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EVALUATION OF THE CONTENT AND COMPOSITION OF ESSENTIAL OIL OF AROMATIC AND BITTER HOP VARIETIES

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Abstract. For hundreds of years, hops, as the main ingredient in brewing beer, have given the beverage not only its traditional bitterness, but also its unique hop aroma. This is due to the variety of essential oils and aromatic substances contained in hop cones, which give beer its special hop aroma. The aim of our work was to investigate the properties and evaluate the variability of the content and composition of essential oil in eleven aromatic and bitter hop varieties, with a particular focus on their genetic stability and suitability for brewing. The hop varieties studied show significant variability in essential oil content, which is crucial for brewing, with an average ranging from 0.42 to 1.87 ml/100 g of dry hops. The maximum content of essential oil (1.98 ml/100 g of dry hops) was found in the cones of the new bitter hop variety Vytiaz, and the minimum amount is found in the cones of the finely aromatic Zatecky-type varieties Klon 18 and Zlato Polissya (from 0.32 to 0.58 ml/100 g). Among the aromatic varieties, the maximum content of essential oil was determined in the Zagrava variety with a range of variation (R) from 1.01 to 1.88 ml/100 g of dry hops, with an average value of 1.25 ml/100 g. The majority components of hop essential oil are hydrocarbons and are represented by terpenes: monoterpenoids – myrcene and sesquiterpenoids – caryophyllene, humulene and farnesene, which together constitute 67.9–84.0 % of its total content. Aromatic varieties demonstrated a myrcene content typical of European varieties. The farnesene content varied significantly, ranging from 0.3 to 19.8 %, with the highest content found in the Klon 18, Zlato Polissya, and Nationalny varieties and the bitter Promin variety. The humulene content ranged from 15.5 to 27.7 %. The study showed that, despite annual fluctuations, the content and composition of essential oil remained within the passport data declared for the variety. The study demonstrates the genetic basis of the composition of essential oil in hops, highlighting its potential as a biochemical criterion for variety identification. The results of the study provide valuable information on sustainable cultivation and optimal use of hops in the brewing industry.

Keywords: hop essential oil, hop varieties, variability, stability, biochemical criteria..

Introduction. Formulation of the problem

The brewing industry is the main consumer of hops in the world, accounting for more than 90 % of global hop production [1, 2]. Hop gives beer its characteristic bitter taste due to unique bitter substances such as alpha acids and beta acids that are not found in other plants [3]. In addition, a complex of hop compounds affects the clarification of beer and foam formation, as well as increases the biological and colloidal stability of the beverage [2, 3], preserving its microbiological stability [4, 5].

In addition to bitterness, hops also give beer a specific aroma, unique spiciness and a delicate hop taste [6]. This is ensured by the variety of aromatic substances in hop essential oil, which are synthesized in the lupulin glands during the formation and ripening of hop cones [7]. Due to the specific composition of the essential oil, each hop variety gives beer individual taste qualities and aromatic properties that can be citrus, floral, fruity notes, spicy, woody or herbal aroma [8, 9]. Therefore, studying the content and composition of hop essential oil is important for the successful development of various types of brewing [6, 8].

Analysis of recent research and publications

With the development of the new Craft beer trend and the creation of signature beer styles, which are growing in popularity, brewers are increasingly using of hop products of variety with different essential oil compositions to create special aroma and taste profiles in beer [10-13]. The creation of such varieties stimulates the search for new source forms and varieties of hops with an increased content of various biologically active substances in the cones, including essential oils [14]. The breeding programmers of the leading countries in the hop industry, namely the Czech Republic, Germany, the United States, China, Poland and others, are currently focused on creating hop varieties with unique characteristics [7, 15, 16].

Beside, the biologically active compounds of hop cones are known for their antioxidant, anti-inflammatory and anti-tumour activity [17], which makes them interesting for the pharmaceutical industry [3, 10, 18]. Hop oils and resins are well known for their sedative and other neuropharmacological properties. Some of these therapeutic properties, especially the sedative effect of hops and their use as a hypnotic, have been attributed to the volatile components of hop oils [19, 20]. They also demonstrate antibacterial and antifungal activity. Thus, the main components of essential oil, such as α-humulene, α-myrcene and β-caryophyllene, have been shown to be active against various strains of gram-positive and gram-negative bacteria [17]. In official medicine, hop essential oil is known for its anaesthetic, antiseptic and sedative effects. It is included in such well-known preparations as Valocardin (used for disorders of the cardiovascular system), Novo-Passit, Valosedan (for stabilizing the nervous system) and Urolesan (for eliminating infectious processes in the kidneys and bladder).

