

UDC 663.423: 663:41:633.791:664.61

OPTIMISATION OF THE RATE OF EXPENSE HOP FOR BREAD BAKING ACCORDING TO THE CONTENT OF BITTER SUBSTANCES

[https://doi.org/ 10.15673/fst.v19i2.3188](https://doi.org/10.15673/fst.v19i2.3188)

Correspondence:

A. Bober

E-mail: bober1980@i.ua,

Cite as Vancouver style citation

Optimisation of the rate of expense hop for bread baking according to the content of bitter substances / Protsenko I. et al. // Food science and technology. 2025;19(2):69-78. [https://doi.org/ 10.15673/fst.v19i2.3188](https://doi.org/10.15673/fst.v19i2.3188)

Цитування згідно ДСТУ 8302:2015

Optimisation of the rate of expense hop for bread baking according to the content of bitter substances / Protsenko I. et al. // Food science and technology. 2025. Vol. 19, Issue 2. P. 69-78. [https://doi.org/ 10.15673/fst.v19i2.3188](https://doi.org/10.15673/fst.v19i2.3188)

Copyright © 2025 by author and the journal

“Food Science and Technology”.

This work is licensed under the Creative Commons Attribution International License (CC BY).

<http://creativecommons.org/licenses/by/4.0>



Introduction. Formulation of the problem

Modern economic and market conditions provide for the application of hops not only as a raw material for brewing, but also in other areas of the food industry.

L. Protsenko¹, PhD, head of the department
N. Koshitska¹, PhD, the leading researcher of the department
S. Ryzhuk¹, Academician of the NAAS, Dr.Sc., professor, head of the Institute
O. Svirchevska¹, Researcher
A. Bober², PhD, associate professor
S. Gunko², PhD, associate professor
I. Bober³, student of bachelor degree

¹ Department of hop and beer biochemistry and biotechnology
 Polissia Institute of Agriculture of the National Academy of Agrarian Sciences

of Ukraine, Kyiv highway, 131, Zhytomyr, Ukraine, 10007

² Department of Storage, Processing and Standardization of Plant Products
 after prof. B.V. Lesik

³ National University of Life and Environmental Sciences of Ukraine
 Heroyiv Oborony str., 13, Kyiv, Ukraine, 03041

³ Taras Shevchenko National University of Kyiv
 Volodymyrska str., 60, Kyiv, Ukraine, 01033

Abstract. With the development of new trends in healthy eating, for consumer satisfaction, with aim to expand the range of bakery products and enrich bread with biologically active compounds of hops, bread production with the addition of cones of this unique plant in terms of bitter and polyphenolic substances, aromatic and essential oils has become widespread. The research conducted to study and substantiate the effective utilization of a complex of technologically valuable substances of Ukrainian fine aromatic hops of the Perlyna variety allowed to establish the possibility and feasibility of its application in baking and its impact on bread quality. The analysis of the results showed that the bittering qualities of hops had a significant impact on the taste of bread. In contrast, polyphenolic substances had a lesser effect on the taste, but in combination with bitter substances, they significantly affect consumer qualities. The results of studies of the application of sourdough starter of Perlyna aromatic hop with different content of alpha acids and polyphenolic substances showed that the bread had high taste qualities when added to the 1 kg of flour: 23.9 to 35.8 mg of bitter substances and 45.2 to 72.1 mg of polyphenolic substances. With lower amounts of bitter substances and higher amounts of polyphenols, the taste of the bread was almost the same as the control sample, although the physicochemical parameters improved. With an increase from 35.8 to 43.4 mg of bitter substances, a subtle bitterness was felt against the background of a pleasant hop aroma. Adding more than 50.8 mg of bitter substances to the 1 kg of flour made the bread noticeably bitter. Based on the example of the Pearl hop variety, the dosage of hop expenses was optimized and the calculation of the rate in baking was proposed, taking into account the content of bitter alpha acids in it. The optimally justified rate of bitter substances of hops to ensure excellent taste and consumer properties of bread is the range of added alpha acids from 23.9 to 43.4 mg per 1 kg of flour. The proposed technology has improved the consumer properties and taste of bakery products by imparting a hop aroma and a stable optimally normalized bread taste with a light, delicate bitterness. At the same time, the volume of bread, porosity, porosity structure and elasticity of the crumb are increased. Reducing the amount of yeast did not affect the fermentation of the dough and the stability of the shape of the final product. This will contribute to the health and preventive effects of the products. ng for modeling the minimum shelf life of oil-based products.

Keywords: bread, hops, hop sourdough, hop variety, alpha acids, quality indicators.

One such industry is bread baking, where, along with the use of modern technologies, there is a return to classic, somewhat lost and forgotten technologies for making bread with hop sourdough, which have been

widely used in Ukraine since ancient times [1, 2]. Along with private mini-bakeries, large bread factories are making adjustments to the baking of new varieties of wheat and rye-wheat bread by adding the cones of this unique plant to the recipe [1, 3]. The efforts of industry experts to adapt the technology of bread making with the application of hops to modern production conditions are also associated with the emergence of new scientific data on the functional physiological properties of hops [2, 4–6] and the desire to enrich bread with its biologically active substances [2, 7]

Analysis of recent research and publications

Hops are a unique plant containing hundreds of phytochemicals that have certain pharmacological potential. The bitter substances, polyphenolic compounds and essential oil of hops are powerful phytoncides that can inhibit the growth of fungi and protozoa and have a general stimulating, anti-inflammatory, regenerative, anti-allergic and other effects on the human body [4, 8–10]. The results of studies of the antifungal properties of hop extract have demonstrated significant inhibition of the hyphal growth of *Aspergillus niger*, *Aspergillus parasiticus*, *Penicillium polonicum*, *Penicillium paneum*, *Penicillium carneum*, *Penicillium chermesinum*, and *Penicillium roque* [2].

It has been established that bitter substances in hops, in particular alpha and beta acids, soft and hard resins and polyphenolic compounds, have antioxidant properties and act as natural preservatives with bread baking. According to the authors [2], sourdough enriched with hop extract had a significantly higher concentration of phenols and antioxidant activity compared to sourdough without hops. The sourdough from hop used in bread production inhibited the growth of pathogenic microflora (up to 14 days), contributing to the production of bread characterized by a higher concentration of free amino acids, antioxidant and phytase activity compared to bread where only baker's yeast was used [2]. Bitter substances, in particular alpha acids and beta acids, are toxic to acid-forming microorganisms, other Gram-positive bacteria, fungi and in high concentrations inhibit Gram-negative bacteria and also demonstrate antibacterial and antifungal activity [5, 11, 12]. Bitter substances and essential oil have insecticidal activity [13, 14].

