ATLANTIS PRESS
Advances in Social Science, Education and Humanities Research, volume 240
2nd International Scientific Conference on New Industrialization: Global, National, Regional Dimension (SICNI 2018)

The Possibility of Using "Accelerated Aging" Method to Predict the Mineral Waters Shelf Life for Non-Alcoholic Industry Enterprises

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Abstract – **The food products shelf life is the most important indicator, that determines the period of storage of finished products, ensuring its safety and quality stability. In the era of new industrialization, modern industrial technologies allow to obtain a quality product with a long shelf life. In order to establish and substantiate the values of the shelf life temporary intervals of the packaged mineral waters, it is necessary to identify and study the risk factors affecting their quality: temperature, degree of carbonization, mechanical effects, packing material, radiation; to control microbiological, physicochemical and organoleptic properties (appearance, smell, taste). Deterioration in the quality of mineral water can be caused by a quantitative change in one or several indicators, for example, a change in the organoleptic characteristics (foreign flavor, loss of transparency, change in taste) and the degree of carbonation. To justify the time intervals for mineral waters storage, a rapid assessment of the expected shelf life is relevant. The method of "accelerated aging" of packaged mineral waters is innovative in solving a complex of tasks, which are set before the industry. Researches have been conducted to study the effect of various temperature and temporary storage conditions on the stability of microbiological indicators and the chemical composition of mineral waters. Experimental data were obtained on the effect of temperature, the container material, its capacity on the chemical composition and the degree of mineral waters carbonization of different salinity, during storage at elevated temperatures. Were obtained the data on the influence of the accelerated aging process on the organoleptic characteristics stability.**

***Keywords** – shelf life, shelf life prediction, accelerated aging, express method, mineral water*

I. INTRODUCTION

One of the promising areas for assessing the change in the quality of food products for long-term storage is the method of "accelerated aging", which allows you to save time and predict certain indicators of quality and shelf life of food products, especially newly developed ones. Such testing is carried out due to the intensification of the effects of many factors causing food spoilage [1, 2].

The accelerated testing method (ASLT) and its combined variants make it possible to get a forecast for some products in just 10-15 days (instead of a year). The kinetic model of this process is the Arrhenius equation. According to this equation, as the temperature rises by 10 °C, the transience of chemical reactions doubles, including in such products: balsams, sweets, drinks, various creams, canned foods, etc. [3-8].

Forecasting the shelf life of food products is a multifactorial task. The first group of factors includes factors, affecting on the stability of the product during storage (product chemical nature, its structure, humidity, storage temperature, type of packaging, etc.). The second group of factors - combines the processes occurring in products during storage (chemical, physical, biochemical, microbiological). The third group of factors includes indicators that most objectively (or subjectively) determine changes in quality (taste, smell, color, amount of oxidized substances, and other parameters). Separately, it is necessary to note the need to constantly expand the field of evaluation criteria for the quality and development of relevant methodological bases [9, 10], including in the framework of the fight against food products falsification [11,12].

For many types of food products, the complexity of predicting shelf life increases as a result of the lack of uniform indicators by which it is possible to assess changes, occurring in a product during the entire storage period [12-17]. Development of an express method of predicting of mineral waters shelf life of various hydrochemical types is an important scientific and economic challenge for non-alcoholic industry, as it allows you to objectively assess the quality and safety of packaged water with a long shelf life (up to 24 months) in a short time.

II. LITERATURE REVIEW

In accordance with the current regulatory documents, mineral waters that are in circulation in the customs territory of the Customs Union for a prescribed expiration date, should be safe when used as intended. The shelf life and storage conditions of mineral waters are set by the manufacturer.

Data analysis of the available in the literature on the food products shelf life establishment has shown, that studies on the assessment and change of food products quality and consumer characteristics during storage, are currently carried out in three areas: traditional tests in accordance with requirements of documentation with a certain periodicity, the use of methods of mathematical modeling of changes in the food products quality and the use of methods of accelerated aging.