In addition to medical purposes, interest in this plant is growing in light of the possible use of its extracts to control harmful plant organisms – fungi [21], mites [22] and insects [23, 24]. This aspect seems especially relevant, since, as is well known, traditional control, particularly of storage pests, has relied primarily on synthetic insecticides such as organochlorines, organophosphates, methyl bromide and phosphine. However, the indiscriminate use of these chemicals has caused long-term problems for human health and the environment, mainly due to their slow degradation in the environment and toxic residues in products, as well as the development of pesticide resistance in pest populations.

From this point of view, aromatic plants, in particular hops are an excellent source of biologically active compounds, some of which are already used as natural insecticides.

The proportion of essential oil in the chemical composition of dry hop cones is only 0.1–4.2 % [6] and consists mainly (60–80 % of the total mass) of hydrocarbons: mono- and sesquiterpenes. Other components of essential oil make up the oxygen-containing fraction: alcohols, acids, aldehydes, esters, ketones, etc. [25]. They are the most representative group in the composition of essential oil, although they account for only 20 % of its total amount [16]. Less than 1 % presented by sulphurous substances, but it is precisely these sulphurous substances that are significantly important active compounds and their influence on the overall aroma of hops is significant [16].

The evaluation of the composition of essential oil, along with bitter substances, is an important task in the study of the properties of hops. The amount of essential oil in hop cones depends on many factors, such as agricultural techniques, fertilizer application, weather conditions, etc. The qualitative composition is determined mainly by the genetic characteristics of the hop variety [6, 26, 27]. Thus, analysis of the content and composition of essential oil can be indicate the origin of the hop variety and data on the composition of the oil can be used to identify hop varieties. Currently, data on the composition of essential oil is used for the biochemical certification of hop varieties.

The purpose of the study was to investigate the properties and assess the variability of the content and composition of essential oil in eleven aromatic and bitter hop varieties listed in the State Register of Plant Varieties Suitable for Distribution in Ukraine, with a particular focus on their genetic stability and suitability for brewing.

To achieve this goal, the following tasks were formulated:

- to study the properties of hop essential oil in eleven aromatic and bitter varieties listed in the State Register of Plant Varieties Suitable for Distribution in Ukraine;
- to evaluate the variability of the content and composition of essential oil in eleven aromatic and bitter hop varieties listed in the State Register of Plant Varieties Suitable for Distribution in Ukraine.

Research materials and methods

The research was conducted in 2020–2024 in the accredited laboratory of hop and beer biochemistry at the Institute of Agriculture of Polissya of the National Academy of Agrarian Sciences of Ukraine and in the production conditions of farms specializing in hop cultivation in the Zhytomyr, Lviv, Khmelnytskyi and Rivne regions of Ukraine. We studied the essential oil of hop samples selected from consignments of eleven aromatic and bitter varieties of Ukrainian selection and one bitter variety of German selection that included to the State Register of Plant Varieties Suitable for Distribution in Ukraine. We studied 7–10 samples from consignments of each hop variety. The average sample weight for identification and biochemical studies was not less than 1 kg of hops.

Ukrainian-bred hops of the fine-aromatic, aromatic, bitter and bitter-aromatic types with a special aroma were studied:

- fine-aromatic varieties of Zatecky-type hop with a delicate hop aroma: Klon 18 and Zlato Polissya with an alpha acid content of 3.0 to 5.5 %, hop variety Slavyanka with an alpha acid content of 4.5–5.5% and hop variety Perlyna with an alpha acid content of 5.0–9.0 %;
- aromatic varieties with hop aroma: Nationalny and Zagrava with an alpha acid content of 5.0 to 9.0 %;
- bitter varieties with a pronounced hop aroma: Alta, Promin and Vytiaz with an alpha acid content of 8.0 to 13.0 %;
- bitter variety of German selection Magnum with a well-pronounced hop aroma with an alpha acid content of 11.0 to 15.0 %;
- bitter-aromatic hop varieties with a special aroma: Ruslan and Xantha, which have fruity, floral, citrus and spicy tones and alpha acid content of 8.0 to 11.0 %.

Modern physical and chemical methods of analyzing hop essential oil were used: capillary gas chromatography, other control methods harmonized with the methods of the European Brewing Convention, as well as mathematical and statistical methods using dispersion and correlation-regression analysis to assess the reliability of the research results obtained.

Methods for researching the quantity and qualitative composition of hop essential oil. The quantity of essential oil was determined using the international Analytica-EBC 7.10 method [28, 29]. The method is based on determining the essential oil content in ml per 100 g of dry hop with obtaining essential oil by hydrodistillation, followed by decantation and collection in a special trap. The chemical composition of essential oil was determined by gas-liquid chromatography, following the official method in Analytica EBC 7.12 [28, 30]. Four selected main components of the essential oil (myrcene, caryophyllene, farnesene, humulene) were identified and quantified using a Crystal-2000M capillary gas chromatograph equipped with a flame ionization detector. The essential oil extracted from hop cones was separated into individual compounds by gas chromatography on 50–60 m columns (Restek Stabilwax®, manufactured in the USA) using 20–30 cm^3 of chromatographic inert nitrogen carrier gas. The chromatography conditions were selected to ensure the separation of the main components of the essential oil. The temperature programme 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 percentage of a particular compound in the essential oil.

