{w.a.}$) was respectively $r=-0.97$, $r=-0.94$. All four indicators are associated with the mass of individual fractions of activated carbon. The

greatest influence on the bulk density is exerted by large fractions with a mass of the residue on a sieve with web № 36 ($F_{N\text{№}36}$).

For the studied active carbons, the fractional composition is typical, which is characterized by a mass portion of the residue on a sieve with cloth № 36 ($F_{N\text{№}36}$) in the range of 0.1–2.1%. It is she (Figure 11-12) that is directly dependent on the mass of ash (M_a) and the mass of water-soluble ash ($M_{w.a.}$). The coefficient of pair correlation (r) between the indicators of the mass fraction of the residue on the sieve with the canvas № 36 ($F_{N\text{№}36}$) and the mass fraction of the ash (M_a) was $r=0.91$. The coefficient of pair correlation (r) between the indicators mass fraction of the residue on the sieve with the canvas № 36 ($F_{N\text{№}36}$) and the mass part of water-soluble ash ($M_{w.a.}$) was $r=0.91$. Consequently, in the largest (largest) fractions of active carbon with a mass part of the residue on a sieve with the canvas № 36 ($F_{N\text{№}36}=2.1\%$) in the macroporous space there is more total ash ($M_a=5.12\%$) and water-soluble ash ($M_{w.a.}=1.95\%$).

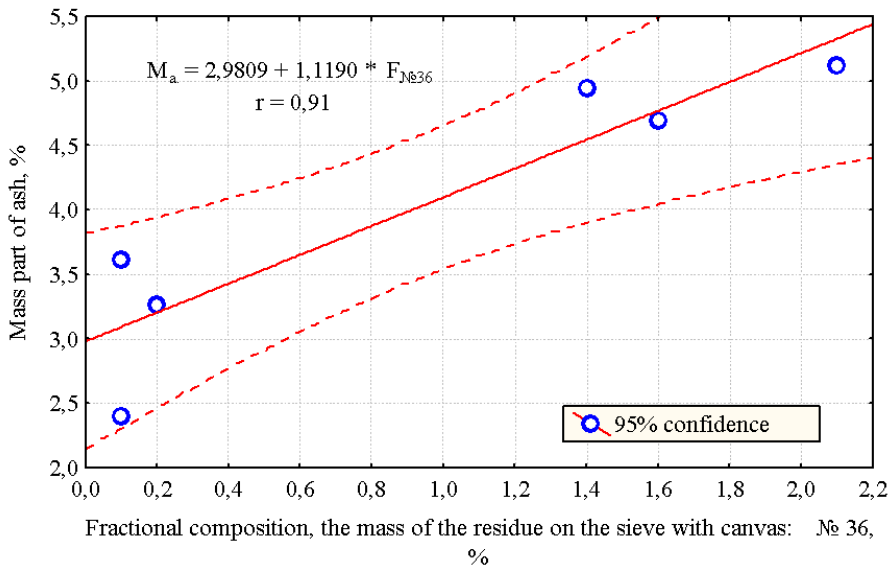


Figure 11. Dependence of fractional composition, the mass of the residue on the sieve with canvas № 36 for mass part of ash

We analyzed the relationship of the fractional composition of activated carbon, taking into account the mass fraction of the residue on the sieve with the canvas № 10 ($F_{N\text{№}10}$), the value of which is in the range of 90.4–98.0%, with the mass portion of the residue on the pallet (F_p) (Figure 13). The coefficient of pair correlation (r) between the indicators of the mass fraction of the residue on the sieve with the canvas № 10 ($F_{N\text{№}10}$) and the mass part of the residue on the pallet (F_p) was $r=-0.97$. Obviously, with an increase in the mass part of the residue on the sieve with the web № 10 ($F_{N\text{№}10}=98\%$), the mass part of the residue on the pallet decreases ($F_p=0.4\%$).

The bulk of the ash (M_a) of the objects studied is in the range of 2.40–5.12%. Its value (Figure 14) is directly related to the mass of water-soluble ash ($M_{w.a.}$). The coefficient of pair correlation (r) between the indicators of the mass fraction of ash and the mass fraction of

water-soluble ash was $r=0.99$. This is characterized by a “very high” correlation force, since the value is in the range of 0.90–1.00. Consequently, the higher the total ash content of the sorbent, the more water-soluble ash is in the composition of the activated carbon.

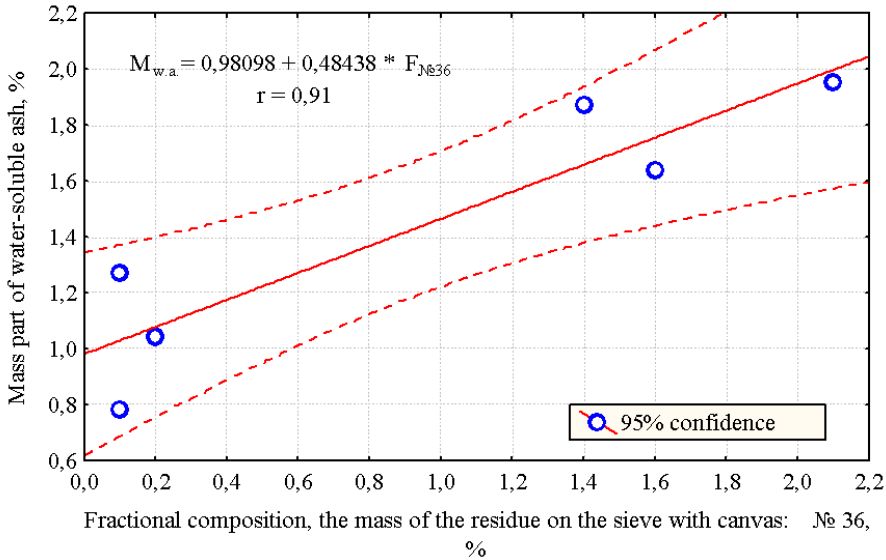


Figure 12. Dependence of fractional composition, the mass of the residue on the sieve with canvas № 36 for mass part of water-soluble ash

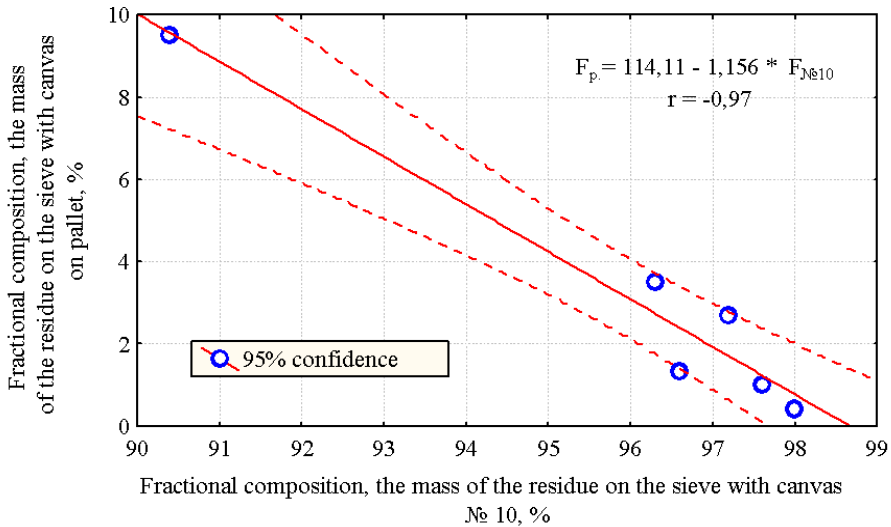


Figure 13. Dependence of fractional composition, the mass of the residue on the sieve with canvas № 10 for fractional composition, the mass of the residue on the sieve with canvas on pallet

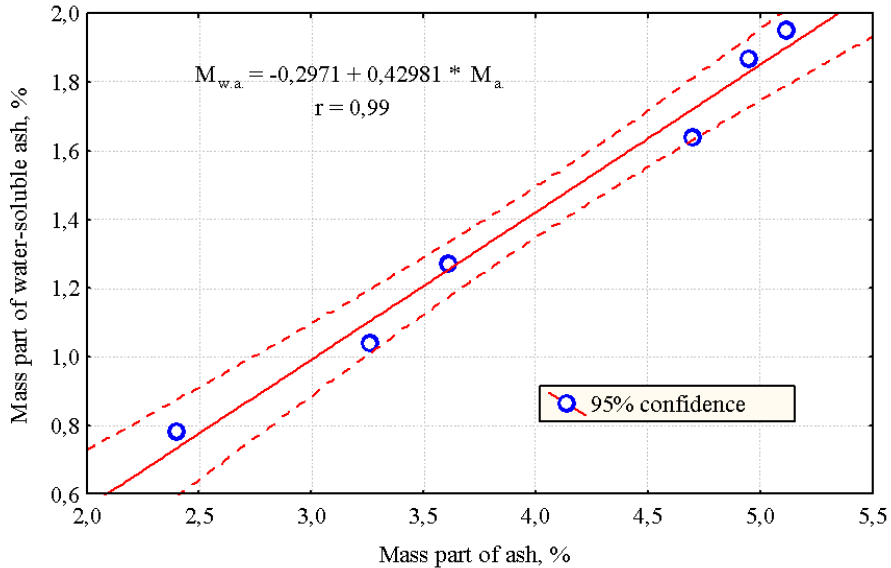


Figure 14. Dependence of mass part of ash for mass part of water-soluble ash

Conclusions

As a result of mathematical and statistical studies of a number of active carbons that are promising for use in alcoholic beverage production, the strength of the linear relationship between the variables was estimated by analyzing standard indicators of active carbons and determining the Pearson correlation coefficients. The interdependencies of such active carbon parameters are shown: iodine adsorption activity and methylene blue adsorption activity; acetic acid adsorption activity and iron content; total pore volume of water and the content of water-soluble ash, bulk density and characteristics of the fractional composition, and others.

It was found that 12 indicators out of 13 (92%) have a strong internal relationship, which is characterized by “very high” correlation strength, because r values are in the range of 0.90–1.00. Only one of the indicators of sorbents (A_r – abrasion resistance) does not have a “very high” correlation force, the highest value of the correlation coefficient ($r = -0,89$) was obtained for a pair of characteristics – the abrasion resistance and the mass portion of the sorbent residue on the sieve canvas № 36 ($F_{№36}$).

The conducted studies are of particular interest for the selection of initial and optimization of the composition of composite sorbents from a number of available active carbons for optimizing the process of obtaining high-quality alcoholic beverages.

References

1. Oliinyk S., Kuts A., Tarasyuk L. (2016), Innovative technology of alcohol drinks. *Food Science for Well-being (CEFood 2016): 8th Central European Congress on Food 2016*,

- 23-26 may 2016, Kyiv, 171.
- Oliinyk S., Prybyl'skyi V., Chuprina N., Dovgun I. (2014), Technological advancement of sorption water purification for alcoholic beverage industry, *Ukrainian Food Journal*, 3(4), 559–565.
 - Kuzmin O., Topol'nik V. (2014), Eduction of unsteady equilibrium in vodkas by means of ^1H NMR spectroscopy, *The advanced science journal*, 10, pp. 43–46.
 - Kuzmin O., Topol'nik V. (2014), Eduction of transitional equilibrium in vodkas by means of ^1H NMR spectroscopy, *The advanced science journal*, 12, pp. 61–64.
 - Kuzmin O., Topol'nik V., Myronchuk V. (2014), Eduction of equilibrium state in vodkas by means of ^1H NMR spectroscopy, *Ukrainian journal of food science*, 2 (2), pp. 220–228.
 - Kuzmin O. (2015), Determination of systems with a steady equilibrium in vodkas, depending on transformation of hydroxyl protons, *Ukrainian Journal of Food Science*, 3(1), pp. 33–41.
 - Kuzmin O., Suikov S., Koretska I., Matiyashchuk O., Poliovyk V. (2017), Identification of equilibrium state of hydroxyl protons in vodkas by ^1H NMR spectroscopy, *Ukrainian Food Journal*, 6 (2), pp. 314–336.
 - 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. ^1H NMR spectroscopy studies, *Ukrainian Food Journal*, 6 (2), pp. 239–257.
 - Kuzmin O., Topol'nik V., Sujkov S. (2013), ^1H NMR analysis of the aqueous-alcoholic mixtures, prepared with drinking water of south-eastern region of Ukraine, *The advanced science journal*, 8, pp. 21–31.
 - Kuzmin O., Topol'nik V., Fatiukha A., Volkova G. (2014), ^1H NMR analysis of the aqueous-alcoholic mixtures, prepared in demineralized by reverse osmosis water, *The advanced science journal*, 8, pp. 235–240.
 - Kuzmin O., Topol'nik V., Fatiukha A., Volkova G. (2014), ^1H NMR analysis of the aqueous-alcoholic mixtures, prepared with softened water using Na-cationization, *The advanced science journal*, 7, pp. 9–14.
 - Kuzmin O. (2017), Mechanism of transformation of protons in the process of creating aqueous-alcoholic mixtures, *Ukrainian Food Journal*, 6 (4), pp. 686–697.
 - Kuzmin O.V., Marynin A.I. (2018), Concerning the prospect of using electrochemical activation in the production of alcoholic products, *Engineering sciences: development prospects in countries of Europe at the beginning of the third millennium: collective monograph*, Economics College in Stalowa Wola, Riga, Izdevnieciba «Baltija Publishing», 1, pp. 260–280.
 - Kuzmin O., Zubkova V., Shendrik T., Korenets Y., Kuzmin A., Bilenkyi P. (2018), Internal mechanisms for establishment of the equilibrium state of water-alcohol mixtures in vodka technology, *Ukrainian Food Journal*, 7(4), pp. 655–670.
 - Mukhin V.M., Polyakov V.A., Burachevskiy I.I. i dr. (2004), Vysokoprochnyye aktivnyye ugli i blochnyye fil'try na ikh osnove, *Likero-vodochnoye proizvodstvo i vinodeliye*, 55, pp. 8–9.
 - Mukhin V.M., Polyakov V.A., Makeyeva A.N., Shubina N.A. (2003), Novyye aktivnyye ugli dlya likero-vodochnogo proizvodstva, *Proizvodstvo spirta i likero-vodochnykh izdeliy*, 3, pp. 36–37.
 - Petrov A.N., Olontsev V.F., Limonov N.V. (2004), Tendentsii v ispol'zovanii aktivnykh ugley v likero-vodochnoy otrasli, *Likero-vodochnoye proizvodstvo i vinodeliye*, 57, pp. 5–7.
 - Petrov A.N., Limonov N.V. (2005), Tendentsii v ispol'zovanii aktivnykh ugley v likero-

- vodochnoy otrasli, *Likerovodochnoye proizvodstvo i vinodeliye*, 67, pp. 8–9.
19. Marsh H., Rodriguez-Reinoso F. (2006), *Activated carbon*, Elsevier, Amsterdam.
 20. Rivera-Utrilla J., Sánchez-Polo M., Gómez-Serrano V., Álvarez P.M., Alvim-Ferraz M.C.M., Dias J.M. (2011), Activated carbon modifications to enhance its water treatment applications. An overview, *J. Hazardous Materials*, 187(1–3), pp. 1–23.
 21. Bansal R.C., Goyal M. (2005), *Activated carbon adsorption*, Boca Raton: Taylor&Francis Group.
 22. Jiaojiao Kong, Qinyan Yue, Lihui Huang, Yuan Gao, Yuanyuan Sun, Baoyu Gao, Qian Li, Yan Wang (2013), Preparation, characterization and evaluation of adsorptive properties of leather waste based activated carbon via physical and chemical activation, *Chemical Engineering Journal*, 221, pp. 62–71.
 23. Juan Matos, Carol Nahas, Laura Rojas, Maibelin Rosales (2011), Synthesis and characterization of activated carbon from sawdust of Algarroba wood. 1. Physical activation and pyrolysis, *Journal of Hazardous Materials*, 196, pp. 360–369.
 24. Kuzmin O., Shendrik T., Zubkova V. (2017), Substantiation of the conditions of obtaining porous carbon materials from pyrolyzed wood wastes by chemical activation of H_3PO_4 , *Ukrainian Food Journal*, 6(1), pp. 103–116.
 25. Kuzmin O., Tamarkina J., Shendrik T., Zubkova V., Koval O., Roman T. (2017), Production of active coal from pyrolyzed wood wastes by alkaline activation of KOH, *Ukrainian Food Journal*, 6(3), pp. 443–458.
 26. Kwiatkowski M., Kalderis D., Diamadopoulos E. (2017), Numerical analysis of the influence of the impregnation ratio on the microporous structure formation of activated carbons, prepared by chemical activation of waste biomass with phosphoric(V) acid, *Journal of Physics and Chemistry of Solids*, 105, pp. 81–85.
 27. Kumar A., Jena H.M. (2017), Adsorption of Cr(VI) from aqueous phase by high surface area activated carbon prepared by chemical activation with $ZnCl_2$, *Process Safety and Environmental Protection*, 109, pp. 63–71.
 28. Zubkova V. (2011), Study on relation of solvent extractable material and resistivity of pyrolysed coal, *Journal of Analytical and Applied Pyrolysis*, 92, pp. 50–58.
 29. Lillo-Ródenas M.A., Marco-Lozar J.P., Cazorla-Amorós D., Linares-Solano A. (2007), Activated carbons prepared by pyrolysis of mixtures of carbon precursor/alkaline hydroxide, *J. Anal. Appl. Pyrolysis*, 80 (1), pp. 166–174.
 30. Kinle KH., Bader E. (1984), Aktivnyye ugli i ikh promyshlennoye primeneniye, Leningrad, Khimiya.
 31. Roshchina T.M. (1998), Adsorbtsionnyye yavleniya i poverkhnost', Sorosovskiy obrazovatel'nyy zhurnal, 2, pp. 89–94.
 32. Lovyahin O.M., Muratov D.V., Shevchenko L.O., Koval'chuk V.P. (2008), Vplyv krotonovoho al'dehidu na yakist' spyrtu ta likero-horilchanoyi produktsiyi, *Naukovi pratsi NUKHT*, 24, pp. 36–38.
 33. Tarasov A.V., Zav'yalov YU.F., Meskhi R.G. (2003), «Serebryanaya fil'tratsiya» – novoye napravleniye v tekhnologii proizvodstva vysokokachestvennykh vodok, *Likerovodochnoye proizvodstvo i vinodeliye*, 39, pp. 1–3.
 34. Zhabkina T.N., Krechetnikova A.N., Revina A.A. (2005) Primeneniye nanochastits serebra dlya modifitsirovaniya fil'truyushchikh materialov, *Proizvodstvo spirta i likerovodochnykh izdeliy*, 1, pp. 20–21.
 35. Hinkle D.E., Wiersma W., Jurs S.G. (2003), *Applied statistics for the behavioral sciences*, Mass: Houghton Mifflin, Boston

Functional properties of maize flour (*Zea mays*) and stability of its paste (*tuwo*) as influenced by processing methods and baobab (*Adansonia digitata*) pulp inclusion

Olajide Emmanuel Adedeji, Nsokpuma Tadawus

Federal University Wukari, Wukari, Nigeria

Abstract

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Corresponding author:

Olajide Emmanuel Adedeji
E-mail: jdadedeji@gmail.com

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Introduction. *Tuwo*, a gel-like dumpling produced by heating maize flour slurry to obtain a smooth dough, is the most important staple food in Northern Nigeria.

Materials and methods. Maize flours (MF) were obtained using “grit non-soaking (GNS)” and “grit soaking (GSM)” methods. Baobab pulp (BPF) at 0, 5 and 10% w/w was incorporated into the MF and *tuwo* was prepared from the blends. Functional and colour order properties of MF, stability and sensory properties of *tuwo* were determined using standard methods.

Results and discussion. Swelling capacity, water absorption capacity, dispersibility, paste clarity and least gelation of blends were 5.44–5.85 mL/g, 2.19–2.49 mL/g, 50.53–61.66%, 1.86–4.50% and 2–6%, respectively. Flour produced by GNS method and containing 10% BPF had highest loose bulk density (0.53 g/mL), packed bulk density (0.77 g/mL) and swelling capacity (5.85%). Peak, breakdown and final viscosity of blends were 473.83–792.63 RVU, 391.17–626.33 RVU and 578.42–905.00 RVU, respectively. L*, a*, b*, hue angle, chroma and colour intensity of blends were 75.30–85.97, -0.30–1.26, 9.14–14.94, 59.33–88.20, 5.67–11.58 and 10.10–20.39, respectively. There was no significant ($p > 0.05$) difference between 100% MF produced by GNS and GSM (control samples) and blends of MF and BPF in terms of swallowability and mouldability while significantly ($p < 0.05$) higher scores were recorded for the control samples in colour, taste, flavour and general acceptability. At the end of the first day of ambient storage, syneresis was 5.6–16.3% and 2.5–10.2% for *tuwo* produced by GNS and GSM, respectively. Syneresis was 2.5–14.9% and 1.8–2.2% for *tuwo* produced by GNS and GSM respectively under refrigeration storage condition.

Conclusion. This study showed improvement in the quality of maize flour and stability of *tuwo* as a result of baobab pulp inclusion.

Introduction

Maize (*Zea mays*) is a popular crop worldwide due to its functionality as a food source for both human and animals [1]. It is a dietary staple for a teeming world population of 400 million who are majorly in Africa and Central America [2]. Maize contains essential nutrients such as carbohydrate and dietary fiber which provide adequate calorie required by the body [1]. Earlier reports showed that maize contains 7 to 13% protein, 1.4 to 6.0% fat, 74 to 80% carbohydrate, 0.81% ash and 414 kCal/100g of calorie [2]. In sub-Saharan Africa, about 65% of maize produced is utilized in the production of different food products such as dumplings, breads, fermented dough, snacks and tortilla [3]. In Nigeria and many West African countries, maize is often consumed in forms of starch, *ogi*, *koko*, *masa*, *eko*, *agidi*, *ekuru* and *tuwo* [4]. Among these, *tuwo*, a gel-like dumpling produced by heating maize flour slurry to obtain a smooth dough, is the most important staple food in Northern Nigeria, a region where many ethnic groups such as Hausa, Fulani, Kanuri, Nupe and Jukum are resident [5]. Popularity of maize *tuwo* has spread to other regions of the country and many West African countries such as Ghana, Togo and Benin.

Acceptability of *tuwo* is often limited due to poor textural quality which is evident in poor mouldability, high rate of retrogradation and instability of gels after cooling [5]. Consequently, several research efforts have been made to alleviate the challenges. Physical modifications of cereal raw materials such as steaming [6], thermoplastic extrusion [7] and hydrothermal treatment [8] have shown to improve physicochemical properties and sensory attributes of *tuwo* and other products. However, it is imperative to improve functional properties of flour using techniques that could be easily adopted by poor population of West African countries who are major consumers of *tuwo*. One of such techniques involves incorporation of stabilizing agent to improve gelling properties and stability of *tuwo*. Bolade and Adeyemi [6] reported improved textural property of *tuwo* produced through incorporation of cassava flour into maize flour.

Baobab fruit pulp is an edible component of an underutilized crop known as baobab (*Adansonia digitata*) tree [9]. Baobab pulp is a rich source of vitamin C (264 mg/100g) and therefore relished as a refreshing drink [10]. It contains 2.16% protein, 0.4% lipids, 5.7% soluble and insoluble fiber, 73.87% carbohydrate, 7.67% ash and 307.6 kCal/g of metabolizable energy [11]. In addition, the main chemical component of baobab pulp which confers it with high viscosity is pectin [12]. There is therefore a new interest in utilization of baobab pulp as gelling or thickening agent in food systems. Ndabikunze et al. [13] reported improved rheological properties of jam stabilized with baobab pulp. They further reported that baobab pulp-stabilized jam compared significantly with commercial pectin-stabilized jam. Furthermore, incorporation of baobab pulp into *ogi* (a fermented maize product) resulted in improvement of its functional and sensory properties [14].

Objectives of this research were to:

- Determine effects of baobab pulp inclusion and processing methods on functional and colour order properties of maize flour;
- Evaluate stability and sensory attributes of *tuwo* produced from MF and BPF blends.

Materials and methods

Materials

Maize grains (*Zea mays*) (white variety) were obtained from the Teaching and Research Farm of Federal University Wukari, Nigeria while baobab (*Adansonia digitata*) fruits were collected from baobab trees found within the Forest Reserves of the same University.

Preparation of maize flour

Maize flour was produced using grit non-soaking (GNS) and grit soaking (GSM) methods described by Bolade et al. [5]. Maize grains were manually cleaned by the removal of stones, damaged kernels and other extraneous materials. The cleaned grains were tempered by sprinkling 5% water (v/w) on the grains coupled with thorough mixing. This was followed by decortication of the grains on a locally fabricated corn decorticating machine, in order to obtain maize grits. The grits obtained was divided into 2 equal halves. For the grit non-soaking method, the first half of the grits was milled using a disc attrition mill (9FC-36, China) followed by sieving using a 40 mesh sieve (0.450 mm). The flour was packaged in airtight polythene bags (Ziploc, China) and stored at 10 ± 2 °C until required. For the grit soaking method, the second half of the grits was soaked in water for 2 hours. Subsequently, the water was drained and the grit was dried in an oven (NL9023A, England) at 50°C for 12 hours. The dried grit was milled using a disc attrition mill (9FC-36, China) followed by sieving using a 40 mesh sieve (0.450 mm). The flour was packaged in airtight polythene bags (Ziplock, China) and stored at 10 ± 2 °C until required.

Preparation of baobab pulp flour

Baobab pulp flour was produced according to the method described by Adejuyitan et al. [14]. Baobab fruits were cracked manually and seeds removed from the pulp by hand. The pulp was then crushed using a blender (CB-8231-D, China), sieved using a 60 mesh sieve (0.250 mm), packaged in polyethylene bags (Ziploc, China) and stored at 10 ± 2 °C until required.

Incorporation of baobab pulp flour into maize flour

Baobab pulp flour was incorporated separately into maize flours produced by grit-soaking and grit non-soaking methods at concentration levels of 0, 5, 10% (w/w). Blends of MF and BPF were homogenized in a laboratory mixer (CB-8231-D, China), packaged in polyethylene containers (ZiLock, China) and stored at 10 ± 2 °C until required.

Preparation of tuwo

Maize *tuwo* was prepared according to an optimized procedure reported by Bolade et al. [5] which gave a final flour to water ratio of 1:3.5 w/v. Slurry was prepared by mixing 100 g of sample with 437.5 mL of water. The slurry was added to 1, 050 mL boiling water and the mixture was stirred vigorously until a pap-like consistency was obtained. With continuous stirring, 400 g of sample was added bit by bit to the boiling pap until a stiff dough was formed. Furthermore, 262.5 mL of water was added to the gel and covered for 5 minutes without stirring. Subsequently, the gel was stirred vigorously until a smooth consistent gel was formed. The *tuwo* was served immediately for sensory evaluation.

Analyses

Bulk density (loose and packed) and least gelation concentration of blends were determined using the method of Kinsella [15]. Water and oil absorption capacity, swelling capacity and dispersibility of blends were determined using the procedure described by Akpata and Miachi [16]. Clarity of flour pastes was determined by the method described by Yadav et al. [17]. Pasting properties of blends were evaluated using a Brabender visco-amylograph (Newport Scientific Pty Ltd. Warriewood NSW, Australia) based on the procedure outlined by Chinma et al. [18]. Colour order characteristics of flour blends were determined using a handheld colorimeter (Chromameter CR-400/410). Sensory analysis of *tuwo* samples was conducted using a 9 point hedonic scale where 0 and 9 represented dislike extremely and like extremely, respectively. Fifty panelists comprising of 62% male and 38% female adults that were familiar with maize *tuwo* were recruited for the analysis. Samples were coded and served to the panelists at 85°C in individual booth under fluorescent light. Samples were rated by panelists for colour, taste, aroma, mouldability, swallowability and general acceptability [6]. Paste stability of *tuwo* during ambient and refrigerated storage was evaluated by determining syneresis of the paste [19]. A 10% aqueous suspension of sample (w/v) was prepared in a screw-capped centrifuge tube and 0.1% sodium benzoate was added to prevent microbial spoilage. The suspension was heated in a boiling water bath (NL420S England) at 85°C for 30 min with constant stirring and then cooled rapidly to room temperature (30±2°C) on ice bath. After cooling, the paste sample was stored for 5 days at refrigeration (4±2°C) and ambient (30±2°C) temperatures. Syneresis was determined daily as percentage of water released after centrifugation at 3000 × g for 15 minutes. All experiments were conducted in triplicates. Data obtained were subjected to 2-way analysis of variance with processing method and blend ratio serving as independent variables. Means were separated with Duncan Multiple Range Test at 5% level of significance. These were achieved with the aid of Statistical Package for Social Scientists (SPSS IBM Corp. USA), version 23.

Results and discussion

Effect of baobab pulp inclusion on the functional properties of maize flour

Table 1 shows the functional properties of MF as influenced by processing methods and level of baobab pulp (BPF) inclusion. Loose bulk density was significantly ($p < 0.05$) influenced by processing methods and concentration of BPF in the blends. Inclusion of 5% BPF in MF produced by GNS method did not cause any significant ($p > 0.05$) change in loose bulk density, however, a significant ($p < 0.05$) increase was recorded in the blend containing 10% BPF. Significant ($p < 0.05$) increase in loose bulk density at 5% BPF level was recorded in MF produced by GSM method. Inclusion of 10% BPF into MF produced by GNS resulted in a significant ($p < 0.05$) increase in packed bulk density. Significant change was not observed at lower concentration (5% BPF) in MF produced by both GSM and GNS methods. Maize flour and BPF blends produced using GSM method had significantly lower ($p < 0.05$) loose and packed bulk density than the corresponding blends produced by GNS. Reduction in bulk density could be due to breakdown of large organic molecules consequent to percolation of water into grits during soaking operation [20]. Soaking also caused a significant reduction in bulk density of millet [21].

Table 1

Functional properties of maize and baobab pulp flour blends

Processing method	MF:BPF (% w/w)	LBD (g/mL)	PBD (g/mL)	WAC (mL/g)	OAC (mL/g)	SC (mL/g)	Dispersibility (%)	Paste clarity (%)	LGC (%)
GNS	100:0	0.48 ^{ab±} 0.02	0.70 ^{b±} 0.04	2.31 ^{b±} 0.04	2.31 ^{ab±} 0.04	5.82 ^{ab±} 0.06	50.53 ^{c±} 2.89	4.50 ^{a±} 1.92	8.00
	95:5	0.49 ^{ab±} 0.02	0.72 ^{b±} 0.01	2.34 ^{ab±} 0.11	2.14 ^{bc±} 0.06	5.80 ^{ab±} 0.04	54.64 ^{bc±} 2.47	1.88 ^{b±} 0.13	8.00
	90:10	0.53 ^{a±} 0.04	0.77 ^{a±} 0.03	2.49 ^{a±} 0.02	2.14 ^{bc±} 0.07	5.85 ^{a±} 0.06	59.55 ^{a±} 0.18	1.86 ^{b±} 0.88	6.00
GSM	100:0	0.45 ^{b±} 0.01	0.68 ^{b±} 0.03	2.34 ^{ab±} 0.06	2.34 ^{a±} 0.13	5.82 ^{ab±} 0.05	57.07 ^{b±} 0.96	2.99 ^{ab±} 0.68	4.00
	95:5	0.47 ^{ab±} 0.01	0.71 ^{b±} 0.01	2.19 ^{b±} 0.06	1.91 ^{d±} 0.01	5.44 ^{b±} 0.19	61.66 ^{a±} 4.77	2.11 ^{ab±} 0.51	2.00
	90:10	0.48 ^{ab±} 0.03	0.71 ^{b±} 0.04	2.30 ^{b±} 0.01	1.99 ^{cd±} 0.00	5.82 ^{ab±} 0.32	52.99 ^{c±} 5.11	3.15 ^{ab±} 0.12	2.00

Values are means ± standard deviations of triplicate scores. Means within a column with different superscripts were significantly ($p < 0.05$) different. GNS- grit non-soaking method; GSM- grit soaking method; MF-maize flour; BPF-baobab pulp flour; LBD- loose bulk density; PBD- packed bulk density; WAC-water absorption capacity; OAC-oil absorption capacity; SC-swelling capacity; LGC-least gelation concentration.

Water absorption capacity of MF produced by the GNS method increased significantly ($p < 0.05$) with increasing level of BPF inclusion. According to Seena and Sridha [22], high water absorption causes high retention of water without dissolution of protein, thus increasing the body and viscosity of gel. Conversely, inclusion of BPF into MF produced by the GSM method reduced water absorption capacity. Bolaji et al. [23] also reported that water absorption capacity of *ogi* (a fermented maize product) reduced with increase in soaking time of maize grains. Variation observed in water absorption capacity could be due to differing particle sizes and starch components of the BPF and MF blends. According to Adegunwa et al. [24], water absorption capacity is dependent on factors such as particle size, amylose/amylopectin ratio and molecular structures of component flours. Grit soaking caused a significant ($p < 0.05$) increase in oil absorption capacity. This corroborated the findings of Ocheme et al. [21] who also reported that soaking of millet grains increased oil absorption capacity of millet flour. Inclusion of BPF into MF caused significant ($p < 0.05$) reduction in oil absorption capacity. This might be due to conformational imbalance between hydrophilic and hydrophobic components of the blends [25]. Ten percent substitution of BPF into MF produced using GNS method increased swelling capacity while the same substitution level did not have significant ($p > 0.05$) effect on MF produced using GSM method. The increase in swelling capacity may be attributed to increased hydration of starch [18]. Irrespective of method of MF production, BPF incorporation into MF increased percentage dispersibility significantly ($p < 0.05$). This implies better reconstitution of flour in water prior to heating. According to Adebowale et al. [26], reconstitution of flour in water is dependent on flour dispersibility. Significantly ($p < 0.05$) higher paste clarity (4.50%) was recorded in flour produced by GNS method compared to the value (2.99%) recorded for flour produced by GSM method. This difference could be due to variation in dispersibility of flours produced by both methods. According to Yadav et al. [17], paste clarity is dependent on dispersion and

retrogradation tendencies of starches. Inclusion of BPF significantly ($p < 0.05$) reduced paste clarity in MF produced by GNS method, however, no significant ($p > 0.05$) change was observed in flour produced by GSM method as a result of BPF inclusion. This phenomenon suggested reduction in retrogradation tendency of MF produced by GSM method, which probably due to grit soaking operation. Soaking is often associated with changes in metabolic activities which result in modification of physicochemical and nutritional qualities of food products [21, 27].

Processing methods affected gelling properties of MF. Maize flour produced using GSM method gelled at 4% while the minimum gelling concentration for MF produced by the GNS method was 8%. Lower gelation concentration attributed to MF produced by GSM method could be due to improved hydration of starch consequent to the soaking operation. This is advantageous because improved gelation properties reduce the amount of heat energy required during preparation of *tuwo*. It will also reduce cooking time. Inclusion of BPF into MF further improved the gelation properties. Inclusion of 5% BPF into MF produced by GSM method lowered gelation concentration to 2% while inclusion of 10% BPF into MF produced by the GNS method reduced gelation concentration to 4%. This clearly showed stabilizing ability of BPF whose inclusion into MF probably increased solubilization of starch and/or protein molecules which resulted in rearrangement of functional groups [28]. Adejuyitan et al. [14] also reported improved gelation property of *ogi* (a fermented maize food) as a result of inclusion of baobab pulp.

Effect of baobab pulp inclusion on the pasting properties of maize flour

Samples showed different pasting properties (Table 2) as a result of different processing methods and baobab pulp level. Significantly ($p < 0.05$) higher peak viscosity was recorded for MF produced by GSM method compared to the corresponding MF produced by GNS method, for example 100% MF produced by GNS method had a peak viscosity of 473.83RVA while 100% MF produced by GSM method had a peak viscosity of 792.63RVA.

Table 2

Pasting properties of maize and baobab flour blends

Method	MF: BPF (%w/w)	Peak viscosity (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (mins)	Pasting temperature (°C)
GNS	100:0	473.83 ^f ± 1.06	436.54 ^a ± 28.58	578.42 ^c ± 5.19	541.13 ^c ± 40.13	5.73 ^a ± 0.06	87.68 ^a ± 0.61
	95:5	549.88 ^d ± 4.77	507.63 ^a ± 0.36	598.54 ^d ± 6.78	556.29 ^c ± 3.36	5.45 ^b ± 0.07	85.22 ^{ab} ± 0.00
	90:10	542.88 ^c ± 1.89	504.88 ^a ± 0.06	581.33 ^c ± 3.42	543.33 ^c ± 1.59	5.33 ^{bc} ±0.03	82.73 ^b ± 0.56
GSM	100:0	753.13 ^b ± 1.71	626.33 ^a ± 0.82	905.00 ^a ± 0.94	778.20 ^a ± 1.59	5.13 ^d ± 0.09	79.61 ^c ± 0.90
	95:5	703.75 ^c ± 3.65	610.71 ^a ± 1.59	779.88 ^c ± 8.54	686.84 ^b ± 6.48	5.33 ^{bc} ± 0.00	80.00 ^c ± 1.90
	90:10	792.63 ^a ± 0.41	391.17 ^a ± 445.2	850.54 ^b ± 0.88	449.08 ^d ± 0.24	5.27 ^{cd} ± 0.09	78.21 ^c ± 1.48

Values are means ± standard deviations of triplicate scores. Means within a column with different superscripts were significantly ($p < 0.05$) different. GNS- grit non-soaking method; GSM- grit soaking method; MF- maize flour; BPF- baobab pulp flour.

Higher peak viscosity recorded for MF produced by the GSM method could be due to higher granule swelling brought about by soaking operation. According to Oluwamukomi and Jolayemi [29], high swelling index is correlated with high peak viscosity. Bolade and Adeyemi [6] also reported increase in peak viscosity of heat-moisture pretreated maize flour. In addition, peak viscosity significantly ($p < 0.05$) increased with increasing BPF level in MF. This could be as a result of increase in water binding activity of the flour due to the inclusion of BPF. This would contribute to better quality of *tuwo* since peak viscosity is often associated with final product quality [30].

There was no significant ($p > 0.05$) difference among the samples in terms of breakdown viscosity. Lowest breakdown viscosity of 391.17RVU was recorded for the blend of MF produced by GSM and 10% BPF. This suggested good stability of the paste owing to its ability to withstand shear-thinning, consequent to prolonged heating [31]. Blends produced by GSM method had a final viscosity of 905.00RVU, compared to a significantly ($p < 0.05$) lower value of 578.42RVU recorded for flour produced by GNS method. Inclusion of BPF caused significant ($p < 0.05$) reduction of final viscosity in flours produced by the GSM method, however, inclusion resulted in increase in final viscosity of flours produced by GNS method. Setback viscosity also followed the same trend. This corroborated finding of Bolade et al. [5] who also reported reduction in setback viscosity of maize flour produced by the GSM method. Reduction in setback viscosity of blends of MF produced by GSM and BPF could be attributed to increased enzymatic activity during grit soaking. This probably led to partial hydrolysis of starch molecules [32]. This could go a long way in reducing retrogradation of pastes [33].

Peak time ranged from 5.13 to 5.73 minutes with 100% MF produced by GSM method and 100% MF produced by GNS having lowest and highest values, respectively. Inclusion of BPF caused a significant ($p < 0.05$) reduction in peak time of MF produced by GNS method. Also, grit soaking significantly ($p < 0.005$) reduced peak time. In the same vein, pasting temperature was significantly ($p < 0.005$) reduced by the inclusion of BPF into MF produced by GNS method, however, no significant ($p > 0.05$) change was observed among samples produced by GSM method. Reduction in peak time and temperature will reduce the total energy and time required for *tuwo* preparation [18].

Effect of baobab pulp inclusion on colour order properties of maize flour

Table 3 shows variation in colour properties of MF as influenced by processing methods and BPF inclusion. L^* ranged from 77.03 to 85.97. There was no significant ($p > 0.05$) difference in L^* among the control samples i.e. 100% GNS and GSM. This contradicted the report of Bolade et al. [5] who reported lower L^* value for MF produced by GSM. Inclusion of BPF into MF caused a significant ($p < 0.05$) reduction in L^* . The reduction might have been due to the effect of baobab pulp which has a creamy white colour [9].

Low a^* ranging from -0.10 to 1.26 were recorded for the samples. These low values imply deviation of the samples from green and red. Bolade et al. [6] also reported low a^* ranging from -0.08 to -0.18 for pre-gelatinized MF. b^* increased significantly ($p < 0.05$) with increasing level of BPF in MF. This implies that colour of the samples tended towards yellow due to the presence of baobab pulp. Hue angle varied between 59.33 and 88.20. This showed deviation towards yellow colour. The movement of hue angle from 0° to 90° indicates colour change from red to yellow [5]. Chroma and colour intensity ranged from 6.14 to 10.17 and 10.10 to 20.39, respectively. Inclusion of BPF increased these colour parameters significantly ($p < 0.05$). Chroma and colour intensity are indices for colour purity [31], therefore, inclusion of BPF improved MF in that regard.