There is a prenylflavonoid – xanthohumol, was also identified in hops, which proved to be the most active compound in biological tests, exhibiting anticancer and antioxidant properties [18, 19]. The authors presented a wide range of antiviral and insecticidal effects of hop xanthohumol [20, 21].

Another reason for the increased attention to the application of hops in baking is the desire of manufacturers to satisfy consumer requirements and expand the range of bakery products by applying microingredients – food additives, baking improvers and various types of non-traditional raw materials [1, 2].

Currently, several methods of bread production using hops have been developed in Ukraine [1, 3]. Some of them have practical application in industry. The application of hops improves the sensory characteristics and extends the shelf life of bakery products [22]. The use of hop sourdough has a positive effect on bread quality and reduces the risk of pathogenic microflora development in finished products [22]. Hops are used as a preservative and a source of biologically active substances to enrich bread with microelements. Hop extracts affect the rheological properties of dough, in particular, they reduce the elasticity and degree of softening of wheat dough [23].

A limiting factor for the application of hops in baking is its dosage due to the intense bitterness of hop raw materials. Hop varieties differ significantly in their biochemical indicators, so the application of different hop varieties will affect the taste of bread in different ways and therefore requires a detailed approach to its standardization in bread baking.

In previous studies, we developed technological solutions for the application of hops in bread baking [24–26]. The possibility and feasibility of using domestic hop varieties: Slavyanka, Zlato Polissya, and Klon 18 in bread production to improve its taste and physical and chemical indicators, taking into account the peculiarities of the biochemical composition and chemical and technological evaluation of these varieties, has been established. However, with the development of new trends towards healthy food and the expansion of the range of yeast-free bakery products at the request of consumers, as well as the appearance of new hop varieties with taste and aroma characteristics that differ from other varieties, today's promising task is to substantiate the effective application of a complex of technologically valuable compounds of new hop varieties in baking, to study their impact on bread quality, to optimization of the dosage of bitter and polyphenolic compounds to ensure the high consumer quality of the final product.

Purpose and objectives of the study.

The purpose of the study was to investigate the effect of biologically active compounds of sourdough of fine-aromatic hop of Perlyna variety on the quality of wheat bread and to optimize the norm of application of bitter and polyphenolic compounds to ensure high consumer quality of the final product.

To achieve this goal, the following objectives were set:

- to determine the physical, chemical and biochemical quality indicators of Perlyna fine-aromatic hop cones;
- to study the effect of biologically active compounds of Perlyna fine-aromatic hop sourdough on the quality of wheat bread;
- to optimize the norm application of bitter and polyphenolic compounds of hops to ensure high consumer quality of bread.

Research materials and methods

The research was conducted in 2021–2024 in an accredited laboratory of the Department of Hop and Beer Biochemistry and Biotechnology at the Polissya Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine. The biochemical quality indicators of cones fine-aromatic hop of Perlyna variety and wheat bread made from hop sourdough of this variety were studied.

The work used modern international physical and chemical methods for analyzing bitter substances, polyphenolic compounds and essential oils of hops: high-performance liquid chromatography, spectrophotometry and other methods for controlling the quality of hop raw materials and finished bakery products.

Each series of experiments was conducted at least three times. The tables and figures show the average values of the parameters of the determined quantities.

Methods for studying bitter substances in hops

The organoleptic indicators of cones and the mass fraction of moisture were determined according to the international method Analytica EBS 7.2. [26, 27]. The amount of alpha acids in them – a conductometric indicator of bitterness – was determined according to the international method Analytica EBC 7.4 [26, 27]. The method is based on conductometric titration of hexane extract of hop bitter substances with lead acetate solution and calculation of the mass fraction of alpha acids.

The content and composition of alpha-, beta-acids and xanthohumol were determined by high-performance liquid chromatography according to the international method EBS 7.7. [26, 27]. Bitter substances of hops: alpha- and beta-acids and their components, in particular, cohumulone, colupulone and xanthohumol, were extracted from hops using an organic solvent – methanol. The ratio between the mass of hops and the extractant was 1:10. The amount of alpha and beta acids and the content of cohumulone and xanthohumol were determined by high-performance liquid chromatography. Chromatography was performed using an Ultimate 3000 liquid chromatograph with a UV detector at a temperature of 35 °C. A 100 x 2.1 mm column filled with Pinnacle DV C18 3 µm sorbent was used. A solution of methanol, water and acetonitrile in a ratio of 38:24:38 was used as the mobile phase. For the quantitative determination of xanthogumol, a xanthogumol standard–etalon with a content of 99.8% of this compound was used and for the bitter components: alpha- and beta-acids – the international etalon of ICF–3 [27].

Methods for determining the quantity and qualitative composition of hop essential oil The quantity of essential oil was determined using the international method Analytica EBS 7.10 [28], which is based on determining the essential oil content in cm³ per 100 g of air-dry substance by obtaining essential oil by

hydrodistillation, followed by decantation and collection in a special trap.

The chemical composition of the essential oil was analyzed by gas chromatography, following the official method in Analytica-EBC 7.12 [29]. Four selected components (myrcene, caryophyllene, farnesene and humulene) were identified and quantified using a Crystal-2000M capillary gas chromatograph equipped with a flame ionization detector. The essential oil obtained from hop pellets was separated into individual compounds by gas chromatography on 50–60 m columns (Restek Stabilwax®, USA) with the application of 20–30 cm³ of chromatographic inert nitrogen carrier gas. The temperature program was as follows: 60 °C (holding time 1 min), 60–190 °C (4 °C/min), 190–220 °C (holding time in isothermal regime 40 min). The injector temperature was 220 °C, the injection volume was 0.3–0.4 µl, and the detector temperature was 250 °C. The results were expressed as the relative % of a particular compound in the essential oil.