In this regard, of great interest are the methods of "accelerated aging", which are innovative and cost-effective, because can significantly save time and predict certain quality indicators. "Accelerated aging" involves the use of temperatures in the range of 37-50 ºC. Such an increase in temperature significantly shortens the test period, for example, to determine the shelf life of chocolates, the samples are kept at a temperature of 37 ± 1 °C for one month. Microbiological indices were chosen as the aging parameter [16,17]. The dynamics of changes in microorganisms with accelerated aging is four times faster. When determining the shelf life of canned fish, they are subjected to thermal aging for 2-3 months in the temperature range from 30 to 500 °C instead of 2-3 years. As parameters of aging, organoleptic evaluation in points and chemical quality indicators are used: the acid value of fat and the total content of sulfhydryl groups [17]. To determine the shelf life of a functional drink, the experiment was performed by the method of accelerated testing at a temperature of 600 °C [18].

Thus, the analysis of literature data showed, that the methods of "accelerated aging" of food products are based on heat treatment at elevated temperatures, the exposure time and control indicators are selected individually for a specific product type.

III. RESEARCH METHODOLOGY

The work is carried out in the laboratory of mineral waters in conjunction with the laboratory of arbitration analyzes and quality control of brewing raw materials and products and the sector of analysis of mineral and drinking waters of the Testing Center of All-Russian Scientific Research Institute of Brewing,

Beverage and Wine Industry.

Water quality was assessed by organoleptic (smell, taste) and physicochemical parameters: the magnitude of mineralization, the content of normalized and toxic compounds. Indicators determination was carried out according to approved methods, registered in the prescribed manner. For the analysis of macrocomponents - anions and cations, volumetric and instrumental methods were used: titrimetry, ion and gas chromatography, inversion voltammetry, fluorimetry, spectrometry, atomic absorption spectrophotometry with a flame and electrothermal atomizer.

Organoleptic evaluation of the mineral waters quality is carried out on a 25-point system for carbonated and on a 19-point system for non-carbonated products. Tasting was performed by the closed method.

Industrially manufactured mineral waters of 3 different hydrochemical types with mineralization from 0.5 to 14.0 g/l, carbonated and non-carbonated, packaged in consumer packaging of polyethylene terephthalate and glass were chosen as study objects. The study objects are presented in Table 1.

TABLE I. STUDY OBJECTS

Sample Cipher	Group Name	Type	M, g/l	Package
1-1	Chloride-hydrocarbonate sodium, healthy-table	non-carbonated	1,1-1,8	PET 2,0 л
1-2	Chloride-hydrocarbonate sodium, healthy-table	carbonated	1,1-1,8	PET 1,5 л
1-3	Chloride-hydrocarbonate sodium boric, healthy	carbonated	10,0-14,0	Glass 0,5 л
2-1	Sulphate-hydrocarbonate sodium, table	non-carbonated	0,5-0,8	PET 0,5 л
2-2	Sulphate-hydrocarbonate sodium, table	carbonated	0,5-0,8	PET 0,5 л

Based on the literature and personal data, the conditions of the experiment were chosen: temperature 60 °C, UV radiation (λ-253.7 nm), exposure time 30 days. Samples of packaged mineral waters were placed in a thermostat in which they were kept for a specified time. Every day, part of mineral water samples were irradiated for 15 minutes. Sampling was carried out on the 15th and 30th day of the experiment.

IV. RESULTS OF EXPERIMENTAL RESEARCHES

In accordance with the research program, the following tasks were set: the establishment and justification of the storage modes of mineral waters for their accelerated aging, the determination of the effect of UV radiation on the quality and products safety during storage, the choice of parameters characterizing the “spoilage” of products. The objectives were to obtain experimental data on the quality and safety of mineral waters, taking into account the peculiarities of using consumer packaging of various capacities, with regard to the stability of their physicochemical and microbiological indicators, under various storage conditions.

For the implementation of the first task, studies were carried out to study the stability of the basic salt composition, micro- and macro-components, physicochemical and microbiological indicators of mineral waters under storage conditions at a temperature of –60 °C for 30 days.