Table 3

Colour order properties of maize and baobab pulp flour blends

Processing method	MF:BPF (% w/w)	L*	a*	b*	Hue angle	Chroma	Colour intensity
GNS	100:0	85.97 ^{a±} 0.82	-0.30 ^f ±0.01	9.64 ^{d±} 0.13	88.20 ^{a±} 0.08	6.14 ^{d±} 0.13	10.10 ^{c±} 0.57
	95:5	75.30 ^{d±} 2.17	0.43 ^{d±} 0.02	11.54 ^{c±} 0.36	87.86 ^{a±} 0.17	8.12 ^{c±} 0.35	20.39 ^{a±} 1.85
	90:10	82.18 ^{b±} 0.42	1.05 ^{b±} 0.03	14.94 ^{a±} 0.09	85.98 ^{a±} 0.09	11.58 ^{a±} 0.10	16.54 ^{b±} 0.24
GSM	100:0	85.15 ^{a±} 2.14	-0.10 ^e ±0.09	9.14 ^{d±} 0.46	59.33 ^{b±} 51.38	5.67 ^{d±} 0.47	10.57 ^{c±} 1.47
	95:5	79.66 ^{bc±} 0.93	0.64 ^{c±} 0.07	11.91 ^{c±} 0.16	86.94 ^{a±} 0.33	8.52 ^{c±} 0.16	16.67 ^{b±} 0.73
	90:10	77.03 ^{cd±} 1.77	1.26 ^{a±} 0.01	13.77 ^{b±} 0.38	84.78 ^{a±} 0.14	10.47 ^{b±} 0.37	19.95 ^{a±} 1.39

Values are means ± standard deviations of 3 replications. Means within a column with different superscripts were significantly (p<0.05) different. GNS = grit non-soaking method, GSM = grit soaking method, MF= maize flour, BPF= baobab pulp flour.

Effect of baobab pulp inclusion on sensory properties of maize flour

Effect of processing methods and inclusion of baobab pulp on sensory properties of maize based *tuwo* is presented in Table 4.

Table 4

Sensory properties of *tuwo* prepared from blends of maize and baobab pulp flours

Processing method	MF:BPF (% w/w)	Colour	Swallowability	Flavour	Mouldability	Taste	General acceptability
GNS	100:0	8.36 ^{a±} 0.76	7.64 ^{a±} 1.11	7.76 ^{a±} 0.88	7.04 ^{ab±} 1.10	7.60 ^{a±} 1.15	7.80 ^{a±} 1.12
	95:5	7.36 ^{c±} 1.32	6.16 ^{b±} 2.03	6.60 ^{c±} 1.68	7.04 ^{ab±} 1.40	6.08 ^{b±} 2.18	6.68 ^{bc±} 1.68
	90:10	7.44 ^{c±} 1.23	6.12 ^{b±} 2.11	6.56 ^{c±} 1.71	6.52 ^{b±} 1.64	5.88 ^{b±} 1.88	6.52 ^{c±} 1.90
GSM	100:0	8.12 ^{ab±} 1.09	7.96 ^{a±} 1.02	7.44 ^{ab±} 1.16	7.44 ^{a±} 0.92	7.52 ^{a±} 1.50	7.88 ^{a±} 1.13
	95:5	7.36 ^{c±} 1.25	7.36 ^{a±} 1.22	6.76 ^{bc±} 1.20	7.08 ^{ab±} 1.32	7.44 ^{a±} 1.47	7.28 ^{abc±} 1.17
	90:10	7.56 ^{bc±} 1.12	7.60 ^{a±} 1.08	7.24 ^{abc±} 1.16	7.04 ^{ab±} 1.59	7.16 ^{a±} 1.57	7.48 ^{ab±} 1.05

Values are means ± standard deviations of 50 scores. Means within a column with different superscripts were significantly (p<0.05) different. GNS- grit non-soaking method; GSM- grit soaking method; MF- maize flour; BPF- baobab pulp flour.

In terms of colour, significantly ($p < 0.05$) higher scores (8.36 and 8.12 for 100% GNS and GSM, respectively) were recorded for the control samples. Nonetheless, appreciable high scores ranging from 7.36 to 7.56 were recorded for samples containing different levels of BPF. Inclusion of BPF reduced colour acceptability probably because the panelists were familiar with *tuwo* prepared from 100% MF. Adejuyitan et al. [14] also reported reduction in colour acceptability of *ogi* fortified with baobab pulp. Inclusion of 5 and 10% BPF into MF produced by GSM method compared significantly ($p < 0.05$) with the control samples in terms of swallowability. Inclusion of baobab pulp reduced flavour of *tuwo* probably due to impartation of sour taste into the product. The control sample produced by GSM method had highest score for mouldability. This corroborated earlier finding of Bolade [33] who reported better textural quality for maize based *tuwo* produced by GSM method. Inclusion of 10% BPF into MF produced by GSM method gave a *tuwo* with high mouldability (7.04 to 7.08) which compared significantly ($p < 0.05$) with the control sample produced by GNS. In terms of taste, there was no significant ($p > 0.05$) difference among *tuwo* samples produced by GSM, however, inclusion of BPF into MF caused significant ($p < 0.05$) reduction in taste of *tuwo* prepared from blends of BPF and MF produced by GNS method. Similar trend was observed for general acceptability.

Effect of baobab pulp inclusion on the stability of maize tuwo

Stability (expressed in percentage syneresis) of *tuwo* as influenced by baobab pulp inclusion under ambient and refrigeration storage conditions is presented in Table 5. Analysis conducted immediately after *tuwo* preparation showed significantly ($p < 0.05$) lower syneresis for *tuwo* containing BPF in both processing methods. The same trend was observed throughout the period of storage for both storage conditions. This could be due to the binding of water molecules within gel matrix formed between starch molecules of maize flour and pectin of baobab pulp. Baobab pulp has been reported to be rich in pectin which has high water binding property [13].

Samples produced using GSM method showed better stability than those produced using GNS method. For example, at the end of the first day of ambient storage, syneresis ranged from 5.6 to 16.3% and 2.5 to 10.2% for *tuwo* produced using GNS and GSM methods, respectively. Furthermore, syneresis ranged from 2.5 to 14.9% and 1.8 to 2.2% under refrigeration storage condition for *tuwo* produced using GNS and GSM methods, respectively. This could be due to increased gel firmness in *tuwo* produced by GSM which could be attributed to reduction in amylopectin crystallization and consequent formation of amylose matrix gel effected by grit soaking operation [19].

Tuwo stored under refrigerated conditions showed improved paste stability compared to those stored at ambient condition. Reduced exclusion of water in *tuwo* stored at refrigeration condition could be due to reduction in inter and intra molecular hydrogen bonding which probably caused lower retrogradation rate [34]. For both storage conditions, syneresis increased with storage time. This is in line with the findings of Yadav et al. [17] who reported increase in syneresis of banana, potato and rice starch blends with storage time. However, *tuwo* samples stored at refrigeration temperature showed a sharp reduction in syneresis after 4 days of refrigeration. This might be due to reduction in crystallite formation which probably resulted to reduction in water separation from the gel matrix [19].

Table 5

Effect of baobab pulp inclusion on the stability of maize *tuwo* under storage

Processing method	MF:BPF (% w/w)	Syneresis (%)					
		Day 0	Day 1	Day 2	Day 3	Day 4	Day 5
Ambient storage (28±2°C)							
GNS	100:0	7.0 ^{a±}	16.3 ^{a±}	19.8 ^{a±}	22.5 ^{b±}	39.2 ^{a±}	72.0 ^{a±}
		1.41	1.27	1.70	1.56	1.41	1.41
	95:5	7.8 ^{c±}	10.1 ^{a±}	10.0 ^{b±}	5.0 ^{d±}	5.9 ^{d±}	60.4 ^{b±}
		0.28	1.41	1.41	0.57	1.56	1.56
	90:10	1.0 ^{c±}	5.6 ^{b±}	12.9 ^{b±}	3.5 ^{d±}	4.7 ^{d±}	28.5 ^{d±}
		0.57	1.98	1.41	1.27	1.27	1.84
GSM	100:0	3.9 ^{b±}	10.2 ^{a±}	18.9 ^{a±}	27.7 ^{a±}	24.0 ^{b±}	33.3 ^{c±}
		0.28	1.70	1.41	1.70	0.71	1.70
	95:5	1.0 ^{a±}	2.5 ^{b±}	17.0 ^{a±}	22.8 ^{b±}	17.8 ^{c±}	7.0 ^{c±}
		0.28	1.41	1.41	1.84	1.56	1.41
	90:10	1.0 ^{c±}	10.8 ^{a±}	12.8 ^{b±}	13.9 ^{c±}	17.8 ^{c±}	8.9 ^{c±}
		0.57	1.70	1.41	1.41	1.41	1.56
Refrigeration storage (4±2 °C)							
GNS	100:0	7.0 ^{a±}	14.9 ^{a±}	16.8 ^{b±}	11.0 ^{c±}	7.9 ^{c±}	5.0 ^{cd±}
		1.41	1.70	1.70	1.41	1.56	1.41
	95:5	7.8 ^{a±}	13.8 ^{b±}	10.0 ^{c±}	16.0 ^{b±}	6.9 ^{cd±}	5.9 ^{c±}
		1.56	1.70	1.56	1.41	1.41	1.41
	90:10	1.0 ^{b±}	2.5 ^{c±}	9.9 ^{c±}	12.9 ^{bc±}	7.9 ^{c±}	5.9 ^{c±}
		0.28	1.56	1.56	1.41	1.41	1.56
GSM	100:0	3.9 ^{b±}	2.2 ^{c±}	8.9 ^{c±}	12.0 ^{c±}	4.0 ^{d±}	2.5 ^{d±}
		1.56	1.41	0.14	1.41	1.41	0.14
	95:5	1.0 ^{b±}	1.8 ^{c±}	13.9 ^{b±}	21.8 ^{a±}	11.9 ^{b±}	19.6 ^{b±}
		0.57	1.56	1.41	1.41	1.56	1.13
	90:10	1.0 ^{b±}	1.8 ^{c±}	21.8 ^{a±}	24.0 ^{a±}	24.0 ^{a±}	22.8 ^{a±}
		0.85	1.70	1.70	1.41	1.41	1.56

Values are means ± standard deviations of 3 scores. Means within a column with different superscripts were significantly ($p < 0.05$) different. GNS- grit non-soaking method; GSM- grit soaking method; MF- maize flour; BPF- baobab pulp flour

Conclusion

Grit soaking operation improved functional and sensory properties of maize flour meant for *tuwo* production. In addition, inclusion of baobab pulp enhanced the stated properties of maize flour produced by both grit soaking and grit non-soaking methods.

Inclusion of 5% baobab pulp gave the best stability of *tuwo* produced by grit soaking method while 10% baobab pulp inclusion gave the best stability of *tuwo* produced by grit non-soaking method.

Tuwo stored under refrigerated conditions showed better paste stability compared to those stored at ambient condition.

References

1. Nuss, E.T., Tanumihardjo, S.A. (2010), Maize: A Paramount staple crop in the context of global nutrition, *Comprehensive Revision in Food Science and Safety*, 9(4), pp. 417–436.
2. Shindano, J. (2007), Functional properties of white maize meal stored under tropical conditions, Thesis submitted in fulfillment of the requirements for the degree of doctor (PhD) in Applied Biological Sciences: Chemistry. Faculty of Bioscience Engineering, Ghent University, Belgium, pp. 23–25.
3. Ranum, R., Pena-Rosas, J.P., Garcia-Casal, M.V. (2014), Global maize production, utilization, and consumption, *Annual New York Academy of Science*, 1325, pp. 105–112.
4. Aworh, O.C. (2008), The role of traditional food processing technologies in national development; the West African experience. In: Robertson, G.L., Lupien, J.R. (eds.) Using food science and technology to improve nutrition and promote national development. International Union of Food Science and Technology, pp. 9–10.
5. Bolade, M.K., Adeyemi, I.A., Ogunsua, A.O. (2009), Influence of particle size fractions on the physicochemical properties of maize flour and textural characteristics of a maize-based nonfermented food gel, *International Journal of Food Science and Technology*, 44, pp. 646–655.
6. Bolade, M.K., Adeyemi, I.A. (2014), Quality dynamics of maize ‘tuwo’ (non-fermented maize-based dumpling) as influenced by steaming of maize grits at different resident time, *Journal of Food Science and Technology*, 51(11), pp. 3217–3225.
7. Souza, V.F., Nascimento, E.M.G., Ascher, J.L.R. (2011), Pasting properties of expanded extrudate and pellets from corn flour and rice flour, *Brazilian Journal of Food Technology*, 14(2), pp. 106–114.
8. Bolade, M.K., Usman, M.A., Rasheed, A.A., Benson, E.L., Salifou, I. (2002), Influence of hydrothermal treatment of maize grains on the quality and acceptability of *tuwo masara* (traditional maize gel), *Food Chemistry*, 79, pp. 479–483.
9. De Caluwe, E., Halamova, K., Van Damme, P. (2010), *Adansonia digitata* – A review of traditional uses, phytochemistry and pharmacology, *African Focus*, 23(1), pp. 11–51.
10. Chadare, F.J., Linnemann, A.R., Hounhouigan, J.D., Nout, M.J.R., Van Boekel, M.A.J. (2009), Baobab food products: A review on their composition and nutritional value, *Critical Review in Food Science and Nutrition*, 49(3), pp. 254–274.
11. Fagbohun, A.A., Ikokoh, P.P., Afolayan, M.O., Olajide, O.O., Fatokun, O.A., Akanji, F.T. (2012), Chemical composition and anti-oxidant capacity of the fruit pulp of *Adansonia digitata*, *International Journal of Applied Chemistry*, 8(3), pp. 165–172.
12. Abdalla, A. A., Mohammed, M. A., Mudawi, M. A. (2010), Production and quality assessment of instant baobab drink, *Advanced Journal of Food Science and Technology*, 2(2), pp. 125–133.
13. Ndabikunze, B.K., Masambu, B.N., Tisekwa, B.P.M., Issa-Zacharia, A. (2011), The production of jam from indigenous fruits using baobab (*Adansonia digitata* L) powder as a substitute for commercial pectin, *African Journal of Food Science*, 5(3), pp. 168–175.
14. Adejuyitan, J.A., Abioye, A., Otunola, E.T., Oyewole, Y. (2012), An evaluation of some properties of baobab fruit powder and ogi mixes, *Transnational Journal of Science and Technology*, 2(7), pp. 91–102.
15. Kinsella, J.E. (1981), Functional properties of protein: Possible relationship between structure and function in foods, *Food Chemistry*, 7, pp. 273–288.
16. Akpata, M.I., Miachi, O.E. (2001), Proximate composition and selected functional properties of *Detarium microcarpum*. *Plant Foods for Human Nutrition*, 56, pp. 297–302.
17. Yadav, R.B., Kumar, N., Yadav, B.S. (2016), Characterization of banana, potato and rice starch blends for their physicochemical and pasting properties, *Congent Food and Agriculture*, 2, pp. 1–12.

18. Chinma, C.E., Anuonye, J.C., Simon, O.C., Ohiare, R.O., Danbaba, N. (2015), Effect of germination on the physicochemical and antioxidant characteristics of rice flour from three rice varieties from Nigeria, *Food Chemistry*, 185, pp. 454–458.
19. Kaur, M., Oberoi, D.P.S., Sogi, D.S., Gill, B.S. (2011), Physicochemical, morphological and pasting properties of acid treated starches from different botanical sources, *Journal of Food Science and Technology*, 48(4), pp. 460–465.
20. Desalegn, B.B. (2015), effect of soaking and germination on proximate composition, mineral bioavailability and functional properties of chickpea flour, *Food and Public Health*, 5(4), pp. 108–113.
21. Ocheme, O.B., Oloyede, O.O., Mikailu, E.S. (2010), Effect of Lime Soaking and Cooking (Nixtamalization) on the Proximate, Functional and Some Anti-nutritional Properties of Millet Flour, *AU Journal of Technology*, 14(2), pp. 131–138
22. Seena, S., Sridhar, K.R. (2005), Physicochemical, functional and cooking properties of under explored legumes, Canavalia of the Southwest coast of India, *Food Research International*, 38, pp. 803–814.
23. Bolaji, O.T., Awonorin, S.O., Olalusi, P.A., Adepoju, P.A. (2011), Evaluation of changes in pasting properties of ogi during storage, *Electronic Journal of Environmental, Agricultural and Food Chemistry*. 10(1), pp. 1865–1872.
24. Adegunwa, M.O., Sanni, L.O., Maziya-Dixon, B. (2011), Effects of fermentation length and varieties on the pasting properties of sour cassava starch, *African Journal of Biotechnology*, 42, pp. 8428–8433.
25. Apotiola, Z.O. (2013), Effect of soaking period on the ogi powder produced from sorghum, *Nigerian Food Journal*, 31(1), pp. 103–107.
26. Adebowale, A., Sanni, L.O., Awonorin, S.O. (2005), Effect of texture modifiers on the physicochemical and sensory properties of dried fufu, *Food Science and Technology International*, 11, pp. 373–385.
27. Kajihansa, O.E., Fasasi, R.A., Atolagbe, Y.M. (2014), Effect of different soaking time and boiling on the proximate composition and functional properties of sprouted sesame seed flour, *Nigerian Food Journal*, 32(2), pp. 8–15.
28. Akubor, P.I., Adedeji, O.E. (2016), Effect of NaCl and pH on the functional properties of locust bean (*Parkia biglobosa*) Pulp flour, *FUW Science and Technology*, 1(2), pp. 344–347.
29. Oluwamukomi, M.O., Jolayemi, O.S. (2012), Physico-thermal and pasting properties of soy-melon-enriched “gari” semolina from cassava, *Agricultural Engineering International*, 14(3), pp. 105–115.
30. Bhupender, S.K., Rajneesh, B., Baljeet, S.Y. (2013), Physicochemical, functional, thermal and pasting properties of starches solated from pearl millet cultivars, *International Food Research Journal*, 20(4), pp. 1555–156.
31. Correia, P.M.R., Soares, A.M., Brites, C. (2016), Quality characteristics of maize flour and breads, *International Journal of Food Engineering*, 2(2), pp. 113–118.
32. Zaidul, I.S.M., Yamauchi, H., Kim, S., Hashimoto, N., Noda T. (2007), RVA study of mixtures of wheat flour and potato starches with different phosphorus contents, *Food Chemistry*, 102, pp. 1105–1111.
33. Bolade, M.K. (2009), Effect of flour production methods on the yield, physicochemical properties of maize flour and rheological characteristics of a maize-based non-fermented food dumpling, *African Journal of Food Science*, 3, pp. 288–298.
34. Senanayake, S., Gumaratne, A., Ranaweera, K.K.D.S., Bamunuarachchi, A. (2014), Effect of hydroxypropylation on functional properties of different cultivars of sweet potato starch in Srilanka, *International Journal of Food Science*,
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Analysis of vitamin C enriched yoghurt by direct extraction of rosehip fruit in cow's milk during storage

Ira Taneva¹, Petar Panayotov²

1 – Trakia University of Stara Zagora, Yambol, Bulgaria

2 – University of Food Technologies, Plovdiv, Bulgaria

Abstract

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Corresponding author:

Ira Taneva
E-mail:
ira_64@abv.bg

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Introduction. The aim of the present study is to obtain enriched in vitamin C yoghurt by direct extraction of rosehip fruit in cow's milk.

Materials and methods. Cow's milk from cows grown in the Yambol region was used to carry out extraction of rosehip fruits (*R. Caniana*). The content of vitamin C in the yoghurt obtained was determined by the Officials methods of analysis, 2000, as well as the total number of lactic acid microorganisms contained according to EN ISO 6610:2006; ISO 7889.

Results and discussion. The active acidity of the yoghurt was monitored during both periods of preparation and storage. At the end of the storage period (14 days), the active acidity reached pH 4,2-4,3. For the same period, the vitamin C content was the highest in sample 2 and varied from 13,65-13,12 mg.g⁻².

The dry matter content in the yoghurt obtained was determined. Higher values of dry matter were observed in samples 2 and 3, with values varying from 12,60% to 13,4%. The higher values of the dry matter content in the product were due to the pectin type substances extracted during the extraction process. The pectin substances extracted into the milk stabilized the coagulum, improved the taste and the nutritious value of the yoghurt obtained.

The total number of viable bacteria in the yoghurts obtained was determined and they were found to increase during the storage period. The highest total number of viable lactic acid bacteria was observed for Sample 2-3,6.10⁸ CFU.g⁻² which is about 10 times more than these in Sample 1 (reference).

Conclusions. The yoghurt obtained by direct extraction of dry rosehip fruits (*Rosa canina* L) into cow's milk at hydromodule 1:15 possessed the properties of functional food because of the content of vitamin C in it which varied from 13,65 to 13,12 mg.g⁻². The preparation of vitamin C enriched yoghurt can be used to produce new lactic acid products providing health benefits.

Introduction

Yoghurt is highly popular fermented milk product on world scale due to its health benefits. It is obtained from cow's milk as a result of acidic coagulation of milk proteins induced by the lactic acid produced by *Streptococcus thermophilus* (*S. thermophilus*) and *Lactobacillus delbrueckii* subsp. *bulgaricus* [17].

It has been established that yoghurt has the same nutritious but higher biologic value compared to raw cow's milk. During the process of fermentation by its preparation, a number of biochemical changes occur which improve the absorption of lactose, lactic proteins and lactic acid by human organism [18].

The yoghurt consumption is high mainly in the Mediterranean countries, Asia and Central Europe. In some regions, yoghurt is produced as high viscosity liquid while on others – in the form of softer gel [8].

Since 2000, the development of new kinds of lactic acid products containing probiotics, prebiotics and components containing biologically active substances has substantially grown. Different methods for preparation of milk products enriched in biologically active substances have been implemented mainly by addition of fruits, vitamins, sweeteners, bee pollen, bee honey, etc., aiming to increase their biological value. [7, 9]. For the preparation of milk products enriched in biologically active substances, extracts of various fruits can be added [4, 24].

The manufacturing of extracts is usually connected with the process of extraction which leads to obtainment of one or several components from solid or liquid mixture by treatment with suitable solvent [21]. According to the solvent type, the extraction processes are classified as aqueous, alcoholic, hydroalcoholic, oil, etc., and according to the process itself – stationary and non-stationary.

No reports about methods related to direct extraction of fruits in raw milk, extraction of biologically active substances and manufacturing of enriched by them milk product (yoghurt) have been found in the literature.

Among plant species, the fruits of rosehip (*R. canina*) are characterized by high content of biologically active components, e.g. vitamins (C, B, P, PP, E, K), flavonoids, carotenes, carbohydrates (mono- and oligosaccharides), organic acids (tartaric and citric acid) microelements, etc. This is why the fruits are valuable raw material for the food and pharmaceutical industries and can be used for preparation of enriched extracts [12].

The aim of the present study is to develop a sample technology for production of vitamin C enriched yoghurt by direct extraction of dry rosehip fruits (*R. canina*) in raw cow's milk.

Materials and methods

Materials

For the manufacturing of vitamin C enriched yoghurt, cow's milk from cows grown in the region of Yambol was used, with M = 3,6%; pH = 6,6; non-fat residue (NFO) = 8,7%. The inoculant used was lyophilized starter culture (*Lactobacillus delbreuckii* ssp *bulgaricus*, *Streptococcus thermophilus*), product of "Laktina" PLC, containing lactic acid bacteria more than $9,5 \times 10^9$ CFU.g⁻¹.

The dry rosehip fruits (*Rosa canina* L.) used were grown in the region of Kyustendil, Bulgaria, harvested in 2016. Before the extraction, the fruits were washed, dried and ground to pieces sized 2,0-4,0 mm.

Methods

A method for preparation of vitamin C enriched yoghurt was developed and it is presented in Fig. 1. After quality control, acceptance, filtering and standardization of the milk by fats, stationary extraction of the raw milk with dry rosehip fruits was carried out. The extraction was performed at two hydromodules (dry rosehip fruits & cow's milk) 1:15 and 1:20, temperature 0-4 °C and extraction duration 3 hours. At the end of the extraction period, the milk was filtered and pasteurized at temperature of 70-72 °C for 25 min. the pasteurized milk was cooled to temperature 44-45 °C and inoculated with lyophilized starter culture (*Lactobacillus delbreukii* ssp *bulgaricus*, *Streptococcus thermophilus*). The amount of the inoculant was 4% vs the mass of the milk. The inoculated milk was kept at temperature 42-45 °C for 3-3,5 hours. After reaching pH 4,6-4,5, the coagulated milk was homogenized (agitated), divided into portions and cooled to 18-20 °C. The yoghurt obtained was further cooled and stored at temperature 0-4 °C.

By the same technological scheme, a reference sample of yoghurt was prepared without extraction.

The samples of yoghurt obtained were analyzed at the moment they were obtained and then on 3rd, 7th and 14th day of their storage. [17, 22].

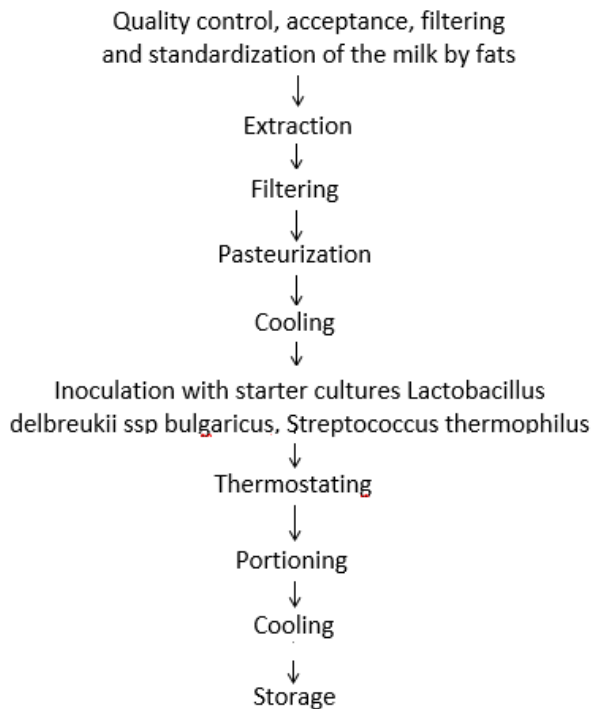


Figure 1. Sample scheme of the technological operations for production of yoghurt by extraction of rosehip fruits with cow's milk

Chemical methods of analysis

Study of the *dry rosehip fruits* for their:

- Content of dry matter,% - [10];
- Titratable acidity,% - [1];
- Ascorbic acid, mg.10⁻². g⁻¹, - [13];
- Tanning matter,% - by exhausting extraction with hot water with reflux and titration of the extract obtained with 0,1 n KMnO₄ and indicator indigo carmine,- [15];

Study of the yoghurt - yoghurt without extraction (Sample 1); yoghurt with extraction of rosehip fruits at hydromodule 1:15 (Sample 2); yoghurt with extraction of rosehip fruits at hydromodule 1:20 (Sample 3):

- Active acidity, pH – potentiometrically, by pH meter (Model MS 2011, Microsyst, Plovdiv, Bulgaria) equipped with electrode (pH electrode Sensorex, Garden Grove, CA, USA);
- Dry matter,% - [5];
- Ascorbic acid, mg.10⁻². g⁻¹, - [13];
- Number of lactic acid bacteria - [2];

Sensory analysis

The yoghurt obtained was estimated by specialists from the Faculty of Technics and Technology, Yambol, branch of the Trakia University of Stara Zagora, according to Badawi et al. [6] by the following properties: taste and flavor, superficies, color and residual taste.

Statistical analysis

The statistical analysis was carried out using OriginPro v.6.1 (OriginLab Corporation, USA), MS Excel and MS Word (Microsoft Corporation, USA).

Differences were considered to be significant at validity of $\alpha=0.95$.

Results and discussion

The chemical properties of the dry rosehip fruits used (*Rosa canina* L) are shown in Table 1. The rosehip fruits were estimated mainly by the contents of ascorbic acid (vitamin C), tanning substances and pectin. The fruits can accumulate up to 1000-4000 mg.g⁻² ascorbic acid and 4,5-6,8% tanning substances [3,14,16]. The chemical composition of the fruits analyzed was comparable with the literary data and the contents of the other components in other representatives of the same family.

Table 1
Chemical properties of rosehip fruits

Dry matter,%	Titratable Acidity,%	Ascorbic acid, mg.g ⁻²	Tanning substances,%
88,7± 0,08	2,4 ± 0,09	2640,9 ± 0,06	5,5 ± 0,05

The high content of ascorbic acid (vitamin C) found in the rosehip fruits has values (2640,9 mg.g⁻²) which allow using them as additive for preparation of vitamin C enriched yoghurt.

The active acidity of the yoghurt obtained (Samples 1, 2 and 3) was measured immediately after its preparation and during the storage period – on 3rd, 7th and 14th day (Fig.2). the values of the active acidity of the yoghurt decreased during the storage, as shown in Fig.2.

The lower values of the active acidity for Sample 2 on the 10th day (pH 4,2) of the storage period was most probably due to the biologically active substances and organic acids extracted from the fruits during the extraction.

The organic acids and pectin introduced during the extraction did not affect the coagulation process because it has been proved that the stabilization of casein is effective in the pH interval 3,2-4,7 [11, 23].

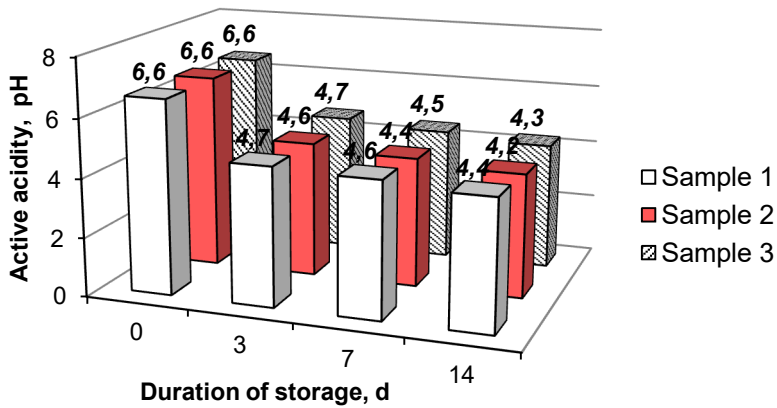


Figure 2. Effect of the storage duration on the active acidity of the yoghurt obtained

Table 3 shows the values of dry matter content in the yoghurt obtained. The dry matter had higher values for samples 2 and 3 and varied from 12,60% to 13,4%. The higher values of dry matter content in the yoghurt were due to the pectin substances extracted during the extraction process. The pectin contained in rosehip fruits varies from 5 to 10% of the absolute dry matter of the fruit [3]. The pectin substances in the milk improve the nutritious value of the yoghurt.

Table 3

Dry matter contents in vitamin C enriched yoghurt

Duration of storage, day	Dry matter, %		
	Sample 1	Sample 2	Sample 3
Fresh	12,1	12,6	13,4
3	12,2	12,7	13,4
7	12,2	12,7	13,4
14	12,2	12,7	13,4

The content of vitamin C (ascorbic acid) in the yoghurt obtained was studied. It is well known that the dry rosehip fruit tissue contains 2200 mg.g⁻² ascorbic acid which makes it 30-40 richer in this vitamin compared to red tomatoes and 300 times richer compared to apples [19].

It is obvious from the results presented in Table 3 that the content of ascorbic acid extracted during the extraction was the highest in Sample 2 – 13,65 mg.g⁻² and remained almost the same until the 14th day of storage of the yoghurt.

For the same period, the values of vitamin C content in Sample 3 were 11,45-11,30 mg.g⁻². The higher vitamin C content in Sample 2 was due to the lower hydromodule used in the extraction process.

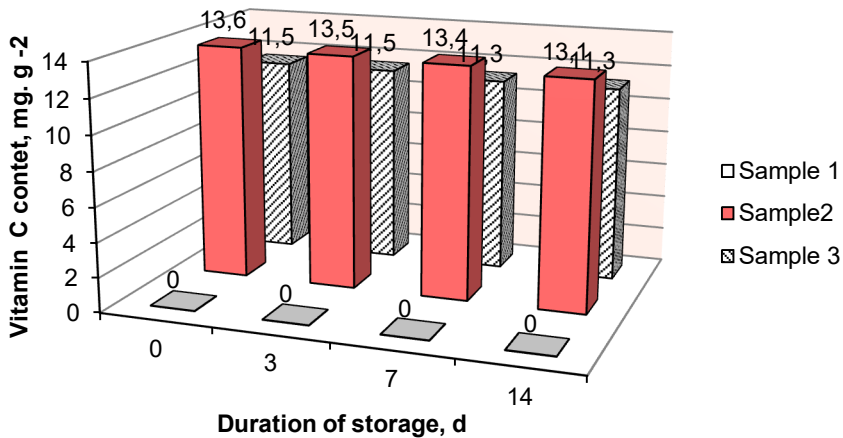


Figure 3. Effect of storage duration on the vitamin C content in yoghurt

The total number of lactic acid bacteria in the yoghurt obtained was studied. The data presented in Table 4 showed that the total number of *Str. thermophilus*, *L. delbrueckii* ssp.bulgaricus had not been affected by the extraction of biologically active substances during the extraction process.

The total number of viable bacteria gradually increased until the end of the storage period. Higher number of bacteria was observed in Sample 2 compared to the reference (Sample 1) at the end of the storage. Similar results were obtained by Stijepic [20] who found that the yoghurt enriched in combination of whey protein concentrate and 4% honey had the highest content of lactic acid during the storage period.

As a result of the studies discussed above, the samples of yoghurt obtained comply with the requirement of Codex alimentarius for the content of probiotic microorganisms in inoculated milk products which should contain at least 10⁷ viable cells.

The organoleptic properties of the yoghurts obtained were determined with respect to their color, taste and fragrance, superficies, residual taste and consistence.

Table 4

Number of lactic acid bacteria in yoghurt during the storage period

No.	Duration of storage,d	CFU g product Sample 1			CFU g product Sample 2		
		Lactobacilli	Strepto cocci	Total	Lactobacilli	Strepto cocci	Total
1.	Fresh	1,2.10 ⁷	4,610 ⁷	5,8.10 ⁷	1,2.10 ⁷	4,6.10 ⁷	5,8.10 ⁷
2.	3	2,3.10 ⁸	2,1.10 ⁹	2,3.10 ⁹	2,4.10 ⁸	2,8.10 ⁹	3,04.10 ⁹
3.	7	1,1.10 ⁸	1,0.10 ⁹	1,1.10 ⁹	1,2.10 ⁸	1,3.10 ⁹	1,4.10 ⁹
4.	14	2,6.10 ⁶	3,2.10 ⁸	3,5.10 ⁷	2,5.10 ⁷	3,4.10 ⁸	3,6.10 ⁸

Table 4 (continue)

No.	Duration of storage,d	CFU g product Sample 3		
		Lactobacilli	Strepto cocci	Total
1.	Fresh	1,2.10 ⁷	4,610 ⁷	5,8.10 ⁷
2.	3	2,1.10 ⁸	2,6.10 ⁹	2,8.10 ⁹
3.	7	1,1.10 ⁸	1,4.10 ⁹	1,5.10 ⁹
4.	14	2,3.10 ⁷	3,1.10 ⁸	3,3.10 ⁸

The yoghurt Sample 2 obtained was given higher values for taste and fragrance, superficies and consistence compared to Samples 1 and 2 (Fig.4). The yoghurt Sample 2 had thicker consistence and more pronounced taste and fragrance. For Sample 2, residual taste of rosehip was perceived as a result of the extraction carried out but it didn't worsen the yoghurt taste.

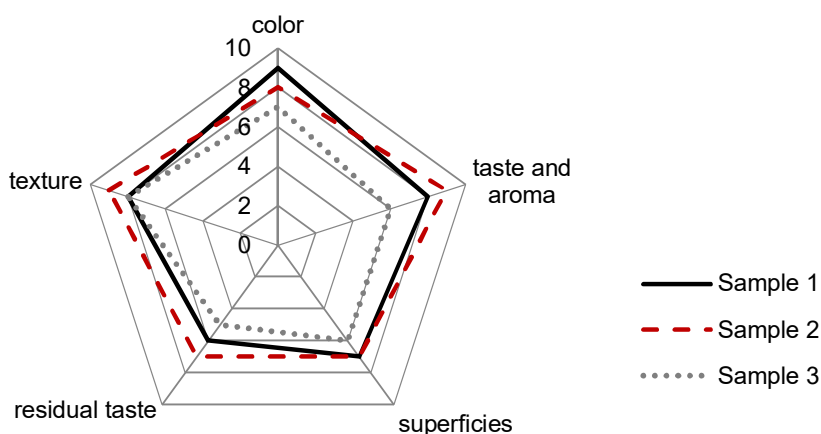


Figure 4. Organoleptic estimation and sensor profile

Conclusion

The yoghurt obtained has properties of a functional food resulting from the direct stationary extraction of dry rosehip fruits (*Rosa canina* L) in cow's milk at two hydromodules 1:15 and 1:20 .

The active acidity of the yoghurt was established in both periods of preparation and storage. At the end of the storage period (14th day), the active acidity reached pH 4,2-4,3. For the same period, the content of vitamin C was the highest in Sample 2 and varied from 13,65-13,12 mg.g⁻².

The total number of viable bacteria in the yoghurts obtained was determined and the values of this indicator were found to gradually increase during the storage period; for Sample 2 it was 3,6.10⁸ CFU.g⁻² which is 10 times higher than that of Sample 1 (reference). It makes the yoghurt obtained a useful and healthy dairy product.

The direct extraction of dry rosehip fruits in raw cow's milk improves the organoleptic properties of the yoghurts obtained.

The preparation of vitamin C enriched yoghurt by direct extraction of fruits can be used for manufacturing new lactic acid products with health benefits.

References

1. AOAC Association of Official Analytical Chemists (2000), Acidity/Titratable Acidity
2. BNS ISO 7889 *Lactobacillus delbrueckii* subsp. *Bulgarius*, ISO 7889 *Streptococcus thermophilus*
3. Zimin E. (2001), Collection variety study of multivitamin and large-fruited rosehip in the Khabarovsk Territory, *Materials of the international seminar "Forest biologically active resources*, Khabarovsk, pp. 313–319.
4. Mustafina A.S., (1999) *Development of technology of fruit extracts for the purpose of their use in the production of dairy products: Author's abstract. dis. Cand. tech. sciences*. Kemerovo.
5. A.O.A.C. Association of Official Analytical Chemists (2000), Official Methods of Analysis of Association of Official Agriculture Chemists. Wiscosin. George Banta Co. Inc.
6. Badawi, R., Hamed, A., Kebary K. and El- Sayed, H. (2008), Effect of replacing milk fat with fat replacers on the quality of stirred yoghurt, *Egyptian J. Dairy Sci.*, 36, pp. 197–206.
7. Bills D., Yang C.S., Morgan M. and Bodyfelt F. (1972) Effect of sucrose on the production of acetaldehyde and acids by yogurt culture bacteria, *Journal of Dairy Science*, 55, pp. 1570–1573
8. Caballero, B., Finglas, P., and Toldrá, F. (2016), Yogurt: The Product and its Manufacture, *The Encyclopedia of Food and Health*, 5, pp. 617–624.
9. Chen L., Mehta A., Berenbaum M., Zangerl A. and Engeseth N. (2000), Honeys from different floral sources as inhibitors of enzymatic browning in fruit and vegetable homogenates, *Journal of Agricultural and Food Chemistry*, 48, pp. 4997–5000 .
10. ISO 1026:1982. Fruit and vegetable products -- Determination of dry matter content by drying under reduced pressure and of water content by azeotropic distillation, Available at: <https://www.iso.org/standard/5498.html>
11. Laurent M., Boulenguer P. (2003), Stabilization mechanism of acid dairy drinks (ADD) induced by pectin, *Food Hydrocolloids*, 17, pp. 445–454,

12. Mabellini M., .E.Ohaco., M. Ochoa, A. Kessler, C. Márquez, A.De Michelis A., (2011), Chemical and Physical Characteristics of Several Wild Rose Species Used as Food or Food Ingredient, *International Journal of Industrial Chemistry*, 2(3), pp. 158–171.
13. (2000), *Official methods of analysis* (14th ed.) Association of Official Analytical Chemist, Arlington, VA, USA, 2000.
14. Orhan N., M. Aslan, S. Hosbas, O. Deliorman (2009), Antidiabetic effect and antioxidant potential of *Rosa canina* fruits, *Pharmacognosy Magazine*, 5(20), pp. 309 – 315.
15. Patel AV, Patel KN, Patel MS. Validated simple redox titration method for the estimation of gallotannins in marketed ayurvedic churna preparations. (2011), *Journal of Chemical and Pharmaceutical Research*, 3, pp. 293–299.
16. Rahnavard A., A. Ghavamaldin, T. Ahmad, T. Mariamalsadat (2013), Evaluation of biochemical compounds *Rosa canina* L. in North of Iran Ramsar and Tonekabon Heights, *Journal of Medicinal Plants Research*, 7 (45), pp. 3319–3324.
17. Robinson, R.K., (2003), Yoghurt types and manufacture. In: Roginski, H., Fuquay, J.W., Fox, P.F. (Eds), *Encyclopedia of Dairy Sciences*, vol. 2. Academic Press and Elsevier Science, Amsterdam, Boston, London, New York, Oxford, Paris, San Diego, San Francisco, Singapore, Sydney, Tokyo., pp. 1055–1058.
18. Savadogo A., C.A.T. Ouattara, I.H.N. Bassole and S.A. Traore. (2006), Bacteriocins and lactic acid bacteria - a minireview, *African Journal of Biotechnology*, 5, pp. 678–683.
19. Soner K., H. Baydar, S. Erb (2009), Variations in chemical compositions of *Rosa damascena* Mill. and *Rosa canina* L. fruits, *Czech Journal of Food Sciences*, 27(3), pp. 178 - 184.
20. Stijepić, M., D. Durđević, J. Jovanaglusac, (2012), Production of low fat yoghurt enriched with different functional ingredients, *Quality of Life (Banja Luka)*, 3(1–2), pp. 5-12.
21. Sukhdev H., S. Preet, S. Khanuja, G. Longo, D. Rakesh. (2008), *Extraction Technologies for Medicinal and Aromatic Plants*, International Centre for Science and High Technology, Italy.
22. Tamime and Robinson, (1999), *Yoghurt science and technology* (2 nd ed.), Cambridge. Woodhead Publishing Ltd.
23. Tanhatan N., François T., M. Ralet. (2008), Citrus pectin: structure and application in acid dairy drinks, *Tree and Forestry Science and Biotechnology*, 2(1), pp. 60–70.
24. Zlatev, Z., Petev M., Dimitrova A., Simeonova V., Dinev S., Dineva J. (2015), Analysis of methods and tools for evaluation the quality of yogurt, *Journal of Innovation and entrepreneurship*, III, pp.41–57.