Preparation of hop extracts for hop sourdoughs

The extraction and accumulation of valuable hop compounds in solution are influenced by boiling time, the presence of a reflux condenser and other factors. According to research [24], the boiling time for the accumulation of bitter and polyphenolic hop compounds in the extract (93–95%) was 60 minutes. After 45 minutes, 85–87% of the total amount of bitter substances was extracted from the hops. In order to reduce energy consumption and the duration of preparation of hop extract for application in bakery products, it is advisable to extract hops at boiling temperature for 45 minutes. The hop extract was prepared by boiling hop cones (10 g of cones per 1 liter of boiling water) for 45 minutes with a reflux condenser, after which the quantitative parameters of the hop extract were taken into account with the normalization of hop consumption.

The bitterness in the hop extract was determined by spectrophotometry using a SECOMAM Uvilight XT 2 spectrophotometer [30]. To determine the polyphenol content in the hop extract, we used the method developed and proposed by the EBC Analytical Committee Yerumanis (variant II) [31].

Preparation of hop sourdough for bread baking

The 1 liter of cooled and filtered solution of hop extract were added 200 g of flour and 75 g of sugar. The sourdough was placed in a warm place (at a temperature of 30–35°C) for two days to pass the fermentation process (depending on the temperature, the fermentation process may take longer or shorter). The finished sourdough was stored in a glass container, covered with a lid with holes, in the refrigerator until application.

Evaluation of bread quality indicators with hops The effect of hops on bread quality indicators was determined by laboratory baking. The dough was prepared from high quality wheat flour using a single-phase method. Hops were added to the dough in the form of sourdough. The amount of yeast was reduced by

half from that specified in the recipe (3% of the flour weight). Wheat bread without the addition of hop sourdough was used as a control sample. The quality of bread made with the addition of hops and the control sample was evaluated according to organoleptic and physicochemical indicators. The organoleptic evaluation of bread was carried out in accordance with DSTU 7044 in accordance with the five-point quality system for bakery products. Organoleptic characteristics included appearance: crust color, product shape stability, surface condition, crumb condition, porosity structure, degree of baking, freshness, smell, and taste of bread. When determining the surface condition, attention was focused on the shape of the crust and its condition. The surface should be smooth, without cracks or breaks. The crumb should be well baked, elastic, not sticky, with developed porosity, without traces of unevenness and compaction of crumbs. When assessing the porosity of the crumb, the size of the pores, their uniform distribution, and the thickness of the pore walls were taken into account. The elasticity of the crumb was assessed by lightly pressing one or two fingers on the cut surface of the product. The structure of the crumb was observed by removing the fingers from the surface. With no residual deformation, the elasticity of the crumb was assessed as good; with slight deformation, it was assessed as average, and with significant residual deformation and crumb compression, it was assessed as bad. The aroma and taste were determined during tasting. Each indicator was evaluated on a five-point scale. The better the indicator for each sample, the higher the score it received for that indicator.

The physical and chemical indicators in bread samples were determined in accordance with DSTU 7045. The physical and chemical indicators of bread quality include: moisture content, acidity, porosity, as well as sugar and fat content in products that contain sugar and fat according to the recipe. The physical and chemical parameters of bread quality were determined no earlier than 3 hours after baking and no later than 24 hours. The physical and chemical properties included specific volume, shape stability, structural and mechanical properties of crumbs, and porosity. The volume of bread in cm³ was measured according to the principle of measuring the volume of bulk filler displaced by bread. The specific volume of bread (volume of 100 g of product, cm³/100 g) was determined by dividing the volume of bread by its weight. The stability of the bread shape was characterized by the ratio of its height (H) to diameter (D). The porosity of bread reflects the volume of pores in a given volume of crumbs, expressed as a percentage of the total volume of bread. An increase in this indicator indicates a larger volume, better appearance and greater crumbly texture.

Results of the research and their discussion

One of the ways to enrich bread with biologically active hop compounds, expand the range of bakery

products, and improve their quality, taste, and aroma is to study and apply hop sourdoughs made from water extract of cones of finely aromatic hop varieties in bread baking.

As a result, boiling of hop water extract, alpha acids are isomerized to form iso-alpha acids, which have a more bitter taste [32, 33]. At the same time, other biologically active substances, in particular polyphenols and essential oils, are also extracted into the solution [34].

The effect of bitter substances, polyphenolic compounds and essential oils of hops on bread quality indicators was determined by laboratory baking. The dough was prepared from high-grade wheat flour using a single-phase method. The determining factor for establishing the maximum possible dose of hops was the taste of the bread. Data obtained in the case of application of hop cones of the Klion 18, Zlato Polissya and Slavyanka varieties showed [24, 35] that when hops were dosed at 0.08% of the flour weight, the taste was typical for bread with a light taste and aroma of hops. At lower doses of hops, the taste and aroma of bread were almost the same as the control sample. When adding hops in an amount of more than 0.10% of the flour weight, a slightly bitter tone was felt, which an increase in the dosage of hops transformed into a more bitter taste. Thus, the maximum possible dose of aromatic hops for bread making was 0.08–0.10% of the flour weight, which was approximately twice the dose known from the literature (0.04%) [25], on the condition that bitter varieties with a high content of α -acids were used.

Study of the effect of a complex of technologically valuable compounds hops of Perlyna variety on the quality indicators of bread.

The study of the effect of a complex of technologically valuable compounds hops of Perlyna variety on the quality indicators of bread, sourdough of hops of this variety was added to the dough in a dosage of 0.1% of the flour weight. The biochemical characteristics of hop cones of Perlyna variety are given in Tab. 1.

The mass fraction of alpha acids in the studied hops was 5.2%, polyphenolic compounds – 4.8%. The aromaticity coefficient, which characterized by the ratio of beta acids to alpha acids was greater than 0.9, confirms that this Perlyna hop variety belongs to the delicately aromatic type of hops. The studied hops also had a high content of farnesene-type essential oil (1.6 ml per 100 g of dry matter).

The amount of yeast was reduced by half from that indicated in the recipe (3% of the flour weight). Wheat bread without the addition of hop sourdough was used as a control sample. The quality of bread made with the application of hops and the control sample was evaluated according to organoleptic and physicochemical indicators.

The effect of bitter, polyphenolic substances and other biologically active compounds of sourdough made from hops of Perlyna variety on the organoleptic indicators of wheat bread is presented in the form of a profilogram in Fig. 1.