The study of the of microbiological indicators stability of carbonated and non-carbonated mineral waters of different mineralization depending on the storage period at a storage temperature of + 60 °C showed that with initial contamination it is much lower than the microbiological standard imposed on mineral waters, there is no growth of microorganisms during storage of mineral water, poured into a polymer or glass packaging of different capacity (Table 2).

TABLE II CHANGES IN MICROBIOLOGICAL MINERAL WATER INDICATORS (TBC AT 37 °C) DURING STORAGE AT 60 °C

Sample Cipher	**Total Bacterial Count, CFU/l**		
	Control	*15 days*	*30 days*
1-3	0	0	0
1-2	0	0	0
1-1	36	3,5	1,5

Studies of mineral water physicochemical parameters during their storage for 30 days at a temperature of 60 °C did not show statistically significant changes in the normalized indicators of the basic salt composition of the investigated mineral waters. In addition to the basic salt composition, which determines the hydrochemical type and the group of mineral waters, studies were made of possible migration products from the packaging material (Table 3).

TABLE III SUBSTANCES MIGRATION FROM PET PACKAGING DURING MINERAL WATERS STORAGE (AT T = 60 °C)

Indicator, mcg/l	**Natural Mineral Drinking Healthy-Table Water (Mineralization 1.1-1.5 g/l) in PET Packaging**					
	non-carbonated			*carbonated*		
	C	*15 days*	*30 days*	*C*	*15 days*	*30 days*
Formaldehyde	< 10	< 10	< 10	< 10	12±4	10±3
Di-2- (ethyl-hexyl) phthalate	<0,1	-	< 0,1	< 0,1	-	0.1± 0.02
Acetaldehyde	<0,02	-	0.03± 0.005	<0,02	-	0,04± 0.006

It has been established that in non-carbonated mineral water, bottled into PET packaging, after 30 days at a temperature of 60 °C there is no migration of formaldehyde and di-2-(ethylhexyl) phthalate. Acetaldehyde was detected from migration products at a concentration of 0.03 µg/l, which is significantly lower than its maximum permissible concentration in drinking water (0.2 mg/l). At the end of the experiment, insignificant concentrations of formaldehyde, acetaldehyde and di-2- (ethylhexyl) phthalate were found in carbonated water, which agrees with the literature data on the increase in the migration of these substances in carbonated water at elevated temperatures [18,19]. For mineral water in a glass bottle (sample 1-3) during storage there was a slight increase in the boron content, the concentration of which did not exceed the established standard for this group of waters.

Since mineral table waters are produced both carbonated and non-carbonated, and healthy-table and healthy (mostly) only carbonated, we studied the changes in carbon dioxide content in mineral water during storage at 60 °C taking into account the packaging material and processing method (Table 4).

TABLE IV THE CHANGE IN CARBON IOXIDE CONTENT OF THE INVESTIGATED MINERAL WATERS DURING STORAGE, DEPENDING ON THE PROCESSING AND PACKAGING MATERIAL

Sample Cipher	**Package**	**Processing Method**	**CO_2 Content, mg/l**		
			C	*15 days*	*30 days*
1-2	PET	t=60 °C	0,37	0,27	0
1-3	Grass	-«-	0,53	0,51	0,31
2-2	PET	t=60 °C + UV	0,45	0	0
2-2	-«-	UV	0,45	-	0,45

Analysis of the obtained data showed that at a temperature of 60 °C, the content of carbon dioxide in mineral water met the necessary requirements for 15 days for PET packaging and 30 days for glass bottles. Additional daily UV irradiation of mineral water in PET packaging stored at 60 °C leads to faster CO_2 migration. Irradiation of mineral water in PET packaging does not affect the concentration of CO_2 during storage of water at room temperature.

An important indicator and practically the only one by which the quality of mineral waters is estimated by the consumer is organoleptic evaluation. Organoleptic assessment of water quality is a mandatory initial procedure for sanitary-chemical water control. The organoleptic evaluation brings a lot of direct and indirect information about the composition of the water and can be carried out quickly and without any devices. Organoleptic characteristics include color, turbidity (transparency), smell, taste and flavour. The substances in drinking water, which are sensed by the organs of taste, usually include inorganic compounds. In the literature, the effect of temperature on the intensity of taste is noted [19].