Antimicrobial and antifungal activity of model drugs on the basis of food plant extracts in the systemic concept of health

Mykola Oseyko¹, Vasyl Shevchyk², Olena Pokryshko³

1 – National University of Food Technologies, Kyiv, Ukraine

2 – "Vasyl Shevchyk's eye microsurgery," Chernigiv, Ukraine

3 – Ternopil State Medical University named after I.Ya. Grobachevsky, Ternopil, Ukraine

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Corresponding author:

Mykola Oseyko
E-mail:
nikios@ukr.net

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Introduction. We analyzed the antimicrobial and antifungal activity of samples of the preparation of KTIOL-BF on standard and resistant test strains of microorganisms. The aspects of microbiology and the systemic concept of health are considered.

Materials and methods. Strains of Gram-positive and Gram-negative microorganisms were used: *S. aureus*, *S. saprophyticus*, *E. coli*, *P. aeruginosa*, *S. Epidermidis*, and *C. albicans* fungi. Model drugs based on pyruvic extracts have been studied. The method of diffusion of substances into agar was used to determine the activity of drugs in relation to strains..

Results and discussion. The present state of physical, psychological and social existence of a person contributes to the accelerated proliferation of pathogenic microorganisms and the emergence of a resistant microflora. In recent years, almost everyone suffers from fungal diseases. The problem of health and healthy lifestyle is topical. Global is the problem of providing humanity with food.

Considered aspects of microbiome (endoeological aspects) the importance of intestinal microbiota in human health and pathophysiology is indisputable.

Suggested the systemic concept of health (The systems KTIOL®: 10 Basic Provisions for Prevention, Recovery, Treatment and Rehabilitation).

The tested microorganisms were sensitive to model specimens of the preparation KTIOL-BF (BF1-BF20). Samples of BF2, BF12, BF17 were found to be the most effective for the *S. Saprophyticus* test strain. It was found that the *S. epidermidis* test-microorganism was the most effective for the sample of the preparation BF34 (growth retardation zone was 30.40 ± 1.29 mm). The highest antifungal activity was found in samples of KTIOL-BF: BF33, BF37. Mushroom growth zones were respectively 20.76 ± 1.65 and 22.62 ± 1.44 mm.

The samples of the KTIOL-BF: BF-70, BF-87, BF-92 were shown to have a high inhibitory effect on clinical resistant strains of microorganisms. The diameter of the inhibition zone of resistant strains in KTIOL-BF87 was 22.17 mm; the diameter of the PVI control sample was 13.05 mm.

Conclusions. The raised antimicrobial and antifungal activity of KTIOL-BF preparations in relation to gram-positive and gram-negative microorganisms, *C. albicans* fungi and resistant strains (PVI control) were revealed.

Introduction

In the complex environmental and economic conditions of today, scientific and practical substantiation of the technologies of functional products, food supplements and preparations of gerontological and ophthalmologic direction is necessary [1,2,3]. At the same time, it is urgent to improve the concept of the endoecology of health as regards prevention, rehabilitation, treatment and rehabilitation of humans [4]. The present state of physical, psychological and social existence of a person contributes to the accelerated proliferation of pathogenic microorganisms and the emergence of a resistant microflora. This microflora interacts with human saprophytic microbes and can affect our physical health. Saprophytic microbes are trillions of microbes living on the surface and inside our body.

The review [5] substantiates the possibility of using plant products as antimicrobial agents. In recent years, the accelerated use and search of drugs and dietary supplements derived from plants. According to the author, it would be useful to standardize in vitro methods of extraction and testing for more systematic searching and ease of interpretation of results.

The study [6] confirmed the strengthening of the resistance of the microflora and drug strains to antibiotics and antiseptics, and, as a result, an increase in the incidence of secondary and postoperative infections.

The purpose of the study is to detect the antimicrobial and antifungal activity of the model specimens of the KTIOI-BF series and to present the basic provisions of the systemic health concept (KTIOI® system).

Ten health problems affecting half the planet's population. The World Health Organization (WHO) experts have announced a five-year strategic plan [7] aimed at helping the three billion people without access to universal insurance and quality health services. As part of the project, WHO experts called the main threats to the health of the planet's population. In particular, the following 10 problems:

1. Air pollution. These air is breathing today 9 of 10 people;
2. Non-communicable diseases (diabetes, cancer or heart failure);
3. The danger of a global flu pandemic. Experts do not exclude that a large-scale epidemic can burst at any moment .;
4. Severe and life-threatening conditions (crises, wars, natural disasters, etc.) endanger the 1.6 billion people (almost 22% of the planet's population);
5. The growth of bacteria resistance to antibiotics does not allow to eradicate tuberculosis and other dangerous diseases;
6. Ebola fever has not yet been cured;
7. Serious threats to humanity are the poorly developed system of primary care, which is typical of many poor countries;
8. Negative people's attitude to immunization (according to WHO data, the number of cases of measles has grown by 30% recently);
9. Dengue infectious fever (up to 390 million infected per year);
10. Undefeated opponent - HIV.

Aspects of quality, safety and packaging of food and functional products. In today's social conditions, as before, the problem of health and healthy lifestyle is topical. After all, most people understand that products and preparations (biologically active additives) should not only be tasty, but functional and safe. In particular, in Japan, the European Union, and the United States, especially in the context of public health, a healthy, creative and active lifestyle [8].

In the world one of the global concerns is the supply of humanity with food, which is connected with annual population growth and global warming of the climate, resulting in reduced areas of cultivated soils. It is important not only to find available sources of food supply but also to create such products that are safe and balanced by the chemical composition of nutrients [8, 9, 10].

According to the data of the group of scientists on the problem of healthy eating [11] it is expedient to introduce in rations all categories of the population, the nutrients enriched with vital, food plants, seafood, etc.).

Innovative pharmacokinetic products, drugs based on medicinal and food plants and auxiliary active ingredients are presented in [1, 4, 9, 12].

In recent years, almost everyone suffers from fungal diseases, and these diseases are not treated with pharmacy drugs. Doctors recommend abandoning the modern (yeast) wi shop bread. The use of yeast bread can lead to various types of intoxication, fungal diseases, immune disorders, chronic and other diseases [13].

In study [14] methodology for testing natural compounds for determination of antifungal activity had been developed with adaptations. The most used are bioautography and agar diffusion with a complex and no defined media. In this study, different methods for determination of antifungal activity of natural products are discussed, and the use of M27-A2 microdilution test from CLSI (Clinical and Laboratory Standards Institute, 2002), a methodology for testing plant extracts activity is recommended as a baseline.

The most common and dangerous defeat of the crumb of bread is potato disease. With the development of the disease, the breadcrumb acquires a hue of rotting fruit, etc. The disease is caused by the bacterium *Bacillus subtilis* - potato stick. Its spores are harmless, but at a temperature of about 40 ° C, combined with humidity and low acidity, they develop into dangerous microbes.

White bread has a shelf life of not more than 24 hours after preparation. In rye bread, these bacteria do not multiply due to high acidity. The quality of baked bread should be monitored by manufacturers. It is advisable for buyers to purchase some bread and store them in "breathing" fabric bags in a cool place. Affected bread cannot be eaten categorically [15].

As a result of the systematic, integrated approach to the innovative technologies of bakery industries and new types of products with respect to their quality and safety [16, 17] developed the composition of polycomponent oxidants "Optical 1" and "Optical 2". Their influence on the length of the technological process, the influence of additives on the biochemical, microbiological, structural and mechanical properties of the dough and bread from the mixture of rye and wheat flour has been revealed. The new types of rye-wheat bread "Metropolitan Symphony" and "New Metropolitan Symphony" [18] were developed and introduced into the recipes and technological instructions on the basis of performed experimental research.

Microbiological studies of inhibitory action on some pathogens based on films with polyvinyl alcohol with nanoparticulate TiO₂ powder are presented in [19]. It was found that the best method was to treat films of TiO₂ (2.5%) with UV radiation. Solutions with TiO₂ did not inhibit mushroom and yeast activity. TiO₂ applied to the film inhibits the growth of bacteria (*E. coli* IEM-1, *B. subtilis* BT-2), growth retardation was not observed. Antimicrobial (TiO₂) and other substances to enhance the nutritional value of products (vitamins C, F, fruit and vegetable powders, probiotics and elamine) should be used to provide the functional properties of biodegradable materials. A draft technical specification for food products has been developed.

It is known that lactic acid bacteria (LABs) produce various antimicrobial compounds and play an important role in bioconservation of food and feed. LABs are of particular interest as a body of biosecurity [20].

In [21], on the basis of integrated feedbacks of wheat bread with edible coating and probiotic microorganisms, the improvement of bread quality was determined by organoleptic and microbiological parameters.

Thus, the protection of products in food technologies using a bioecological design in the form of high-quality and safe edible films or coatings is appropriate and relevant. The community of microorganisms formed during a person's life is a complex dynamic microecosystem whose change in composition can lead to illness of the oral cavity [22,23].

The increasing clinical and microbiologic resistance of *Candida* spp. isolates to several antifungal agents are becoming a serious problem. It is now reasonable to propose the use of antifungal susceptibility testing in *Candida* spp. isolates from patients who have failed conventional therapy, before the selection of empirical therapy. The good diffusion test is simple, easy to reproduce, inexpensive, easy both to read and interpret and has a good correlation to the reference NCCLS microdilution test and may represent an alternative method for antifungal drug susceptibility testing of *Candida* spp., mainly in laboratories with few resources [24].

In [25] studied of antimicrobial and antifungal activity of different concentrations of the drug on the representative's oral microflora. It was concluded that the drug has antibacterial activity, and it is not selective. An increase in antimicrobial activity was observed with an increase in the concentration of the drug. Antifungal has indicated the effect of high concentrations of the drug.

The diverse collections of microorganisms associated with humans and other animals, collectively referred to as their "microbiome," are critical for host health, but the mechanisms that govern their assembly are poorly understood. This has made it difficult to identify consistent host factors that explain variation in microbiomes across hosts, despite large-scale sampling efforts. These results illustrate the importance of microbial dispersal to animal microbiomes and motivate its integration into the study of host–microbe systems [26].

Repair of tissue wounds is a fundamental process of restoring the integrity of tissues and regular function. It is important that infection is a major contributor to wound healing. Multicellular organisms have developed an arsenal of host defense molecules, including antimicrobial peptides (AMPs), aimed at controlling the proliferation of microbial organisms and modulating the host's immune response to a variety of biological or physical stroke. The role of AMR as endogenous wound healing mediators and their promising therapeutic potential for the treatment of skin-friendly skin and other epithelial injuries is showing [27].

According to the author's team [28], the importance of intestinal microbiota in human health and pathophysiology is indisputable. Despite the abundance of metagenomics data, the functional dynamics of gut microbiota in human health and disease remain elusive. Urolithin A (UroA), a major microbial metabolite derived from polyphenolics of berries and pomegranate fruits displays anti-inflammatory, anti-oxidative, and anti-ageing activities. Cumulatively, the results highlight how microbial metabolites provide two-pronged beneficial activities at gut epithelium by enhancing barrier functions and reducing inflammation to protect from colonic diseases.

Systemic concept of health (The systems KTIOL®: 10 Basic Provisions for Prevention, Recovery, Treatment, and Rehabilitation). The study of antimicrobial and antifungal model samples of drugs is based on the theory and practice of using KTIOL-I and KTIOL-II systems [1, 3, 4, 8, 9, 12].

The preamble to the Charter of the WHO states that health is not only a lack of illness or physical defects but a state of complete physical, mental and social well-being. That is, health is the living conditions of the Personality when all organs fulfill their vital functions.

The system KTIOL-I (Comprehensive Technologies, Engineering, Equipment, Lines) was initially aimed at the synthesis of lipid-containing products of special purpose. Thus, based on the use of a systematic approach and analysis of identified problems, effective products, materials, drugs were created. In particular, for the oil and oil, petrochemical and metallurgical industries, the lipophilic substitute for palm oil K2, the lubricating and cooling technological equipment, technological and special me a m users correct twice as many mistakes as free users, on average: T6P, TVS, KTIOL-76, 77, 15. For the production of a range of special paste made of micron artificial diamonds and/or carbide - titanium fractions justified the use of hydrophilic - lipophilic systems based on oil, fatty, and substitutes of a number of KTIOL®.

Basic principles of the system KTIOL-I are:

- providing the structure of the product (preparation) on the micro and nano levels;
- ecological and economic efficiency;
- a systematic approach to the methodology of safe food production, pharmaceutical and cosmetic products and drugs.

The system of KTIOL-II (Integrated therapy of individual health improvement) was started by analyzing indicators of quality and safety of water, food products, nutritional supplements and preparations, environmental and endoecological aspects of personal health.

The system KTIOL-II includes the following provisions (keywords and phrases):

A. Hygiene of thoughts. This is a positive, critical, rational thinking.

B. With Prevention. This is self-monitoring and periodic systemic examinations: ophthalmologic, dental, endoecological, electrocardiographic, gerontological, control of the body mass index, blood control for cholesterol, sugar, iodine, etc. It's time to spend time on your own health;

C. Water for health. Drinking water for consumption in a set of indicators should meet international standards of quality and safety. Drinking water of high quality should be specially prepared. The water that we constantly consume and in the required amount (approximately 30 ml per kg body weight) should be a healing o-treatment. Quantity, conditions and time of consumption of good water are specified individually and seasonally. Good water has a positive effect on the quality of blood, on metabolic processes in the body and, accordingly, on the improvement of the health of the person;

D. Healthy eating. This is food therapy and a correct, individual gerontological balanced diet. Given the age, profession, state of the organism, active and creative life, nutrition in the realities of the present must be individually oriented: preventive, recreational, health-curative, medical and rehabilitation. Everyone should be identified and give up inappropriate food. It should also be remembered that vitamins that come from food are very important biological compounds for the normal functioning of all systems of the body.

In today's ecological and social conditions, people are beginning to think about the quality and safety of food in public and fast food establishments. In place of fast food, there are lay-foods – institute ions of leisurely wellness nutrition. It is known that the health or illness of a person depends, besides other factors, whether it eats the bacteria fermenting or rotting, and also consumes enough food with enough food fibers;

E. Healthy breathing.

F. Motion is life. More physical exercise in the wild should be used: walking, swimming, water excercises, active walks, Nordic walking, ball games, yoga excercises, etc. All these individual excercises contribute to the improvement of the organism and its

immunity, especially in clear sunny weather. Keep track of your feelings, control your own pulse, the frequency of breathing, relax in time;

G. Microbial - is an individual, diverse collection of microorganisms in the body (preferably without their resistance). The microbial condition in the body is influenced by a healthy, active lifestyle, water, nutrition therapy, acid-base balance control, personal know-how, etc.);

H. Massage. Massages are known to be used for daily activation of the body and prevention. In particular, morning (immediately after sleep), general, local, point (for example points E-36, GI-4, etc.), combined and special. Massages significantly contribute to strengthening the body's protective forces;

I. Individual know-how: personal and/or based on the use of the systemic health concept (KTIOL® system). This is the personal possession of tech, that is, knowledge, skill (skills, experience) and individual art with respect to its organism, self-control, self-perfection, and management of its own microbiome.

From the above provisions, we see that in addition to the hygiene of thoughts, systematic prevention, and improvement of the body, changes in nutrition and the influence of other factors, each person for the individual physical and mental well-being must have a high level of quality and safe microbial.

Materials and methods

Materials to be explored

Strains of Gram-positive and Gram-negative microorganisms were used: *S. aureus* (ATCC 6538), *S. saprophyticus* (ATCC 15305), *E. coli* (ATCC 25922), *P. aeruginosa* (ATCC 9027), *S. Epidermidis* and *C. albicans* fungi. The density of the microbial suspension was determined according to the standard of turbidity 0,5 by McFarland (equal to 1.5×10^8 colony-forming units (CFU)/ml).

The study used samples of KTIOL-BF series. These functional and antioxidant drugs have been obtained on the basis of the systemic concept of health. The drugs of KTIOL-BF (biologically functional) series were used as model samples [4, 8].

Povidone-iodine, PVI (e.g., BETADINE, which is based on a solution of povidone-iodine, surface-active and auxiliary substances) were used as a control.

Research order

- Methodology analysis
- Preparation of exploratory strains of Gram-positive and Gram-negative microorganisms, model preparation of KTIOL-BF series and control drug
- Execution of planned research, processing and discussion of the results, conclusions.

Evaluating research results

According to the diameter of the microbial growth inhibition zone the following degrees of susceptibility to the antibacterial solutions were adopted:

- highly susceptible to drug sample – if the diameter of the growth inhibition zone of microorganisms exceeded 20 mm;
- susceptible if the diameter was from 14 to 20 mm;
- low susceptible - from 8 to 14 mm.

All tests were performed triplicate, and average values were recorded.

After the second layer of the agar was sealed, the cylinders were also removed in the formed wells; the samples of the investigational drugs were 0.3 ± 0.03 ml. In one cup, Petri studied the activity of four or five different samples.

The seeds were incubated at 37°C . for 48 hours. The results were determined in the presence of zones of growth retardation test-microorganisms, which were clearly visible around the walls.

By the degree of sensitivity of microorganisms to antibacterial solutions, we measured the diameter of the zone of suppression of microorganisms.

As a scientific and practical basis in the planning and implementation of this study, the systemic concept of health [4, 8] was used. This concept includes two systems of KTIOL.

Antimicrobial activity screening of KTIOL-BF against *Candida* spp.

The objects of study were KTIOL-BF numbered from 1 to 37. The antimicrobial activity screening of KTIOL-BF against *Candida* spp. According to WHO recommendations the test-strain *C. albicans* ATCC 885-653 was used to investigate their antifungal effects.

In vitro studies were conducted using the wells method. Standardization of the substances diffusion into agar was provided using the thickness of nutrient media of 10 mm and the size of well 6 mm. A suspension of the daily culture of the test microorganism was added at a concentration of 10^7 CFU/ml, which was determined by optical turbidity standard by McFarland. After inoculation of the test-strain onto the nutrient medium, the wells were filled with drops of BF. Further, Petri dishes were placed in an incubator at 37°C . After 24 hours the results were registered by measuring the diameters of microbial growth inhibition around the well in millimeters. The evaluation of fungal susceptibility was performed according to the following criteria:

the absence of inhibition zone and zone up to 10 mm were evaluated as unsensitivity of *C. albicans* to KTIOL-BF;

- the inhibition zone from 11 to 15 mm – low sensitivity of test-strain to BF;
- the inhibition zone from 15 to 20 mm – sufficient sensitivity of test-strain to BF;
- the inhibition zone more than 20 mm – high sensitivity of test-strain to BF.

Povidon-iodine was used as a positive control.

The antifungal activity of each substance was checked out 10 times. Statistical analysis of the obtained results was carried out by the method of variation statistics.

Results and discussion

Taking into account the principles of the systemic concept of health and the physiologically functional system of KTIOL-II, samples of type KTIOL-BF [4, 8] included hydrophilic lipophilic extracts from plant and/or animal raw materials, antioxidants, biologically active and auxiliary components. The results of the study are presented in Tables 1, 2, 3 and 4.

Table 1

Research of model samples of KTIOL-BF (BF1-20)

KTIOL-BF	Microorganisms / growth retardation zone, mm			
	Gram-positive microorganisms		Gram-negative microorganisms	
	<i>S. aureus</i>	<i>S. saprophyticus</i>	<i>E. coli</i>	<i>P. aeruginosa</i>
BF1	12,25±1,07	16,81±1,08	12,40±1,50	12,63±1,71
BF2	12,41±1,50	20,25±1,16	12,71±1,34	13,45±1,57
BF3	11,78±1,83	16,57±1,80	11,49±1,67	11,86±1,92
BF4	12,65±1,54	12,24±1,64	15,73±1,58	14,58±1,34
BF5	10,54±1,56	14,12±1,73	10,08±1,73	13,44±1,39
BF6	14,07±1,08	18,46±1,24	14,54±1,60	14,46±1,68
BF7	13,60±1,81	16,58±1,75	10,41±1,47	12,18±1,81
BF8	14,69±1,06	16,47±1,24	13,80±1,08	14,72±1,08
BF10	11,58±1,72	11,51±1,45	13,35±1,53	12,54±1,37
BF11	14,03±1,59	13,72±1,87	13,43±1,51	12,67±1,65
BF12	16,27±1,62	20,49±1,39	22,13±1,73	20,43±1,60
BF13	12,29±1,58	13,36±1,56	12,04±1,94	11,86±1,53
BF14	11,90±1,90	13,80±1,09	12,06±1,87	11,74±1,76
BF15	12,72±1,65	11,71±1,63	10,08±1,54	13,40±1,35
BF16	16,47±1,43	15,76±1,69	12,82±1,08	14,87±1,25
BF17	14,20±1,82	20,47±1,23	16,32±1,55	12,48±1,70
BF18	12,09±1,08	15,41±1,83	12,49±1,39	12,28±1,64
BF19	16,53±1,87	17,56±1,62	16,34±1,65	18,36±1,52
BF20	16,98±1,04	15,71±1,09	14,49±1,82	12,46±1,09

Table 2

Research of model samples of KTIOL-BF (BF 23-39)

KTIOL-BF:	Microorganisms / growth retardation zone, mm			
	Gram-positive microorganisms		Gram-negative microorganisms	
	<i>S. aureus</i>	<i>S. epidermidis</i>	<i>E. coli</i>	<i>P. aeruginosa</i>
BF23	16,56±1,28	20,09±1,67	14,72±1,54	16,53±1,09
BF24	12,80± 1,52	13,93±1,82	14,56±1,20	12,80±1,41
BF25	18,27±1,71	14,08±1,30	16,49±1,85	0
BF26	14,53±0,57	15,42±1,43	14,60±1,63	0
BF27	16,39±1,71	16,47±1,84	13,82±1,67	0
BF28	17,57±1,64	18,09±1,41	16,87±1,72	0
BF29	18,45±1,60	24,53±1,39	14,81±1,40	16,70±1,84
BF30	15,71±1,79	20,47±1,68	12,49±1,71	14,39±1,60
BF31	14,70±1,36	18,60±1,72	11,62±1,83	13,81±1,72
BF32	18,37±1,59	27,49±1,74	16,83±1,80	18,71±1,41
BF33	14,40±1,73	18,71±1,52	17,29±1,73	12,84±1,60
BF34	0	0	0	30,40±1,29
BF35	19,61±1,80	20,58±1,40	18,59±1,42	18,61±1,67
BF36	15,72±1,71	14,55±1,60	15,81±1,56	12,73±1,34
BF37	16,76±1,43	20,70±1,32	13,67±1,75	12,55±1,39
BF38	12,59±1,27	16,72±1,38	10,20±1,09	0
BF39	14,82±1,67	17,86±1,81	12,57±	12,48±1,46
BF40	12,80±1,52	14,07±1,86	11,50±	0
PVI	11,86±1,39	11,57±1,81	0	0

Table 3

Degree of susceptibility of the *C. albicans* ATSC 885-653 to the tested KTIOI-BFs

N	KTIOI-BF:	Zone of growth inhibition, mm	Degree of susceptibility of <i>C. albicans</i> ATCC 885-653
1	BF1	12,12±1,09	low sensitivity
2	BF2	12,14±1,34	low sensitivity
3	BF3	14,07±1,53	low sensitivity
4	BF5	12,05±1,56	low sensitivity
5	BF6	13,45±1,72	low sensitivity
6	BF7	14,06±1,64	low sensitivity
7	BF8	16,05±1,52	sufficient sensitivity
8	BF10	10,06±1,46	no sensitivity
9	BF11	12,42±1,24	low sensitivity
10	BF12	17,38±1,92	sufficient sensitivity
11	BF13	10,08±1,48	no sensitivity
12	BF14	12,24±1,32	low sensitivity
13	BF15	9,84±1,89	no sensitivity
14	BF16	14,24±1,43	low sensitivity
15	BF17	13,83±1,08	low sensitivity
16	BF18	12,05±1,59	low sensitivity
17	BF19	15,82±1,44	sufficient sensitivity
18	BF20	16,04±1,81	sufficient sensitivity
19	BF23	12,65±0,98	low sensitivity
20	BF24	18,42±1,59	sufficient sensitivity
21	BF25	15,93±1,57	sufficient sensitivity
22	BF26	11,83±1,28	low sensitivity
23	BF27	16,07±1,52	sufficient sensitivity
24	BF28	15,75±1,46	low sensitivity
25	BF29	17,61±1,88	sufficient sensitivity
26	BF30	16,64±1,34	sufficient sensitivity
27	BF31	13,72±1,08	low sensitivity
28	BF32	18,04±1,43	sufficient sensitivity
29	BF33	20,76±1,65	sufficient sensitivity
30	BF34	0	no sensitivity
31	BF35	18,29±1,37	sufficient sensitivity
32	BF36	15,82±1,72	low sensitivity
33	BF37	22,62±1,44	sufficient sensitivity
34	BF38	17,31±1,90	sufficient sensitivity
35	BF39	17,55±1,31	sufficient sensitivity
36	BF40	17,09±1,69	sufficient sensitivity
37	PVI	14,02±1,87	low sensitivity

Table 4

Testing of KTIOL-BF specimens on clinical polyresistant strains

KTIOL-BFN	E. coli	P.aeruginosa	S. aureus 5	S. aureus 6	S. aureus 5	Citrobacter	In average
	Intestinal rod	Blue-purulent sticks	Golden Staphyloco ccus	Golden Staphyloco ccus	Golden Staphyloco ccus	Zitrobakter	
BF70	24	18	18	22	20	20	20,3
BF82	14	18	10	18	12	14	14,33
BF83	14	16	10	12	0	14	11
BF87	26	20	21	20	22	24	22,17
BF88	18	0	16	15	16	-	13
BF89	20	16	13	12	14	20	15,83
BF92	24	16	20	22	22	20	20,67
BF93	22	16	14	18	18	14	17
BF98	18	18	24	16	18	16	18,33
BF99	22	22	22	18	16	16	19,33
PVI	12	10	14	18	12	12	
	14	10	12	15	10	10	
	12	10	20	18	12	14	
In average: PVI	12,66	10	15,33	17	11,33	12	13,05

As shown in the results obtained (Table 1), the samples of the KTIOL-BF sample tested with the antimicrobial activity of different strength were relatively promising test microorganisms.

Samples of the KTIOL-BF (BF1-BF20) to which test-microorganisms were susceptible were detected. Samples of BF2, BF12, BF17 were found to be the most effective for the S. Saprophyticus test strain. The growth retardation zones of S. saprophyticus were respectively 20.25 ± 1.16 , 20.49 ± 1.39 and 20.47 ± 1.23 mm.

Based on the results of the analysis of Table 2 data, samples of KTIOL-BF (BF23-BF39) showed the antimicrobial activity of varying strength in relation to the proposed test microorganisms.

The test strain of S. epidermidis was insensitive to only 2 drugs: BF24, BF34. It was found that the S. epidermidis test-microorganism was the most effective for the sample of the preparation BF34 (growth retardation zone was 30.40 ± 1.29 mm). But to other test strains, this sample was inert.

Good antimicrobial activity among others was demonstrated by BF32 and BF35. The PVI control test was low-susceptible to gram-positive and non-susceptible to gram negative test microorganisms.

The KTIOL-BF (BF1-BF39 specimens) have also been shown to have antimicrobial activity in relation to the C. Albicans ATCC 885-653 microbial test strain (Table 3). The test strain was insensitive to only 4 KTIOL-BF specimens (BF10, BF13, BF15, BF34). The C.

albicans anti-yeast fungi were KTIOL-BF samples: BF8, BF12, BF17, BF19, BF24, BF28, BF29, BF30, BF32, BF35, BF37. The inhibition zones of fungal growth were $13,25 \pm 1,19$ mm on average. The highest antifungal activity was found in samples of KTIOL-BF: BF33, BF37. Mushroom growth zones were respectively $20,76 \pm 1,65$ and $22,62 \pm 1,44$ mm. Test strain *C. Albicans* ATCC 885-653 was sensitive to 5% of PVI (Povidone-iodine) in the low-grade - $12,09 \pm 1,92$ mm.

According to Table 4, according to the diameters of the inhibition zone of resistant strains of microorganisms, the following is observed.

Samples of KTIOL-BF: BF-82, BF-89, BF-93, BF-98, BF-99 were sufficiently susceptible to the diameter of the inhibition zone of growth of microorganisms. The high susceptibility of resistant strains to samples of KTIOL-BF: BF-70, BF-87, BF-92 was revealed. The best sample of KTIOL-BF87 (22.17 mm) was the best in the largest diameter of the inhibition zone of resistant strains of microorganisms from the three samples of KTIOL-BF (BF-70, BF-87, BF-92).

The average diameter of the zone of inhibition of growth of microorganisms in the control sample PVI was 13.05 mm, that is, the inhibition of growth of microorganisms was low in susceptibility.

time the possibility of high antimicrobial action of samples of the preparation of KTIOL-BF32 and38 on the *E. coli* strain (30 mm growth retardation diameter) was confirmed.

It was found that samples of the KTIOL-BF model preparations compared with the control agents (BETADINE /PVI, Chlorophyllipt) showed higher and good antimicrobial properties for *S. Aureus*, *S. Saprophyticus*, *E. coli*, *P. Aeruginosa*, and integral strains.

The obtained data confirmed the expediency of further in- depth studies of antimicrobial and antifungal activity of hydrophilic and/or lipophilic drugs of a number of KTIOL in the systemic concept of health, in particular in the treatment of ophthalmic and gerontological prophylaxis, treatment and rehabilitation.

Conclusions

On the basis of analytical and experimental research, new data on the antimicrobial properties of samples of model preparations of KTIOL-BF on the basis of two-phase extracts from animal and plant raw materials were obtained.

For the first time, the possibility of high antimicrobial action of samples of the preparation of KTIOL-BF32 and38 on the *E. coli* strain (30 mm growth retardation diameter) was confirmed.

It was found that samples of the KTIOL-BF model preparations compared with the control agents (BETADINE /PVI, Chlorophyllipt) showed higher and good antimicrobial properties for *S. Aureus*, *S. Saprophyticus*, *E. coli*, *P. Aeruginosa*, and integral strains.

The obtained data confirmed the expediency of further in- depth studies of antimicrobial and antifungal activity of hydrophilic and/or lipophilic drugs of a number of KTIOL in the systemic concept of health, in particular in the treatment of ophthalmic and gerontological prophylaxis, treatment and rehabilitation.

References

1. Oseyko M.I. (2008), Gerodiyetichni produkty, BAD i geroprotektory v sisteme KTIOL, *Molochnaya promyshlennost'*, 3, pp. 51–56.
2. Nikberg I.I. (2011), Functional foods in the structure of modern power, *International Journal of Endocrinology*, 6(38).
3. Oseiko N.I., Shevchyk V.I. (2015), Gerontological aspects of prevention of ophthalmic diseases in the system KTIOL II, *Pharmacology, Pharmaceutical Technology and Pharmacotherapy in Active Longevity: a book of abstracts of the II International Scientific Conference*, OIHN, Vilnius, 60, p. 46.
4. Mykola Oseyko, Vasyl Shevchyk, Tetiana Romanovska (2017), Functional products and preparations in the systemic concept of health, *Ukrainian Food Journal*, 6(4), p. 661–673.
5. Cowan M.M., (1999), Plant products as antimicrobial agents, *Clin. Microbiol. Rev.*, 12:564–582.
6. Willy Chin, Guansheng Zhong, Qinqin Pu (2018), A macromolecular approach to eradicating multidrug-resistant bacterial infections while mitigating drug resistance onset, *Nature Communications*, 9, Article number: 917.
7. WHO has named the main threats to the health of people affecting half the planet's population (2019), Available at <https://politeka.net/zdorovye/880575-voz-nazvala-glavnye-ugrozy-zdorovju-ljudej-v-opasnosti-3-milliarda/> 20.01.2019.
8. Oseyko M., Romanovska T., Shevchyk V. (2017), Funktsional'nyy produkt v kontseptsiiy endoekolohiyi zdorov'ya (Functional products in endoecology health concepts), *Scientific Works of NUFT*, 23(3), p. 192–203.
9. Oseyko N.I. (2006), *Tekhnolohiia roslynnykh olii*, Varta, Kyiv.
10. Romanovska T.I. (2006), *Fizyko-khimichni aspekty kharchovykh tekhnolohiy*, Naukova dumka, Kyiv.
11. Tutel'yan V.A., Vyalkov A.I., Razumov A.N., et ai. (2010), *Nauchnye osnovy zdorovogo pitaniya*, Panorama, Moscow.
12. Mykola Oseyko, Vasyl Shevchyk, Olena Pokryshko (2018), Antimicrobial properties of model drugs in the systemic concept of health, *Ukrainian Food Journal*, 7(3), p. 434–442.
13. *Magazynnyy drozhzhevoy khleb nanosit vred zdorov'yu* (2018), Sudebno-yuridicheskaya gazeta / Store yeast bread harms the health (2018), *Judicial and Legal Newspaper*, 12-14 (431-433) April 9, Available at <https://sud.ua/ru/news/obshchestvo/117277-chem-opasen-khleb-iz-magazynnaya-vrac-h-obyasnili>
14. The use of the standard methodology for determination of antifungal activity of natural products against medical yeasts candida sp and cryptococcus sp. (2007), Liliana Scorzoni, Tatiane Benaducci, et al., *Brazilian Journal of Microbiology* 38, pp. 391–397.
15. *Kogda khleb stanovitsya opasnym dlya zdorov'ya* / When bread becomes hazardous to health (2019), Available at: <https://ukrhealth.net/mediki-poyasnili-koli-xlib-staye-nebezpechnim-dlya-zdorovya45754/>
16. Syl'chuk T.A. Drobot V.I. Antonyuk M. (2005), Obrobka zhytn'o-pshenychnoho khliba, *Khlibopekars'ka i kondyters'ka promyslovist'*, 1, pp. 3–5.
17. Drobot V.I., Hryshchenko A.M., Syl'chuk T.A. (2016), Innovatsiyni tekhnolohiyi diyetychnykh ta ozdorovchykh khlibobulochnykh vyrobiv: monohrafiya, Kondor, Kyiv.
18. Sylchuk T., Bilyk O., Kovbasa V., Zuiko V. (2017), Investigation of the effect of multicomponent acidulants on the preservation of freshness and aroma of rye-wheat bread, *Eastern-european journal of enterprise technologies*, 5/11(89), pp. 4–9.
19. Anastasiya Chorna, Oksana Shulga, Larisa Arsenieva et al., (2016), Antibacterial biodegradable films for foods, *Ukrainian Food Journal*, 5(1), pp. 88–95.
20. Messens, W., De Vuyst, L. (2002), Inhibitory substances produced by Lactobacilli isolated from sourdoughs - a review, *Int. J. Food Microbiol.*, 72, pp. 31–43.
21. Chernaya A.I., Shul'ga O.S., Arsen'yeva L.Yu. (2017), Otsenka organolepticheskikh i mikrobiologicheskikh pokazateley kachestva pshenichnogo khleba so s'yedobnym pokrytyem, sodержashchim probioticheskiye mikroorganizmy (2017), *Voprosy pitaniya*, 86(3), pp. 101–107.

22. Borovskiy Ye.V., Mashkilleyson A.L. (2001), *Zabolevaniya slizistoy obolochki polosti rta i gub*, Medpress, Moscow.
23. Gracheva I.V., Yepisheva A.A. (1999), Mesto i rol' gribov roda *Candida* v klinike krasnogo ploskogo lishaya, Dostizheniya, nereshennyye problemy i perspektivy razvitiya stomatologii na Urale, *Materialy itogovoy nauchno-prakticheskoy konferentsii*, pp. 65–66.
24. Well diffusion for antifungal susceptibility testing (2004), Magaldi S, Mata-Essayag S, Hartung de Capriles C, et al., *Int J. Infect Dis.*, 8(1), pp. 39–45.
25. Protopopova T.A., Porseva J.D., Lunitsyna J.V., et al., (2013), The antimicrobial properties of the drug based on the extract Grapefruit seed (experimental study) *Dentistry problem*, 2, pp. 42–45.
26. Adam R. Burns, Elizabeth Miller, Meghna Agarwa (2017), Interhost dispersal alters microbiome assembly and can overwhelm host innate immunity in an experimental zebrafish model, *PNAS published ahead of print*, Available at <https://doi.org/10.1073/pnas.1702511114>
27. Maria Luisa Mangoni, Alison M. McDermott, Michael Zasloff (2016), Antimicrobial peptides and wound healing: biological, and therapeutic considerations, *Experimental Dermatology*, 25(3), Available at: <https://doi.org/10.1111/exd.12929>.
28. Rajbir Singh, Sandeep Chandrashekhara, Sobha R. Bodduluri (2019), Enhancement of the gut barrier integrity by a microbial metabolite through the Nrf2 pathway, *Nature Communications*, 10, Article number: 89.

Scientific explanation of the composition and technological modes of manufacture of dairy ice cream with vegetable puree

Viktoriia Sapiga, Galyna Polischuk, Tetiana Osmak,
Artur Mykhalevych, Maksym Maslikov

National University of Food Technologies, Kyiv, Ukraine

Abstract

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Corresponding author:

Tetiana Osmak
E-mail:
osmaktg@ukr.net

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Introduction. The modern assortment of ice cream on milk base with vegetable fillers has been analyzed. The choice of vegetable raw material as a promising functional and technological ingredient in composition of milk ice cream is substantiated.

Materials and methods. Object of research – ice cream technology. The subject of the study – vegetable puree from beet and broccoli fresh and heat-treated, ice cream and milk-vegetable blends. The cryoscopic temperature of the blends was determined with the aid of a measuring complex, dynamic viscosity by Geppler viscometer, resistance to melting – the melting time of hardened ice cream samples, the air bubbles size – the microscopy of soft ice cream samples in the chamber Goryaev, ice cream overrun – by the weight method.

Results and discussion. Scientifically confirmed the expediency of using in composition of the milk ice cream vegetable puree with a high content of soluble pectin due to thermoacid hydrolysis protopectin. The possibility of partial replacement of the stabilizer of the structure on pectin containing puree is established, which, in addition to the structural function, acts as a natural dye and a taste-aromatic ingredient, enriches the product with a complex of carbohydrates and minerals. By the magnitude of dynamic viscosity coefficient, rational regimes of maturing milk-vegetable blends with different ratios between the milk and vegetable component were substantiated. It has been established that functional and technological vegetable puree in the amount of 10–20% practically does not affect the cryoscopic temperature of ice cream blends, which makes it possible to apply commonly accepted freeze modes to obtain a product of guaranteed quality.

Conclusions. A new kind of dairy ice cream with concentrate vegetable puree of high nutritional value can be recommended for widespread introduction in accordance with the classical technological scheme of production with refinement of maturing regimes.

Introduction

At the present stage of development of the food industry, the production of food products enriched with biologically valuable components, with reduced fat content, is becoming increasingly relevant. Thanks to refreshing action, pleasant taste and high nutrition value, ice cream has become a daily product of mass consumption for children and adults. The assortment of frozen desserts on milk basis contains more than 1000 names, but in the domestic market practically there is no ice cream from vegetable raw materials. Vegetables give the product not only a pleasant original taste, but also have many beneficial properties.

It is known ice cream recipes on the basis of marinated ginger, with vegetable raw materials, in particular with mashed pumpkin, carrots, cucumbers, tomatoes. True exotic ice cream types for true gourmets are ice cream, made in France – with the taste of basil, onion, mustard, black pepper and cheese rockfor, as well as truffles and foie gras [1].

At the same time, table beet, which cultivated in Ukraine contains up to 6-12% sucrose, as well as a significant amount of fructose, glucose, polysaccharides (pectin substances and fiber), organic acids (oxalic, apple, lemon), and by content Iodine is one of the leaders among vegetables [2]. Nutritional value of 100 g of table beet: calorie content – 42 kcal, protein content – 1,5 g, fat – 0,1 g, carbohydrates – 8,8 g, food fibers (including pectin substances) – 2,5 g, organic acids – 0.1 g, water – 86 g, mono- and disaccharides – 8,7 g, starch – 0,1 g, ash – 1 g [3].

In cabbage, broccoli also contain a significant amount of biologically valuable compounds – protein, pectin, vitamin C, B vitamins, and micro and macro elements. Broccoli is a low-calorie product, so this cabbage can be included in the diet of people who follow a diet for medical reasons or to maintain a healthy lifestyle [4].

Vegetable raw materials in the composition ice cream due to the moisture binding ability can prevent the formation of a defect "coarse-crystalline structure", during hardening and storage, especially in case of violation of the temperature regimes in the freezer compartment. Vegetable raw materials contain color pigments (anthocyanins, beta-carotene, chlorophyll, etc.), are able to structure food systems [4], affect the technological processes of production, improve the organoleptic and physico-chemical characteristics of ice cream. The formation of foam structure of ice cream is a complex process, which is essentially related to the chemical composition of the product and its physical properties. Therefore, the study of the peculiarities of the formation and stabilization of the structure of ice cream with new types of plant material requires additional research [5].