Table 1 – Biochemical quality indicators of hop cones of Perlyna variety

Hop variety	Mass fraction of alpha acids, % to DM	Cogumolone in the composition of α -acids, %	Aromaticity coefficient, β/α	Total polyphenol content, %	Xanthohumol content, %	Essential oil, ml per 100 g of DM	Farnesene content in essential oil, %
Perlyna	5.2±0.42	24.7±1.98	0.92±0.31	4.8±0.54	0.47±0.034	1.6±0.09	13.9±1.37

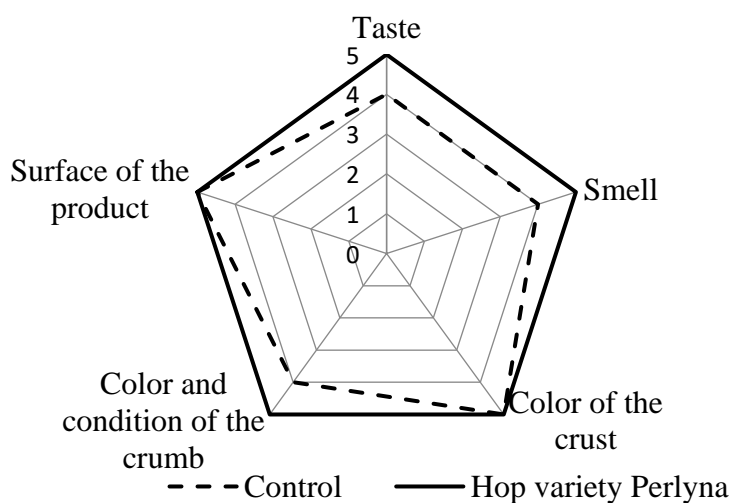


Fig. 1. Profiling diagram of organoleptic properties of wheat bread with application of hop sourdough from cones of Perlyna variety

All repeated variants of bread made with the addition of sourdough from aromatic hop cones of Perlyna variety had a pleasant taste and aroma of hops. Compared to them, the control sample had an aroma characteristic only of bread. The color of the bread crust in the experimental variants ranged from light yellow to golden yellow. The control sample had a light yellow crust. The addition of hop sourdough did not deteriorate the color and shape of the bread, the condition and color of the crumb, or its physical and chemical properties. Reducing the amount of yeast and adding hop sourdough instead had a positive effect on dough fermentation. The porosity in the control sample was uniform. In the experimental samples, the porosity was improved (homogeneous, medium, fine), which was due to better dough fermentation. The results of the study are in agreement with the results of studies by other scientists [1–3]. The color of the crumb in all samples, including the control sample, was light cream. The crumb was elastic and not sticky. The specific volume remained normal for all variants.

Optimization of hop dosage for sourdough preparation according to its alpha acids content.

In the technology of sourdough preparation from hops, it was reasonable to regulate the content of bitter substances in it, which would ensure the stability of the taste characteristics of the finished product and a certain level of bactericidal action in the fermentation medium of sourdough during the formation of its microbiological composition. Based on this, in order to ensure sufficient quality-standardized bitterness of bread, it became necessary to regulate hops taking into account the content of bitter alpha acids, which determined its consumer and technological value. For establishing the application of the optimal amount of bitter substances per unit of flour, a series of experiments was conducted on the preparation of sourdough from hops of Perlyna variety with different contents of bitter substances and polyphenolic compounds. The reason for choosing this variety was that among the aromatic varieties, the Perlyna variety had a high content of essential oil—up to 1.6 ml per 100 g of dry hops, which also has antibacterial properties and affects the smell of the product.

Experimental samples were selected to study the formation of economically valuable indicators of hop

cones of Perlyna variety from August 4 to September 15, during the period from the beginning of hop cone formation to the stage of full technical ripeness. The results of the dynamics of the accumulation of bitter substances, polyphenolic compounds, and the load of polyphenols per 1 g of alpha acids are presented in Fig. 2.

As can be seen from Fig. 2, hop cones at the beginning of their formation had a low content of bitter substances, in particular 1.32% alpha acids, and a high content of polyphenolic compounds (10.12%). As the cones ripen, bitter substances are synthesized, the amount of alpha acids increasing from 1.32 to 5.95% by the phase of full technical ripeness of the cones. The amount of polyphenolic compounds, on the contrary, decreases from the beginning of cone formation to the phase of full technical ripeness from 10.12 to 4.81%. The polyphenolic compound load coefficient per 1 g of alpha acids also decreases significantly from 7.7 to 0.8 in technically ripe cones.

Further studies were conducted with these samples hop of Perlyna variety with different alpha acid content in the amount of 0.1% of flour weight in the form of sourdough.

The content of bitter substances and polyphenolic compounds in bread was determined by calculation, based on the condition that with a hop dosage of 0.1% of the flour weight, the requirement for hops with a standard moisture content of 10% was 1.0 g for the preparation of bread from 1 kg of flour.

The calculation of the amount of alpha acids (AA) and polyphenolic compounds (PC) per 1 kg of flour, taking into account the moisture content of hop cones, is shown in the example of the first hop sample of Perlyna variety.

$$AA = 1.0 \times 0.0132 \times 0.9 = 0.01188 \text{ g} = 11.88 \times 10^{-3} \text{ g of alpha acids}$$

$$PC = 1.0 \times 0.1012 \times 0.9 = 0.09108 = 91.08 \times 10^{-3} \text{ g polyphenolic compounds}$$

The research results are presented in Table 2.