It should be noted, that the appearance of samples of carbonated mineral waters in PET packaging during storage at 60 °C has changed - the bottles have somewhat swollen, the bottom has become convex. After cooling and opening (tightness is not broken), the bottles returned to their former form.

Organoleptic evaluation of the mineral waters quality with various methods of treatment are presented in Table 5.

TABLE V ORGANOLEPTIC EVALUATION OF MINERAL WATER SAMPLES

Sample Cipher	**Processing Method**	**Norm (Points)**	**Organoleptic Characteristics (Points)**		
			C	*15 days*	*30 days*
Non-carbonated					
1-1	t=60 °C	Excellent 17-19 Good 15-17 Satisfactorily 14-15	18,0	17,7	16,2
2-1	t=60 °C + UV		18,5	14,8	13,5
	UV		18,5	18,2	17,5
Carbonated					
1-2	t=60 °C	Excellent 22-25 Good 19-22 Satisfactorily 15-19	23,8	20,0	18,0
1-3	t=60 °C		25,0	24,2	21,8
2-2	t=60 °C + UV		24,5	16,8	15,0
	UV		24,5	24,5	24,3

The studied mineral waters (control), both carbonated and non-carbonated, were distinguished by high organoleptic characteristics.

The appearance of the investigated waters is a clear liquid without foreign inclusions, without sediment of mineral salts. Color is a colorless liquid. Taste and smell are characteristic of the complex contained in water substances.

It was established that during storage at 60 °C in non-carbonated mineral water for 30 days a certain decrease in the organoleptic characteristics (light outsider taste) by the end of the experiment occurs. Additional UV treatment leads to a more rapid decline in performance (to taste - the appearance of chemical taste and bitterness). Processing mineral water by UV, stored at room temperature does not significantly affect the organoleptic characteristics of non-carbonated mineral water. For carbonated water, joint treatment (temperature + UV) also leads to a rapid decrease in organoleptic characteristics during storage for 30 days.

V. CONCLUSION

As a result of the work, it was found that the method of "accelerated aging" can be used to predict the shelf life of packaged mineral waters of various hydrochemical types. It is innovative and cost-effective both for manufacturers and for governing authorities, as it allows assessing the quality and safety of products in a short time.

Analysis of the obtained data showed that the most optimal mode of mineral waters "aging" is an elevated temperature (up to 600 °C) + UV irradiation. At the same time, for carbonated water in PET packaging, it is necessary to select the temperature regime, which excludes the loss of the bottle shape.

Microbiological indicators can't be used as an indicator of product damage for an express method for predicting shelf life.

The establishment of an optimal mineral waters "aging" mode, an indicator of damage to products and time of exposition require additional studies of other temperature conditions with a large sample of research objects.

VI. RESULTS DISCUSSION

Analysis of literature data and our own research showed, that the mineral waters quality and safety during storage is influenced by the material and volume of consumer packaging, the period and temperature conditions of storage. Our previous studies have established that mineral waters of various hydrochemical types and salinity, packaged in plastic or glass packaging, within 15 months of storage at a temperature of 25 ± 2 °C corresponded to the requirements of current regulatory documents on organoleptic indicators, basic salt composition, microbiological and chemical safety [20]. Currently, the shelf life of mineral waters, subject to storage conditions in plastic packaging is from 3 months to 18 months, in glass - up to 24 months: a specific period is set for different waters individually.

Taking into account the variety of mineral waters, produced in our country, as well as a different choice of packaging materials, the development of a rapid method for predicting the shelf life of mineral waters of various hydrochemical types is a relevant scientific study, that requires new approaches to the assessment of shelf life and storage conditions.

As a result of this work, it was found that for mineral waters, the most objective factor of quality change is organoleptic characteristics (taste, smell, and other parameters), as well as possible physicochemical reactions, leading to changes in the hydrochemical type of mineral water.

Creating new ways to predict the storage stability of bottled water will increase the economic efficiency of enterprises. The costs associated with the introduction of new technologies and production losses will be reduced.

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