In view of the above, the relevance of scientific work is to expand the range of ice cream with functional and technological and biologically complete vegetable raw materials.

The purpose of the research is to substantiate the composition and technological regimes of the production of milk-vegetable ice cream with vegetable puree on the basis of table beet and broccoli cabbage.

Main tasks of scientific work:

- Scientifically substantiate the recipe of a new type of milk ice cream with vegetable filler;
- To clarify technological regimes of production of ice cream milk-vegetable.

Materials and methods

The soft ice-cream was made with the help of a frizzer of periodic action of the brand FPM-3,5/380-50 "Elbrus-400" (manufacturer – JSC "ROSS", Ukraine). The volume of one-time pouring of the mixture into the screw chamber was 4,0 dm³. The frequency of the auger

stirrer during the cooling mode (mode number 1) was 270 min⁻¹, under the freezing mode (mode number 2) – 540 min⁻¹. Duration of modes №1 and №2 – 3 minutes.

The freezing and storage of ice cream were carried out in a freezer "Caravell" A/S (Denmark) at a temperature of minus (20±2) °C.

Sampling and preparation for analysis [6].

The cryoscopic temperature of ice cream blends was determined on a measuring complex [7]. The temperature was recorded on a personal computer using NDCONUTIL v.3xx.

Resistance to melting was determined by the time of the first drop appearance of the liquid phase and the flowing time of 10 cm³ of the liquid phase from the hardened ice cream sample at a temperature of 20±1 °C.

The size of the air bubbles was determined by microscopy of samples using a camera Goryaeva for an increase of x150.

The overrun of soft ice cream (B,%) was determined by the weight method and calculated by the formula:

$$B = \frac{M_1 - M_2}{M_2} \times 100 \quad (1)$$

where M₁ – the mass of the mixture filling the glass, g; M₂ – weight of ice cream filling a glass, g.

Dynamic viscosity of the mixtures (μ, mPa·c) was determined by Geppler viscometer. The calculation of the coefficient of dynamic viscosity of the mixture μ (mPa·s) was carried out according to the formula:

$$\mu = k \times (\rho_1 - \rho_2) \times t \quad (2)$$

where k is the ball constant, mPa·cm³/g; ρ₁ and ρ₂ are the density of materials of the ball and the mixture, g/cm³; t – the duration of passing the ball between the circular labels, s.

The content of pectin in fresh and concentrated vegetable purée vegetable was determined by the calcium-pectate method [8].

For the development of milk-vegetable ice cream recipes, it was necessary to be guided by regulatory requirements for its chemical composition. As a control, was produced milk ice cream with a mass fraction of fat was made at least 5%, sugar – not less than 14,5%, SZMZ – 12%, dry matter – not less than 30%. Normative indicators of milk-vegetable ice cream: fat – 5%, sugar – not more than 10%, SZMZ – 11%, dry matter – not less than 30%, dry matter of vegetable filler – not less than 4%.

For use puree of beet and broccoli in composition of ice cream, according to organoleptic ally established ratio of 1:1 between it was prepared in such a way to activate the functional and technological properties of the plant filler via by hydrothermal treatment to increase the content of the soluble pectin due to partial destruction of protopectin. For this purpose the vegetables were washed, the beets were cleaned from the peel by steam, cut and chopped, stirred the mixture, heated to a temperature of 70–90 °C, carry out hydrolyzation of protopectin plant tissue with citric acid at pH 2,8–3,2 for up to 90 minutes. Hydrolyzed and boiled up to 20% of dry matter vegetable mass was cleaned and cooled in accordance with the existing method for producing pectin-containing vegetable puree [9]. Received vegetable puree are highly viscous, with time does not stratify, it has a bright cherry color and a pleasant sweet flavor.

Experimental samples of ice cream were obtained according to the following scheme: preparation of milk mixture (40–45 °C); preparation of vegetable filler (cutting and blanching of vegetables, rubbing, heat treatment at 80–85 °C for 20 minutes), mixing of milk mix and vegetable filler (40–45 °C); filtering milk-vegetable mixture; pasteurization of the mixture (83–87 °C, 2–3 min); homogenization of the mixture (12–15 MPa, 80–85 °C); cooling and maturation of the mixture (0–6 °C); freeze of the mixture; dosing and forming portions of soft ice cream; hardening of ice cream (from -20 to -25 °C) [10].

Results and discussion

In the first stage, the distribution of pectin substances in vegetable puree was investigated before and after hydrothermal treatment under the above conditions.

The mass fraction of dry matter (DM), pectin substances (PS), soluble pectin (SP), protopectin (PP) of fresh and heat-treated puree from beet and broccoli for ratio 1:1, as well as the mass fraction of SB from the content of PP in percentages are shown in the table. 1

Table 1
Content and distribution of pectin substances in vegetable puree of different degree of processing ($P \geq 0,95$; $n=3$)

Kind of raw material	Mass fraction of DM, %	Mass fraction of PS, %/ 100 g puree	Mass fraction of SP, %	Mass fraction of PP, %	Contents of SP, %, from PS
Fresh puree	13,37±0,67	1,88±0,07	0,71±0,02	1,17±0,04	37,77±1,05
Activated puree	20,07±0,93	2,80±0,10	2,10±0,09	0,70±0,01	75,00±2,36

According to the results of the study, given in Table 1, the expediency of thermoacid processing of vegetable puree is understandable, due to which the increased content of SP will activate the technological properties of vegetable filler. Significant change in the ratio between the SP and the PP (from 1,65 to 0,33) in the direction of increasing the content of SP and the corresponding concentration of dry matter of vegetables to 20% makes it possible to replace part of the blend of ice cream with a mass fraction of dry matter about 30% without a significant change of balance for this indicator.

The thermoacid degradation of PP, which results in an elevated SP content, can provide vegetable filler with additional water-binding and structuring ability and shorten the maturing time of the blends. Therefore, at the next stage of the study, the rational regimes of maturation of fresh and activated vegetable puree were determined, compared to the control sample of a blend containing 0,5% of stabilizer (guar gum), with the most significant characteristic – the coefficient of dynamic viscosity.

The mass fraction of vegetable puree was given arbitrarily, at the level of 10%, according to typical recipes of ice cream with vegetable fillers (from 10 to 15%). To determine the possibility of a partial replacement of the stabilizer with the technologically activated vegetable filler, milk-vegetable samples of blends were prepared with a half the content of the stabilizer of the structure (Figure 1). Since the recommended values of the coefficient of dynamic viscosity of mixtures of milk ice cream are those that are not lower than 140 mPa·s [11], this is the minimum allowable value chosen as a criterion for the effectiveness of blends structuring.

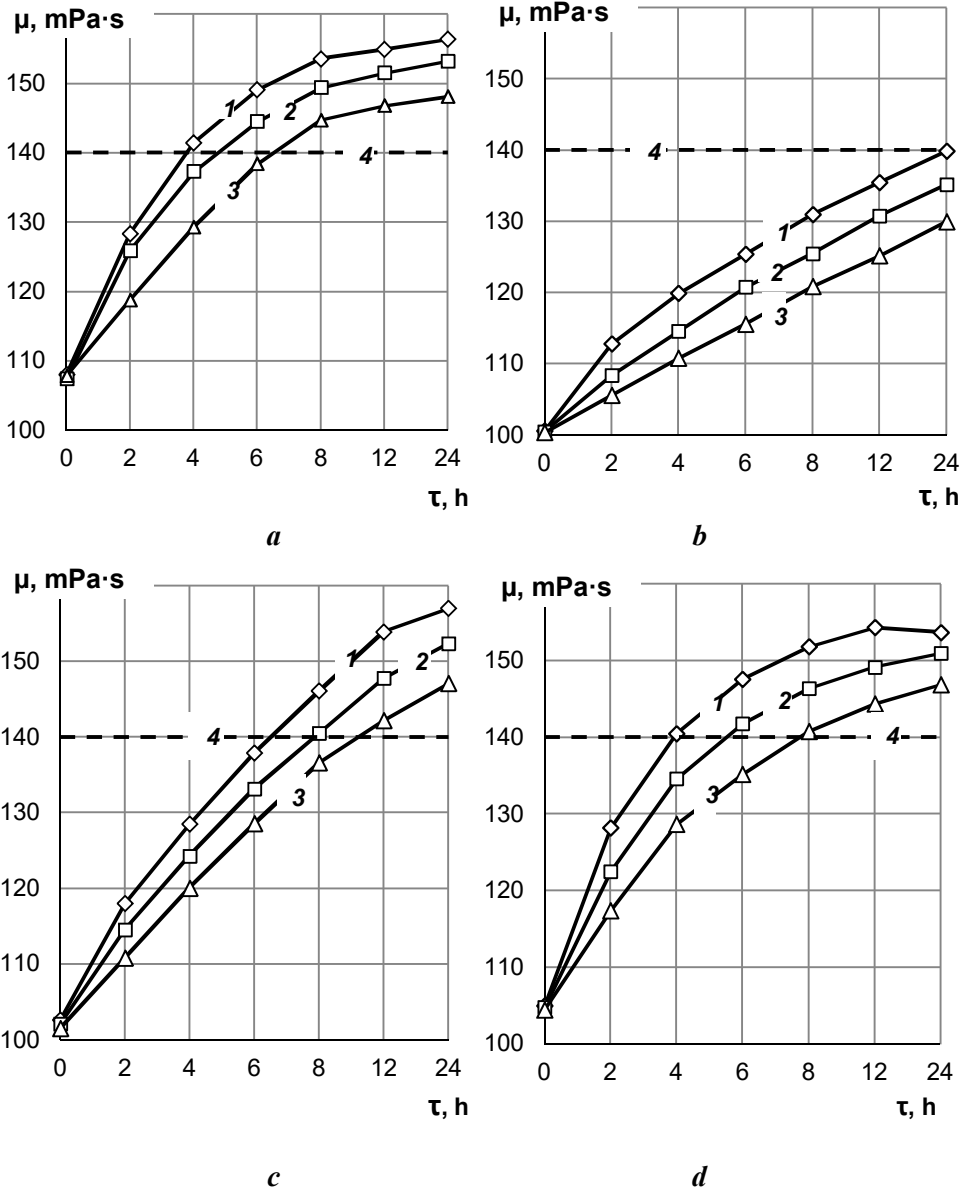


Figure 1. Effect of the maturing time (τ) on the coefficient of dynamic viscosity (μ) of ice cream blends:
a – milk with 0.5% stabilizer (control);
b – milk with 10% fresh puree without stabilizer;
c – milk with 10% fresh puree and 0,25% stabilizer;
d – milk with 10% activated puree and 0,25% stabilizer
 Temperature of blend, °C: 1 – 0; 2 – 4; 3 – 6.
 4 – the minimum value of dynamic viscosity

As can be seen from Figure 1, achieving lowest purposeful amount of dynamic viscosity coefficient at a temperature of 0°C to control observed through 4 hours, for milk with fresh vegetable puree and 0,25% stabilizer – in 8 hours, and for milk with vegetable concentrated puree and 0,25% stabilizer – after 6 hours. At the same time, a mixture of milk ice cream with fresh puree without stabilizer acquires the required viscosity at the lowest maturation temperature (0 °C) only after 24 hours [12]. This confirms the need to introduce into the composition of blend a stabilizer of structure or vegetable puree with high content of SP, or combining them. Thus, it is possible to use vegetable paste with a high content of SP at the simultaneous 50% replacing of structure stabilizer in blends at the expense of pectin stabilizing action in the composition of vegetables.

To justify rational content vegetable paste in milk ice cream at the next stage of the study determined cryoscopic temperature (t_{cr}) of milk-vegetables blends, which contain from 5 to 20% activated filler. This t_{cr} affects the proportion of bound water, what causing the formation of creamy consistency of the finished product after the hardening process and regimes of freezing in the technological cycle of production of ice cream.

Experimentally set values t_{cr-m} of ice cream blends of traditional composition and milk-vegetable were compared with the data obtained by calculating the depression of freezing temperature of the studied mixtures according to sucrose equivalent $t_{cr.c}$ [13, 14]. Chemical composition and t_{cr} of ice cream blends with a mass fraction of fat 5% and a mass fraction of sugar 15,5% for various ratios between milk and vegetable bases are shown in Table 2. Mass fraction of stabilizer were changed proportionally to activated puree and at achievements of mass fraction of soluble pectin 0,4% in the paste composition completely excluded the stabilizer from formulation.

Table 2
Chemical composition and cryoscopic temperature of ice cream blends with different contents of vegetable puree

Milk Ice Cream (mass fraction of fat 5%; mass fraction of sugar 15,5%)	Composition of the blend,%					$t_{cr.m}/t_{cr.c}/\Delta t, ^\circ C$
	DNDR	Stabilizer	Water	DM of vegetables	SP	
Control	10,0	0,50	69,0	-	-	-2,51/-2,18/0,33
5% puree	9,5	0,38	68,62	1,0	0,105	-2,56/-2,18/0,38
10% puree	9,0	0,25	68,25	2,0	0,210	-2,59/-2,18/0,41
15% puree	8,5	0,13	67,87	3,0	0,315	-2,62/-2,17/ 0,45
20% puree	8,0	0	67,50	4,0	0,420	-2,64/ -2,16/0,48

According to the analysis of the chemical composition of all samples, a slight change in the dry matter content in ice cream (from 69 to 67,5%) should be noted, even with a maximum 20% replacement of the milk blend in vegetable puree. That is, the balance of dry matter in the mixtures is practically preserved in the established range of changes in the content of vegetable paste.

Despite the slight increase in water content in ice cream during increasing the amount of vegetable puree, there is a slight decrease in the cryoscopic temperature from minus 2,51 to minus 2,64 °C. Moreover, the difference between measured and calculated values of this indicator increases. This effect can be explained, first of all, by the extremely high water-binding ability of the soluble pectin, which significantly reduces the free water content of the

blends, thereby increasing the concentration of solutions of single, double carbohydrates and salts in its residue. In vegetable raw materials also are contained about 5–6% monosaccharides and disaccharides, which partially replenish the lactose deficiency in reducing the content of milk components in milk-vegetable blends. Thus, partial replacement of the milk blend in vegetable puree in the studied range will not cause deterioration of the physical and chemical indicators of ice cream quality and will not significantly affect the technological parameters of its production. Taking into consideration the above, the introduction of a new type of ice cream with vegetable puree will not require the technical re-equipment of the existing production provided the vegetable component is delivered on request from the canning industry enterprises.

At the next stage, physicochemical indicators of milk ice cream with vegetable paste were studied (Table 3, Table 4).

Table 3
Physico-chemical parameters of milk ice cream with vegetable paste ($P \geq 0.95$; $n = 3$)

Indicator	Mass fraction of vegetable paste, %				
	0	5	10	15	20
Overrun, %	75,0±1,5	73,0±1,6	72,0±1,6	70,0±1,6	65,0±1,6
Resistance to melting, min	48,2±1,1	46,5±0,9	45,0±0,9	44,0±0,	43,0±0,9
Average diameter of air bubbles, mcm	47,6±0,4	46,0±0,4	45,5±0,4	43,7±0,4	40,2±0,4
The temperature of the soft ice-cream on the exit from the freezer, °C	-3,5±0,1	-3,5±0,1	-3,5±0,1	-3,4±0,1	-3,3±0,1

Table 4
Quality indicators of milk ice cream and milk-vegetable

Indicator	Mass fraction of vegetable paste, %				
	0	5	10	15	20
Appearance	Homogeneous mass with high ability to formation				
Structure and consistency	Homogeneous, slightly snowy consistency		Homogeneous, plastic, creamy		Homogeneous, too soft, creamy
Taste and smell	Pure, characteristic for milk ice cream, without foreign flavors and odors	Pure, characteristic for milk ice cream, with barely noticeable taste of vegetable filler	Pure, characteristic for milk ice cream, with a pleasant flavor of vegetable paste		Pure, with too much flavor of vegetables
Color	White, uniform in mass	Weak pronounced pink tint	Moderate pink, uniform in all masses		Dark pink, uniform in all masses

In the specified range of content, vegetable filler improves the ability to form ice cream, its consistency, resistance to melting, as well as the dispersion of the air phase. Ice cream with vegetable puree is pleasant pink color and plastic consistency. The overrun of ice cream with vegetable raw material practically does not differ from the control sample and corresponds to the recommended value (not less than 60%).

The prospect of further research is to study the influence of vegetable puree in the specified range of content on the quality of ice cream during storage.

Conclusions

1. New recipes of milk ice cream with vegetable puree from broccoli and table beet (for a ratio of 1: 1) in the amount of 10 to 15% were developed, which ensures high quality of the finished product.
2. According to the values of the cryoscopic temperature of ice cream blends with vegetable puree, the possibility of ice cream production under the generally accepted modes of processing was confirmed.
3. According to the values of the coefficient of dynamic viscosity rational regimes of maturation of milk-vegetable mixtures are substantiated: at a temperature of 0–4 °C – up to 6 hours; for 6 °C – up to 8 hours.
4. The implementation of a new type of ice cream with vegetable puree does not require the technical re-equipment of existing production and will contribute to the expansion of the range of domestic ice cream of high nutritional value.

References

1. Turchin I., Slivka NB, Melnyk O.R., Kopach V. (2013), Use of nonconventional components in ice cream technology, *Ecotrophology. Progress, problems, prospects of environmentally safe production. Materials IV International scientific-practical conference devoted to the 10th anniversary of the Department of Ecotrophology, BNAU*, pp. 92–93.
2. Shaiko T.V. (2015), Beet Pasta – A promising direction of extension of the range of food products, *Food resources. Series: Technical Sciences*, 4, pp. 7–10.
3. Brovenko T., (2016), Culinary use of table beets, *Food industry of agrarian and industrial complex*, 1–2, pp. 39–42.
4. Didi O., (2016), Yield and quality of broccoli cabbage hybrids in the Western Forest-steppe of Ukraine, *Visnyk of Lviv National Agrarian University. Series: Agronomy*, No. 20, pp. 98–102.
5. Martich V.V., Polischuk G.E., Serbova M.I., (2013), Research of Wheat Germ Foaming Capacity in Dairy Ice-Cream Composition, *Nauka ta Innovacii*, 9(5), pp. 10–16.
6. Marshall R. T., Goff H. D., Hartel R. W., (2013), Ice cream, Springer US, New York.
7. Potapov SG, Maslikov MM (2009), Laboratory Installation for Continuous Monitoring and Registration of Gas Environment Parameters, *NUHT Scientific Papers*, 29, pp. 78–80.
8. Zgursky A., Polischuk G., Krapivnytska I., (2011), Redistribution of pectin substances in vegetable raw materials in the production of ice cream, *Food industry*, №10, pp. 50–55.
9. Hartel R.W. (2010), Mechanisms of Ice Crystallization in Ice Cream Production, *Comprehensive reviews in food science and food safety*, 9(2), pp. 213–222

10. Kosoy V. L., Dunchenko NN, Egorov AV (2008), Engineering Rheology in Ice Cream Production, DeLi Prints, Moscow.
11. Christiaens S., Mbong V. B., Buggenhout S.V., David C. C., Hofkens J., Hendrickx M.E., (2012), Influence of processing on the pectin structure–function relationship in broccoli purée, *Innovative Food Science & Emerging Technologies*, №15, pp. 57–65.
12. Guldiken B., Gamze Toydemir G., Memis K. N., Okur S., Boyacioglu D., Capanoglu E., (2016), Home-Processed Red Beetroot (*Beta vulgaris* L.) Products: Changes in Antioxidant Properties and Bioaccessibility, *International journal of molecular sciences*, 17(6), pp. 858.
13. Bahramparvar V., Tehrani M. M., (2011), Application and Functions of Stabilizers in Ice Cream, *Food Reviews International*, 27(4), pp. 389–407.
14. Polischuk GE, Semko T.V., (2012), Investigation of the water phase of mixtures and ice cream with natural structuring components, *Collection of scientific works of Vinnytsia National Agrarian University*, 2(1), pp. 109–116.

Amino acid content in extruded feed mixtures

Tetiana Trakalo, Oleh Shapovalenko, Tetiana Yaniuk

National University of Food Technologies, Kyiv, Ukraine

Abstract

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Corresponding author:

Tetiana Trakalo
E-mail:
tanya.yao.ty@
gmail.com

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Introduction. To determine amino acid profile of extruded feed mixes containing flax feed extract based on water, amino acid profile amino acid profile and biological value of extruded feed mixes of different formulating composition has been studied.

Materials and methods. We investigated extruded feed mixes made of wheat, maize, wheat mill-run and flax feed extract based on water (FFEBW) having different percentage. Ratio (wheat:corn:FFEBW) for mixture 1 is 40:40:20, for mixture 2 is 45:45:10. Ratio (wheat mill-run:corn:FFEBW) for mixture 3 is 40:40:20. The mixture was mixed and extruded at 110–120 °C temperature, 2–4 MPa pressure decontaminating it. The concentration of free amino acids was determined by the method of ion-exchange chromatography.

Results and discussions. Undertaken researches of amino acid composition of the extruded feed mixtures allowed to identify and numerically define 9 essential amino acids (valine, leucine, isoleucine, lysin, methionine, phenylalanine, threonine, arginine, histidin) and 8 nonessential amino acids (aspartic, cysteine, serine, tyrosine, glutaminic acid, glycine, pyrrolidine carboxylic acid, and alanine), calculations of amino acids score of extruded feed mixtures are also described that allows to get data on every amino acid, to define the first limited amino acid, calculate the coefficient of divergence amino acid score (CDAAS) and index of protein biological value (BV) of the investigated standards of extrudate.

The most essential amino acids contains mixtures № 1 – 42,82% on 100 g of protein and № 2 – 41,27% on 100 g of protein.

Content of leucine, lysin and threonine in protein of mixtures presents 8,34–9,8% 100 g, 3,44–3,84% 100 g, and 2,67–3,75% 100 g, accordingly, that confirms high protein value of extruded feed mixtures.

With the help of calculations, it is determined that the greatest biological value has protein of mixture № 1 – 70,25%. This mixture appeared the most balanced among amino acid composition comparatively with other mixtures. The least index of biological value is set in mixture № 3 – 65,25%, that is explained by more considerable divergence amino acid score than other amino acids.

Conclusion. It is recommended to add flax feed extracts in the complement of grain mixtures as an effective method of biological value increase of extruded feed mixtures, as hit allows to increase the content of protein and amino acids.

Introduction

Feeding has dramatic impact on growth, development, health and productivity of agricultural animals and poultry. It is known, the food value of feed cannot be expressed by one index, it must be complex. In the system of complex estimation of food value of feed the special role belongs to protein. Providing of feed of animals' protein is one of major questions in organization of feeding [1].

Disintegration and synthesis of proteins pass constantly in the organism. In the digestive route proteins are disintegrated to the amino acids and soak through into blood. From amino acids cells synthesize own proteins. It is impossible to replace proteins by other nutritives, as their synthesis in the organism it is possible only from amino acids, but protein can be replaced by fats and carbohydrates, it is used for the synthesis of these species [2]. There are 20 amino acids in vegetable and animal feed. Not all amino acids that contain proteins are equivalent for the organism. Some amino acids cannot be synthesized in the organism and must be involved in feed. These amino acids are named vitally necessary or essential [7].

Essential and nonessential amino acids participate in the processes of metabolism, construction of organism's tissues, adjusting of antibodies' synthesis and others like that. The exchange of vitamins and mineral substances is closely connected with amino acids. Some amino acids directly provide energy muscular tissue, serve as neurotransmitters or their predecessors [1, 2].

Large value has free proteogenic amino acids in feed, it is those, that are not in the complement of proteins, but are in the free state [4]. Free amino acids directly from feed are soaked through into blood and join in the processes of metabolism, passing the stage of hydrolysis in gastrointestinal tract, that is very important for young cattle that grow, or patients [3]. From 20 proteogenic amino acids, agricultural cattle are not able to synthesize 10, in particular arginine, histidine, lysine, methionine, phenylalanine, threonine, tryptophane, valine, isoleucine and leucine [7]. Thus, these 10 amino acids must be in feed for agricultural cattle and is essential. If growing stock will not get these essential amino acids with feed, then they stopped to grow [8].

Absence or lack of these amino acids in feed results to metabolic disturbance – negative nitrogen balance, grow stopping, regeneration of proteins, origin of pathological changes in the nervous system, visceral organs of excretion, composition of blood. The appropriate decline of the enzymic systems' activity comes, the functions of liver, kidneys are violated and others [6].

For example, at the lack of protein in the rations of pigs that are on fattening, they spend 10–12 feed per 1 kg of increase, and at balance ration is 4–4,5 feed.

Feed proteins, that contain all vital amino acids in the composition, are named valuable. Animal protein (milk, eggs, meat) belong to them [11]. Those protein, that does not have or contain insufficient amount of amino acids, necessary for synthesis proteins of animals' body, are named inferior (vegetable protein). For comparative description of a protein food value of different feed it is necessary to know their amino acid composition. The more essential and especially critical (lysine, methionine, tryptophane) amino acids will have feed, the more it will be valuable, comparatively with other feed, where will be less amount of these amino acids [13].

Materials and methods

Materials

Materials for researches were the standards of of extruded feed mixtures tests with addition of flax feed extract for agricultural animals. The samples of feed were grated in advance in porcelain mortars to the powdery state.

Methods of determination of amino acids in feed mixtures of fodder mixtures

Extraction of amino acids was conducted in mixture by chloroform-water in correlation 1:1, at the permanent shaking off during 3 hours. Then centrifuging during 15 minutes at 8000 revolution per minute. Water phase was selected and made subsidence of proteins by sulfosalicylic acid during 30 minutes at 4 °C, with further centrifuging (15 minutes at 800 revolution per minute). The got supernatants were conducted of 0,6 M lithium-citrate buffer solution (pH 2,1).

The concentration of free amino acids was determined by the method of ion-exchange chromatography on the amino acid analyzer of «BIOTRONIK LC 6001» (Germany). The essence of the method is based on photometric determination (570 nm) of the painted complex of ninhydrin with amino acids and further transformation of coefficient of transmissivity into the coefficient of asorptance, proportional concentration of permeate by means of logarithmic strengthener, that allows to carry out this transformation, facilitating further calculations [4]. As the standard of amino acids was used «Amino Acid Calibration Standard» (Benson Company, USA). This method is one of the best highly sensitive quantitative methods in protein chemistry. It gives absolute and exact (to 10 nmol) values to content of amino acids in any physiology liquids, extracts of tissues, food mixtures and others.

It is istinguished biologically valuable and less valuable (inferior protein). The first ones contain all essential amino acids. The composition of less valuable proteins is scarce for one or a few essential to amino acids. An important value had both essential and nonessential amino acids, also it is important to have balance of essential amino acids in the product. For determination of biological value of proteins different methods (chemical, biological, calculated) are used.

Methods of determining the biological value of feed mixtures

The biological value of feed mixtures is stipulated by composition and content of essential amino acids, that is determined by comparison of amino acid composition of investigated protein on the certificate scale of amino acids of hypothetical «ideal» protein. This methodical approach got the name of amino acid score. Amino acid score is the index of biological value protein that presents by part percentage ratio of the certain essential amino acid of general content of amino acids in the investigated protein to the standard (recommended) value [5, 6].

There are some methods of amino acid score calculation, and the simplest is the relation of every essential amino acid in the tested protein to the amount of the same amino acid in hypothetical «ideal» protein, fully balanced after amino acid content. FAO/WHO offered the standard amino acid scale that compare composition of investigated protein. Calculation of amino acid score of every essential amino acid it was expected

$$C_j = \frac{AK_i}{AK_{rs}} \times 100, \quad (1)$$

where C_j is amino acid score i - of essential amino acid of protein,%; AK_i is content of essential amino acid of protein of extruded feed mixture, g/100 g protein; AK_{rs} is the contents of essential amino acid in the standard protein, g/100 g of standard protein. It is considered that the limited biological value of amino acid is score that has the least value [9].

The coefficient of divergence of amino acid score (CDAAS) shows the average surplus of amino acid score of essential amino acids in comparison with the least score level of any essential amino acid (surplus amount of essential amino acids that is not used on plastic necessities). CDAAS is calculated by the formula (2):

$$CDAAS = \frac{\sum_{j=1}^n \Delta RAC}{n}, \quad (2)$$

where ΔRAC is divergence amino acid score of amino acid that is calculated by the formula (3):

$$\Delta RAC = C_i - C_{min}, \quad (3)$$

where C_i is score surplus of i - essential amino acid%; C_{min} is the minimum of scores of essential amino acid of investigated protein in relation to the standard%; n is the amount of essential amino acids.

The size of biological value is determined by the formula (4):

$$BV = 100 - CDAAS, \quad (4)$$

If the size of CDAAS less, the highest quality of protein is [8, 10].

Results and discussions

Undertaken researches of amino acid composition of the extruded feed mixtures allowed to identify and numerically define 9 essential amino acids (valine, leucine, isoleucine, lysin, methionine, phenylalanine, threonine, arginine, histidin) and 8 nonessential amino acids (aspartic, cystein, serine, tyrosine, glutaminic acid, glycine, pyrrolidine carboxylic acid, and alanine), calculations of amino acids score of extruded feed mixtures are also described that allows to get data on every amino acid, to define the first limited amino acid, calculate the coefficient of divergence amino acid score (CDAAS) and index of protein biological value (BV) of the investigated standards of extrudate. The sum of sulfur-containing amino acids was also taken into account, such as methionine, that in the organism changes into cystein, the sum of aromatic amino acids, because phenylalanine transforms into tyrosine. The got results are given in the table.

Table 1

Amino acid composition of extruded grain mixtures in% to protein mass

Amino acid	Rank FAO/ WHO	Equivalence ratio (wheat:corn:FFEBW)				Equivalence ratio (wheat mill-run:corn: FFEBW)			
		mixture № 1 40:40:20		mixture № 2 45:45:10		mixture № 3 40:40:20		mixture №4 45:45:10	
		Contents	Score	Contents	Score	Contents	Score	Contents	Score
Valine	5,0	3,06	61	2,79	56	2,91	58	2,6	52
Lysin	5,5	3,84	70	3,65	66	3,5	64	3,44	63
Leucine	7,0	9,8	140	9,4	134	8,52	122	8,34	120
Isoleusine	4,0	2,38	60	2,44	61	1,57	40	1,54	40
Threonine	4,0	3,66	92	3,75	94	2,84	71	2,67	67
Methionin+ cysteine	3,5	3,31	95	3,25	93	3,19	91	3,07	88
Phenylalanine+ tyrosine	6,0	8,04	134	7,65	128	6,71	112	6,39	107
Histidin	-	2,61	-	2,31		2,14		2,01	
Arginine	-	6,42	-	6,03		6,07		5,94	
Sum of essential amino acid		42,82		41,27		37,45		36,0	
Σ ΔRAC			232		220		278		257
CDAAS			29,75		27,5		34,75		32,13
BV			70,25		72,5		65,25		67,87

The value of the content of nonessential amino acids of extruded feed mixtures is given in the table.

It is known [10,12], that the full value of proteins is determined not only by quantitative content of amino acids but also by certain their correlation, balanced, easy changing and by good comprehensibility.

At determination of amino acid composition of protein of extruded grain mixtures (table 1) it is set that the great number of essential amino acids is contained in mixtures № 1 – 42,82% on 100 g of protein and № 2 – 41,27% on 100 g of protein. The least content of essential amino acids mixture is differ in №4 – 36% on 100 g of protein, however, looking at the table, this mixture leads on the contest of nonessential amino acids 64% on 100 g of protein.

Analysing amino acid composition of protein of extruded feed mixtures, it follows to mark, that among essential amino acids with high content is distinguished leucine, lysin and threonine. Their content in protein of mixtures presents 8,34.9,8% 100 g, 3,44.3,84% 100 g, and 2,67.3,75% 100 g, accordingly, that confirms high protein value of extruded forage mixtures.

It is known [11, 13, 15], that leucine is needed for construction and development of muscular tissue. This amino acid assists synthesis of protein in muscles and liver, restoration

processes in tissues and prevents destruction of muscles' protein. Considerable content of leucine from 9,8 g/100 g in mixture №1 a to 8,34 g/100 g in mixture № 4 talks that extruded feed mixtures can be attributed to the rich natural sources of this amino acid next to the eggwhite, casein, by protein of hazel-nut and others.

Lysin is acyclic amino acid and belongs to the group of diamino-carohylic acids. In nature it meets only in L- form. In the process of metabolism during amino acid exchange lysin occupies the special place as it participates in the reactions of transamination. After removal of missile group of proceeding of lysin iterating from other sources of nitrogen it does not take place.

It is determined [14,16-21], that lysin influences on mineral exchange (assists consumption of calcium and phosphorus and iron inhausting; in bowels it is able to execute the functions of cations of potassium at the deficit in the ration of this element), influences on hematopoietic function of marrow, transformation of carotin in vitamin A, the state of the nervous system, activity of enzymes.

In most cases lysin is the first most scarce amino acid in the rations of pigs, bird and even ruminant animals. It is needed for continuation of height, dairy productivity and forming of the skeleton. At its defect they are marked muscular degeneration, height oppression, decline of dairy productivity [17].

All investigated standards of extruded feed mixtures had approximately identical amount of lysin – from 3,44% 100 g of protein mixture № 4 to 3,84% 100 g of protein mixture № 1, that fully provide day's requirement of animals in lysin, that presents 1,5 – 4 g [16].

Threonine has two asymmetric atoms of carbon in α - and β -positions. For the actions of aldolase, threonine fissions on athanal and glycine that also is important amino acid for growing stock of cattle. Threonine is included in hypoplastic amino acids, acetylformic acid is appeared that is an initial substance for biosynthesis of glucose and heptatin. It stimulates immunity, assisting making of antibodies, together with methionine participates in the exchange of fats and positively influences on liver work. Necessary threonine and for proteins synthesis of skeletal muscles, collogen and elastin, glycerin, digestive enzymes, supporting activity of gastrointestinal tract, it is important for normal development of cattel organism [19, 20, 22].

It is set that extruded feed mixtures have also enhanceable contents of threonine, that assists supporting of normal protein balance in the animals' organism. The great amount of its quality was educed in mixture № 1 – 3,75 g/100 g protein.

Sulfur-containing amino acids serve as the source of sulphur in the organism of animals, that participates in providing of many biochemical processes. The major functions of these amino acids are structural and catalytic contents of redox and transport of electrons. The lack of cystein in the ration, methionine becomes the basic donor of sulphur. At these terms cystein appears from methionine, as the result of the requirement of animals' organism which is provided in this amino acid. However, this process is undesirable, because methionine is the most essential amino acid and the its lack is resulted to brake of proteins synthesis and reduction of productivity. At the same time methionine is the most toxic substance, that in surplus predetermines decomposition of cholesterol, and also liming of vessels and formation of malignant desease. Day's necessity of agricultural animals of all age-related groups presents 1,5 – 3 g [15].

Researches showed that extruded feed mixtures have the content of methionine and cystein that is presented 3,07.3,31 g/100 g of protein, that fully provide cattle's supply in food.

Calculated amino acid score is shown that protein of extruded feed mixtures is valuable source of phenylalanine and leucine. After these amino acids score is equal to «standard» protein.

On content of methionine and threonine of protein of extruded feed mixtures goes to «standard» – 3,5 and 4 g/100 g.

The least indexes of amino acid score were marked in the investigated mixtures of isoleucine and valine. It should be noted that score of these amino acids was in the limits of 40.61%.

Calculated amino acid score can not fully represent biological value of protein, because it does not take into account its balanced of all essential amino acids [22]. Thus, for determination of biological value of protein of extruded feed mixtures the coefficient of divergence of amino acid score of protein of investigated standards was calculated.

The given calculations testify, that the greatest biological value is owned by protein of mixture № 1 – 70,25%. This mixture is the most balanced after amino acid composition comparatively with other mixtures. The least index of biological value is set in mixture № 3 – 65,25%, that is explained by more considerable divergence of amino acid score of some amino acids.

Conclusions

1. Undertaken researches in relation to extruded feed mixtures with the use of flax extract on the basis of water were identified 9 essential and 8 nonessential amino acids. Among essential amino acids phenylalanine and leucine had enhanceable content, among nonessential is glutamic acid, glycine and aspartic acid. After amino acid composition of protein of extruded feed mixtures is valuable, as all essential amino acids including major of them are methionine and lysin are included in its composition.
2. Biological value of protein of extruded feed mixtures after amino acid score, that is in the limits of 65,25–70,25%. It is estimated that methionine and threonine of protein of extruded feed mixtures goes to «standard» – 3,5 and 4 g/100 g.

References

1. Zapadniuk V., Kuprash L., Zaika M., (1982), *Amino acids in medicine*, Health, Kyiv.
2. Richard J. R., Farrukh A. C., Andrew T. G., Robert H. E., (2000), Amino acid transport System A resembles System N in sequence but differs in mechanism, *PNAS*, 97, pp. 115–120.
3. Harper A. E., Benevenga N. J., Wohlhueter R. M., (2007), *Effects of Ingestion of Disproportionate Amounts of Amino Acids*, *Physiological Reviews*, 60(3), pp. 1123–1127.
4. James R., Benson Ph. D., (1976), Instruction manual single-column amino acid analysis, *Chemical Corporation*, California, USA.
5. Alvarez B., (2003), Peroxynitrite reactivity with amino acids and proteins, *Amino Acids*, 25(3-4), pp. 295–311.
6. Madura J. D., Lombardini J. B., Briggs J. M., (2007), Physical and structural properties of taurine and taurine analogues, *Amino Acids*, 13(2), pp. 131–139.
7. Antinenko P., Masiuk D., Peretiak U., (2000), *The principles of adequate pig feeding*, Art-Press, Dnipro.

8. Dubinina A., Lehnert S., Khomenko O., (2014), Amino acid composition of protein and its biological value in seeds of peanut sorts widen in Ukrainian, *Journal of International Scientific Publications: Agriculture and Food*, 2, pp. 501–510.
9. Lipatov N., Lisitsin A., (1996), Sovershenstvovanie metodiki proektirovaniya biologicheskoy tsennosti pischevyih produktov, *Hranenie i pererabotka selhosyirya*, 2, pp. 24–35.
10. Rogov I., (2008), *Himiya pischi. Printsipy formirovaniya kachestva myasoproduktov*, Sanct-Peterburg.
11. Bakanov V., Menkyn V., (2009) *Kormlenie selskohozyaystvennyih zhyvotnyih*, Agroprompublishing, Moscow.
12. Bohdanov V., Melnychuk D., Bohdanov G., (2006), *Hodivlia silskohospodarskykh tvaryn*, Kyiv.
13. Boyarskyi L., (2001), Tekhnolohiia kormiv i povnotsinne hoduvannia silskohospodarskykh tvaryn, *Veterynariia ta tvarynnytstvo*, Phoenix, Rostov-na-Donu.
14. Hohrin S., (2004), *Hodivlia silskohospodarskykh tvaryn*, Kolos, Moscow.
15. Podobed L., (2010), *Proteinovoe i aminokislotoe pitanie selskohozyaystvennoy ptitsyi: struktura, istochniki, optimizatsiya*, ART-PRESS, Dnipro.
16. Rymbak M., Hummer Y., (2008), Usvoyaemye aminokisloty–stroitelnyy material dlya podderzhki i produktivnosti, *Uspeh v hlevu*, 1, pp. 16-28.
17. Svezhentsov A., Gorlach S., Martyniak S., (2008), *Kombikorma, premiksi, BVMD dlya zhyvotnyih i ptitsyi*, ART-PRESS, Dnipro.
18. Holden J. T., (2000), *Amino acid Hools*, Elsevier, Amsterdam.
19. Yegorov I., Selin N., (2006), Novi tendentsii v hodivli ptitsi eding, *Tvarynnytstvo Ukrainy*, 6, pp. 4–8.
20. Filippovych Y., (2000), *Osnovy biohimii*, Agar, Moscow.
21. Urdzyk R., (2007), Aminokislotoe pitanie kur-nesushek, *Efektivni kormy ta hodivlia*, 2, pp. 38–42.
22. Fisinin V., (2004) Biologicheskyy progress v pitanii ptitsyi i nekotorye prakticheskie aspekty, *Selkohozyaystvennaya Biologiya*, 2, pp. 112–121.

Main directions of application of active carbons in alcoholic beverage production

Tatiana Shendrik¹, Leonid Levandovskiy²,
Anatolii Kuts³, Vitalii Prybylskiy³, Olena Grabovska³

1 – L.M. Litvinenko Institute of Physical–Organic Chemistry and Coal Chemistry of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

2 – Kyiv National University of Trade and Economics, Kyiv, Ukraine

3 – National University of Food Technologies, Kyiv, Ukraine

Abstract

Keywords:

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Introduction. The purpose of the publication is to assess the quality and to usage of natural charcoal of activated charcoal by physical and chemical indicators for alcoholic beverage production – for the purification of water-alcohol mixtures from impurities in the technology of vodka.

Materials and methods. Activated charcoal – as a raw material for the purification of water-alcohol mixtures in the technology of vodkas. Methods of research: adsorption activity by iodine; adsorption activity by acetic acid; adsorption activity by methylene blue; total volume of pores in water; bulk density of activated carbon; fractional composition; mass of ash; bulk iron; bulk moisture content; abrasion strength.