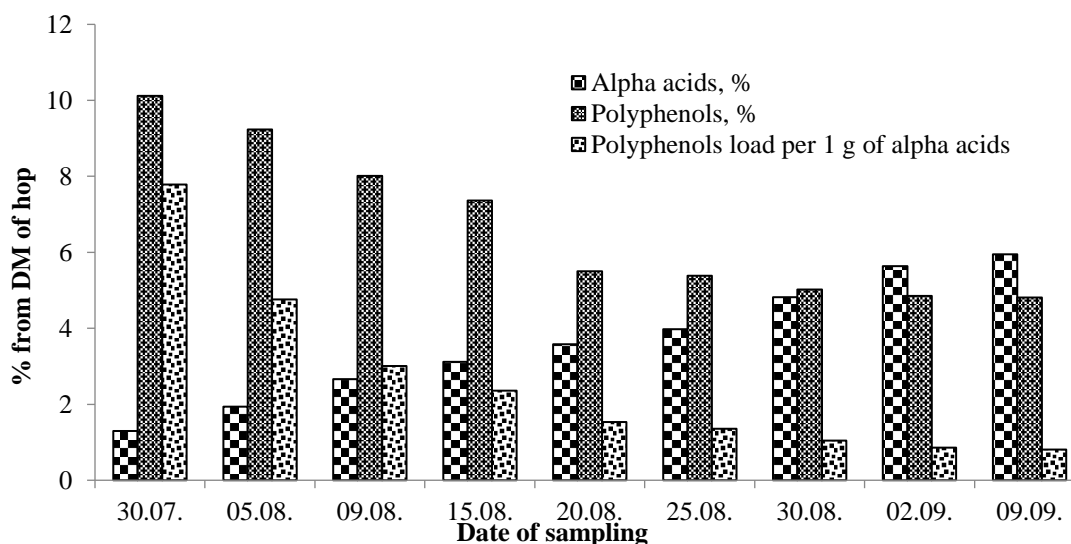


Fig. 2. Content of alpha acids and polyphenolic compounds in hop cones of Perlyna variety harvested at different stages of ripeness

Table 2 – Technological characteristics of hop samples and hop sourdough of the Perlyna variety

Sample No.	Hop indicators, % to DM		Added with hop sourdough, g /1 kg of flour	
	mass fraction of alpha acids	mass fraction of polyphenolic compounds	alpha acids	polyphenolic compounds
1	1.32±0.01	10.12±0.03	$(11.88±0.05) \times 10^{-3}$	$(91.08±0.37) \times 10^{-3}$
2	1.94±0.01	9.23±0.05	$(17.46±0.07) \times 10^{-3}$	$(83.07±0.33) \times 10^{-3}$
3	2.66±0.01	8.01±0.04	$(23.94±0.09) \times 10^{-3}$	$(72.09±0.29) \times 10^{-3}$
4	3.12±0.01	7.36±0.03	$(28.08±0.11) \times 10^{-3}$	$(66.24±0.21) \times 10^{-3}$
5	3.58±0.01	5.50±0.03	$(32.22±0.12) \times 10^{-3}$	$(49.50±0.21) \times 10^{-3}$
6	3.98±0.02	5.38±0.02	$(35.82±0.14) \times 10^{-3}$	$(48.42±0.19) \times 10^{-3}$
7	4.82±0.02	5.02±0.02	$(43.38±0.16) \times 10^{-3}$	$(45.18±0.18) \times 10^{-3}$
8	5.64±0.02	4.85±0.02	$(50.76±0.18) \times 10^{-3}$	$(43.65±0.18) \times 10^{-3}$
9	5.95±0.03	4.81±0.02	$(53.55±0.21) \times 10^{-3}$	$(43.29±0.18) \times 10^{-3}$

The results of studies on the application of sourdough made from aromatic hops of Perlyna variety with different contents of alpha acids and polyphenolic compounds showed that bread had high taste qualities with the addition of up to 1 kg of flour: from 23.9×10^{-3} to 35.8×10^{-3} g of bitter substances and 45.2×10^{-3} to 72.1×10^{-3} g of polyphenolic compounds. The taste of the bread with less bitter substances and more polyphenols was almost the same as the control sample, although the physical and chemical indicators improved. As a result, increase amount of bitter substances from 35.8×10^{-3} to 43.4×10^{-3} g, a slightly noticeable bitterness was felt against the background of a pleasant hop aroma. The addition of 1 kg of flour more than 50.8×10^{-3} g of bitter substances, the bread acquired a noticeable bitterness. Thus, a reasonable norm of hop bitter substances to ensure excellent taste and consumer properties of bread is in the range of 23.9 to 43.4 mg of added alpha acids per 1 kg of flour.

Analysis of the results showed that the bitter qualities of hops had a significant effect on the taste of bread. In contrast, polyphenolic compounds had less influence on taste, but in combination with bitter substances had a significant effect on consumer qualities, in particular on the microbiological purity of bread, which prolongs its shelf life and increases its stability and specific volume (Fig. 3).

The dosing of hops in the studied samples with different contents of bitter substances, which are represented by alpha acids, different amounts of them are added to bread therefore the stability of the addition of bitter substances is not ensured. The results of studies on the application of hop sourdoughs based on the Perlyna hop variety with different contents of alpha acids and polyphenolic compounds and the results of tasting evaluation of bread samples showed that the

optimally justified norm of hop bitter substances, which ensures excellent taste and consumer properties of bread, is $(23.9 + 43.4)/2 = 33.7$ mg or 33.7×10^{-3} g per 1 kg of flour. Similar results were obtained for other aromatic varieties [24]. Therefore, to ensure stable, optimally standardized bitterness of bread, it is advisable to calculate the mass of hops added based on the alpha acid content per unit of flour.

An analysis of the principle of normalizing hop application in the brewing industry showed that its calculation was based on a number of indicators aimed at ensuring a pleasant hop bitterness for a particular beer and increasing its colloidal stability during storage. Based on the data presented above and taking into account the purpose of application of hop sourdough in baking, as well as the consumer properties of bread, a simplified method for calculating the amount of hops, g, per 1 kg of flour, as a recipe component, was proposed, which will allow producing finished products with stable bitterness:

$$m_x = \frac{33.7 \times 10^{-3} \times 100 \times 100}{\alpha \times (100-w)}, \text{ g/kg}$$

or

$$m_x = \frac{337}{\alpha \times (100-w)}, \text{ g/kg}$$

where m_x – weight of hop, g/kg;

α – mass fraction of alpha acids in hops, % to DM;

w – mass fraction of moisture in hops (actual), %.