Results and discussion. Activated charcoal of plant origin BAU-A, BAU-A-LVZ, BAU-A-Ag, MeKS, KAU-A, KDS-A according to the complex of indicators does not fully meet the high requirements of alcoholic beverage production. The active charcoal grades BAU-A have the standard values of indicators: adsorption activity by iodine – 62%; adsorption activity by acetic acid – 64 ml; adsorption activity by methylene blue – 129 mg/g; total pore volume by water – 1.72 cm³/g; bulk density – 215 g/dm³; mass fraction of the balance on a sieve with a linen: № 36 – 1.6%; № 10 – 98%; on the pallet – 0.4%; mass of ash – 4.7%; mass fraction of water soluble ash – 1.64%; mass fraction of iron – 0,12%; mass moisture content – 3.8%; abrasion resistance – 52.8%. To expand the range of values of indicators, it is necessary to create different combinations based on the BAU-A grades of coal or their modifications BAU-A-LVZ, BAU-A-Ag together with activated charcoal stone (MeKS), coconut (KAU-A) and anthracite (KDS-A). Activated charcoal of the mark MeKS in relation to BAU-A has higher values: adsorption activity by iodine by 32%; adsorption activity by acetic acid by 45.3%; adsorption activity by methylene blue at 52.7%; bulk density at 62.4%; tensile strength at 37.3%. In relation to BAU-A, activated charcoal MeKS has lower values: the total volume of pore water by -9.6%; mass of the remainder on a sieve with a linen: № 36 on -1.5%; № 10 at -7.6%; on a pallet of 9.1%; mass of ash at -1.1%; a mass of water-soluble ash -0.4%; bulk of iron by 0.1%; mass moisture content -0.6%. At the same time low indicators of one activated carbon can be offset by high indicators of other coal.

Conclusion. Creation of combined activated charcoal with optimized parameters (increased durability, high adsorption and catalytic properties, developed porous structure) will allow to meet the high requirements of alcoholic beverage production and to more actively absorb organic impurities, improving the organoleptic parameters of vodkas.

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Corresponding author:

Tatiana Shendrik
E-mail:
shendriktg@
gmail.com

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Introduction

The search for new active carbons used for alcoholic beverage production is associated with a number of difficulties. Until recently, this issue was resolved intuitively, based on the experience of manufacturers of active carbons, as well as distillers production technologists. This is due to the high complexity of the process of obtaining active carbons, as well as the subsequent process of cleaning the sorting with active carbon. These processes are characterized by an abundance and variety of various internal links between active carbon and the water-alcohol mixture.

Therefore, the *purpose* of the publication is to assess the quality and to usage of natural charcoal of activated charcoal by physical and chemical indicators for alcoholic beverage production – for the purification of water-alcohol mixtures from impurities in the technology of vodka.

Analysis of recent researchs and publications

In order to select the optimal technological process of sorting with active carbon, it is necessary to compare the various modes of the technological process. It is necessary to take into account and analyze the effect of a large number of factors on the parameters of the process. All this should be done in a limited time frame for developing the technological process. Therefore, it is have to choose the best options of the technological process, as well as the best conditions (modes) of its implementation.

Naturally, such a state of affairs cannot satisfy the rapidly growing and increasingly complex alcoholic beverage production. The emergence of new adsorbents (López-Garzón et al, 1999; Tzvetkov et al, 2016; Kwiatkowski et al, 2017; Marsh, Rodriguez-Reinoso, 2006; Acikyildiz et al, 2014; Rivera-Utrilla et al, 2011) [1-6] for the distillery production (Kuzmin et al, 2017; Kuzmin et al, 2015, 2017) [7-10] causes significant changes in the optimization of the technological process of sorting with active carbon (Muhin et al, 2003; Muhin et al, 2004) [11, 12].

At present, the main types of active carbons can be distinguished in the alcoholic beverage industry (Petrov et al, 2004; Mank, Melnik, 2007) [13, 14]. They are made from materials that contain complex organic compounds that can form a solid carbon residue under certain conditions. Classification of sorbents (activated carbons by nature of origin for alcoholic beverage production (Figure 1): *natural origin* (crushed active wood BAU-A; modified BAU-A activated carbons for alcoholic beverage production; modified activated carbons by metal ions; active carbons from fruit stones, nutshells; active carbons from various organic wastes, active carbons from fossil coals, natural minerals); and *synthetic origin* (silica gel).

Charcoal activated wood crushed BAU-A

The classical technology of using traditional active carbons of the BAU-A brand in alcoholic beverage production is typical for 80% of alcoholic beverage enterprises in Ukraine, which are used at the stage of processing water-alcohol mixtures with active carbon.

Charcoal activated wood crushed brand BAU-A refers to the active coal gas type, which is made from (birch wood) charcoal brand A, followed by treatment with water vapor at a temperature of 800-950°C, with preliminary or subsequent crushing (Petrov et al, 2004; Portnoj, 2004) [13, 15]. The quality of BAU-A coal depends on the quality of the initial wood or carbonizate, as well as the technological parameters in the process of wood carbonization and subsequent activation (Petrov et al, 2004) [13].

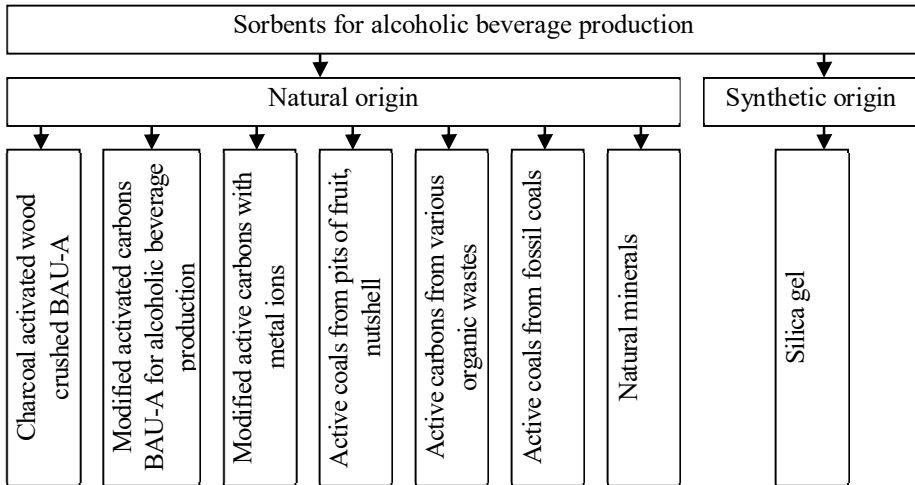


Figure 1. Classification of sorbents for alcoholic beverage production

Requirements of the normative documentation for activated carbon BAU-A: appearance – black grains without mechanical impurities; adsorption activity by iodine – at least 60%; total pore volume of water is at least 1.6 cm³/g; bulk density – not more than 240 g/dm³; fractional composition, mass fraction of the residue on the sieve with the web: № 36 – not more than 2.5%, № 10 – not less than 95.5%, on the pallet – not more than 2.0%; mass part of ash – no more than 6%; mass of moisture – no more than 10%; abrasion resistance (%) – not regulated.

The advantages of coal BAU-A:

- high specific surface area of the porous space (500-800 m²/g), due to which adsorption of organic impurities from the solution and catalytic processes of formation of new substances take place (Petrov et al, 2004) [13];
- treatment of aqueous-alcoholic solutions with active carbon is accompanied by a course of redox reactions and a multicomponent adsorption process of ethyl alcohol microimpurities (Portnoj, 2004) [15];
- high organoleptic characteristics of water-alcohol mixtures (vodka) after treatment with active carbon.

Disadvantages of BAU-A coal:

- high alkalinity of the surface of active carbon (pH of active carbons after vapor-gas activation – 9–11) (Petrov et al, 2004) [13];
- the presence of mineral impurities in the structure of active carbon (water soluble ash) – 0.5–0.7% by weight (Petrov et al, 2004) [13];
- low mechanical strength 37–42%, which leads to significant losses of coal in the process of working coal columns (Muhin et al, 2003; Muhin et al, 2004) [11, 12];
- the presence of powdered particles of activated carbon, which requires the installation of additional filtration systems after coal columns and increases the consumption rate of coal (Petrov et al, 2004) [13];
- low values of the bulk density of activated carbon up to 240 g/dm³ reduce its mechanical strength;
- large range of granulation of active carbon. With the dynamic method, it is self-sorted: large-sized coal grains are located in the middle of the coal column, smaller grains are thrown to the

periphery, as a result of which the water-alcohol mixture moves across the cross-section of the coal column differently;

- replacement of birch or beech raw coal with a mixture of soft wood, and therefore increases the consumption of active carbon for the treatment of water-alcohol mixtures;
- a small amount of micropore space, which characterizes the low absorption capacity in comparison with other coals of gas type.

The above indicators of active carbon BAU-A do not fully meet the requirements of alcoholic beverage production (Petrov et al, 2004) [13].

Therefore, we need an additional analysis of active carbon according to the following indicators:

- abrasion resistance up to a value of 70% (Petrov et al, 2004; Portnoj, 2004) [13, 15];
- adsorption activity according to the method of Schulman and Babkova (Petrov et al, 2004; Portnoj, 2004) [13, 15];
- adsorption activity by acetic acid (Oshmyan method) to a value of 70–110 cm³ (Petrov et al, 2004; Portnoj, 2004) [13, 15], which characterizes the catalytic properties of activated carbon (Petrov et al, 2004) [13].

Modified activated carbons BAU-A for alcoholic beverage production

Wood activated charcoal brand BAU-LV was developed specifically for alcoholic beverage production and is characterized by specific normalized indicators: abrasion resistance, adsorption activity by acetic acid (Petrov et al, 2004) [13].

Requirements of regulatory documentation for activated carbon brand BAU-LV: appearance – black grain without mechanical impurities; adsorption activity by iodine – at least 65%; total pore volume of water is at least 1.6 cm³/g; bulk density – not more than 240 g/dm³; fractional composition, mass fraction of the residue on the sieve with the web: № 36 – no more than 2.5%, № 10 – not less than 96.5%, on the pallet – not more than 1.0%; mass part of ash – no more than 6%; mass of moisture – no more than 10%; abrasion resistance – at least 45%; adsorption activity by acetic acid – not less than 70 ml.

Charcoal active wood shredded brand BAU-A-LVZ. Requirements of regulatory documentation for activated carbon BAU-A-LVZ: appearance – black grain without mechanical impurities; adsorption activity by iodine – not less than 65–70%; total pore volume of water is at least 1.6 cm³/g; bulk density – not more than 240 g/dm³; fractional composition, mass fraction of the residue on the sieve with the web: № 36 – not more than 2.5%, № 10 – not less than 95.5%, on the pallet – not more than 2.0%; mass of ash – no more than 3%; mass of moisture – no more than 10%; adsorption activity by acetic acid – not less than 70 ml; abrasion resistance – at least 60%.

Modified active carbons with metal ions

To enhance the catalytic component of the sorting treatment process, active carbons are applied with additives that accelerate the chemical reactions taking place and are catalysts for this process (Petrov et al, 2004) [13]. In addition to the acquisition of catalytic activity by such carbon materials, the possibility of a significant increase in the capacity and selectivity of carbon sorbents when modifying them with metal ions in sorption processes has been established (Zhabkina et al, 2005) [16]. The highest sorption for activated carbons is observed for silver ions (Petrov et al, 2004; Zhabkina et al, 2005) [13, 16], gold, metals of the platinum group, where direct interaction with the matrix of coal occurs, which leads to the formation of surface complexes or reduction (Zhabkina et al, 2005) [16]. This makes it possible to obtain drinks with qualitatively new or better organoleptic and physicochemical parameters (Zhabkina et al, 2005) [16].

Requirements of normative documents for active impregnated grade A coal: silver content –

0.08–0.11%; bulk density is fixed; fractional composition, mass fraction of the residue on the sieve with a hole diameter: 3.6 mm – not more than 2.5%, 1.0 mm – not standardized, 0.5 mm – not more than 3.0%; on the pallet – 2,0%; mass of water – no more than 15%.

Requirements of regulatory documents for impregnated active grade B grade coal: silver content – 0.06–0.08%; bulk density is fixed; fractional composition, mass fraction of the residue on the sieve with a hole diameter: 3.6 mm – not more than 2.5%, 1.0 mm – not standardized, 0.5 mm – not more than 3.0%; on the pallet – 2,0%; mass of water – no more than 10%.

Requirements of the normative documentation for active BAU-A-Ag silver impregnated coal: silver content – 0.08–0.11%; bulk density – not more than 240 g/dm³; grain size: >3.6 mm – not more than 2.5%, <3.6...1.0 mm – not standardized, <1.0 mm – not more than 2.0%; mass of moisture – no more than 10%.

Impregnation of activated carbons with metal ions has several disadvantages, the main of which is the gradual leaching of silver from the surface of the coal (Zhabkina et al, 2005) [16].

Active coals from pits of fruit, nutshells

The use of active carbons obtained from fruit pits, nutshell (cedar, walnut, coconut), leads to the optimal technological processing modes of sorting, which are significantly different from the modes of using traditional BAU-A (Petrov et al, 2004) [13].

Obtaining active carbon from the seeds of fruit of fruit trees (apricot, peach) of the MeKS brand is carried out by their carbonization (pyrolysis at 450–550 °C), crushing to the required particle size and subsequent activation (Muhin et al, 2003) [11].

The production of active carbon from coconut shell carbonisate is performed by the vapor-gas activation method at a temperature of 850–870 °C and a consumption of water vapor 5–10 kg per 1 kg of coal (Muhin et al, 2003) [11].

To clean the water-alcohol solutions in the distillery production, the active coal KAU-2 is used – the product of treatment of a coconut shell at high temperature. According to physico-chemical parameters of coal, activated KAU-2 should be without mechanical impurities and correspond to the following indicators: appearance – coarse-grained, black without mechanical impurities; adsorption activity by methylene blue – not less than 270 mg/g; mass fraction of water – no more than 10%; bulk density (g/dm³) – is not standardized; fractional composition: particles in the size from 3.6 to 5.0 mm – not more than 2.5%; particles in the size from 1.0 to 3.6 mm – not less than 96,5%; particle size less than 1.0 mm – not more than 1.0%; mass fraction of ash - not more than 10%; durability at abrasion – not less than 72%.

Active carbons from various organic wastes

Activated charcoal is obtained from materials that form a solid carbon residue. Among them stand out: wood – 36%, coal – 28%, brown coal – 14%, peat – 10%, shell coconut – 10%, organic materials and waste – 2% (Kuzmin et al, 2017) [7]. Only 2% of organic material and waste are used to produce activated carbon. Therefore, there are actual searches for alternative materials with the use of existing technologies in the food industry, the waste of which can be used for the production of adsorbents (Kuzmin et al, 2017) [7].

The proposed method of production of activated charcoal from pyrolyzed wood waste, which is formed after the smelting of food products, followed by carbonization of non-isothermal heating and activation at lower temperatures to 500–700 °C in the presence of H₃PO₄. This allows to obtain sorbents with a large yield factor of 80–90% and fractional composition of particles in the size of 1,0-3,6 mm (Kuzmin et al, 2017) [7]. Parameters of the porous structure of activated carbon from pyrolyzed wood waste (Kuzmin et al, 2017)

[7]: total pore volume $V_{\Sigma}=0.187 \text{ cm}^3/\text{g}$ (100%); Volume of macropores $V_{ma}=0.047 \text{ cm}^3/\text{g}$ (25%); volume of mesopores $V_{me}=0.049 \text{ cm}^3/\text{g}$ (26%); volume of micropores $V_{mi}=0.091 \text{ cm}^3/\text{g}$ (49%).

The method of production of activated carbon from wood carbonisation is proposed, which includes mixing of carbonaceous raw materials with potassium hydroxide KOH at an activation temperature of 600–800 °C, with a yield factor of 70–80% and a fractional composition of particles in the size of 1,0-3,6 mm. Parameters of the porous structure of activated carbon from pyrolyzed wood waste (Kuzmin et al, 2017) [9]: total pore volume $V_{\Sigma}=0.421 \text{ cm}^3/\text{g}$ (100%); volume of macropores $V_{ma}=0.034 \text{ cm}^3/\text{g}$ (8.08%); volume of mesopores $V_{me}=0.091 \text{ cm}^3/\text{g}$ (21.61%); volume of micropores $V_{mi}=0.296 \text{ cm}^3/\text{g}$ (70.31%).

Active coals from fossil coals

The production of activated carbons from anthracite brand KDS-A is carried out by the vapor-gas activation method at a temperature of 850–870 °C and a consumption of water vapor of 5...10 kg per 1 kg of coal (Muhin et al, 2003) [11].

It is promising to obtain activated charcoal from brown coal at an activation temperature of 600 °C; activating agent – KOH; exit rate 40.0%; total pore volume $V_{\Sigma}=0,500 \text{ cm}^3/\text{g}$ (100%); volume of macropores $V_{ma}=0,040 \text{ cm}^3/\text{g}$ (8%); volume of mesopores $V_{me}=0.220 \text{ cm}^3/\text{g}$ (44%); volume of micropores $V_{mi}=0.240 \text{ cm}^3/\text{g}$ (48%) (Tamarkina et al, 2011) [17].

Natural minerals

Clay minerals have a very high adsorption capacity, together with their high dispersion and extremely developed surface (Sokolov, 1996) [18]. Five main types of microstructures of clay rocks were identified – cellular, skeletal, matrix, turbulent and laminar, which affects their properties during use (Osipov et al, 1989; Grabovska-Ol'shevska et al, 1984) [19, 20].

For the selection of effective sorbents in the distillery production (Mank, Melnik, 2007) [14], natural dispersed minerals are considered: mordenite, clinoptilolite, Cherkassky montmorillonite, saponite, glauconite, hydromica, palygorskite. The presented minerals actively adsorb higher alcohols, reducing their initial content by 3–4 times (Mank, Melnik, 2007) [14].

Each adsorbent has its own advantages in improving the quality of sorting. Therefore, it is advisable to use the combined compositions of sorbents, consisting of a mixture of several natural minerals for the adsorption of impurities (Mank, Melnik, 2007; Melnik et al, 2014; Mank, Melnik, 2004) [14, 21, 22].

Advantages:

– by a number of attributes, zeolites belong to molecular sieves, natural sodalite from a wet mixture of gases adsorbs only water, and the same aluminosilicates, to a greater or lesser extent, absorb all components of complex mixtures (Kubasov, 1998) [23];

– zeolites containing a significant number of cations, are able to effectively and selectively extract various ions from solutions, to ensure their concentration. These qualities determine the widespread use of zeolites as ion exchangers (Kubasov, 1998) [23].

Disadvantages:

– low absorption capacity (adsorption volume) (Kubasov, 1998) [23];
– adsorption occurs mainly, only small molecules – water, oxygen (Kubasov, 1998) [23];
– zeolite, which consists of compounds of aluminum and lead, is dangerous to human health (Kurtov et al, 2003) [24].

Silica gel

When methanol is adsorbed on silica gel, the vapors of this alcohol are sorbed on the surface of the silica gel irreversibly – they cannot be pumped out even in vacuum. During adsorption, a chemical reaction occurs between the silanol groups of the surface and methanol (Braun et al, 1985) [25]. With prolonged contact with coal, the content of aldehydes increases in sorting, therefore, with a dynamic treatment method, it is recommended to lay a layer of silica gel in the columns, which is the best aldehyde adsorbent than active carbon.

Materials and methods

The object of the study was active carbons of various types: crushed activated wood charcoal BAU-A; charcoal activated wood crushed BAU-A-LVZ; BAU-A silver impregnated active carbon (BAU-A-Ag); active stone coal (MeKS); coconut activated carbon (KAU-2); anthracite active coal (KDS-A).

The research methods are based on the research methods of active carbons by physicochemical parameters: adsorption activity by iodine; adsorption activity by acetic acid; total pore volume by water; bulk density; fractional composition; mass of ash; bulk iron; mass of moisture; abrasion resistance.

The method for determining the mass fraction of moisture is based on the drying of a sample of coal in a drying cabinet to a constant mass at 105 °C, followed by weighing of the dried sample.

The method for determining the mass fraction of ash is based on determining the unburnt balance of coal after burning it in a muffle furnace at a temperature of 600-650 °C.

The method for determining the mass of 1 dm³ of activated carbon is based on the pre-drying of activated charcoal to a constant mass. The dried charcoal is placed in a pre-weighed cylinder with a capacity of 100 cm³ and weighed with an error of up to 0.01 g.

Method of determination of grains. Weighing 100 g of charcoal is sprayed on sieves with rounded eyes in diameter of 5.0; 3.6 and 1.0 mm. The residues are weighed on the fractions and determine the mass of each fraction as a percentage of the weight of dry coal.

Methods of determination of activity of activated carbon. The activity of coal used to clean water-alcohol mixtures is determined by several methods:

- Titerometric method, which is based on the determination of adsorption of acetic acid (according to Oshmyan): the amount of acetic acid adsorbed by coal is directly dependent on the activity of coal;
- Iodometric method, which is based on titerometric determination of the amount of iodine by the difference of the initial amount of iodine taken for analysis and which is not absorbed by coal.

Determination of the total pore volume by water. The method is based on the determination of the mass of water, which filled all pores when the boiling water was used in the water after the removal of excess water from the surface of the grains.

Results and discussions

As a result of experimental studies of active carbons for alcoholic beverage production, the following characteristics were obtained:

Active carbon of BAU-A: adsorption activity by iodine – 62%; adsorption activity by acetic acid – 64 ml; adsorption activity by methylene blue – 129 mg/g; total pore volume of water – 1.72

cm³/g; bulk density – 215 g/dm³; fractional composition, mass fraction of the residue on the sieve with canvas: № 36 – 1.6%; № 10 – 98.0%; on the pallet – 0.4%; mass of ash – 4.70%; mass fraction of water-soluble ash – 1.64%; mass fraction of iron – 0.12%; mass of moisture – 3.8%; abrasion resistance – 52.8%.

Active carbon of BAU-A-LVZ: adsorption activity by iodine – 69%; adsorption activity by acetic acid – 73 ml; adsorption activity by methylene blue – 141 mg/g; total pore volume of water – 1.91 cm³/g; bulk density – 221 g/dm³; fractional composition, mass fraction of the residue on the sieve with cloth: № 36 – 1.4%; № 10 – 97.6%; on the pallet – 1.0%; mass of ash – 4.95%; the mass part of water-soluble ash is 1.87%; mass fraction of iron – 0.13%; mass fraction of moisture – 4.1%; abrasion resistance – 59.6%.

Active carbon of BAU-A-Ag: adsorption activity by iodine – 73%; adsorption activity by acetic acid – 82 ml; adsorption activity by methylene blue – 169 mg/g; total pore volume of water – 2.0 cm³/g; bulk density – 228 g/dm³; fractional composition, mass fraction of the residue on the sieve with canvas: № 36 – 2.1%; № 10 – 96.6%; on the pallet – 1.3%; mass fraction of ash – 5.12%; mass fraction of water-soluble ash – 1.95%; mass fraction of iron – 0.15%; mass of moisture – 4.5%; abrasion resistance – 63.1%.

Active carbon of MeKS: adsorption activity by iodine – 94%; adsorption activity by acetic acid – 117 ml; adsorption activity by methylene blue – 273 mg/g; total pore volume of water – 1.57 cm³/g; bulk density – 572 g/dm³; fractional composition, the mass fraction of the residue on the sieve with canvas: № 36 – 0.1%; № 10 – 90.4%; on a pallet – 9.5%; mass fraction of ash – 3.61%; mass fraction of water soluble ash – 1.27%; mass fraction of iron – 0.19%; mass of moisture – 3.2%; abrasion resistance – 90.1%.

Active carbon of KAU-2: adsorption activity by iodine – 82%; adsorption activity by acetic acid – 67 ml; adsorption activity by methylene blue – 265 mg/g; total pore volume of water – 1.23 cm³/g; bulk density – 524 g/dm³; fractional composition, mass fraction of the residue on the sieve with cloth: № 36 – 0.2%; № 10 – 96.3%; on a pallet – 3.5%; mass of ash – 3.26%; mass fraction of water-soluble ash – 1.04%; mass fraction of iron – 0.13%; mass fraction of moisture – 2.1%; abrasion resistance – 86.7%.

Active carbon of KDS-A: adsorption activity by iodine – 51%; adsorption activity by acetic acid – 62 ml; adsorption activity by methylene blue – 117 mg/g; total pore volume of water – 1.43 cm³/g; bulk density – 691 g/dm³; fractional composition, the mass fraction of the residue on the sieve with canvas: № 36 – 0.1%; № 10 – 97.2%; on a pallet – 2.7%; mass of ash – 2.4%; mass fraction of water-soluble ash – 0.78%; mass fraction of iron – 0.10%; mass of moisture – 2.9%; abrasion resistance – 79.3%.

BAU-A coal is a standard activated carbon for alcoholic beverage production. The «dynamic method» of cleaning water-alcohol mixtures with activated carbon from impurities is the classic technology of vodka. In the further analysis, we will use the characteristics of the BAU-A active carbon as basic for further analysis and comparison with other active carbons.

BAU-A coal has an adsorption activity by iodine of 62% (Figure 2). The BAU-A active carbon group specially modified for alcoholic beverage production - BAU-A-LVZ and BAU-A-Ag has adsorption activity by iodine of 69% and 73%, respectively. These coal has an adsorption activity by iodine of 7% and 11% more than the base BAU-A. At the same time, the stone active carbon (MeKS) and coconut active carbon (KAU-2) have a high adsorption activity by iodine by 32% and 20%. The first conclusion can be made that stone coal (MeKS) has better sorption characteristics than other coals. Low adsorption activity by iodine showed active carbon from fossil coal grade KDS-A (-11%).

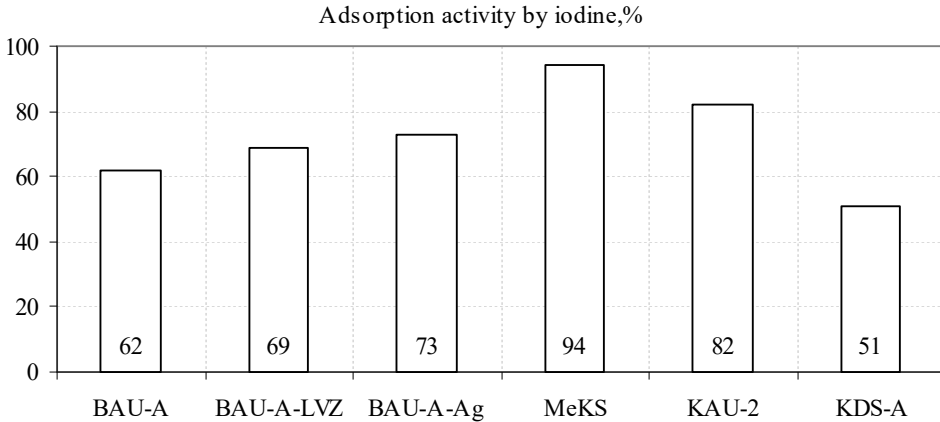


Figure 2. Dependence of adsorption activity by iodine on the type of active carbon

The volume of acetic acid adsorbed by coal is directly dependent on the adsorption activity of coal. BAU-A coal has 64 ml adsorption activity by acetic acid (Figure 3). Modified active carbons BAU-A-LVZ and BAU-A-Ag have 73 ml and 82 ml adsorption activity by acetic acid, which is 12.3% and 22.0% more than standard BAU-A active carbon. At the same time, the stone coal brand MeKS is 45.3% more adsorbing acetic acid and has a greater sorption activity for acetic acid among all active carbons (117 ml). Coconut active carbon brand KAU-2 has a standard adsorption activity by acetic acid – 67 ml. Active carbon from fossil coal has the lowest value of adsorption activity by acetic acid (62 ml).

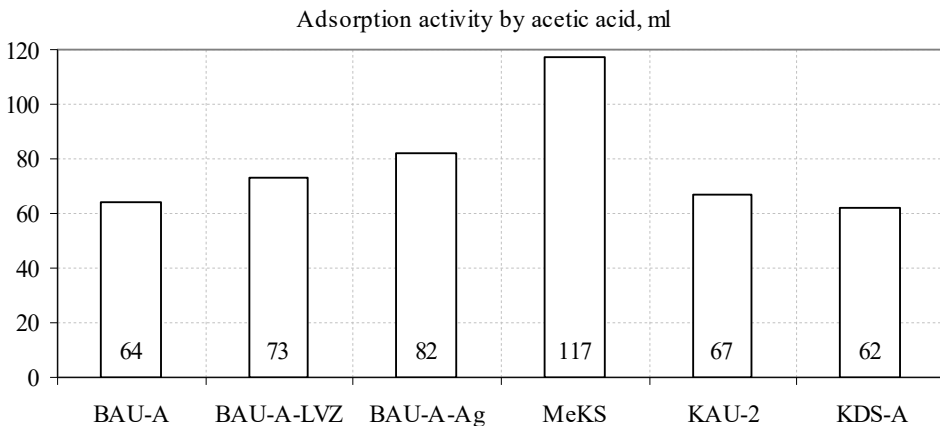


Figure 3. Dependence of adsorption activity by acetic acid on the type of active carbon

BAU-A coal has adsorption activity by methylene blue – 129 mg/g (Figure 4). Modified active carbons BAU-A-LVZ and BAU-A-Ag have 141 mg/g and 169 mg/g adsorption activity by methylene blue, which is 8.5% and 23.7% more than standard BAU-A active carbon. At the same time, MeKS stone coal, by 52.7%, adsorbs methylene blue more and has

a large sorption activity for methylene blue among all active carbons (273 mg/g). Coconut active carbon KAU-2 has sorption activity for methylene blue – 265 mg/g. Active carbon from fossil coal (KDS-A) has the lowest value of adsorption activity by acetic acid (117 mg/g).

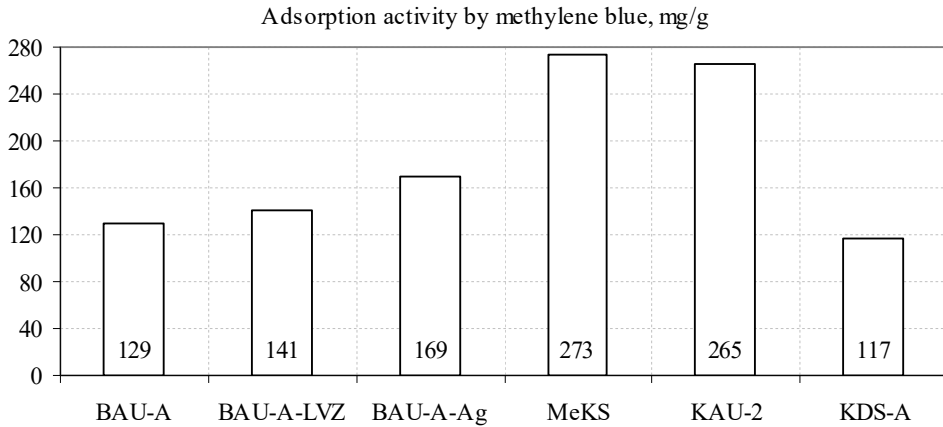


Figure 4. Dependence of adsorption activity by methylene blue on the type of active carbon

BAU-A, BAU-A-LVZ, BAU-A-Ag coals have a larger total pore volume of water of 1.72–2.00 cm³/g than stone fruit (1.57 cm³/g), coconut (1.23 cm³/g), active carbon from fossil coal (1.43 cm³/g) (Figure 5). This means that BAU-A, BAU-A-LVZ, BAU-A-Ag coals have a larger volume of sorbing pores and a greater absorption capacity for organic impurities.

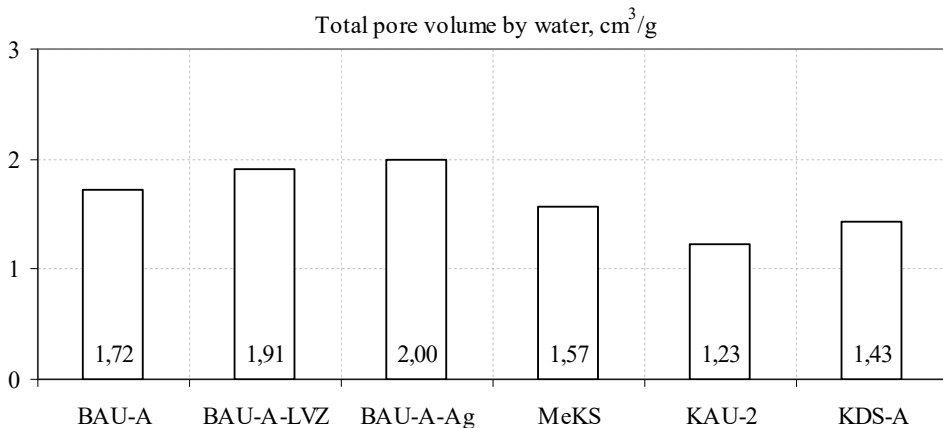


Figure 5. Dependence of the total pore volume of water on the type of active carbon

Bulk density of coals of stone MeKS (572 g/dm³), coconut KAU-2 (524 g/dm³), active carbon from fossil KDS-A coal (691 g/dm³) is more than 2 times higher than the bulk density of the group of BAU-A coal (215-228 g/dm³) (Figure 6). This will increase the speed of filtering sorts with the same cleaning efficiency.

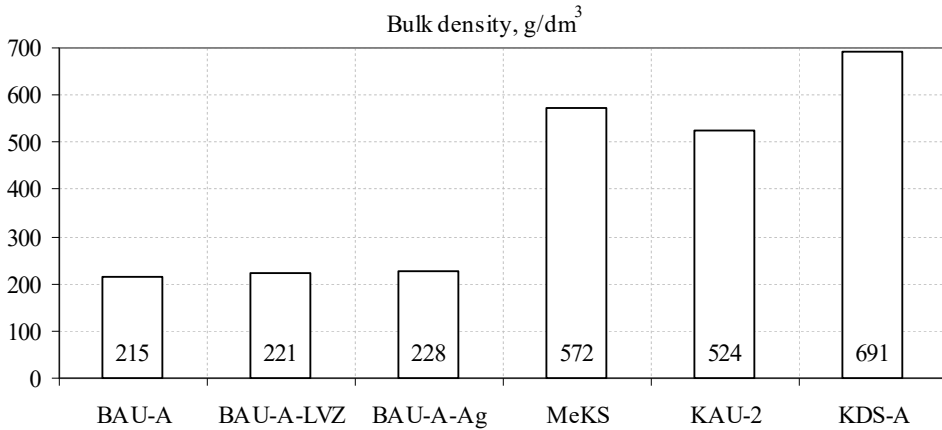


Figure 6. Dependence of bulk density on the type of active carbon

BAU-A, BAU-A-LVZ, BAU-A-Ag coals have a mass fraction of ash of 4.70–5.12%, which is more than that of stone fruit (3.61%), coconut (3.26%) and active coal from fossil coal (2.40%). It can be concluded that the BAU-A, BAU-A-LVZ, BAU-A-Ag coals are less pure adsorbents, since they contain a larger amount of ash, as well as a water-soluble part of the ash (Figure 7).

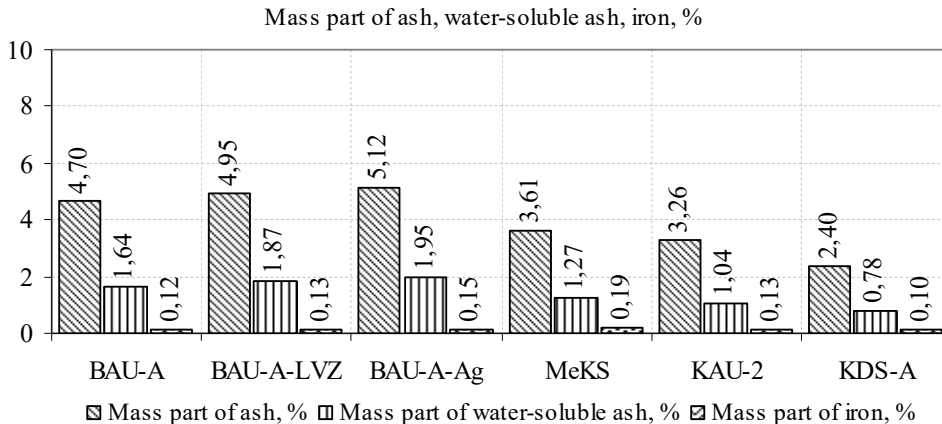


Figure 7. Dependence of the mass part of ash, water-soluble ash, the mass of iron on the type of active carbon

BAU-A, BAU-A-LVZ, BAU-A-Ag coals have a mass fraction of iron of 0.12–0.15%, which is less than stone fruit (0.19%). Coconut active coal (0.13%) and active coal from fossil coal (0.10%) have a mass fraction of iron comparable to BAU-A grade coal (Figure 7).

The abrasion resistance of the active carbons of the BAU-A group (52.8–63.1%) is lower than that of the stone stones (90.1%), coconut (86.7%) and active coal from fossil coal (79.3%), which allows reducing the consumption rate of active carbons (Figure 8).

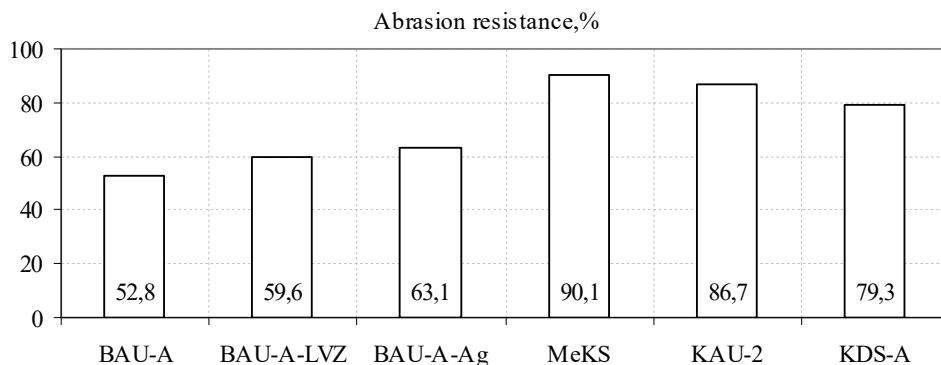


Figure 8. Dependence of abrasion resistance on the type of active carbon

The fractional composition of activated carbons of the BAU-A group more meets the requirements of the distillery production than that of stone stone (MeKS), coconut (KAU-A) and active coal from fossil coal (KDS-A), which allows reducing the consumption rate of active carbons (Figure 9-10).

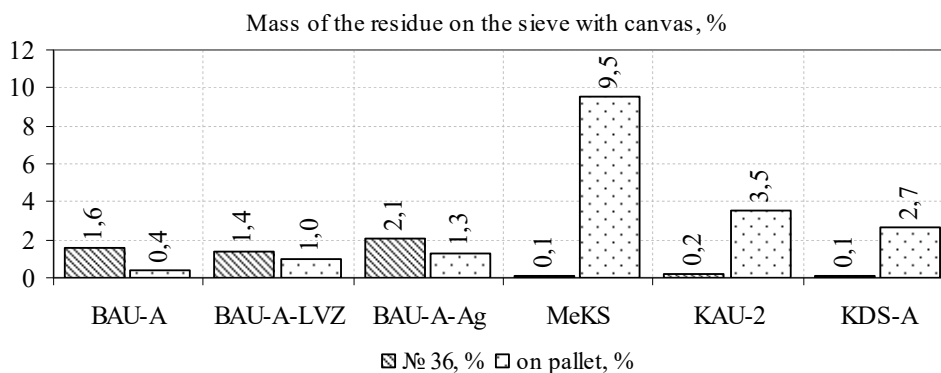


Figure 9. Dependence of fractional composition on the type of active carbon

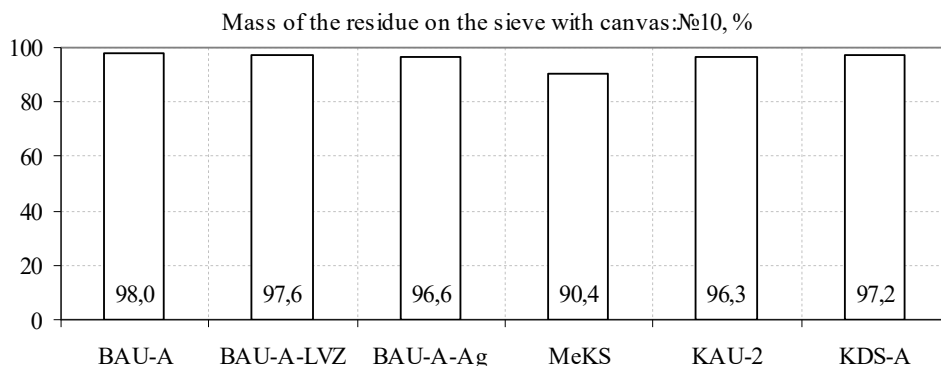


Figure 10. Dependence of fractional composition on the type of active carbon

Conclusions

As a result of the research, we can conclude that there is not a single one of the reviewed active carbons that would satisfy the increased requirements of alcoholic beverage production. To do this, it is necessary to create various combinations on the basis of BAU-A grade coal or its BAU-A-LVZ, BAU-A-Ag coal together with stone fruit (MeKS), coconut (KAU-A) and active carbon from fossil coal (KDS-A). The low performance of some active carbons will be compensated by the high performance of other carbons. Low values of abrasion resistance of active coals of the BAU-A group (52.8–63.1%) can be compensated for by the stone stones (90.1%), coconut (86.7%) or active coal from fossil coal (79.3%), which can be used in the frontal layer of coal columns. Combined coal will increase the strength to withstand the pressure of the liquid in the coal columns when the coal particles rub against each other. Combined active carbons will have adapted sorption and catalytic performance. The developed porous structure will make it possible to extract from the aqueous-alcoholic solutions and retain organic impurities in the volume of sorbent pores. This will improve the tasting properties of vodka.

References

1. López-Garzón F.J., Fernandez-Morales I., Moreno-Castilla C., Domingo-García M. (1999), Carbon materials as adsorbents for vapour pollutants, *Studies in Surface Science and Catalysis*, 120(B), pp. 397–433.
2. George Tzvetkov, Simona Mihaylova, Katerina Stoitchkova, Peter Tzvetkov, Tony Spassov (2016), Mechanochemical and chemical activation of lignocellulosic material to prepare powdered activated carbons for adsorption applications, *Powder Technology*, 299, pp. 41–50.
3. Mirosław Kwiatkowski, Vanessa Fierro, Alain Celzard (2017), Numerical studies of the effects of process conditions on the development of the porous structure of adsorbents prepared by chemical activation of lignin with alkali hydroxides, *Journal of Colloid and Interface Science*, 486, pp. 277–286.
4. Marsh H., Rodriguez-Reinoso F. (2006), *Activated carbon*, Amsterdam, Elsevier.
5. Acikyildiz M., Gurses A., Karaca S. (2014), Preparation and characterization of activated carbon from plant wastes with chemical activation, *Microporous and Mesoporous Materials*, 198, pp. 45–49.
6. Rivera-Utrilla J., Sánchez-Polo M., Gómez-Serrano V., Álvarez P.M., Alvim-Ferraz M.C.M., Dias J.M. (2011), Activated carbon modifications to enhance its water treatment applications. An overview, *J. Hazardous Materials*, 187(1–3), pp. 1–23.
7. Kuzmin O., Shendrik T., Zubkova V. (2017), Substantiation of the conditions of obtaining porous carbon materials from pyrolyzed wood wastes by chemical activation of H₃PO₄, *Ukrainian Food Journal*, 6(1), pp. 103–116.
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. ¹H NMR spectroscopy studies, *Ukrainian Food Journal*, 6 (2), pp. 239–257.
9. Kuzmin O., Tamarkina J., Shendrik T., Zubkova V., Koval O., Roman T. (2017), Production of active coal from pyrolyzed wood wastes by alkaline activation of KOH, *Ukrainian Food Journal*, 6(3), pp. 443–458.
10. Kuzmin O., Suikov S., Koretska I., Matiyashchuk O., Poliovyk V. (2017), Identification of equilibrium state of hydroxyl protons in vodkas by ¹H NMR spectroscopy, *Ukrainian*

- Food Journal*, 6 (2), pp. 314-336.
11. Muhin V.M., Poljakov V.A., Makeeva A.N., Shubina N.A. (2003), Novye aktivnye ugli dlja likjorovodochnogo proizvodstva, *Proizvodstvo spirta i likjorovodochnyh izdelij*, 3, pp. 36–37.
 12. Muhin V.M., Poljakov V.A., Burachevskij I.I., Shubina N.A., Makeeva A.N. (2004), Vysokoprochnye aktivnye ugli i blochnye fil'try na ih osnove, *Likerovodochnoe proizvodstvo i vinodelie*, 55, pp. 8–9.
 13. Petrov A.N., Oloncev V.F., Limonov N.V. (2004), Tendencii v ispol'zovanii aktivnyh uglej v likero-vodochnoj otrasli, *Likerovodochnoe proizvodstvo i vinodelie*, 57, pp. 5–7.
 14. Mank V., Melnik L. (2007), Adsorptive purification of food raw materials and semi-finished products with help of carbon and natural adsorbents, *Carbon for Energy Storage and Environment Protection: The 2nd International Conference CESEP, 2-6 September, Krakow*, 142.
 15. Portnoj S.V. (2004), Aktivnye ugli OAO «Sorbent» dlja likerovodochnoj promyshlennosti, *Likerovodochnoe proizvodstvo i vinodelie*, 53, pp. 5.
 16. Zhabkina T.N., Krechetnikova A.N., Revina A.A. (2005), Primenenie nanochastic serebra dlja modifitsirovaniya fil'trujushchih materialov, *Proizvodstvo spirta i likerovodochnyh izdelij*, 1, pp. 20–21.
 17. Tamarkina Ju.V. ta in. (2011), Pat. 61059 Ukrai'na, Sposib otrymannja poruvatogo vuglecevogogo materialu z burogo vugillja, Bjul. № 13.
 18. Sokolov V.N. (1996), Mikromir glinistyh porod, *Sorosovskij obrazovatel'nyj zhurnal*, 3, pp. 56–64.
 19. Osipov V.I., Sokolov V.N., Rumjanceva N.A. (1989), *Mikrostruktura glinistyh porod*, Nedra.
 20. Grabovska-Ol'shevska B., Osipov V.I., Sokolov V.N. (1984), *Atlas mikrostruktur glinistyh porod*, Varshava.
 21. Melnik L., Turchun O., Tkachuk N. (2014), Water-alcohol adsorbing cleaning out of higher alcohols by shungite, *Ukrainian Journal of Food Science*, 2 (2), pp. 312–317.
 22. Mank V., Melnik L. (2004), Using paligorskite for purifying the aqueous-alcoholic solutions, *XVII Conference on Clay Mineralogy and Petrology, 13-17.09.04, Prague*, 46.
 23. Kubasov A.A. (1998), Ceolity – kipjashhie kamni, *Sorosovskij obrazovatel'nyj zhurnal*, 7, pp. 70–76.
 24. Kurtov V.D., Furmanov Ju.A., Mahrovskaja N.K., Davidenko I.P. (2003), *Jelektroaktivirovannaja voda – istochnik zhizni i zdorov'ja*, NPF «JekoVod».
 25. Braun T., Navratil J.D., Farag A.B. (1985), *Polyuretane Foam Sorbent in Separation Science*, Boca Raton, CRC Press.

Integrated software and hardware system for power consumption and supply automated control in food industry enterprise

Serhii Baliuta, Liudmyla Kopylova, Iuliia Kuievda

National University of food Technologies, Kyiv, Ukraine

Abstract

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Corresponding author:

Iuliia Kuievda
E-mail:
julika@gmail.com

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Introduction. The research of power consumption and supply controlling process of the food industry enterprise (FIE) was conducted in order to increase the efficiency of transmission and use of electricity resources.

Materials and methods. The research is based on information systems design methods and modern technical equipment for automation of power system elements.

Results and discussion. To design the information structure of the control system an information data model is used, which is constructed according to the object-oriented principle.

The decomposition of the power supply and power management processes is performed then the control functions, the interaction between them and the users of the system are established.

The tasks of power consumption and supply control are realized with the help of the integrated software and hardware system (ISHS) of power consumption and supply automated control system in FIE (PCSACS FIE). The software part of the ISHS includes algorithms for solving the problems of operational control of power consumption and supply, the tools of system components interaction with the database and operating system (OS), as well as the graphical user interface of interaction of the information computation system with the power system dispatcher. Links between top-level PCSACS FIE devices are organized as Ethernet local area network using TCP/IP protocol with a transmission rate at least 10 Mbps. Communication channels between the upper PCSACS FIE level and the lower level controllers should be as a rule fiber-optic, providing absolute noise immunity. The design of the ISHS takes into account the conditions for the information security assurance.

Conclusions. The use of integrated software and hardware system created on the basis of information structure, developed in accordance with the UML methodology, ensures high efficiency of the power supply and consumption automated control system in the food industry enterprises.

Introduction

The problem of development of automated control systems, that are used to ensure the reliability of electric power (EP) supply and regulatory norms for the EP quality indices along with the reduction of EP consumption, is relevant for the food industry, since it allows to increase the efficiency of generating capacities utilization and to reduce the energy intensity of products produced by enterprises. Adoption and implementation of adequate and effective management decisions for controlling the power consumption and supply of food industry enterprise (FIE) are provided on the basis of improving the structure, models and methods of management, the use of modern information technology and human-machine procedures.

We will consider scientific works devoted to the problems of software and hardware used in designing of automated control systems for power consumption and supply of industrial enterprises. Article [1] presents the structure and technical means of the automated system for registration of EP consumption "E1 - Energouchet". The system has two levels. At the lower level electronic counters "Euro Alpha" and "Alfa Plus" with digital communication channels are installed, and on the top level - modern computers with dispatcher's automated workplaces. The system is based on the client-server architecture and allows you to support the work of any number of client computers with dispatcher's automated workplaces. However, this system solves only the problem of monitoring the EP consumption.

The article [2] presents the software and technical means of the EP fiscal metering system made by the company "Energomera". The software, in the form of a set of software modules, allows you to organize the EP commercial metering of the power consumption objects. The set of technical means provides automation of the dispatcher's workplace, reports generation for creation of various forms of documents; data collection and database managing; determining the parameters of the devices of the electricity consumption metering system.

As a result of the analysis of works [1,2] it was established that the software and technical means represented in these works solve only the problems of the EP metering and do not allow to deal with problems of electric power consumption and supply automated control for industrial objects.

Recently, modern industrial controllers and SCADA systems are widely used in the design of automated power management systems [4]. The use of the listed above technical means allows to solve in real-time the problems of commercial metering of EP consumption, technical metering and monitoring of electrical loads of industrial enterprises, interaction of the operator with the information system, which is the basis for solving the problems of controlling the power consumption and supply of FIE.

Analysis of works [4-6] showed that the represented software and technical means provide only functions to control the electric power and the EP consumption. However, these means do not allow implementing the functions of monitoring the state of the electricity supply system, as well as standardization, planning, predicting and optimal control of power consumption and supply of industrial enterprises, which allow obtaining the main economic effect.

Objectives of research: to develop the information structure, software and to choose technical means for designing of an automated control system for power consumption and supply in the food industry enterprise on the basis of data collection and computer systems.

Materials and methods

The process of managing power consumption and supply of FIE is studied, an information structure of the automated system, software algorithms are designed and the choice of technical means is carried out.

The research was conducted in the following order:

- a use case diagram has been constructed, in which the control system is represented by sets;
- the information structure of the automated control system of power consumption and supply of the FIE is developed;
- the software requirements are determined and the choice of technical means is made.

The UML methodology is used to build the information structure, which provides the development of representative models for the organization of interaction between the customer and the developer of information systems (IS) as well as different groups of IS developers, and also contains mechanisms for the expansion and specialization of basic concepts of language.

Results and discussion

Let us consider the features of power consumption and supply systems as control plants.

Power supply and consumption systems of FIE are the most complex and important objects in comparison with other control plants. Their main features are as follows:

- at every moment electricity generation strictly corresponds to its consumption (there is no “electricity warehouse”);
- in the case of failures, electrical transients are so fast that operational personnel can't prevent accidents propagation, without automatic control it is impossible to ensure reliable operating of the power supply system;
- failure of some element of the power consumption and supply system can lead to a complete disbalance of production, transmission, distribution and consumption of electricity and to the collapse of power system, as well as to the technological process violations, leading to enormous losses;
- returning to the normal operating mode can take a relatively long time; it is supposed that if within half an hour it wasn't possible to restore the normal mode, then the recovery period may be delayed for several days due to the batteries discharging and the loss of operational current when closing switches without the additional equipment is impossible.

Therefore, for power consumption and supply automated control system (PCSACS), it's significant to have high performance at the main levels of control, which is adequate to the speed of processes occurring in electric networks. At the PCSACS's lower level one uses specialized high-speed devices for powers system protection, oscillographic recording of fast transient failures and accidents propagations. At the upper level, one sets the minimum response time of the system and the fastest level of providing information. In order to find out the reason of failure, to analyze and compare the events and processes that occur in different parts of the power supply system, they need the same reference time. In addition, these processes must be time-bound with the events occurring in the power grid. Therefore, PCSACS provides the common timing system (CTS) for all controllers of the lower level, which are distributed over the enterprise's area. The accuracy of the binding of events to the CTS is determined by the high-speed processes taking place in the power consumption and

supply system of the food industrial enterprise (PCSSFIE). CTS usually provides a temporal binding of the primary information, coming from the object, to the state scale of a common time with an accuracy of not less than 5 - 20 ms. For PCSACS's equipment it's required high level of protection from electromagnetic interference (noise), since a significant part of the equipment is spatially located in zones which are prone to this effect. All devices and means of measurement must meet the special requirements for interference protection.

Taking into account the specifics of processes and different professional levels of the operational personnel of the dispatching control systems of mechanical and electrical processes, the complex objects require independent operator's workplaces. Territorially technical means of automated electrical and thermal-mechanical control systems are usually not combined. Digital power relay protection devices, reactive power compensation and power quality assurance devices, devices for communication with the object and sensors (current and voltage transformers, sensors of discrete signals, etc.). Electrical devices control systems are located in the substations of 0.4 kV and switchgears of 6 -220 kV accessed only by specially trained electrotechnical personnel, on the other hand residual-current devices of technological automated control systems and their sensors (temperature, pressure, losses, etc.) as well as individual consumers of electric energy are placed in the premises of technological equipment who's access do not require special electrotechnical training.

Features of PCSACS software structure

These features are: the availability of optimization tasks of PCSSFIE's operating modes, power system reconfigurations, improving the EP quality, emergency protection automatics, emergency automated control for providing static and dynamic stability, remote change of set points, registration and storage of transient and emergency information, processing oscillograms with the symmetric components detection and the construction of vector diagrams, switching consumers-regulators (CR) etc. For these purposes, in addition to high response rate, there is a need for large amounts of memory in control devices and the specialized centralized data store, on the basis of which these tasks could be solved. In PCSACS design one also takes into account the special aspects of maintenance of electrical devices and climatic conditions of PCSSFIE.

PCSACS combines the above-mentioned control systems of individual electrotechnical objects, automation, control and protection devices into a single information and control system, which enables operating personnel to control the operating modes of PCSSFIE and external power supply system. It should be taken into account that these devices and automatics solve the problems of local control of individual objects, relatively independent, geographically they can be in different parts of the PCSSFIE and provide the implementation of a single task ensuring the functioning of the PCSSFIE, coordinated with each other in accordance with the principles of operation, control algorithms and parameters triggering The autonomy of these devices is the main principle of the reliability of their operation in normal, emergency and post-failure modes.

Algorithms and methods of power consumption and supply control in FIE

To ensure the effective operation of PCSACS it is necessary to perform an analysis of PCSSFIE: the functions that ensure system's operating modes and the interaction between the automated control system (ACS) and the system's users. These functions are: gathering information and verifying it for reliability; monitoring of the technical state of the electric network; interactive interface of the power system dispatcher with the information and

computing system (ICS), which provides visualization of the issued recommendations and immediate reasonable decision-making process for power consumption and supply problems in real-time mode.

For the construction of ready-made solutions in PCSACS there is a subsystem of control procedure selecting, which is supposed to be a functional block. Solutions, formed by the automated subsystem of control procedure selecting, are complete, on their basis one can uniquely make corresponding management decisions. However, the final decision on choosing the control command, depending on the situation, can be made by the dispatcher. This is due to the fact that by no means always quantitative analysis of the situation provides the only correct solution.

It should also be noted that effective control of power consumption and supply in FIE implies the availability to the dispatcher of necessary information about the current and predicted state of the PCSSFIE. This requirement leads to the need to monitor the production cycle parameters. This does not mean the need to create an additional system of data collection, since in many cases, monitoring of technological processes already exists and it is only necessary to obtain the necessary data from the corresponding automated control system (ACS) service server of the technological process or from the enterprise's ACS server.

In the studied system the users are (Figure 1):

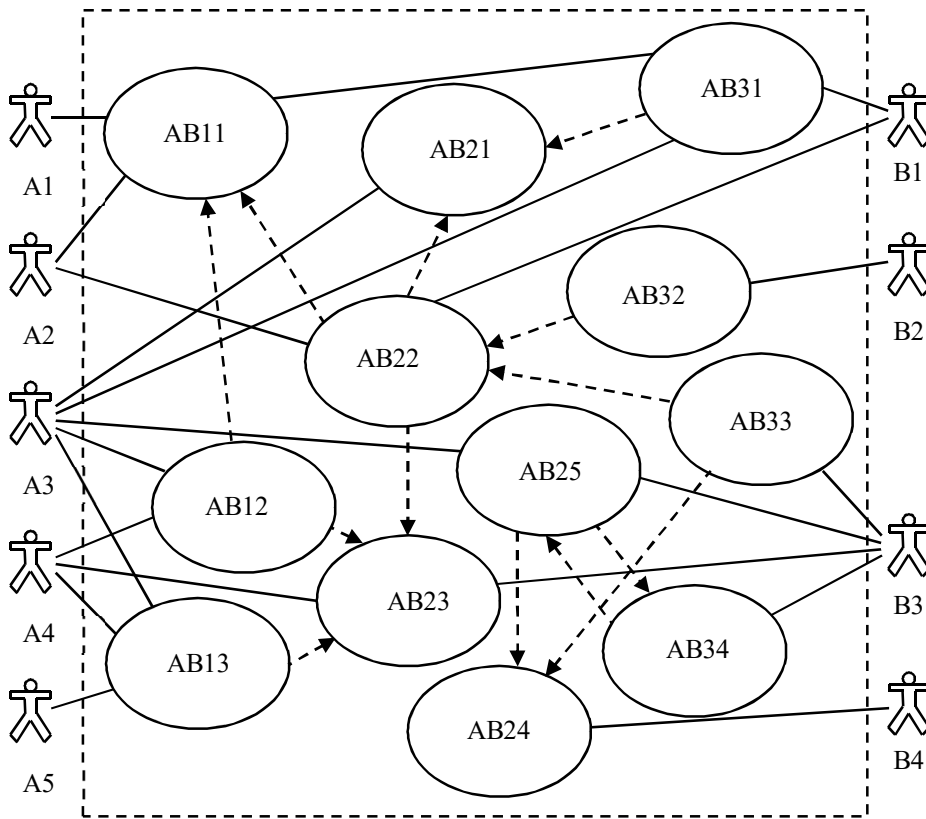


Figure 1. The Use Case Diagram of power consumption and supply control system

A1: Control Plant (CP). A control plant of power consumption and supply is the electric network of FIE and electrical devices.

A2: Receiving and transmitting devices (RTD). These are tools used for polling sensors and getting their data. Industrial controllers, digital relay protection and specialized hardware devices for data collecting and transmitting, all they serve as RTD.

A3: Information and Computing System (ICS). The system, which implements a set of mathematical methods and software tools for their implementation, aimed at solving the tasks of controlling the power consumption and supply of FIE.

A4: Power system dispatcher. He is a member of Chief Power Engineer's Department (CPED), who interactively manages the power consumption and supply of the FIE in the real-time mode interacting with ICS.

A5: Application specific workstations (ASW). These workstations are a set of hardware and software tools for the employee to fulfill their official duties.

B1: Power consumption and supply control database of FIE. The database is a source of data. It stores the data of meters and sensors, which is necessary for PCSACS tasks completing.

B2: Technological Department Dispatcher (TDD). The specialist who monitors the production process and performs in real-time mode control of repairing and restoration tasks on the enterprise's power system.

B3: Electrical engineer. He is a specialist of CPED, which controls the work of all users.

B4: Chief Power Engineer. Its function includes interaction with other structural subdivisions of the enterprise and external organizations.

Functions performed by PCSACS of FIE:

AB11: Registration of measured data. For the registration of telemetering data, polling of meters and sensors at predetermined time intervals and transmission of their reading to ICS are carried out.

AB12: Monitoring of technical condition. The main regulatory duty of the power system dispatcher is to control the operation of the FIE's power system and its consumers. Using the data stored in the database, as well as the recommendations of the ICS, CPED staff ASWs receive the relevant data on the status of controlled system elements. Based on it, a conclusion about the quality of the power system operation is made.

AB13: Displaying operational data about the status of PCSSFIE. With the help of the interface, the ICS translates data from the database to CPED staff ASWs.

AB21: Data verification. Efficiency of power consumption and supply control of FIE is largely determined by the reliability and quality of data coming from measuring devices. Therefore, a separate task is to ensure the reliability of the measurement data – the detection of error (abnormal) measurements of controlled quantities. This task is an integral part of any control system, since unresolved gross errors in measurements determine the reliability of the data used to make control decisions.

AB22: Searching for solutions for operational-dispatch control (ODK) tasks. The main ODK tasks are operative restoration of FIE's power supply and normal parameters of released electricity; creation of the most reliable post-failure scheme and operating modes of FIE's power system; determination of the state of disconnected electrical equipment and restoration of its electricity supply; switching on and off consumers-regulators to maintain rational levels of power consumption. This is done by reconfiguring the FIE's power system by changing the position of the switches and redistributing the load between power consumers.

AB23: Choosing a network topology and selecting control actions. This function describes a possibility of choosing a new topology of the FIE's power system in cases of

emergency situations as well as during power equipment repairing period and power shortages in external power system.

AB24: Determining of the power consumption level declared by FIE. Every day, a summary of power consumption indicators of by production units are consolidated: actual and planned absolute and specific power consumption, coefficients of use of the established limits, cost rates. On the basis of this data, decisions are made to maintain the power consumption parameters of FIE within the specified limits. ODK decisions preparing is carried out using the decision support subsystem.

AB25: Predicting and normalizing electrical loads. Proceeding from the tendency of changes in power consumption and quantity of released products, the prediction of electrical loads and the normalization of power consumption are carried out at the power system nodes, to which separate technological facilities are connected.

AB31: Maintaining of the system's database. For efficient control of power consumption and supply electricity of FIE in real-time mode, an information database on electric power system is filled and maintained in the actual state. Its main functions are the execution of tasks scheduled by the administrator and transferring of data to remote clients – ASW (Chief Power Engineer ASW, Electrical Engineer ASW, Power System Dispatcher ASW, etc.).

AB32: Prohibiting performing control actions (CA). In the event that the actions of the Power System Dispatcher to change the position of the switches and disconnect the electrical receivers contradict the schedule of planned repairs, the Chief Dispatcher shall prohibit the implementation of such actions.

AB33: Determining of power supply modes indicators.

AB34: Determining of power consumption modes indicators. The operating of the power system and of the electric consumers, as an integral part of PCSSFIE, is characterized by a set of indicators whose values determine the operating mode of the power system and consumers in time. Quantitative indicators of the operating mode are the values of electric energy, power, voltage, current, EP quality indices and other parameters determined by the tasks solved by the system.

On the basis of the Use Case Diagram, the information structure of PCSACS in Data Flow Diagram (DFD) notation was developed (Figure 2).

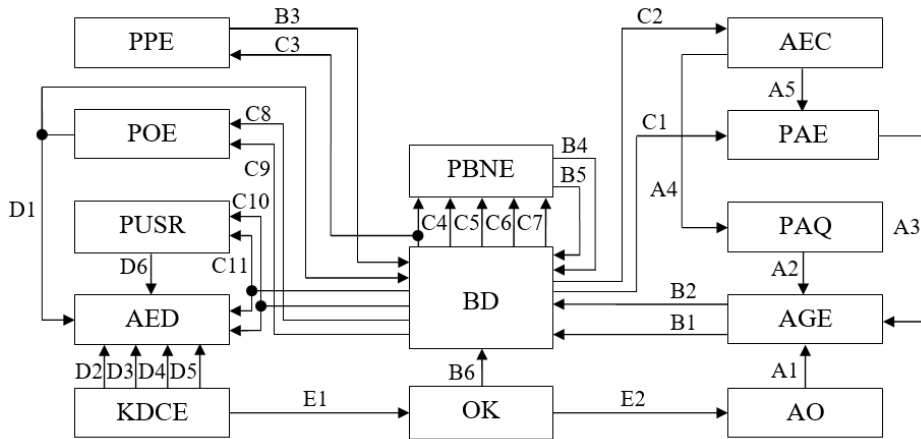


Figure 2. Information structure of PCSACS

Functioning of the information system is provided by the following users and subsystems: OK – control plant (PCSSFIE); AO – Production Department Dispatcher ASW; AGE – Chief Power Engineer ASW; AEC – electrical department ASW; AED – Power System Dispatcher ASW; PAQ – subsystem (module) of power consumption modes analysis; PAE – subsystem (module) of power supply modes analysis; BD – PCSACS database, PBNE – subsystem (module) for calculating balances, norms of EP expenses; PPE – subsystem (module) for predicting EP consumption; POE – subsystem of power supply modes optimization; PUSR – selecting subsystem SR and power consumption optimization; KDCE – generating subsystem of control actions for FIE power consumption and supply control.

The following Data Flows are used for control actions generating and decision making: A1 – limitations on the power supply system (PSS) topology and of the CR list; A2 – cost plan and CR list, A3 – decisions to ensure normative values of EP quality indices (EPQI), optimal modes and PSS topology; A4 – data concerning power consumption and CP selecting; A5 – data on PSS modes and decisions; B1 – approved decisions on the normalization of EPQI and the PSS topology selecting; B2 – approved EP and CR cost plan; B3 – estimated EP values; B4 – balances and EP consumption rates; B5 – list of enabled CRs; B6 – data concerning the control plant status; C1 – balance and expenses of EP, actual and predicted power consumption levels and CRs; C2 – operational data on the state of the PSS; C3 – actual costs of EP; C4 – decisions taken on CRs; C5 – data on production output; C6 – actual costs of EP and EP limits; C7 – approved EP schedule; C8 – PSS mode parameters; C9 – list of disconnected CRs; C10 – recommended topology of PSS; C11 – approved levels of EPQI. As a result of system operating, the following control actions are formed: D1 – control actions for PSS optimizing; D2 – EPQI controlling decisions; D3 – prohibiting performing control actions; D4 – decision on PSS topology; D5 – made decisions on power system management; E1 – control actions transmitted to the control plant; E2 – information required for selecting the CR and PSS topology.

Application specific workstations (ASW)

PCSACS includes ASWs of Administrator, Chief Power Engineer, Power System Engineer, Power System Dispatcher, Equipment Repair Engineer and Economist, which include a set of functions assigned to them.

Administrator's ASW should provide: access to the configuration of the logical scheme of the control system; creating and editing of database queries used by other ASWs; data exchange between databases and Microsoft Office programs; maintaining a system event log and accessing its records.

Power System Engineer's ASW should provide: analysis of the company's power consumption, calculation of power consumption and power balance; choosing optimal control parameters of FIE power consumption.

Chief Power Engineer's ASW should provide: on demand displaying of the necessary current and reporting information about the company's power supply.

Power System Dispatcher's ASW should provide: displaying electric schematic diagram with state of switching equipment; displaying current and summary expenses of electric power for power consumption units; displaying of daily charts of power consumption by power consumption units in tabular and graphic form; displaying the enterprise's power consumption predicted values and warning about possible exceeding of the established limits; FIE power supply control on the basis of human-machine dialogue in real-time mode.

Electrical Equipment Repair Engineer's ASW should provide: making and displaying of the repairing schedule for electrical equipment; displaying data on demand about the current technical condition of electrical equipment.

Power Management Engineer's ASW should provide: implementation of the power consumption limits regulated by the power supplying company; analysis of the enterprise's power consumption in economic terms, obtaining necessary reports and transferring information to other departments of the enterprise.

The hierarchical structure of the information control system is presented in Figure 3. To provide the functioning of the information system, an integrated software and hardware system (ISHS), consisting of hardware and software components, has been developed.

Software part of ISHS

The main element of this part of ISHS is the information and computing system (ICS), which includes software modules that implement algorithms for solving power consumption and supply control tasks, the means of interaction with the enterprise power system database and operating system (OS), as well as the IEC graphic user interface for a dispatcher, a power system engineer, an power management engineer, a chief power engineer. To solve the above-mentioned tasks, the following software modules (subsystems) are supposed:

- module of digital relay protection and emergency automatics terminals (DRPA);
- I/O module for data which is not transmitted through the DRPA terminals;
- precise astronomical time input module;
- module of the central (common for generating units) and local (in area of the switchgear) alarm;
- module for power supply system control;
- module for electric power quality control in PSS;
- module of automated configuration of power supply system;
- module of automated control of FIE power consumption.

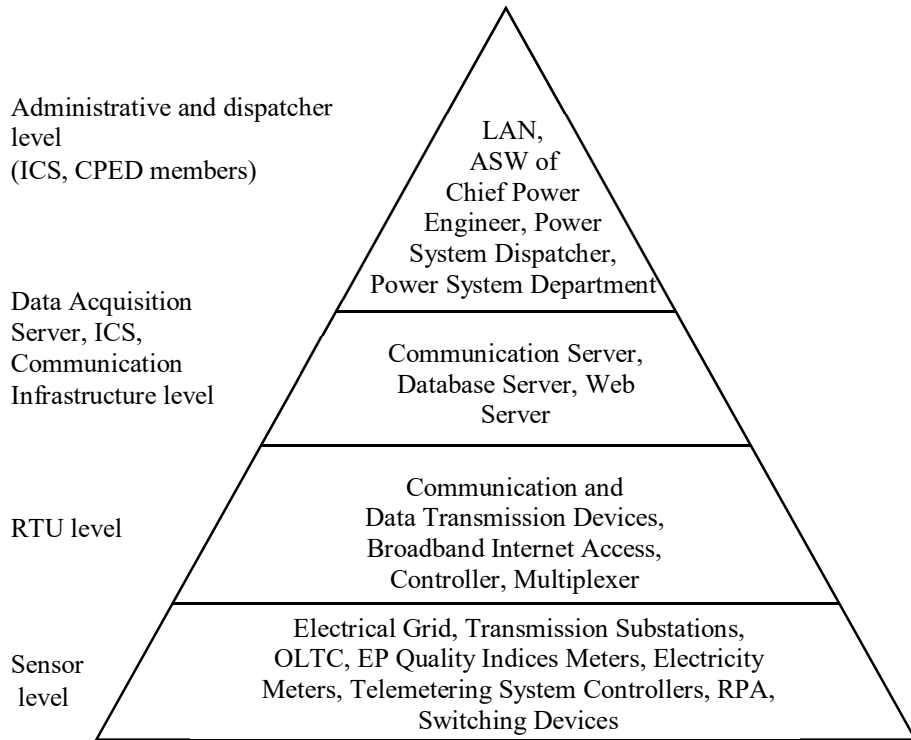


Figure 3. Hierarchical structure of information system of power consumption and power supply management

Hardware part of ISHS

The hardware part of ISHS is based on a local area network (LAN). It's a distributed system, which includes geographically remote objects. The main source of data in PCSACS is the multifunctional digital relay protection and automatics of power supply system (DRPA terminals), which are at the same time devices of the PCSACS lower level. In addition, remote control units for electrical equipment (RCU) may be used. They provide the collecting and transferring to operator's level about 90% of data necessary for the PSS operational control. Naturally, PCSACS is constructed, as a rule, on the basis of serial specialized control systems of the manufacturer of digital terminals.

The data received from DRPA terminals is used on workstations to form the mimic diagram of the switchgear, display current parameters, control and other purposes. However, when the feeder is out of service, when there is no operational current, the terminal stops transmitting data. Therefore, in order to obtain on the workstation's screen the image of circuit breaker under repair, the disconnectors and grounding blades position, the data from the block contacts of these devices is transmitted through the remote terminal units (RTU), which have independent operational current.

Power supply of RTU and connected circuits is organized using a separate circuit breaker, since it should not depend on the feeder operational current. The data from DRPA, RTU and ACS is transmitted via digital fiber-optic channels to the server that takes a central place in the PCSACS. The server has connection channels to the lower level of control,

operators' workstations (computers), the common time system, automated system of energy resource technical registration and the router.

The main technology control system and dispatcher control system are connected to PCSACS through a router, which connects these different networks and forwards data packets between them.

General principles of data exchange organization in ISHS

Data flow from electrical devices to workstations, adjacent and higher level systems, as well as control commands in reverse direction, is carried out using lower and upper level LAN.

The lower level LAN transmits data from electrical devices to the server and the control commands in the reverse direction.

Connection of electrical devices to the lower level LAN is carried out through the data communication ports available in the DRPA devices, local automation systems and in RTU. The upper level LAN transmits information from the server to PCSACS workstations, adjacent and higher level systems, as well as control commands in the reverse direction. Requests for server data and sending control commands are performed by workstations called clients, and the structure of network architecture - client-server or dedicated server. For the data exchange in the networks of the lower and upper levels PCSACS uses the physical communication channels through which the data is transmitted in the form of electric, optical or radio signals (electrical or optical cables, radio or satellite communication channels). Data transmission is carried out according to certain rules, defined in data communication protocols. Data communication protocols are implemented in network software.

Organization of data transfer to ISHS

For data transmission, communication lines of RS-485, RS-422, RS-232C interfaces are used. Depending on the used interface only the electrical parameters of transmitters, receivers, as well as the construction of communication lines will be different. In these lines, data is transmitted in packets ranging from tens to several hundred bytes. It uses an asynchronous serial start/stop data transmission in which the bytes of each packet are transmitted sequentially one after another, bit per bit. In the case of asynchronous data transmission, there is no special line for synchronization of the transmitter and the receiver. The data to be transmitted is the control commands; signals characterizing the state of the equipment and its operating mode; emergency and warning alarms; measured values of currents, voltages, frequencies; other technological parameters and discrete signals. The software in DRPA, RTU, controllers, and other devices runs in a loop that can only be affected by extraordinary events, such as the appearance of device events requiring immediate processing and causing program loop interruptions. The program loop can range from one to hundreds of milliseconds.

Connection of DRPA terminals, electronic meters and security terminals is provided through high-speed interfaces. High speeds of data transmission and processing allow the same interfaces and data communication protocols to be used at the lower and upper levels of the ACS, which simplifies its structure. On the other hand, the modern development of telecommunication technologies allows designing highly reliable networks due to the use of duplicated communication channels and specialized protocols for relay protection Modbus, TCP/IP, IEC 61850 and others, reserve the Ethernet network star topology. Consider the option of the PCSACS structure, where at the lower level ABB's REX 600-th series terminals

(RET 615, REF 620, REM 620, etc.) are installed. These terminals can be equipped with an additional communication module that has two independent optical Fast Ethernet ports (100Base-FX interface). For working in Fast Ethernet networks terminals include protocols IEC 61850, DNP3, TCP/IP. Using these communication modules, one can build a completely redundant network for the "star" or "ring" topology.

In the redundant network of "star" topology there are two Ethernet switches. Each switchboard is connected to one optical port of the communication modules of all DRPA terminals. On the PCSACS server, two network adapters are installed, each of which connects to the corresponding switch. In fact, such a network consists of two independent networks. If one of the networks fails, data transmission will continue in the second network with zero switching time. The main advantage of such a scheme is its high reliability through 100% redundancy, network independence of state of the individual terminals, which switching off or malfunction does not affect the rest of the network. As disadvantage of this scheme one can consider the need to lay a large number of cables – two from each terminal to the switches. It should also be noted that, since there are no direct links between the terminals, the GOOSE messages will be transmitted through an additional element - the switch.

SCADA systems specifications

SCADA systems are the basis of operational-dispatching control systems of power consumption and supply operating modes.

To create Windows-like user interfaces, communications with meters and actuators, SCADA-based systems on the MS Windows platform are used. They contain standard data interfaces and API functions that facilitate the development of individual control subsystems and their integration into power system ACS of the enterprises' ICS (integration with ERP-systems SAP, "Galaxy", etc.). The software is developed using both built-in languages of SCADA systems or languages that allow designing interface to them, using the known CASE-tools and the universal modeling language UML (Rational Rose and ARIS), what greatly simplifies the process and reduces design time of control system.

When developing the software it's reasonable to use existing, ready-made COTS (Commercial Off-The-Shelf) problem-oriented tools.

An approximate list of criteria for evaluating SCADA systems can be conventionally divided into three large groups of indicators:

- specifications;
- cost characteristics;
- performance characteristics.

Hardware platforms for SCADA systems. The analysis of the list of such platforms is necessary, since it decides the question whether the implementation of this SCADA system is possible on the available computing tools, as well as assessment of the cost of system's technical support (being developed in one operating environment, the application can be implemented in any that supports the selected SCADA package). In different SCADA systems, this issue is solved in different ways.

At the same time, such SCADA systems as RealFlex and Sitex accept as the basis for software only one operating system – real-time OS QNX.

The vast majority of SCADA-systems are implemented on MS Windows platforms. These are such systems that offer the most complete and easy to upgrade MMI - tools.

Tools of SCADA-systems network support. Obviously, for the efficient functioning in this heterogeneous environment, the SCADA system should provide a high level of network service. It is desirable that it should support standard network environments (ARCNET, ETHERNET, etc.) using standard protocols (NETBIOS, TCP/IP, etc.), and also should provide support for the most popular network standards from the class of industrial interfaces (PROFIBUS, CANBUS, LON, MODBUS, etc.) These requirements anyway satisfy practically all of the SCADA systems considered, with the only difference that the set of supported network interfaces, of course, is different.

Built-in command languages. Most SCADA systems have built-in high-level languages, VBasic-like languages, which allow you to generate an adequate response to events associated with changing the value of a variable, with a certain logical condition, with a keystroke, as well as with the execution of some fragment with given frequency relative to the whole application or a separate window.

Database support. One of the main tasks of dispatch and control systems is the data processing: collection, real time analysis, storage, compression, forwarding, etc. Thus, in the system to be created, there should be a database.

Almost all SCADA systems, including Genesis, InTouch, and Citect, use the ANSI SQL syntax that is independent of the database type. Thus, applications are virtually isolated, which allows you to modify the database without seriously changing the application itself, create independent software for analyzing information, use the already developed software, focused on data processing.

Graphic features. Functionally graphical interfaces of SCADA-systems are very similar. Each of them has a graphical object-oriented editor with a certain set of animation functions. The vector graphic makes it possible to perform a wide range of operations on the selected object, as well as to quickly update the image on the screen using the animation tools.

It is also extremely important to support the GUI (Graphic Users Interface) in these systems. Since most of the SCADA systems are running under Windows, it determines the type of GUI used.

Openness of systems. The system is open, if it identifies and describes the data formats used and the procedural interface, allowing it to connect to the "external", independently developed components.

Development of own software modules. In the face of the automation system developers, the question often arises about the creation of their own (not provided within the framework of SCADA systems) software modules and their inclusion in the created automation system. Therefore, the issue of system openness is an important characteristic of SCADA systems. In fact, the openness of the system means the availability of system specification calls (in the sense of SCADA) that implement one or another system service. It can also be access to graphic functions, functions of operating with databases, etc.

I/O drivers. Modern SCADA systems don't restrict the choice of lower-level hardware, since they provide a large set of drivers or I/O servers and have well-developed means for creating their own software modules or drivers for new lower-level devices. The drivers themselves are developed using standard programming languages. The question, however, is

whether the SCADA-engineer needs only the specifications for access to the system kernel supplied by the firm-developer in the standard set (Trace Mode), or he requires for the creation of drivers special packages (FactoryLink, InTouch), or, in general, developing drivers must be ordered from the developer company.

The development of a control system using SCADA systems includes the following steps:

- Development of the automation system architecture as a whole. At this stage, the functional purpose of each node of the automation system is determined.
- Solving issues related to the possible support of a distributed architecture, the need to create hot node backups, etc.
- Creating an applied control system for each node. At this stage, a specialist in the field of automated processes provides the nodes of architecture with algorithms, the totality of which allows you to solve automation tasks.
- Matching the application system parameters with the information exchanged between lower-level devices (for example, programmable logic controllers – PLC) with the outside world (processor sensors, actuators, etc.).
- Setup of the created application in the mode of emulation.

Technical means for power supply system automation

Currently, modern protection, automation and control microprocessor devices (RPA terminals) of various primary electrical equipment are widely implemented at all voltage levels of 0.4-110kV and above. Terminals are used in secondary switching circuits for use as primary and back-up protections.

Complete devices of protection, control and automatics. Simultaneously with the implementation of the relay protection functions, RTU-terminals are lower level interface devices in control systems. Terminals can transmit measurable values, parameters of emergency modes, set point values, oscillograms, the equipment state in the control system, and also perform remote control of the control plant. Integration of relay protection terminals into the ACS allows reducing the capital costs of the RTU equipment when creating the power supply ACS.

Terminals of protection and control are designed on a microprocessor element base for protection of various primary electrical equipment. Terminals are used in circuits of secondary switching for use as main and reserve protection with voltage 0.4 - 35kV.

Process controllers and telemechanics devices are used as controllers and easy to adapt to different transmission environments and traffic modes. Terminals have a modular structure and can be used on objects with a number of signals from 20 to 1800. Terminals allow flexible programming of collection, primary processing and transmission of data and provide execution of local automation functions.

Alarm devices are intended for organization of the local or central signaling system of the power unit.

The device displays on the local panel a group or individual alarm, it manages an audible alarm. It is equipped with a communication port for connecting to the ACS a portable electrician ASW (relay) to work with protections and an event printer. The standard protocols ANSI and MODBUS are used for the exchange of upper level control systems.

The device for receiving and transmitting data (DRTD) is intended to provide the functioning of the local automated metering system the enterprise and performs the following functions:

- collection of measurements from digital and pulse outputs of meters;
- calculation of the named parameters of electric power;
- maintaining archives;
- support for communication with local ACS and remote ASW Energosbut.

The device performs functions of collecting, pre-processing and storing data.

Electricity metering and control systems

For technical and commercial electricity metering, installed counters with pulsed outputs or intelligent digital counters (for example, "Alpha") are used. Intelligent counters perform the following functions: electricity metering for 4 tariffs, 4 seasons, 4 types of weeks with an accuracy class of 0.2 and 0.5; measurement of active and reactive power in two directions; power quality control; load schedule storage; transmission of measurement results via digital and pulse channels.