For 100 kg of flour, the requirement for hops will

be:

$$m_x = \frac{337 \times 100}{\alpha \times (100-w)}, \text{ g/100 kg}$$

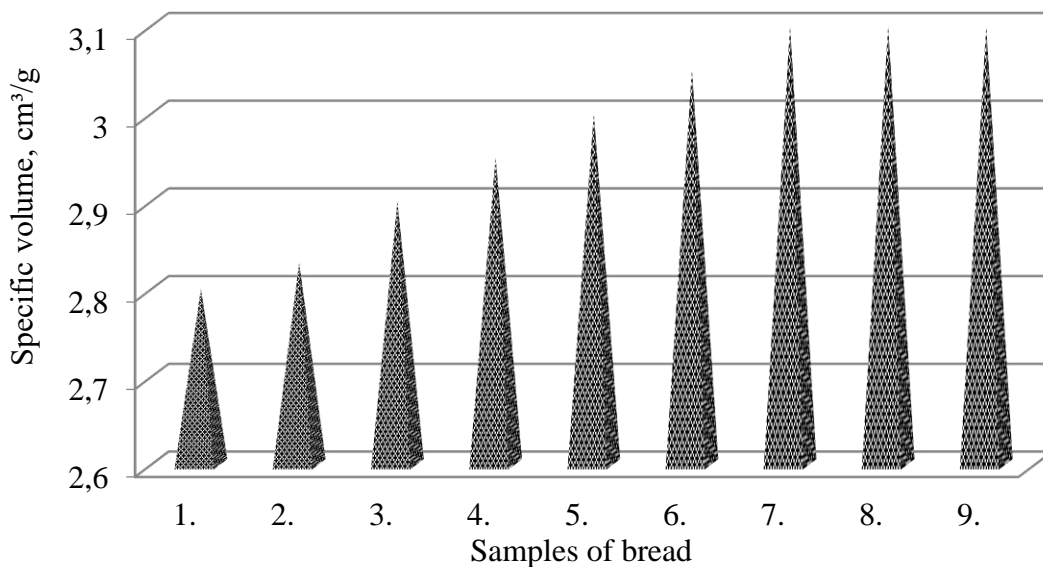


Fig. 3. Specific volume of bread samples made with the application of hop sourdough of Perlyna variety with different contents of bitter substances and polyphenolic compounds

For example, to make wheat bread with the use of delicately aromatic hop of Perlyna variety with an alpha acids content of 2.7% and a moisture content of 9%, 1 kg of flour requires the following amount of hops when boiling the hop extract for 45 minutes:

$$m_x = \frac{337}{2.7 \times (100-9)} = 1.4 \text{ g/kg}$$

For 100 kg of flour, the amount of hops required will be:

$$m_x = \frac{337 \times 100}{2.7 \times (100-9)} = 140 \text{ g/100 kg}$$

Thus, the proposed method allows calculating the required amount of hops that should be added to flour in the form of sourdough, ensuring a certain content of alpha acids for the finished bread with a pleasant aroma and stable taste, which will improve its quality and consumer properties.

This will contribute to expanding the product range, giving products a preventive and health-promoting effect, improving the taste and aroma of bread, enriching bread with biologically active substances, extending the shelf life of bakery products, and ensuring their microbiological purity

Conclusion

The possibility of applying fine-aromatic hop of Perlyna variety in bread production has been

investigated. However, it is necessary to take into account the peculiarities of the biochemical composition and chemical-technological evaluation of hops. It has been established that bitter substances, essential oil and polyphenolic compounds of hops had a significant effect on the taste of bread. The application of sourdough made from the delicately aromatic hop of Perlyna variety improved the quality of bread, in particular its taste and aroma. The volume and porosity of bread also increased and the structure of porosity and elasticity of the crumb improved. The reduction in the amount of yeast did not affect the fermentation process of the dough and the stability of the final product. The dosage of hop sourdough was optimized and a calculation of hop use in baking was proposed, taking into account the content of bitter alpha acids in it. The optimally justified norm of bitter substances in hops to ensure excellent taste and consumer properties of bread is a range of added alpha acids from 23.9 to 43.4 mg per 1 kg of flour. The proposed technology improved the consumer properties and taste qualities of bakery products by giving them a hop aroma and a stable, optimally normalized taste with a slight delicate bitterness. The application of hops was aimed at improving the taste and physical and chemical characteristics of bread, giving it preventive and health-promoting properties.

References

- Rak V, Yurchak ., Bilyk O, & Bondar V. Investigation of the efficiency of using hop leavens in the technology of wheat bread, *EUREKA: Life Sciences*. 2018; 1: 61-68. <https://doi.org/10.21303/2504-5695.2018.00562>
- Nionelli L, Pontonio E, Gobetti M, & Rizzello C. Use of hop extract as antifungal ingredient for bread making and selection of autochthonous resistant starters for sourdough fermentation, *International Journal of Food Microbiology*. 2018; 266: 173–182. <https://doi.org/10.1016/j.ijfoodmicro.2017.12.002>
- Rak V, Yurchak V, Bilyk O, & Bondar, V. Research into techniques for making wheat bread on hop leaven, *Eastern-European Journal of Enterprise Technologies*. 2018; 1/11(91): 4-9. <https://doi.org/10.15587/1729-4061.2018.121677>
- Protsenko L, Liashenko M, Vlasenko A, Hryniuk T, & Dobrovolny O. Investigation of properties of biologically active substances and their content in cones of Ukrainian hop varieties, *Agricultural Science and Practice*. 2018; 5(2): 52-63. <https://doi.org/10.15407/agrisp5.02.052>
- Van Cleemput M, Cattoor K, De Bosscher K, Haegeman G, De Keukeleire D, & Heyerick A. Hop (*Humulus lupulus*)-derived bitter acids as multipotent bioactive compounds, *Journal of Natural Products*. 2009; 72: 1220-1230. <https://doi.org/10.1021/np800740m>
- Paventi G, Acutis L, Cristofaro A, Pistillo M, Germinara G, Rotundo G. Biological Activity of *Humulus lupulus* (L.) Essential Oil and Its Main Components against *Sitophilus granaries* (L.). *Biomolecules*. 2020; 10(8): 1108. <https://doi.org/10.3390/biom10081108>
- Karabın M, Hudcová T, Jelínek L, Dostálek P. Biologically Active Compounds from Hops and Prospects for Their Use. 2016; 15(3): 542-567. <https://doi.org/10.1111/1541-4337.12201>
- Hrněč M, Španinger E, Košir I, Knez Ž, Bren U. Hop Compounds: Extraction Techniques, Chemical Analyses, Antioxidative, Antimicrobial, and Anticarcinogenic Effects. *Nutrients*. 2019; 11(2): 257. <https://doi.org/10.3390/nu11020257>
- Karabın M, Hudcová T, Jelínek L, & Dostálek P. Biologically active compounds from hops and prospects for their use, *Comprehensive Reviews in Food Science and Food Safety*. 2016; 15: 542-567. <https://doi.org/10.1111/1541-4337.12201>
- Tronina T, Popłoński J, & Bartmańska A. Flavonoids as phytoestrogenic components of hops and beer, *Molecules*. 2020; 25(18): 4201. <https://doi.org/10.3390/molecules25184201>
- Bocquet L, Rivière C, Dermont C, Samaillie J, Hilbert J.-L., Halama P, Siah A, Sahpaz S. Antifungal activity of hop extracts and compounds against the wheat pathogen *Zymoseptoria tritici*. *Industrial Crops and Products*. 2018; 122: 290-297. <https://doi.org/10.1016/j.indcrop.2018.05.061>
- Jirovetz L, Bail S., Buchbauer G, Denkova Z, Slavchev A, Stoyanova A, Schmidt E, Geissler M. Antimicrobial testings, gas chromatographic analysis and olfactory evaluation of an essential oil of hop cones (*Humulus lupulus* L.) from Bavaria and some of its main compounds. 2006; 74: 189-201. <https://doi.org/10.3797/scipharm.2006.74.189>
- Bedini S, Flamini G, Cosci F, Ascritti R, Benelli G, Conti B. *Cannabis sativa* and *Humulus lupulus* essential oils as novel control tools against the invasive mosquito *Aedes albopictus* and fresh water snail *Physella acuta*. *Industrial Crops and Products*. 2016; 85: 318-323. <https://doi.org/10.1016/j.indcrop.2016.03.008>
- DeGrandi-Hoffman G, Ahumada F, Probasco G, Schantz L. The effects of beta acids from hops (*Humulus lupulus*) on mortality of *Varroa destructor* (Acari: Varroidae). *Experimental and Applied Acarology*. 2012; 58: 407-421 <https://doi.org/10.1007/s10493-012-9593-2>