To store electrical quantities analog values in the system special devices can be used that combine the functions of sensors and control the quality of electric power.

The system should provide the following system-wide functions: maintenance of a single system-wide database; system administration with the availability of different levels of access, ensuring access control of database users; software integration with existing system development tools; configuration settings for the system menu for ASWs; the maintenance of a system log of events.

The implemented software system solutions should provide the opportunity to further increase the number of control plants, types of energy sources, types of information analysis and number of ASWs, as well as integration of the system with other ACS subsystems.

Conclusions

The use of the UML methodology to analyze the power consumption and supply control process of FIE allows identifying the users of the control system and the basic control functions. The design of the information structure is performed according to the DFD methodology, which reflects the main data flow that provides control of power consumption and supply. To implement the control functions the integrated software and hardware system is developed. It consists of modules that ensure the operation of PCSACS. For data transmission communication lines are utilized, which are built using interfaces such as RS-485, RS-422, RS-232C. The SCADA systems are the basis of power consumption and supply modes operational-dispatcher control systems. The technical means of PCSACS are modern microprocessor protection, automation and control devices (relay protection terminals) of various primary electrical equipment of all levels of voltage 0.4-110kV and above.

References

1. Bulaev Iu.V., Tabakov V.A., Eskin V.V. (2001), Kompleksnaia avtomatizatsiia energosnabzheniia predpriatiia, *Promyshlennaia energetika*, 2, pp. 11–15.
2. Mirzoian Iu. T. (2000), Programmnoe obespechenie KTS «Energomera», *Energetik*, 8, pp. 42–44.

3. Kapitonova B. Tuganov V. Satarov L. (1996), Territorialno-raspredelennaia avtomatizirovannaia sistema ucheta i kontrolia elektropotrebleniia, *Sovremennye tekhnologii avtomatizatsii*, 1, pp. 78–80.
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), *Energoberegaiushchie rezhimy elektrosnabzheniia gornodobyvaiushchikh predpriatii*, Nedra, Moscow.
9. Rezhnikov A.F., Ivashchenko V.A. (2008), Upravlenie elektropotrebleniem promyshlennykh predpriatii, 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-Hausmann 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.

Performance analysis of means of mitigating overhead power lines wires sag designed in Ukraine and USA

Anatoliy Ukrayinets, Volodymyr Shesterenko,
Volodymyr Romaniuk

National University of Food Technologies, Kyiv, Ukraine

Abstract

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Corresponding author:

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

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Introduction. Conducting a comprehensive analysis of methods and tasks for ensuring the effective implementation of innovative thermal compensating devices.

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

Results and discussion. The compensation of overhead power lines wires sag creates conditions under which it is possible either to increase spans, or to reduce the height of the towers while preserving the existing estimated spans. As a result, the specific consumption of the supports, linear fittings, insulation is reduced, and the time for construction of the power lines is also reduced. Taking into account the existing norms, it is possible to increase the span of the power line of different voltage classes by 7–10%.

As a result of the conducted research, a method for calculation and optimization of existing devices for thermal compensation of power lines wires sag has been developed. A multifunctional device for compensation of temperature arcs of sagging of power lines, which allows to optimize both working and projected power lines is proposed.

Conclusions. The results of this work should be used in electrical networks with overhead power lines of all voltages. The Ukrainian thermal compensator is a new class of equipment for power lines, which solves the problem of temperature extension of wires, using a material that responds to the temperature changes by changing its geometric shape and size and is more reliable than the American one.

Introduction

The purpose of this work is the development and analysis of multifunctional devices for compensation of temperature sagging of power lines wires, optimization of their parameters, analysis of combined work of wires in spans with such devices. The results of this research can be applied to power lines of any voltage ratings.

Increasing the efficiency of operation of electrical networks by introducing the latest technologies and equipment requires solving a number of complex scientific and practical problems, among which the problem of imperfect regulatory framework and insufficient information provision on innovation activity is central. [1,3,4,13,15,17].

Materials and methods

Increasing the length of the power lines spans or reducing the height of the towers while maintaining the existing estimated spans can significantly reduce the cost of building materials, linear fittings, isolation during the construction of power lines. Optimization of power lines can be achieved by using special devices that increase the tension force in the wires with increasing temperature and reduce the temperature induced sag of the wires. Such devices by the authors were called thermal compensators of power line arcs of sagging. The active thermocompensation of the arcs of sagging can be achieved with the help of force elements, which are fastened to the wire and act on it. The production of devices with negative temperature extensions for a certain temperature range became possible after the discovery of the unique property of some alloys to "memorize" the shape [1,2,4,12,14,16].

Most clearly this property is expressed in the alloy of nickel with titanium - nitinol. The sample of this alloy is heated for transition to a high-temperature modification and in this state it is given a certain shape. Then the alloy is straightened out below critical temperature and is transferred to another, low temperature phase. This phenomenon reminds the thermoelastic transformation. Due to the fact that the material with a "shape memory effect" (SME) has a significant impact strength, a high endurance limit, easy to forge, efficiently 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, from this material it is possible to make a power element in the form of a thread with the length 1-8 m and to attach it parallel to the segment of the wire in each span [2,4,15,17]. (Patent of Ukraine №17994, F03G 7/06./Ukrayinets A.I. Shesterenko V.Ye., Patent of Ukraine №19634./Ukrayinets A.I. Shesterenko V.Ye., Patent of Ukraine № 42169, H01R 11/00./Ukrayinets A.I., Shesterenko V.Ye., USA Patents №US 2014/0021327 A1, №6864421B1).

Results and discussion

The main requirement for the operation of the thermal compensator with SME: the length of the section of the wire, parallel to which the thermal compensator attaches, must 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 must be equal to the absolute elongation of the wire in the given temperature range [1,2,4].

American thermal compensator

The Sagging Line Mitigator (SLIM) is able to automatically compensate for sag in a suspended or hanging line, such as a power line. It uses a material that changes its dimensions as a function of temperature. One such material is shape memory alloy (SMA) which undergoes a phase transformation upon temperature change and produces a significant change in size and geometry. In this invention, the SMA will contract as its temperature increases. The contraction of the SMA produces a pulling force (increasing tensile force) which is indirectly transferred to the suspended line, effectively pulling in the slack and reducing sag. SLIM uses at least one lever to amplify the SMA length change and transfer it to the suspended line.

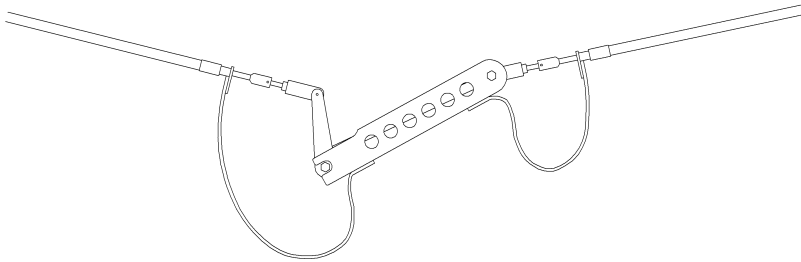


Figure 1. Thermal compensator “SLIM”, designed in USA, simplified general view (USA patent US6864421B1).

Ukrainian thermal compensator, principle of operation

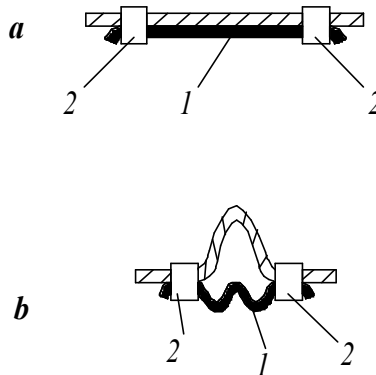


Figure 2. Principle of thermal compensation of an arc of sagging on power line, a) thermal compensator in the initial state; b) thermal compensator after triggering.

Using unique properties of SME material it became possible to have zero or negative extension of power line wire with increase in temperature [1,17]. A dependence between thermal compensator deformation and temperature is shown on Figure 3.

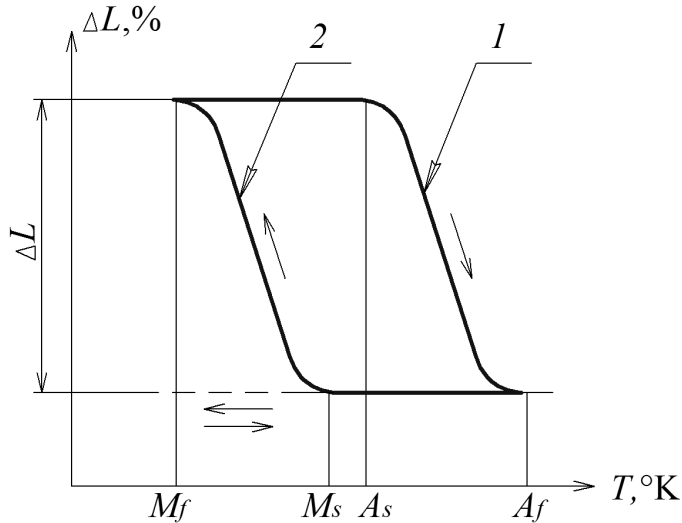


Figure 3. Dependence between SME element deformation and temperature, 1 – reverse transformation; 2 – direct transformation.

Thermosensitive element 1 is compressed at maximum temperature (Figure 2b), tension in the wire increases and sag decreases. If temperature of the wire drops below martensitic point (around 288°K), thermosensitive element 1 loses its rigidity and under the influence of the weight of the wire straightens out (Figure 2b). At the next increase in temperature thermal compensator renews its shape (Figure 2b) [1,15,17].

The temperature of the beginning and the end of the martensitic transformation, respectively $M_s \approx 282^\circ\text{K}$, $M_f \approx 278^\circ\text{K}$ (Figure 3) and the beginning and end of the reverse martensitic transformation, respectively $A_s \approx 285^\circ\text{K}$, $A_f \approx 306^\circ\text{K}$. The shape of the curve of the dependence $\Delta L=f(T)$ is determined by the speed of heating and cooling.

Composition of the material with SME affects the magnitude of the hysteresis. Temperature of thermal compensator triggering depends on its load. That is the points for the same material are not stable and can shift by couple degrees [2,4,12,17].

Multifunctional thermal compensator of an arc of sagging on power line wires.

Figure 4 schematically shows a thermal compensator, connected to two adjacent spans.

Wire 1 of the overhead power line is suspended on the towers. Minimum distance from the wires to the surface of the earth without the thermal compensator is indicated by H_0 (wire position 3), in the presence of the thermal compensator – H_1 (wire position 2) and H_2 (wire position 1).

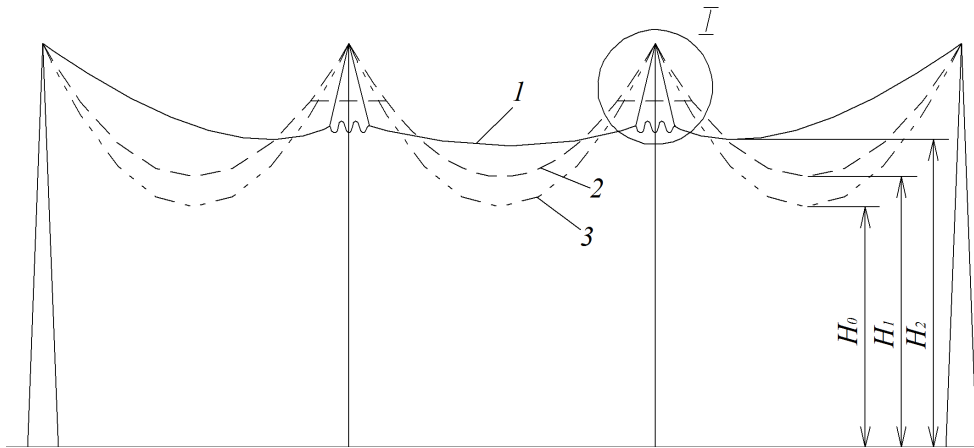


Figure 4. Influence of the thermal compensator on the minimum distance to the ground, 1,2,3 – position of the wire depending on the thermal compensator operation.

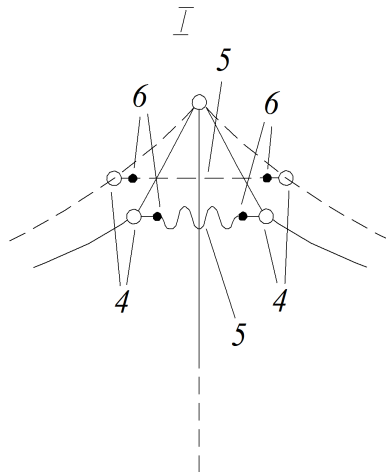


Figure 5. Fastening point of the thermal compensator, 4 – clamp, 5 – thermal compensator made from SME material, 6 – insulator.

Thermal compensator 5 is attached to the wire by the clamps 4 and insulating elements 6.

Since thermal compensator connects two spans of the wire, the force it perceives, is limited only by the horizontal component of the tension in the wire, which allows to significantly reduce the cost of materials for the thermal compensator. In addition, such method of thermal compensator connection, thanks to the flexible coupling of two adjacent spans of the wire gives an opportunity to influence the vibration of the wires. In this case, the energy of the oscillations 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 thermal compensator, the amplitude, frequency and phase of the

oscillations change, and the overlap of such oscillations leads to their weakening. Thus, the damping effect of the thermal compensators is similar to the action of vibration dampers [2,4,15].

When wires are frosted, an additional energy source in the mobile laboratory can be connected to the thermal compensator. The rapid heating of the thermal compensator causes its compression. The wire from position 3 goes to position 1. At the same time, snow and ice are removed from the wire. The insulating inserts 6 allows you to reduce the energy consumption of removing snow and ice that accumulates on the wires.

When examining the compined operation of the wire and the thermal compensator, made of SME material, we will use the piecewise-linear approximation of the performance characteristics of the thermal compensator (Figure 3).

When the air temperature increases, the length of the wire increases, tension in the wire decreases – upper part of the curve (Figure 3). When the ambient temperature reaches the temperature of the beginning of the reverse martensitic transformation of the thermal compensator, it begins to pull the wire by changing its own length [15,17]. With further increase in temperature, the wire continues to increase its length, and the thermal compensator – to decrease.

At the point A_f thermal compensator completely restores its shape.

When temperature drops, thermal compensator keeps its shape because of its hysteresis ($A_f - M_s$).

Lowering the temperature to the point of the beginning of a direct martensitic transformation (point M_s) causes deformation of the thermal compensator. Tension in the wire in the temperature range from the beginning of direct martensitic transformation (point M_s) to its end (point M_f) changes along the curve $M_s - M_f$. With further decrease in temperature, the thermal compensator does not participate in the work of the wire and the wire tension changes according to the natural characteristic [2,4].

In electrical grids, the dependence of the tension in the wire that came from the load and the temperature is expressed by the mathematical models.

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 thermal compensator according to Figure 3 and Figure 4 [12,15,17].

For the section of characteristic of the material with SME $M_f \leq t \leq A_s$, where the thermal compensator does not significantly affect the work of the wire, the equation of the state of the wire is not different from the equation without the thermal compensator:

$$\sigma - \frac{v^2 \cdot E \cdot l^2}{24 \cdot \sigma^2} = \sigma - \frac{v^2 \cdot E \cdot l^2}{24 \cdot \sigma_0^2} - \alpha \cdot E \cdot (t - t_0), \quad (1)$$

where: v_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;

v, σ, t – specific load, tension, and temperature in the final state.

At the section of the characteristic $A_s \leq t \leq A_f$ (Figure 3, Figure 4) the thermal compensator triggers and restores its shape. 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 [2,4]:

$$\sigma - \frac{v^2 \cdot E \cdot l^2}{24 \cdot \sigma^2} = \sigma_0 - \frac{v_0^2 \cdot E \cdot l^2}{24 \cdot \sigma_0^2} - \alpha \cdot E \cdot (t - t_0) - \frac{l_k \cdot \alpha_k \cdot E}{l} \cdot (t - A_s), \quad (2)$$

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

$$\alpha_k = \frac{\varepsilon}{100 \cdot \Delta t_{ph}}, \quad (3)$$

where: ε – maximal elongation (compression) of the material with SME, %;
 Δt_{ph} – temperature range of phase transformation.

In the range $M_s \leq t \leq A_f$ temperature of the wire lowers but shape of the thermal compensator remains intact, because of its hysteresis. Mathematical model of the state of the wire for the given range:

$$\sigma - \frac{v^2 E l^2}{24 \sigma^2} = \sigma_0^2 - \frac{v_0 E l^2}{24 \sigma_0^2} - \alpha E (t - t_0) + \frac{\Delta l_k E}{l}, \quad (4)$$

where: Δl_k – maximal compression of the thermal compensator.

In the range $M_f \leq t \leq M_s$ thermal compensator loses its elastic properties and under the influence of the weight of the wire straightens out [12,15,17].

In this case mathematical model of the state of the wire becomes:

$$\sigma - \frac{v^2 l^2 E}{24 \sigma^2} = \sigma_0 - \frac{v^2 E l^2}{24 \sigma_0^2} - \alpha E (t - t_0) - \frac{l_k \alpha_k E}{l} (t - M_s) \quad (5)$$

Magnitude of the temperature induced elongation of the wires Δl , which needs to be compensated is always known. Therefore stroke of the thermal compensator is also known and it also equals Δl .

Because maximal permissible elongation of SME material is ε , the length of the thermal compensator will be:

$$l_k = \frac{100 \cdot \Delta l}{\varepsilon}, \quad (6)$$

Second main requirement for the operation of the thermal compensator is equality of the force generated by thermal compensator P_k and tension T_w in the power line wire [1,2,4]:

$$P_k = F_k \sigma_k, \quad (7)$$

where: F_k – cross-sectional area of the thermal compensator;

σ_k – maximal force generated by the thermal compensator per unit of cross-sectional area.

After calculation of the cross-sectional area of the thermal compensator F_k , we can find the mass of the thermal compensator. In the case if $P_k < T_w$ thermal compensator will not provide compensation of the wire elongation. The stroke of the thermal compensator will be less than Δl . If $P_k > T_w$ thermal compensator will not return in the previous (deformed) state.

Influence of the additional loads on the wire with the thermal compensator (e.g. wind) is not taken into account because the wire will be effectively cooled by the wind [12,15,17].

Mechanical tension generated in the thermal compensator:

$$\sigma = \frac{\rho \Delta Q}{\varepsilon_t} \ln \frac{A_f}{A_s}, \quad (8)$$

where: ρ – density of the SME material,

$$\varepsilon_t = \frac{l_t - l_0}{l_0}, \quad (9)$$

where: l_t , l_0 – the length of the SME element after heating and with initial temperature accordingly.

Device for installing the thermal compensator on power line wires.

The American thermal compensator (SLIM) may be installed between the tower and the suspended line, or may be installed within the span of the suspended line. The device may be installed using techniques similar to those used for installation of a "splice" or a "dead-end" on such lines. The "splice" technique is achieved by cutting the line at two positions at a given distance from each other and installing the device by connecting the device ends to the cut ends of the line. In case of a "dead-end" technique, installation is achieved by cutting the power line at one location at a given distance from its end connecting point to a fixed structure, such as a tower, and installing the device between the cut location of the line and the fixed structure and connecting the ends of the device to the cut end of the line and the fixed structure. Also, multiple devices can be installed in series if needed by cutting longer pieces of the power line.

The Ukrainian variant of the thermal compensator uses special device for installing the thermal compensator on power line (Figure 6).

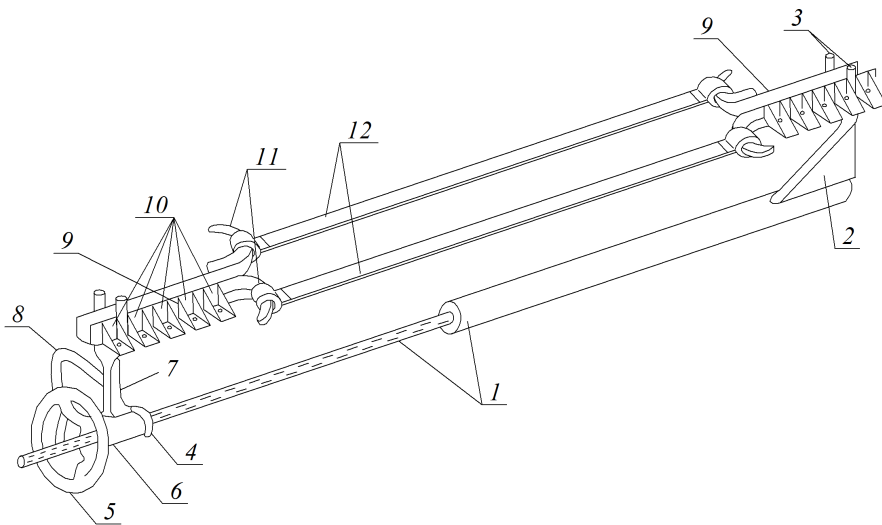


Figure 6. Installation device with thermal compensator on it.

Simplification of the installation of the thermal compensators on the power line wires is achieved when the thermal compensator is preheated to the temperature of the end of the reverse martensitic transformation, the wire is pulled up by the magnitude of its absolute temperature extension in the given temperature range, regardless of the ambient temperature, and the thermal compensator is fastened to the wire loop, which appeared during the installation process [2,4,17].

Due to the fact that the length of the thermal compensator is less than 1% of the length of the span, the influence of the temperature extension of the wire, parallel to which the thermal compensator attaches, can be neglected.

After installing the thermal compensator and releasing the wire, the thermal compensator will pull the wire and take one or another position, depending on the temperature of the wire and the environment, as well as the tension in the wire.

After the temperature lowers below the M_f , the thermal compensator will be deformed due to the tension in the wire (Figure 3).

The installation device with the thermal compensator installed is shown on Figure 6. The device consists of a rod 1, on one side it has a thread, on the other – a mounting bracket 2 with a fork 3. On the threaded side there is a bushing 4 with an internal thread and a flywheel 5. On the bushing there is a coupling 6 with a bracket 7 and a fork. From the side of the coupling 6 and bracket 7, handle 8 is placed. Forks planes are perpendicular to the rod 1. Forks have semi-circular enclosures 9 (wire fastening points). Brackets 10 with holes, located symmetrically to the axis of the enclosure are attached to the lateral walls of the enclosures. The enclosure, on the one hand, has brackets 11, to which the power elements of the thermal compensator 12 are attached. The distance between the teeth of the forks is equal to the width of the enclosure 9, and the thickness of the teeth of the forks is equal to the distance between the side brackets 10 [1,17].

The mounting point for the thermal compensator is shown on Figure 7.

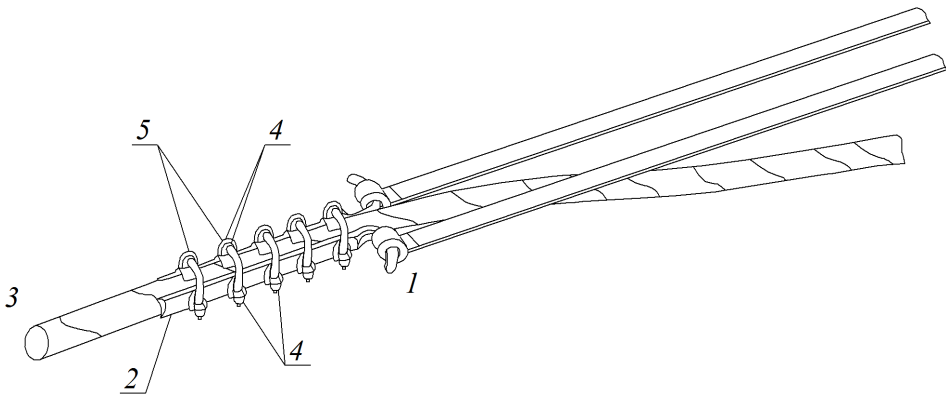


Figure 7. Thermal compensator mounting point,
1 – bracket, 2 – housing, 3 – wire, 4,5 – connection clamps.

The wire 3 passes through the housing 2. The tensioning bolts 4 with the dies 5 press the wire 3 to the housing 2. The brackets 1, located on one side of the housing 2, are located symmetrically to the geometric center of the wire 3.

Usually the installation of a thermal compensator proceeds at a temperature higher than the temperature of the end of the direct martensitic transformation, which causes additional complications, since at such a temperature the thermal compensator is already beginning to recover its shape [12,15,17].

Conclusions

1. Thermal compensator reduces wire sag automatically. Changes of the environment which induce the sag (temperature, force and direction of the wind, solar radiation) will act on the device which in response will reduce the wire sag.
2. Thermal compensator will reduce wire sag without need to replace the power line to a new one with bigger capacity or with lower characteristic of wires sag.
3. Thermal compensator will reduce wire sag without need to bundle conductors.
4. Thermal compensator will reduce wire sag without need to modificate the power line towers.
5. Thermal compensator will reduce wire sag which allows to construct power line towers on a bigger distance from one to another. This allows to construct smaller amount of tower.
6. Thermal compensator will reduce wire sag which allows to construct lower power line towers.
7. Thermal compensator will reduce wire sag without lowering the power line current.
8. Thermal compensator is a new class of power line hardware that solves the temperature induced elongation of the wires problem by using a material which reacts to temperature change by significantly changing its own size and geometry,
9. American thermal compensator was designed later than Ukrainian one. Authors in different ways were trying to bypass patent information of Ukrainian thermal compensator. This has led to complication of the thermal compensator design and as result to increased cost. It is worth noting that thermal compensators work in very harsh conditions. Reliability of the device with rotating parts is extremely low. The axles will fail during very first year of operation. Installation of an American thermal compensator requires cutting of the wire. This is labor-intensive work, that can lead to problems with power supplying. Ukrainian variant of installing the thermal compensator on power line is much more simple and cost efficient. Thermal compensator mounting point allows to increase reliability of the work of the wire.

References

1. Ukrayinets A., Shesterenko V. (2017), Innovative local control of alternating voltage, *Ukrainian Journal of Food Science*, 5(1), pp. 305–318.
2. Shesterenko V., Mashchenko O., Romaniuk O. (2018), Optimization of external power delivering system of object by mechanical influence on the work of power line wires, *Ukrainian Journal of Food Science*, 6(1), pp. 127–135.
3. Shesterenko V.Ye. (2011), *Systemy elektrospozhyvannia ta elektropostachannia promyslovykh pidpriemstv*, Nova knyha, Vinnytsia.
4. Shesterenko V.Ye. (2001), *Optymizatsiia system elektrospozhyvannia promyslovykh pidpriemstv*, Hlana, Kyiv.

5. Shesterenko V.Ye., Shesterenko O.V. (2013), *Elektropostachannia promyslovykh pidprijemstv*, Nova knyha, Kyiv.
6. Abhik Banerjee, V. Mukherjee, S.P. Ghoshal (2014), Intelligent fuzzy-based reactive power compensation of an isolated hybrid power system Original Research Article, *International Journal of Electrical Power & Energy Systems*, 57, pp. 164–177.
7. Binod Shaw, V. Mukherjee, S.P. Ghoshal (2014), Solution of reactive power dispatch of power systems by an opposition-based gravitational search algorithm Original Research Article, *International Journal of Electrical Power & Energy Systems*, 55, pp. 29–40.
8. Salles D., Jiang C., Xu W., Freitas W., Mazin H. E. (2012), Assessing the collective harmonic impact of modern residential loads - Part I: Methodology, *IEEE Trans. Power Del.*, 27(4), pp. 1937–1946.
9. Jiang C., Salles D., Xu W., Freitas W. (2012), Assessing the collective harmonic impact of modern residential loads - Part II: Applications, *IEEE Trans. Power Del.*, 27(4), pp. 1947–1955.
10. Lihachev V.A., Kuz'min S.L., Kamenceva Z.P. (1987), *Jeffekt pamjati formy*, LGU, Leningrad, p.218.
11. Otsuka K., Wayman C.M. (1999), *Shape Memory Materials*, Cambridge University Press, New York, pp. 27–44.
12. Duerig T.W., Pelton A.R. (1994), Ti-Ni shape memory alloys, *Materials Properties Handbook: Titanium Alloys*, pp. 1035–1048.
13. K. Oocuka, K. Simidzu, Ju. Sudzuki i dr. (1990) *Splavy s jeffektom pamjati formy*, per. s japonskogo pod red. A.M. Glezera, Metallurgija, Moscow.
14. Barvinok V.A. et al. (1987), Malogabaritnoe oborudovanie i instrument s silovym privodom iz splava s pamjat'ju formy, prednaznachennye dlja vypolnenija remontno-montazhnyh rabot, *Problemy kosmicheskoi tehnologii metallov, Trudy IJeS im. Patona*, pp. 99–103.
15. Kornilov I.I. et al. (1977), *Nikelid titana i drugie splavy s jeffektom pamjati formy*, Nauka, Moscow.
16. Barvinok V.A., Bogdanovich V.I., Lomovskoj O.V., Vishnjakov M.A., Groshev A.A. (2011), Razrabotka reversivnyh silovyh privodov iz materialov s jeffektom pamjati formy dlja ustrojstv, primenjaemyh v uzlah raschekovki kosmicheskikh apparatov, *Izvestija Samarskogo nauchnogo centra RAN*, 13, 4(2), pp. 301–305.
17. Letenkov O.V., Filippov D.A. (2016), Raschet sistemy privoda: pruzhina iz materiala s jeffektom pamjati formy – kontrpruzhina, *Mezhdunarodnyj nauchno – issledovatel'skij zhurnal*, 11(53, 4), pp. 77–81.
18. Wilkes K.E., Liaw P.K. (2000), The fatigue behavior of shape-memory alloys, *The Journal of The Minerals, Metals & Materials Society (TMS)*, 52(10), pp. 45–46.

Globalization and food insecurity in Middle East and North Africa: A panel cointegration and causality analysis

Yilmaz Bayar

Usak University, Usak, Turkey

Abstract

Keywords:

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Introduction. It was researched the role of the globalization process in partial improvements in both undernourishment and hunger through decreasing the food insecurity in sample of Middle East and North Africa region over the 1999-2015 period.

Materials and methods. Westerlund and Edgerton (2007) cointegration test and Dumitrescu and Hurlin (2012) causality test were employed to analyze the short and long run impacts of various globalization types on the food insecurity.

Results and discussion. The cointegration coefficients revealed that trade globalization, financial globalization, social globalization, and political globalization negatively affected the prevalence of undernourishment. In other words, the components of globalization decreased the food insecurity in overall panel. However, trade globalization decreased the food insecurity in Djibouti, Egypt, Israel, Oman, Saudi Arabia, United Arab Emirates, and Yemen, but increased the food insecurity in Algeria, Iran, Iraq, Jordan, Lebanon, Morocco, and Tunisia. On the other side, financial globalization reduced the food security in Algeria, Iran, Iraq, Israel, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Tunisia, and United Arab Emirates reduced the food insecurity, while financial globalization had no significant effects on the food insecurity in Djibouti, Egypt, and Yemen. Furthermore, social globalization decreased the food security in Algeria, Iran, Iraq, Israel, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Tunisia, and United Arab Emirates and had no significant effects on food insecurity in Djibouti, Egypt, and Yemen. Lastly, political globalization reduced food insecurity in Algeria, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Lebanon, Oman, Saudi Arabia, Tunisia, and United Arab Emirates, but political globalization had no significant effects on the food security in Djibouti, Morocco, and Yemen. Furthermore, the causality analysis revealed a one-way causality from trade globalization/financial/political globalization to the food security, and a two-way causality between food security and social globalization. So, the main globalization types also had significant effects on the food insecurity in the short run.

Conclusions. The economic, social, and political globalization made a significant contribution to the relatively decreasing food insecurity in Middle East and North African region.

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Corresponding author:

Yilmaz Bayar
E-mail:
yilmaz.bayar@
usak.edu.tr

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Introduction

Food is the persons' most basic need together with water and essential to survive, grow, develop and maintain a healthfully life for all the human beings. In this regard, food security is commonly defined as the physical, economic, and social access of all the persons to adequate, safe and nutritive food for a healthy, productive and active life at any time and the main components of the food security are food availability, access, utilization, and stability [1,2]. In this context, provision of food security is essential for the human development, as one of the main components of growth and economic development of the nations [3]. Therefore, it is one of the leading priorities for the governments to plan and execute the right policies for the sufficient the food security level.

The undernourishment, malnourishment and hunger are the major results of the food insecurity. The globalized world experienced gradual improvements in the number of undernourished people and the number of people undernourished decreased 914.5 million in 1999 to 784.4 million in 2015, but the trend has seemed to become reversed and projected to be 820.8 million in 2017 and corresponded to about one out of every nine people in the world [4]. The determination of the causes underlying the food security is very important to take right measures in fight with food insecurity. In this regard, many institutional, social, economic, and political factors, poverty, and natural disasters (floods, droughts, earthquakes), and epidemic illnesses have been documented as the main drivers of the food insecurity.

Globalization process eliminated the boundaries to a large extent among the countries and raised the integration of economies in terms of goods, services and capital flows, also led the cultural, technological and political integration [5]. The benefits and costs of the globalization are one of the much-debated issues in the related literature. The scholars generally have focused the effect of globalization and major globalization types (e.g. financial globalization, trade globalization, political globalization, and social globalization) on the growth, financial sector development, poverty, inequality, environment [6, 7, 8, 9]. However, globalization process may affect the food insecurity through increasing economic growth, efficiency, transfer of technology and know-how, the change of relative prices, price volatility, climate change, but the net influence of the globalization on the food insecurity depends on the sum of aforementioned factors' effects. Furthermore, increasing trade openness may raise the amount of food availability and range to the counties and thus make a contribution to the food security [10].

Middle East & North African (MENA) region has a heterogeneous structure in terms of economic development and food insecurity as seen in Table 1. MENA region is one of the richest oil and gas reserves regions and made 45% of global crude oil exports and 31% of global liquefied natural gas in 2017 [11]. However, MENA region is the least peaceful region in the world [12]. The civil wars in Syria, Iraq, Libya, and Yemen has given damages to physical capital and human capital and in turn to the production. Further, the pressure imposed to the Qatar by Bahrain, Egypt, Saudi Arabia, and the UAE has raised the instability in the region. Also the economic and political instability, and internal conflicts in the region countries and the fluctuations in commodity prices are the major threats to the development of the countries. Algeria, Djibouti, Morocco, and Oman experienced significant improvements in the food security taking into account all of these. Only deteriorations were seen in the food security of Lebanon, Yemen and Jordan, but Iraq has high food insecurity levels majorly resulting from the raising civil war. Lastly, Egypt, Iran, Israel, Saudi Arabia, Tunisia, and UAE from the MENA region sustained their reasonable food insecurity levels.

Table 1
Prevalence of undernourishment and economic development in MENA region

Countries	Prevalence of undernourishment		Real gross domestic product per capita	
	1999	2015	1999	2015
Algeria	10.7	4.7	10,248.75	13,692.85
Djibouti	48.1	19.7	2,465.69	3,015.13
Egypt	5.2	4.8	8,249.54	11,308.58
Iran	4.9	4.9	12,463.25	16,065.25
Iraq	28.3	27.7	Not available	14,429.99
Israel	<2.5	<2.5	24,803.00	32,038.70
Jordan	12.6	13.5	7,061.78	8,490.29
Lebanon	<2.5	10.9	12,825.73	17,553.62
Morocco	6.8	3.9	4,598.92	7,554.50
Oman	11.9	5.4	39,338.85	43,987.80
Saudi Arabia	6.1	5.5	42,371.76	51,608.70
Tunisia	4.9	4.9	7,333.91	10,765.87
United Arab Emirates (UAE)	<2.5	2.5	95,012.82	63,606.11
Yemen	29.9	34.4	3,769.32	2,912.48

Source: [13, 14]

The relevant literature revealed many economic, social, and institutional determinants of the food insecurity. However, the limited number of scholars have focused on the effect of accelerating globalization process as of late 1980s on the food security. The studies generally have researched the effect of trade openness or liberalization of agriculture sector on the food security as seen in literature review section. However, the globalization is a multifaceted process and not only trade globalization but also financial globalization, social globalization, and political globalization may affect the food insecurity. In this study, we aim making a contribution to the relevant literature by focusing on the untouched area and using second generation econometric tests considering the cross-sectional dependence and heterogeneity in relevant literature. Within this scope, our sample is MENA region, because MENA region experienced a similar globalization pattern with the world as seen in Figure 1 and the region also is one of the least food insecure regions in the world.

The rest of the article is constructed as the following. The forthcoming part briefly summarizes the relevant literature on the effect of globalization on the food security. Then the dataset and empirical analysis method are defined, and the empirical analyses are performed and the main findings of the analyses are presented. Lastly, the conclusions are presented.

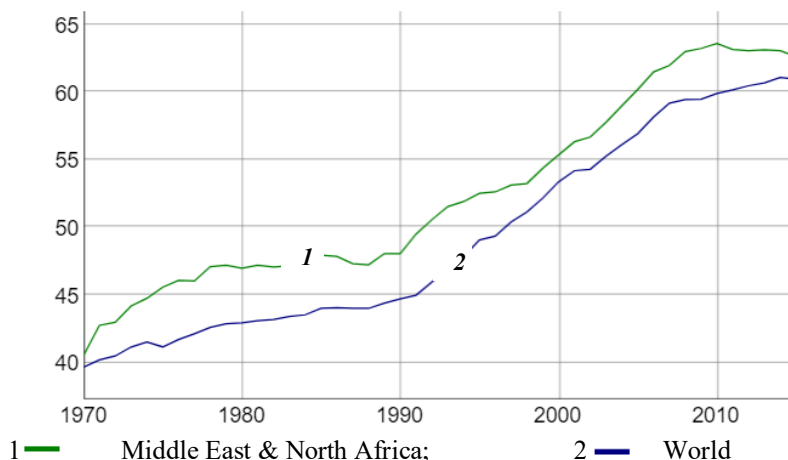


Figure 1. KOF globalization index of MENA and world

Source: KOF Swiss Economic Institute, 2018

Literature review

Food security and its implications are one of the most discussed and to be sought for solution in the globalized world. Globalization process, the crucial development of the past four decades, have potential to affect the food insecurity through its main components food access, availability, utilization, and stability by raising the economic growth, efficiency, and mobility of goods, services, and capital, transfer of technology and know-how, the change of relative prices, price volatility, and change of climate and environment. As a result, the interaction between types and implications of globalization and food insecurity have been researched widely until now, but most of the studies focus on theoretical considerations about food security [e.g. see 15, 16, 17]. Only a limited number of scholars have empirically researched the effect of globalization represented by agricultural trade openness and trade openness on the food security and reached mixed findings as described below.

In one of the studies, [18] investigated the influence of trade liberalization on the food security in India with general equilibrium model and revealed that both growth and poverty reduction resulting from trade liberalization did not raise the food security. [19] researched the effect of agricultural trade openness on the food security in Sub-Saharan Africa by a dynamic general equilibrium model and the analysis revealed that the net effects of agricultural trade openness over the food security changed depending on comparative advantage at sectoral level.

[20] researched the effect of trade liberalization on the food availability in 37 developing countries, and revealed that trade liberalization negatively affected the food availability in the short run, but trade liberalization had no significant effects on the food availability in the long run. On the other side, [21] analyzed the effect of trade openness on the food security in Sri Lanka and China over the 1980-2009 period with regression analysis and discovered no significant relationship between food security and trade openness in China, but a negative relationship for Sri Lanka.

[22] examined the influence of trade openness on the food security in 151 countries during the 1980-2007 period with regression analysis and discovered that trade openness

increased the food security in the panel. [23] analyzed the influence of trade openness on the food security with 41 policy reforms by synthetic control method over 1960-2010 period and revealed that trade liberalization decreased the food insecurity in 19 cases, increased food insecurity in 3 cases. [24] researched the impact of agricultural trade openness on food security in Iran over the period 1999-2013 with ARDL approach and revealed that agricultural trade openness raised the food security in Iran in the long run. Lastly, [25] researched the influence of regional integration over the food security in ECOWAS countries by panel regression analysis over the 1995-2012 period and revealed that international trade affects the food security positively, but regional integration had no significant effects on food security.

Data and econometric methodology

Data

In the empirical analysis, food insecurity was represented with prevalence of undernourishment calculated by Food and Agriculture Organization of the United Nations (FOA) and it reflects the share of the population who cannot consume sufficient amount of calories to cover their energy requirement for an active and healthy life. There have been different indicators showing the food security such as Global Food Security Index of Economist Intelligence Unit, and prevalence of severe food insecurity in the total population of FOA. But we selected indicator of undernourishment prevalence, because the other indicators showing the food security exists for relatively too shorter periods.

On the other side, globalization was proxied by globalization index of KOF Swiss Economic Institute. The Institute calculates the composite index based on economic, social, and political dimensions (see [5] for detailed information about the index). In the study, two components of economic globalization including trade globalization and financial globalization and social globalization and political globalization, because trade globalization and financial globalization are the featured aspects of the globalization process and also the related literature generally have concentrated on the effect of trade liberalization on the food security. Further, de facto indexes of trade and financial globalization were used, because they are calculated based on the flows of inter-country goods, services, and capital and the globalization indices generally base on de facto globalization, while de jure trade and financial globalization indexes are calculated based on trade taxes and regulations, investment restrictions, tariffs, and capital account openness. The economic globalization including trade globalization and financial globalization reflects the raising interdependence of the economies arising from the growing cross-border flows of goods, services, capital and rapidly spread of the technologies [26]. Social globalization consists of transnational movement of cultures, while political globalization reflects the raising political cooperation among the countries [27].