15. Kovalev V, Kozlik T, Protsenko L, Bober A, & Kormiltsev B. Extending and maintaining the in vitro collection of (inter)national hop varieties in Ukraine. *Agricultural Science and Practice*. 2020; 7(3): 61-71. <https://doi.org/10.15407/agrisp7.03.061>
16. Protsenko L, Janse L, Koshytska N, Ryzhuk S, Liashenko M, Bober A, Gunko S. Variability and stability of essential oil composition in Ukrainian hop varieties. *Kvasny prumysl*. 2023; 69(6): 811-821. <https://doi.org/10.18832/kp2023.69.811>
17. Protsenko L, Ryzhuk S, Koshitska N, Lyashenko M, Bober A, Gunko S, Kazmirchuk V. Comparative estimation of the quality of ukrainian and european hop pellets. *Food Science and Technology*. 2023; 17(2): <https://doi.org/10.15673/fst.v17i2.2604>
18. Wei S, Sun T, Du J, Zhang B, Xiang D, & Li, W. Xanthohumol, a prenylated flavonoid from hops, exerts anticancer effects against gastric cancer in vitro. *Oncology Reports*. 2018; 40(6): 3213-3222. <https://doi.org/10.3892/or.2018.6723>
19. Zhang X.-L, Zhang Y.-D, Tao, Wang Y, Guo H.-Y, Liu Q.-M, & Su H.-X. Evaluation on antioxidant effect of xanthohumol by different antioxidant capacity analytical methods. *Journal of Chemistry*. 2014; (1): 249485. <https://doi.org/10.1155/2014/249485>
20. Żolnierczyk A, Baczyńska D, Potaniec B, Kozłowska J, Grabarczyk M, Woźniak E, & Anioł M. Antiproliferative and antioxidant activity of xanthohumolacyl derivatives. *Medicinal Chemistry Research*. 2017; 26(8): 1764-1771. <https://doi.org/10.1007/s00044-017-1887-9>
21. Aydin T, Bayrak N, Baran E, Kahir A. Insecticidal effects of extracts of *Humulus lupulus* (hops) L. cones and its principal component, xanthohumol. *Bulletin of Entomological Research*. 2017; 107(4): 543-549. <https://doi.org/10.1017/S0007485317000256>
22. Chaplygina I, Batura G, Matyushev V, Tipsina N, & Shmeleva Zh. The hop sourdough use to improve bread microbiological safety. *IOP Conference Series: Earth and Environmental Science*. 2020; 421(3): 032030. <https://doi.org/10.1088/1755-1315/421/3/032030>
23. Sokolova, N. Effect of hop extracts on rheological properties of wheat dough, *IOP Conf. Series: Materials Science and Engineering*. 2021; 1031 (1): 012097. <https://doi.org/10.1088/1757-899X/1031/1/012097>
24. Protsenko L, Ryzhuk S, Litvynchuk S, Shevchenko A, Bober A, Shevchenko O. (2022). Application of Valuable Hop Compounds in Bakery. In: Paredes-López, O., Shevchenko, O., Stabnikov, V., Ivanov, V., eds., *Bioenhancement and Fortification of Foods for a Healthy Diet*, CRC Press, Boca Raton, USA. 2022; 29-46. <https://doi.org/10.1201/9781003225287-3>
25. Rak V, Yurchak V, Protsenko L, Pasichnyk I. Application of hops for enrichment of bread with biologically active substances. *Food Industry*. 2010; 9: 39-42. Access regime: <https://dspace.nuft.edu.ua/server/api/core/bitstreams/d40f56c2-c5d1-4eee-8465-fb852a1d2901/content> (in Ukrainian)
26. Protsenko L, Lyashenko M, Svirchevska O, Grynuk T, Vlasenko A. Methodology for evaluating hops and hop products. *Zhytomyr. Ruta*. 2020. Access regime: <https://isgpnau.org/vidavnychia-diylanist/226.html> (in Ukrainian)
27. Analytica EBC (Analytica European Brewery Convention). *Methods 7.2, 7.4, 7.5, 7.7*. 6th Ed. Nürnberg, Verlag Hans Carl Getränke-Fachverlag, 2006.
28. Analytica-EBC, 7.10 (Analytica European Brewery Convention) (2002). Hop Oil Content of Hops and Hop Products. <https://brewup.eu/ebc-analytica/hops-and-hop-products/hop-oilcontent-of-hops-and-hop-products/7.10>
29. Analytica-EBC, 7.12 (2006). Hop Essential Oils by Capillary Gas Chromatography Flame Ionization Detection. <https://brewup.eu/ebc-analytica/hops-and-hop-products/hop-essential-oils-by-capillary-gas-chromatography-flame-ionization-detection/7.12>
30. Ahalitka – EBC, European Brebery Convention, fourth edition, 1987: 271 p.
31. Jerumanis G. Über die Veränderung der Polyphenols in Verlauf des Mälzens ind Maisches. *Brawissechaft*. 1972; 23(10): 313-318
32. Chen C, Lv, C. Interaction Between Iso- α -Acid Extracted from Hops and Protein Z Improves Beer Foam Quality and Stability. *Chemistry*. 2025; 7(2): 65. <https://doi.org/10.3390/chemistry7020065>
33. Wang L, Hong K, Agbaka J, Song Y, Lv C, Ma C. Characterization of bitter-tasting and antioxidant activity of dry-hopped beers. *J. Sci. Food Agric*. 2022; 102: 4843-4853. <https://doi.org/10.1002/jsfa.11847>
34. Sabbatini G, Mari E, Ortore M, Di Gregorio A, Fattorini D, Di Carlo M, Galeazzi R, Vignaroli C, Simoni S, Giorgini G, et al. Hop Leaves: From Waste to a Valuable Source of Bioactive Compounds – A Multidisciplinary Approach to Investigating Potential Applications. *Heliyon*. 2024; 10: e37593. <https://doi.org/10.1016/j.heliyon.2024.e37593>
35. Protsenko LV, Lyashenko MI, Svirchevska OV, Vlasenko AS, Grynuk TP. Suitability of modern hop varieties for application in bread baking. *Agroindustrial production of Polissya*. 2019; 12: 64-72. Access regime: http://nbuv.gov.ua/UJRN/avpol_2019_12_13 (in Ukrainian)

ОПТИМІЗАЦІЯ НОРМИ ВИТРАТ ХМЕЛЮ В ХЛІБОПЕЧЕННІ ЗА ВМІСТОМ У НЬОМУ ГІРКИХ РЕЧОВИН

Л. Проценко¹, к.т.н., зав. відділу, *E-mail*: Lidiya.procenko@ukr.net,

Н. Кошицька¹, к.с.-г.н., провідний н.с. відділу, *E-mail*: Ninakoshitska@gmail.com

С. Рижук¹, академік НААН, доктор к.с.-г.н., професор, директор інституту, *E-mail*: isgpo_zt@ukr.net

О. Свірчевська¹, н.с. відділу, *E-mail*: Svirchevskaya79@ukr.net

А. Бобер², к.с.-г.н., доцент кафедри, *E-mail*: bober_1980@i.ua

С. Гулько², к.т.н., доцент кафедри, *E-mail*: cgunko@gmail.com

І. Бобер³, студент бакалавр, *E-mail*: irairabober14@gmail.com

¹ Відділ біохімії хмелю і пива та біотехнології

Інститут сільського господарства Полісся НААН України, шосе Київське, 131, г. Житомир, Україна, 10007

² Кафедра технології зберігання, переробки та стандартизації продукції рослинництва ім. проф. Б.В. Лесика

Національний університету біоресурсів і природокористування України
вул. Героїв Оборони, 13, м. Київ, Україна, 03041

³ Київський національний університет імені Тараса Шевченка,
вул. Володимирська 60, м. Київ, Україна, 01033

Анотація. З розвитком нових тенденцій до здорового харчування та задоволення потреб споживача, для розширення асортименту хлібобулочних виробів та збагачення хліба біологічно активними сполуками хмелю, широкого розповсюдження набуло виробництво хліба з додаванням шишок цієї унікальної за вмістом гірких речовин, поліфенольних сполук, ароматичних та ефірних олій рослини. Проведені дослідження із вивчення та обґрунтування ефективного використання комплексу технологічно цінних сполук українського тонкоароматичного хмелю сорту

Перлина дозволили встановити можливість і доцільність його використання у випічці та вплив на якість хліба. Аналіз отриманих результатів показав, що гіркі якості хмелю мали значний вплив на смак хліба. На відміну від цього, поліфенольні сполуки мали менший вплив на смак, але в поєднанні з гіркими речовинами значно впливають на споживчі якості. Результати досліджень використання закваски хмелю ароматичного сорту Перлина з різним вмістом альфа-кислот та поліфенольних сполук показали, що хліб мав високі смакові якості при додаванні до 1 кг борошна: від 23,9 до 35,8 мг гірких речовин та 45,2 – 72,1 мг поліфенольних сполук. З меншою кількістю гірких речовин та більшою кількістю поліфенолів смак хліба майже не відрізнявся від контрольного зразка, хоча фізико-хімічні показники покращилися. При збільшенні з 35,8 до 43,4 мг гірких речовин на фоні приємного хмелевого аромату відчувалася ледь помітна гірчинка. При додаванні до тіста з 1 кг борошна більше 50,8 мг гірких речовин хліб набував помітної гіркоти. На прикладі хмелю сорту Перлина, оптимізовано дозування витрат хмелю та запропоновано розрахунок норми його споживання в хлібопеченні з урахуванням вмісту в ньому гірких альфа-кислот. Оптимально обґрунтованою нормою гірких речовин хмелю для забезпечення відмінних смакових і споживчих властивостей хліба є діапазон внесених альфа-кислот від 23,9 до 43,4 мг на 1 кг борошна. Запропонована технологія покращила споживчі властивості та смакові якості хлібобулочних виробів з наданням аромату хмелю та стабільного оптимально-нормалізованого смаку хліба з легкою ніжною гірчинкою. При цьому зростає об'єм хліба, пористість, покращується структура пористості та еластичність м'якушки. Зменшення кількості дріжджів не вплинуло на процес бродіння тіста та стабільність форми кінцевого продукту. Це сприятиме оздоровчим та профілактичним ефектам продуктів.

Ключові слова: хліб, хміль, хмелева закваска, сорт хмелю, альфа-кислоти, показники якості.