Table 2

Data description

Variables	Description	Source
FOODINSEC	Prevalence of undernourishment (%)	[13]
TG	Trade globalization, de facto index	[28]
FG	Financial globalization, de facto index	[28]
SG	Social globalization index	[28]
PG	Political globalization index	[28]

The data availability determined the sample and time duration of the study. The sample is composed of 14 states from MENA region (Algeria, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Tunisia, United Arab Emirates, and Yemen except Bahrain, Kuwait, Libya, Qatar, Syria, West Bank and Gaza). The time duration was 1999-2015 and all the data were annual. The econometric analysis were conducted by software of E-views 10.0 and Gauss 10.0 and Stata 14.0. The main characteristics of the dataset were shown in Table 3. The mean of food insecurity level in the panel is about 11.3, but the highest level was 48.1, and the lowest level was about 1.5 and the standard deviation was 10.

Table 3

Main characteristics of the dataset

	FOODINSEC	TG	FG	SG	PG
Mean	11.31131	60.58867	55.01497	52.03005	67.74370
Median	6.100000	62.31761	55.30032	54.28485	67.49583
Maximum	48.10000	96.50836	92.62033	74.22993	93.41541
Minimum	1.500000	10.68345	14.07935	22.69474	27.93740
Std. Dev.	10.07732	18.84615	17.75916	14.52326	15.60165
Skewness	1.455990	-0.317382	-0.125680	-0.201320	-0.255629
Kurtosis	4.008895	2.891854	2.775700	1.744227	2.104507

Econometric methodology

[29] cointegration test rests on the Lagrange multiplier (LM) developed by [30] and takes notice of cross-sectional dependence among the series. The cointegration test statistic (LM_N^+) is calculated as following:

$$LM_N^+ = \frac{1}{NT^2} \sum_{i=1}^N \sum_{t=1}^T \widehat{w}_i^{-2} s_{it}^2 \quad (1)$$

The partial sum of error terms (s_{it}^2) and long term variances (\widehat{w}_i^{-2}) is derived from cointegration model estimated by full modified ordinary least squares model. The null hypothesis supporting the presence of cointegration is tested by LM_N^+ and critical values generated by bootstrap method are utilized in the event of cross-sectional dependence. Furthermore, the test gives robust results in case of small samples due to the implemented Monte Carlo simulations. The cointegration coefficients were estimated by DSUR (Dynamic Seemingly Unrelated Cointegrating Regression) estimator of [31] considering the presence of cross-sectional dependence.

Lastly, the causal relation among food insecurity and main components of globalization was analyzed by [32] causality test rest on VAR. The test considers heterogeneity, but assumes cross-sectional independence. However, the Monte Carlo simulations denoted that the test can produce robust results even in the event of cross-sectional dependence. [32] causality test provides individual Wald statistics ($W_{i,T}$) for each cross-section and then calculates panel Wald statistic by taking arithmetic mean of the cross-sections. [32] suggest that $Z_{N,T}^{HNC}$ test statistic with asymptotic distribution should be used in case of $T > N$, while Z_N^{HNC} test statistic with semi- asymptotic distribution should be used in case of $N > T$.

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2K}} (W_{N,T}^{HNC} - K) \tag{2}$$

$$Z_N^{HNC} = \frac{\sqrt{N} [W_{N,T}^{HNC} - N^{-1} \sum_{i=1}^N E(W_{i,T})]}{\sqrt{N^{-1} \sum_{i=1}^N var(W_{i,T})}} \tag{3}$$

Empirical analysis

The presence of cross-sectional dependence among the series of food insecurity and globalization components was investigated by [33] LM test and [34] LM adjusted test, since time dimension was higher than cross-section dimension and the test results were demonstrated in Table 4. The null hypothesis of cross-section independence was declined in consideration of p values. So we inferred the presence of cross-section dependence. Then homogeneity of the cointegration coefficients was tested with adjusted delta tilde test of [35] and the results were shown in Table 4. The cointegration coefficients were found to be heterogeneous in consideration of p values of the test.

Table 4

Cross-sectional dependency and homogeneity tests' results

Cross-sectional dependence tests		
Test	Test statistic	Prob. value
LM test	32.781	0.001
<i>LM_{adj.}</i> test	39.066	0.002
Homogeneity tests		
Test	Test statistic	Prob. value
Delta tilde	8.909	0.001
Delta_tilde_adj	7.653	0.016

The stationarity of the variables were explored after pre-tests of cross-sectional dependence and homogeneity. The cross sectional Augmented Dickey-Fuller (CADF) unit root test of [36] regarding the presence of cross-sectional dependence, was employed to examined the availability of unit root in the variable series and the test results were demonstrated in Table 5. Maximum lag length was applied as 2 and Schwarz information criterion was considered in determination of optimal lag length. The results revealed that all the variables were non-stationary, but became stationary after first-differencing.

Table 5

Panel CIPS unit root test results

Variables	Level		First differences	
	Constant	Constant + Trend	Constant	Constant + Trend
FOODINSEC	-1.184	-1.166	-7.531*	-9.744*
TG	-1.230	-1.202	-9.556*	-9.902*
FG	-0.973	-1.105	-7.099*	-8.126*
SG	-0.877	-1.083	-6.451*	-7.449*
PG	-1.141	-1.156	-7.834*	-8.238*

* it is significant at 5% significance level

The existence of cointegration relationship among food security and main components of the globalization was explored by [29] LM bootstrap cointegration test and the test results were demonstrated in Table 6. Further, bootstrap probability values were generated from 10000 simulations and asymptotic p-values were obtained from standard normal distribution. Lag and leads were taken as 2. Bootstrap critical values were taken in consideration due to the presence of cross-sectional dependence. Hence, the null hypothesis stating the presence of cointegration was accepted. So all the series move together in the long run.

Table 6

LM Bootstrap cointegration test results

LM_N^+	Constant			Constant+Trend		
	Test statisti c	Asymptoti c p-value	Bootstra p p- value	Test statisti c	Asymptoti c p-value	Bootstra p p- value
	0.893	0.161	0.287	6.924	0.004	0.381

The cointegration coefficients were forecasted by DSUR estimator taking notice of the presence of cross-sectional dependence and heterogeneity and the test results were demonstrated in Table 7.

Table 7

Estimation of cointegrating coefficients

Countries	Coefficients			
	TG	FG	SG	PG
Algeria	0.192*	-0.275*	-0.151*	-0.381*
Djibouti	-0.074*	0.175	0.144*	-0.251
Egypt	-0.095*	0.284	0.219*	-0.386*
Iran	0.187*	-0.187*	-0.247*	-0.337*
Iraq	0.214*	-0.155*	-0.213*	-0.293*
Israel	-0.364*	-0.128*	-0.085*	-0.065*
Jordan	0.108*	-0.062*	-0.208*	-0.188*
Lebanon	0.085*	-0.091*	-0.149*	-0.231*
Morocco	0.137*	-0.136*	-0.165*	0.276
Oman	-0.275*	-0.228*	-0.125*	-0.218
Saudi Arabia	-0.254*	-0.381*	0.254*	-0.351*
Tunisia	0.091*	-0.104*	-0.201*	-0.053*
United Arab Emirates	-0.374*	-0.299*	-0.191*	-0.375*
Yemen	-0.119*	0.162	0.083*	0.229
Panel	-0.217*	-0.235*	-0.208*	-0.249*

The results indicated that trade globalization, financial globalization, social globalization, and political globalization negatively affected the prevalence of undernourishment. In other words, the components of globalization decreased the food insecurity in overall panel. However, trade globalization decreased the food insecurity in Djibouti, Egypt, Israel, Oman, Saudi Arabia, United Arab Emirates, and Yemen, but increased the food insecurity in Algeria, Iran, Iraq, Jordan, Lebanon, Morocco, and Tunisia. On the other side, financial globalization reduced the food security in Algeria, Iran, Iraq, Israel, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Tunisia, and United Arab Emirates reduced the food insecurity, while financial globalization had no significant effects on the food insecurity in Djibouti, Egypt, and Yemen. Furthermore, social globalization decreased the food security in Algeria, Iran, Iraq, Israel, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, Tunisia, and United Arab Emirates and had no significant effects on food insecurity in Djibouti, Egypt, and Yemen. Lastly, political globalization reduced food insecurity in Algeria, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Lebanon, Oman, Saudi Arabia, Tunisia, and United Arab Emirates, but political globalization had no significant effects on the food security in Djibouti, Morocco, and Yemen.

The barriers over cross-country flows of goods, services, and capital have been considerably released and also cross-country foreign direct investments and portfolio investments, in turn transfer of technology and know-how have been raised significantly. However, frequency and severity and contagiousness of the economic and financial crises, change of relative prices and price volatility, climate and environment deteriorations have been experienced relatively more when compared with the past. So on one hand, globalization process can raise food security by increasing food availability and access, economic growth through efficiency, transfer of technology and know-how and provision of financing and better public management. On the other hand, globalization can increase the food insecurity through raising frequency and severity and contagiousness of the economic and financial crises, change of relative prices and price volatility, climate and environment deteriorations. As a consequence, the net effect of globalization and its main types over food insecurity can vary from country to country. Our empirical analysis revealed that globalization and its major components decreased the food insecurity in most of countries in the sample. However, trade globalization raised the food insecurity in countries of Algeria, Iran, Iraq, Jordan, Lebanon, Morocco, and Tunisia which experienced serious civil wars, internal disturbances, embargo, and weak economic fundamentals. Furthermore, financial and political globalization had no significant effect on the food insecurity in Yemen experiencing serious civil war, in Djibouti with weak economic fundamentals and public management,

The causal interaction among food security and the components of globalization were examined with [32] causality and the test results were demonstrated in Table 8. The results revealed a one-way causality from trade globalization/financial/political globalization to the food security, and a two-way causality between food security and social globalization. So, the main globalization types also had significant effects on the food insecurity in the short run.

Table 8

Causality test results

Null hypothesis	Test	Statistics	Prob.
FOODINSEC→TG	<i>W</i> _{bnc}	1.296	0.287
	<i>Z</i> _{bnc}	1.442	0.293
	<i>W</i> _{bnc}	1.075	0.195
TG→FOODINSEC	<i>W</i>_{hnc}	4.732	0.000
	<i>Z</i>_{hnc}	5.029	0.000
	<i>Z</i>_{tild}	4.726	0.001
FOODINSEC→FG	<i>W</i> _{bnc}	0.954	0.187
	<i>Z</i> _{bnc}	0.833	0.291
	<i>Z</i> _{tild}	0.907	0.125
FG → FOODINSEC	<i>W</i>_{hnc}	3.732	0.000
	<i>Z</i>_{hnc}	2.877	0.001
	<i>Z</i>_{tild}	3.023	0.003
FOODINSEC→SG	<i>W</i>_{hnc}	4.202	0.000
	<i>Z</i>_{hnc}	3.761	0.002
	<i>Z</i>_{tild}	5.281	0.025
SG →FOODINSEC	<i>W</i>_{hnc}	4.384	0.000
	<i>Z</i>_{hnc}	3.945	0.001
	<i>Z</i>_{tild}	4.113	0.000
FOODINSEC→PG	<i>W</i> _{bnc}	1.287	0.274
	<i>Z</i> _{bnc}	1.375	0.256
	<i>Z</i> _{tild}	0.988	0.197
PG →FOODINSEC	<i>W</i>_{hnc}	5.606	0.000
	<i>Z</i>_{hnc}	3.734	0.011
	<i>Z</i>_{tild}	4.563	0.008

Conclusion

The undernourishment, malnourishment and hunger have been the serious problems of the humankind resulting from the food insecurity. However, improvements in both undernourishment and hunger have been experienced partially together with accelerating globalization as of 1990s. However, most of the studies theoretically analyzed the interaction between globalization, especially trade openness/agricultural trade openness and food security in the related literature, but the number of empirical studies about the globalization-food insecurity nexus has remained restricted. This study investigates the roles of various globalization types on the food insecurity in Middle East and North African countries over the period 1999-2015 with panel cointegration and causality analyses considering the untouched area in the relevant literature.

The empirical analysis revealed that trade, financial, social, and political globalization generally made a significant contribution to the relatively decreasing food insecurity in Middle East and North African region in both short and long run. So, the benefits of globalization outweigh the costs in terms food insecurity. However, MENA region includes very heterogeneous countries in terms of economic and institutional development, demographic, religious, and social structure, and natural resources (especially oil and natural

gas). Furthermore, the region is also the least peaceful part of the world and some countries (e.g. Yemen, Iraq, and Lebanon) are experiencing serious civil wars, while the others (e.g. Morocco, Saudi Arabia, and Tunisia) had serious internal conflicts, political instability, and weak economic fundamentals. Lastly, the variations in the prices of oil and natural gas seriously affect the economies of oil and gas-rich countries. Consequently, the effect of major globalization types on food security can be raised by the countries to take measures to increase the peaceful environment and decrease the dependence of the countries on the energy.

References

1. Food and Agriculture Organization of the United Nations (1996), World Food Summit, Available at: <http://www.fao.org/docrep/003/w3613e/w3613e00.htm>
2. Food and Agriculture Organization of the United Nations (2006). Food Security, Available at: http://www.fao.org/fileadmin/templates/faoitally/documents/pdf/pdf_Food_Security_Cocept_Note.pdf
3. World Bank (2006), *Repositioning nutrition as central to development: A strategy for large-scale Action*, Washington.
4. Food and Agriculture Organization of the United Nations (2018a), *The State of Food Security and Nutrition in the World: Building Climate Resilience for Food Security and Nutrition*, Rome
5. Gygli S., Haelg F., Sturm J.E. (2018), The KOF Globalisation Index – Revisited. KOF Working Papers, No. 439, Available at: <https://www.research-collection.ethz.ch/handle/20.500.11850/238666> (18.11.2018)
6. van Veen-Groot D.B., Nijkamp P. (1999), Globalisation, transport and the environment: New perspectives for ecological economics, *Ecological Economics*, 31(3), pp. 331-346, DOI: 10.1016/S0921-8009(99)00099-3
7. Wade R.H. (2004), Is globalization reducing poverty and inequality? *World Development*, 32(4), pp. 567-589, DOI: 10.1016/j.worlddev.2003.10.007
8. Ying Y.H., Chang K., Lee C.H. (2014), The impact of globalization on economic growth, *Romanian Journal of Economic Forecasting*, 27(2), pp. 25-34.
9. Zahonogo P. (2018), Globalization and economic growth in developing countries: Evidence from Sub-Saharan Africa, *International Trade Journal*, 32(2), pp. 189–208, DOI:10.1080/08853908.2017.1333933
10. Guha-Khasnobis B., Acharya S.S., Davis B. (2007), *Food security indicators, measurement, and the impact of trade openness*, Oxford University Press WIDER Studies in Development Economics Series.
11. BP (2018), BP Statistical Review 2018, Available at: <https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review/bp-stats-review-2018-middle-east-insights.pdf>
12. Institute for Economics & Peace (2018), Global Peace Index 2018, Measuring Peace in a Complex World, : <http://visionofhumanity.org/reports>
13. Food and Agriculture Organization of the United Nations (2018b), Food Security Indicators, http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.W_EJLegzZPY
14. World Bank (2018), GDP per capita (constant 2010 US\$), <https://data.worldbank.org/indicator/NY.GDP.PCAP.KD>)

15. Kaufmann C., Heri S. (2007), Liberalizing trade in agriculture and food security—Mission impossible? *Vanderbilt Journal of Transnational Law*, 40, pp. 1039–1070.
16. Mukherji I.N. (2014), Agricultural trade liberalization for food security in South Asia. United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) Development Papers 1404.
17. Stefanis C. (2014), Global food security: An agricultural perspective. *Journal of Agriculture and Sustainability*, 6(1), pp. 69–87.
18. Panda M., Kumar A.G., (2009), Trade liberalization, poverty, and food security in India, IFPRI Discussion Paper 00930.
19. Chikhuri K. (2013), Impact of alternative agricultural trade liberalization strategies on food security in the Sub-Saharan Africa region, *International Journal of Social Economics*, 40(3), pp. 188–206, DOI:10.1108/03068291311291491
20. Bezuneh M., Yiheyis Z. (2014), Has trade liberalization improved food availability in developing countries? An empirical analysis, *Journal of Economic Development*, 39(1), pp. 63–68.
21. Herath H.M.S.P. (2014), Has trade liberalization improved food security? A comparative study on China and Sri Lanka. *European Journal of Business and Management*, 6(18), pp. 62–67.
22. Dithmer J., Abdulai A. (2017), Does trade openness contribute to food security? A dynamic panel analysis, *Food Policy*, 69, pp. 218–230, DOI:10.1016/j.foodpol.2017.04.008
23. Olper A., Curzi D., Swinnen J.F.M. (2017), Trade liberalization and child mortality: A synthetic control method. LICOS Discussion Paper Series, No. 387, LICOS, Leuven
24. Arsalan B., Hamid M. (2018), The effect of agriculture trade openness on food security in Iran (ARDL Approach), *Journal of Agricultural Economics Research*, 10(2), pp. 81-103.
25. Tinta A.A., Sarpong D.B., Ouedraogo I.M., Hassan R.A., Mensah-Bonsu A., Onumah E.E. (2018), The effect of integration, global value chains and international trade on economic growth and food security in ECOWAS, *Cogent Food & Agriculture*, 4, pp. 1–15, DOI: 10.1080/23311932.2018.1465327
26. Shangquan G. (2000), *Economic globalization: Trends, risks and risk prevention*, Available at:
http://www.un.org/en/development/desa/policy/cdp/cdp_background_papers/bp2000_1.pdf
27. Goryakin Y., Lobstein T., James P.T., Suhrcke M. (2015), The impact of economic, political and social globalization on overweight and obesity in the 56 Low and Middle Income countries, *Social Science & Medicine*, 133, pp. 67–76, DOI: 10.1016/j.socscimed.2015.03.030
28. KOF Swiss Economic Institute (2018), KOF globalisation index, <https://www.kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html>
29. Westerlund J., Edgerton D.L. (2007), A panel bootstrap cointegration test, *Economics Letters*, 97(3), pp. 185–190, DOI: 10.1016/j.econlet.2007.03.003
30. McCoskey S., Kao C. (1998), A residual-based test of the null of cointegration in panel data, *Econometric Reviews*, 17(1), pp. 57–84.
31. Mark, N., Ogaki M., Sul D. (2005), Dynamic seemingly unrelated cointegrating regressions. *Review of Economic Studies*, 72(3), pp. 797–820.

32. Dumitrescu E.I., Hurlin C. (2012), Testing for Granger non-causality in heterogeneous panels, *Economic Modelling*, 29(4), pp. 1450–1460, DOI:10.1016/j.econmod.2012.02.014
33. Breusch T.S., Pagan A.R. (1980), The lagrange multiplier test and its applications to model specification tests in econometrics, *Review of Economic Studies*, 47, pp. 239–53.
34. Pesaran M.H., Ullah A., Yamagata T. (2008), A bias-adjusted LM test of error cross-section independence, *Econometrics Journal*, 11(1), pp. 105–127.
35. Pesaran M. H., Yamagata, T. (2008), Testing slope homogeneity in large panels, *Journal of Econometrics*, 142, pp. 50–93.
36. Peseran M.H. (2007), A simple panel unit root test in the presence of cross-section dependency, *Journal of Applied Econometrics*, 22, pp. 265–312.

Анотації

Харчові технології

Гістологічні дослідження котлет із використанням борошна сочевиці

Ірина Сімонова¹, Людмила Пешук², Олег Галенко²

1 – Львівський національний університет ветеринарної медицини та біотехнологій ім. Гжицького

2 – Національний університет харчових технологій

Introduction. Проведено гістологічні дослідження посічених напівфабрикатів, до складу яких входить м'ясо птиці та борошно пророщеної сочевиці з метою визначення складових рецептури та їх характеристики для подальшої ідентифікації цих компонентів.

Materials and methods. Для гістологічного дослідження відповідні зразки посічених напівфабрикатів фіксували у 10% нейтральному розчині формаліну. Після цього фіксований матеріал зневоднювали у ряді розчинів спирту з висхідними концентраціями 70, 80, 90, 96°, ущільнювали у двох порціях хлороформу та заливали в парафін. На санному мікротомі виготовляли зрізи, завтовшки від 5 до 15 мкм, які фарбували гематоксиліном та еозином. Світлову мікроскопію і мікрофотографування гістопрепаратів здійснювали за допомогою мікроскопа.

Results and discussion. Під час замочування сочевиці з метою пророщування, початкова вологість становила 15%, а після 8 год досягла ступеня замочування 35%, що впливає на процеси росту та обміну речовин у зерні, на утворення ферментів. Для мінімізації втрат поживних речовин під час пророщування контролюють тривалість пророщення й температуру пророщування, що в середньому триває від 72 год до 88 год при температурі 17 ± 2 °C.

Гістологічне дослідження дослідних посічених напівфабрикатів виявило полігональні і круглі м'язові волокна з вираженими ядрами під сарколемою, що відповідає доброякісній м'ясній сировині, тобто використано охолоджене м'ясо. Додавання у виробі борошна сочевиці пророщеної призводить до покращення ступеня набрякання волокон і більш активного накопичення між частинками фаршу дрібнозернистої білкової маси, що покращує умови формування виробів та їх структуру. Клітини оболонки борошна сочевиці фарбуються у рожевий колір, формують щільні напівпрозорі структури, які схожі на нитку клітин з помітною целюлозною оболонкою фіолетового кольору. Структура фаршу є рівною і гомогенною, компоненти добре перемішані, в результаті чого спостерігається розпушування волокон.

Conclusions: Охарактеризовано метод отримання борошна пророщеної сочевиці та ідентифіковано компоненти посічених напівфабрикатів. Борошно сочевиці пророщеної має вигляд нитки клітин фіолетового кольору, клітини перцю та цибулі – коричневий колір.

Ключові слова: м'ясо, птиця, сочевиця, борошно, котлети.

Кореляційний взаємозв'язок між показниками якості активного вугілля, що застосовується у технології горілки

Тетяна Шендрік¹, Леонід Левандовський²,
Анатолій Куц³, Віталій Прибыльський³, Маргарита Карпугіна³

1 – Інститут фізико-органічної хімії і вуглехімії імені Л.М. Литвиненка НАН
України, Київ, Україна

2 – Київський національний торговельно-економічний університет, Київ, Україна

3 – Національний університет харчових технологій, Київ, Україна

Вступ. Метою публікації є встановлення кореляційних зв'язків між показниками якості активного вугілля (АВ), яке використовується у лікеро-горілчаному виробництві у технології горілки.

Матеріали і методи. АВ природного походження, яке застосовується для лікеро-горілчаного виробництва. Стандартні методи визначення та кількісні характеристики показників якості АВ. Математико-статистичні методи дослідження – лінійний кореляційний аналіз за коефіцієнтом кореляції Пірсона.

Результати. Знайдено, що коефіцієнт парної кореляції (r) між адсорбційною активністю за йодом (A_i), яка характеризує кількість і об'єм мікропор АВ з діаметром $D_{mi} < 2$ нм, у тому числі нанопор з діаметром $D_{mi} < 1$ нм, і за метиленовим блакитним ($A_{m.b.}$), яка залежить від об'єму мезопор з діаметром $D_{me} = 2 \dots 50$ нм, дорівнює 0,93. Сумарний об'єм мікро- і мезопорового простору визначає сумарну сорбційну здатність АВ відносно органічних домішок, присутніх у водно-спиртових сумішах. Сорбційна активність АВ залежить також від його фракційного складу. Встановлена кореляція (зворотня залежність) між адсорбційною активністю за оцтовою кислотою ($A_{o.a.}$) і масовою часткою залишку сорбенту на ситі з полотном № 10 ($F_{№10}$) з коефіцієнтом $r = -0,94$. Зменшення масової частки залишку на ситі з полотном від 97...98% до 62...64% призводить до збільшення адсорбційної активності АВ за оцтовою кислотою до 117 мл проти 62 мл. Це прямо пов'язано з тим, що залишки сорбенту на ситі № 10 мають велику площу поверхні мікропорового і мезопорового простору через зменшені розміри зерен. Сумарний об'єм пор сорбентів по воді ($T_{p.v.}$) знаходиться в прямій залежності від масової частки водорозчинної золи ($M_{w.a.}$) $r = 0,92$ і масової частки вологи (M_m) при $r = 0,99$. З метою звільнення АВ від водорозчинної золи і збільшення об'єму порового простору логічно буде процедура відмивання АВ підготовленою водою з наступним його сушінням до вмісту води у вугіллі до 2%. Встановлено, що масова частка залишку сорбенту на ситі з полотном № 36 ($F_{№36}$) знаходиться у прямій залежності від масової частки золи (M_a) ($r = 0,91$) і масової частки водорозчинної золи ($M_{w.a.}$) ($r = 0,91$), що опосередковано свідчить про вплив неорганічних компонентів АВ на його механічну міцність. Припущено, що в найбільших за розмірами фракціях АВ з масовою часткою залишку на ситі з полотном № 36 ($F_{№36} = 2,1\%$) вміщується в макропоровому просторі більше золи ($M_a = 5,12\%$), у тому числі водорозчинної золи ($M_{w.a.} = 1,95\%$).

Висновки. В результаті аналізу стандартних показників якості АВ та дослідження їхніх взаємних залежностей за допомогою математико-статистичного методу з використанням коефіцієнтів парної кореляції Пірсона встановлено, що 92% (12 з 13) показників мають сильні внутрішні взаємозв'язки, які характеризуються «дуже високою» силою кореляції з коефіцієнтами $r = 0,90 \dots 0,99$.

Ключові слова: активне вугілля, сорбція, горілка, кореляція.

Протимікробна і протигрибкова активність модельних препаратів на основі рослинних екстрактів у системній концепції здоров'я

Микола Осейко¹, Василь Шевчик², Олена Покришко³

1 - Національний університет харчових технологій, Київ, Україна

2 - "Мікрохірургія очей Василя Шевчика", Чернігів, Україна

3 - Тернопільський державний медичний університет імені І.Я. Гробачевський, Тернопіль, Україна

Вступ. Ми проаналізували протимікробну та протигрибкову активність зразків препарату КТІОЛ-БФ на стандартні та резистентні тест-штами мікроорганізмів. Розглянуто аспекти мікробіоми та системної концепції здоров'я.

Матеріали і методи. Були використані штами грам-позитивних та грам-негативних мікроорганізмів: *S. aureus*, *S. saprophyticus*, *E. coli*, *P. aeruginosa*, *S. epidermidis* і *C. albicans* гриби. Досліджено модельні препарати на основі рослинних екстрактів. Метод дифузії речовин в агар був використаний для визначення активності препаратів щодо штамів.

Результати і обговорення. Сучасний стан фізичного, психологічного та соціального існування людини сприяє пришвидшеному розповсюдженню патогенних мікроорганізмів і виникненню резистентної мікрофлори. В останні роки майже всі страждають від грибкових захворювань. Актуальною є проблема здоров'я і здорового способу життя. Глобальною є проблема забезпечення людства їжею. Розглянуто аспекти мікробіому (ендоекологічні аспекти). Важливість мікробіоти кишечника в здоров'ї людини і патофізіології є безперечною. Запропоновано системну концепцію здоров'я (Система КТІОЛ[®]: 10 основних положень щодо профілактики, оздоровлення, лікування та реабілітації).

Досліджуемі тест-мікроорганізми були чутливими до модельних зразків препарату КТІОЛ-БФ (BF1-BF20). Найефективними щодо тест-штаму *S. Saprophyticus* виявилися зразки BF2, BF12, BF17. Виявлено що до зразка препарату BF34 тест-мікроорганізм *S. epidermidis* був найефективним (зона затримки росту становила $30,40 \pm 1,29$ мм). Найвищу протигрибкову активність мали зразки КТІОЛ-БФ: BF33, BF37. Зони росту грибів становили відповідно $20,76 \pm 1,65$ і $22,62 \pm 1,44$ мм. Високу інгібуючу дію до клінічних резистентних штамів мікроорганізмів проявили зразки препарату КТІОЛ-БФ: BF-70, BF-87, BF-92. Діаметр зони інгібування резистентних штамів у КТІОЛ-БФ87 склав 22,17 мм, діаметр у контрольного зразка PVI був 13,05 мм

Висновки. Виявлено підвищену протимікробну та протигрибкову активність препаратів КТІОЛ-БФ щодо грам-позитивних і грам-негативних мікроорганізмів, грибків *S. Albicans* та резистентних штамів (контроль PVI). Показано, що кожній людині необхідно мати якісний і безпечний мікробіом.

Ключові слова: КТІОЛ, екстракт, мікроорганізм, резистентність, мікробіом.

Технологічні аспекти процесів визрівання та фризрування сумішей молочно-овочевого морозива

Вікторія Сапіга, Галина Полішук, Тетяна Осьмак,
Артур Михалевич, Максим Масліков

Національний університет харчових технологій, Київ, Україна

Вступ. Проведено аналіз сучасного асортиментного ряду морозива. Обґрунтовано вибір рослинної сировини, як перспективного інгредієнту молочного морозива.

Матеріали та методи. М'яке морозиво виготовляли за допомогою фризера періодичної дії. Відбір проб, підготовку їх до аналізу та оцінку якісних показників сумішей для морозива та зразків морозива проводили на основі визначення кріоскопічної температури, опору таненню, розмірів повітряних бульбашок, збитості м'якого морозива та динамічної в'язкості сумішей.

Результати і обговорення. На основі комплексного аналізу теоретичних і експериментальних матеріалів досліджень розроблено новий вид молочно-овочевого морозива, до складу якого входить функціонально-технологічний наповнювач – паста із буряка та броколі у кількості 10–20%, що дає змогу отримати продукт з гарантованими показниками якості. Встановлений діапазон значень кріоскопічної температури нового виду молочно-овочевого морозива практично співпадає з таким для морозива молочного жирністю від 0,5 до 7,5% і становить від $-2,22$ до $-2,67^{\circ}\text{C}$. Підтверджено можливість виробництва морозива за загальноприйнятими режимами низькотемпературного оброблення. За величинами коефіцієнта динамічної в'язкості обґрунтовано раціональні режими визрівання молочно-овочевих сумішей.

Висновки. Новий вид молочно-овочевого морозива характеризується високою харчовою цінністю і може бути рекомендований до широкого впровадження.

Ключові слова: *морозиво, буряк, броколі, паста.*

Вміст амінокислот у екструдованих кормових сумішах

Тетяна Тракало, Олег Шаповаленко, Тетяна Янюк

Національний університет харчових технологій, Київ, Україна

Вступ. Досліджено амінокислотний склад екструдованих кормових сумішей із використанням лляного екстракту на основі води. Розраховано амінокислотний скор та визначено біологічну цінність білка екструдованих кормових сумішей.

Матеріали і методи. Ми досліджували екструдовані кормові суміші з пшениці, кукурудзи, пшениці, екстракту на основі води, що мають різний відсотковий вміст. Суміші перемішували і екструдували при температурі 110–120 °С, тиску 2–4 МПа. Концентрацію вільних амінокислот визначали методом іонообмінної хроматографії.

Результати та обговорення. Проведені дослідження амінокислотного складу екструдованих кормових сумішей дозволили ідентифікувати і чисельно визначити 9 незамінних амінокислот (валін, лейцин, ізолейцин, лізин, метіонін, фенілаланін, треонін, аргінін, гістидин) і 8 замінних амінокислот (аспарагінова кислота, цистеїн, серин, тирозин, глутамінова кислота, гліцин, аланін), також описані розрахунки оцінки амінокислот екструдованих кормових сумішей, що дозволяють отримати дані про кожну амінокислоту, визначити першу лімітуючу амінокислоту, обчислити коефіцієнт

розбіжності амінокислотного скору та біологічну цінність досліджуваних зразків екструдата.

Найбільше незамінні амінокислоти містять суміші № 1 – 42,82% на 100 г білка і № 2 – 41,27% на 100 г білка.

Вміст лейцину, лізину і треоніну в білку сумішей становить 8,34-9,8% 100 г, 3,44-3,84% 100 г, і 2,67-3,75% 100 г, відповідно, що підтверджує високу білкову цінність екструдованих кормових сумішей.

За допомогою розрахунків визначено, що найбільшою біологічною цінністю володіє білок суміші №1 – 70,25%. Ця суміш виявилася найбільш збалансованою за амінокислотним складом порівняно з іншими сумішами. Найменший показник біологічної цінності встановлено в суміші № 3 – 65,25%, що пояснюється більшою різницею амінокислотних показників, ніж інші амінокислоти.

Висновок. Додавання льяних екстрактів до складу зернових сумішей є ефективним методом підвищення біологічної цінності екструдованих кормових сумішей, так як екстракт дозволяє збільшити вміст білка і амінокислот.

Ключові слова: білок, амінокислота, лізин, екструзія, льон, екстракт, корм.

Основні напрями застосування активного вугілля у лікеро-горілчаному виробництві

Тетяна Шендрік¹, Леонід Левандовський²,
Анатолій Куц³, Віталій Прибильський³, Олена Грабовська³

1 – Інститут фізико-органічної хімії та вуглехімії імені Л.М. Литвиненка НАН
України, Київ, Україна

2 – Київський національний торговельно-економічний університет, Київ, Україна

3 – Національний університет харчових технологій, Київ, Україна

Вступ. Метою публікації є оцінка якості та перспектив застосування активного вугілля природного походження за його фізико-хімічними показниками для лікеро-горілчаного виробництва – для очищення водно-спиртових сумішей від домішок у технології горілки.

Матеріали і методи. Активне вугілля – як сировина для очищення водно-спиртових сумішей у технології горілок. Методи дослідження: адсорбційна активність за йодом; адсорбційна активність за оцтовою кислотою; адсорбційна активність за метиленовим блакитним; сумарний об'єм пір по воді; насипна щільність активного вугілля; фракційний склад; масова частина золи; масова частина заліза; масова частина вологи; міцність на стирання.

Результати. Активне вугілля рослинного походження марок БАУ-А, БАУ-А-ЛВЗ, БАУ-А-Аг, МеКС, КАУ-А, КДС-А за комплексом показників не в повному обсязі задовольняє підвищеним вимогам лікеро-горілчаного виробництва.

Активне вугілля марки БАУ-А має стандартні значення показників: адсорбційна активність за йодом – 62%; адсорбційна активність за оцтовою кислотою – 64 мл; адсорбційна активність за метиленовим блакитним – 129 мг/г; сумарний об'єм пор по воді – 1,72 см³/г; насипна щільність – 215 г/дм³; масова частина залишку на ситі з полотном: № 36 – 1,6%; № 10 – 98%; на піддоні – 0,4%; масова частина золи – 4,7%; масова частина водорозчинної золи – 1,64%; масова частина заліза – 0,12%; масова частина вологи – 3,8%; міцність на стирання – 52,8%.

Для розширення діапазонів значень показників необхідно створювати різні

комбінації на базі вугілля марки БАУ-А або їх модифікацій БАУ-А-ЛВЗ, БАУ-А-Аг спільно з активним вугіллям кісточковим (МеКС), кокосовим (КАУ-А) і антрацитом (КДС-А). Активне вугілля марки МеКС по відношенню до БАУ-А має вищі значення: адсорбційної активності за йодом на 32%; адсорбційної активності за оцтовою кислотою на 45,3%; адсорбційної активності за метиленовим блакитним на 52,7%; насипної щільності на 62,4%; міцності при стиранні на 37,3%. По відношенню до БАУ-А активне вугілля МеКС має нижчі значення: сумарного об'єму пор по воді на -9,6%; масової частини залишку на ситі з полотном: № 36 на -1,5%; № 10 на -7,6%; на піддоні на 9,1%; масової частини золи на -1,1%; масової частини водорозчинної золи на -0,4%; масової частини заліза на 0,1%; масової частини вологи на -0,6%. При цьому низькі показники одного активного вугілля можуть компенсуватися високими показниками іншого вугілля.

Висновки. Створення комбінованого активного вугілля з оптимізованими показниками (збільшеною міцністю, високим адсорбційними та каталітичними властивостями, розвиненою пористою структурою) дозволить йому відповідати підвищеним вимогами лікєро-горілчаного виробництва та активніше сорбувати органічні домішки, поліпшуючи органолептичні показники горілок.

Ключові слова: *активне вугілля, алкоголь, горілка, очищення.*

Процеси, обладнання і системи контролю

Програмно-апаратний комплекс автоматизованої системи керування електроспоживанням та електропостачанням підприємства харчової промисловості

Сергій Балюта, Людмила Копилова, Юлія Куєвда

Національний університет харчових технологій, Київ, Україна

Вступ. Проведені дослідження процесу керування електроспоживанням та електропостачанням підприємства харчової промисловості з метою підвищення ефективності передавання та використання електроресурсів.

Матеріали та методи. Дослідження виконані на основі методів побудови інформаційних систем та сучасного технічного обладнання автоматизації енергетичних об'єктів.

Результати і обговорення. Для побудови інформаційної структури системи керування використовується інформаційна модель даних, яка будується за об'єктно-орієнтованим принципом.

Виконано декомпозицію процесу керування електропостачанням та електроспоживанням і встановлені функції керування, взаємодія між ними та із користувачами системи.

Задачі керування електроспоживанням та електропостачанням реалізуються за допомогою програмно-апаратного комплексу (ПАК). Програмна частина ПАК включає в себе алгоритми рішення задач оперативного керування електроспоживанням та електропостачанням, засоби взаємодії компонентів системи із БД і операційною системою (ОС), а також графічну оболонку взаємодії інформаційно-обчислювального комплексу з енергодиспетчером. Зв'язки між пристроями верхнього рівня АСКЕЕПП організують у вигляді локальної обчислювальної мережі Ethernet по

протоколу TCP/IP зі швидкістю передачі не менше 10 Мбіт /с. Канали зв'язку між верхнім рівнем АСКЕЕПП і контролерами нижнього рівня повинні бути, як правило, волоконно-оптичними, що забезпечує абсолютну перешкодозахищеність. При побудові ПТК враховуються умови забезпечення інформаційної безпеки.

Висновки. Використання програмно-апаратного комплексу, створеного на основі інформаційної структури, розробленої згідно методології UML, забезпечує високу ефективність систем керування електроспоживанням та електропостачанням підприємства харчової промисловості.

Ключові слова: електроенергія, керування, електроспоживання, електропостачання, алгоритм.

Технічна оцінка ефективності засобів термокомпенсації стріл провисання проводів леп, розроблених в Україні та США

Анатолій Українець, Володимир Шестеренко, Володимир Романюк
Національний університет харчових технологій, Київ, Україна

Вступ. Проведення комплексного аналізу методів і задач для забезпечення ефективного впровадження інноваційних термокомпенсуючих пристроїв.

Матеріали і методи. Використовувались фізичне та математичне моделювання процесів, положення теорії автоматичного керування, теорія нечіткої логіки.

Результати і обговорення. Компенсація провисання проводів повітряних ліній електропередачі (ЛЕП) створює умови, за яких можливо або збільшувати прольоти, або знижувати висоту опор при збереженні існуючих розрахункових прольотів. У результаті знижується питома витрата опор, лінійної арматури, ізоляції, скорочуються терміни будівництва ЛЕП. Враховуючи існуючі норми можна збільшити габаритний прольот ПЛ різних класів напруг на 7–10%.

За результатом проведеного дослідження розроблено методику розрахунку та оптимізації існуючих пристроїв термокомпенсації стріл провисання проводів ЛЕП. Запропоновано багатофункціональний пристрій компенсації температурних стріл провисання ЛЕП, що дозволяє оптимізувати як діючі ЛЕП, так і запроектовані.

Висновки. Результати роботи доцільно використати в електричних мережах з повітряними лініями електропередачі всіх напруг. Український термокомпенсатор є новим класом обладнання для ЛЕП, який вирішує проблему температурного подовження проводів, використовуючи матеріал, який реагує на зміни температури зміною своєї геометричної форми та розмірів, і відрізняється вищою надійністю, ніж американський.

Ключові слова: термокомпенсатор, стріла провисання, прольот, провід, електропередача.

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Для всіх (!) елементів статті шрифт – **Times New Roman**, кегль – **14**, інтервал – 1, абзац – 1 см.

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5. Ключові слова, 3–5 слів, **але не словосполучень (!)**.

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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 Vinciguererra, 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 mikrobykh poverkhnevo-aktyvnykh rehovyn u biolohii ta medytsyni, *Biotekhnolohiia*, 4(2), pp. 24–38.

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Автори (рік), *Назва книги (курсивом)*, Видавництво, Місто.

Всі елементи після року видання розділяються **комами**.

Приклади:

1. Harris L. (1991), *Money theory*, McGraw-Hill Companies, Hardcover
2. Rob Steele (2004), *Understanding and measuring the shelf-life of food*, CRC Press.

Приклад оформлення статті, оригінал якої українською або російською мовою:

1. Kirianova H.A. (2008), Udoskonalennia tekhnolohii termostabilnykh zheleinykh nachynok shliakhom ratsionalnoho vykorystannia hidrokoloidiv roslynnoho ta mikrobnogo pokhodzhennia: PhD tethis, NUHT, Kyiv.
2. Zalutskyi I.R., Tymbaliuk V.M., Shevchenko C. H. (2009), Planuvannia i diahnostyka diialnosti pidpriemstva, *Novyi svit*, Lviv.

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<http://ufj.ho.ua/Archiv/UKRAINIAN%20FOOD%20JOURNAL%202013%20V.2%20Is.2.pdf>
2. (2013), *Svitovi naukovometrychni bazy*, available at:
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Адреса редакції:

E-mail:

Національний університет
харчових технологій
Вул. Володимирська, 68
Київ
01601
Україна

Ukrfoodscience@meta.ua

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