The quantity and composition of essential oil (passport data) of the studied varieties are presented in Table 1.

Table 1 – Total quantity of essential oil and its qualitative composition in the studied hop varieties (passport data*)

Hop varieties	Total essential oil, ml/100 g dry hops	% to total content			
		myrcene	caryophyllene	humulene	farnesene
Fine aromatic hop varieties					
Klon 18	0.4–0.8	20.0–35.0	25.0–35.0	8.0–12.0	15.0–20.0
Zlato Polissya	0.4–0.9	20.0–40.0	25.0–35.0	6.0–10.0	14.0–20.0
Slavyanka	1.3–2.0	30.0–50.0	9.0–15.0	4.0–8.0	13.0–18.0
Perlyna	1.1–2.3	28.3–39.7	10.3–16.0	3.5–8.7	12.7–17.5
Aromatic hop varieties					
Nationalny	0.8–1.2	30.0–40.0	10.0–20.0	8.0–10.0	14.0–18.0
Zagrava	1.4–2.5	30.0–45.0	15.0–20.0	5.0–8.0	10.0–15.0
Bitter hop varieties					
Alta	1.0–2.0	35.0–50.0	25.0–30.0	8.0–12.0	≤ 1
Promin	1.2–2.5	40.0–60.0	15.0–20.0	5.0–7.0	15.0–20.0
Bitter-aromatic hop varieties with a special aroma					
Ruslan	2.0–3.0	40.0–60.0	15.0–20.0	5.0–8.0	≤ 1
Xantha	1.0–1.5	30.0–40.0	25.0–35.0	8.0–12.0	≤ 1

* Source [31].

Results of the research and their discussion

Essential oil, like bitter substances, is synthesised and accumulates during the formation and ripening of cones and is concentrated mainly in the lupulin of hop cones. Moreover, the main amount of essential oil accumulates at the final stage of bitter substance synthesis and after it. During the formation and ripening of hop cones, the amount of essential oil increases, reaching its maximum at the stage of physiological ripeness.

Fig. 1 shows the minimum, average and maximum essential oil content of hops in varieties selected in Ukraine.

Among the fine-aroma hop varieties: Klon 18, Zlato Polissya and Slovyanka had the lowest oil content during the years of research was determined in the cones of the Klon 18 variety, which was 0.32–0.55 ml/100 g of dry hops, that was average of 0.42 ml/100 g. Almost the same amount, with a difference between the limits of the estimated sign of 0.41–0.58 ml/100 g of dry hops, was determined in Zlato Polissya with an average of 0.49 ml/100 g of dry hops. According to the passport data for these varieties, published in the Atlas of Ukrainian Hop Varieties [31], the oil content is in the range of 0.4–0.8 and 0.4–0.9 ml/100 g of dry hops. The results we obtained for these varieties are closer to the lower limit. Significantly more oil (0.92 ml/100 g) was found in the cones of the finely aromatic Slavyanka variety and 1.23 ml/100 g of dry hops in the Perlyna variety.

Among the aromatic varieties (Nationalny, Zagrava), the maximum amount of essential oil was found in the hop variety Zagrava with a range of variation (R) from 1.01 to 1.88 ml/100 g of dry hops, with an average value of 1.25 ml/100 g. In the group of bitter and bitter-aromatic varieties with a special aroma (Alta, Promin, Magnum, Vytiaz, Ruslan and Xantha), a stabile high amount of oil was determined in the cones of the Vytiaz variety, which is included in the State Register, with a difference between the limits of the indicator of 1.76–1.98 ml/100 g of dry hops, with an average value of 1.87 ml/100 g of dry hops.

Thus, from the analysis of the data in Fig. 1, over the years of research, there has been a decrease in the amount of essential oil in all hop varieties without exception, since the results for these varieties are closer to the lower limit of the passport data for these varieties [31], which may be associated with the abnormal natural and climatic conditions of these years [32]. However, the range of variation in essential oil content for Ukrainian varieties over the years of research was within the range of content of this compound according to the passport data of the studied varieties.

Hop essential oil, which significantly determines the taste and aroma of beer, is a mixture of more than 300 components. Their composition is represented by different classes of organic compounds and depends on the variety, year of harvest, place of cultivation, harvest time, drying and storage technology. The characteristics of the components of hop essential oil, in particular the composition of monoterpenes and sesquiterpenes, are constantly changing – from the beginning of hop cone formation, the arrival of technical and physiological ripeness, the processing of hops into the corresponding hop product and its use in brewing [33].

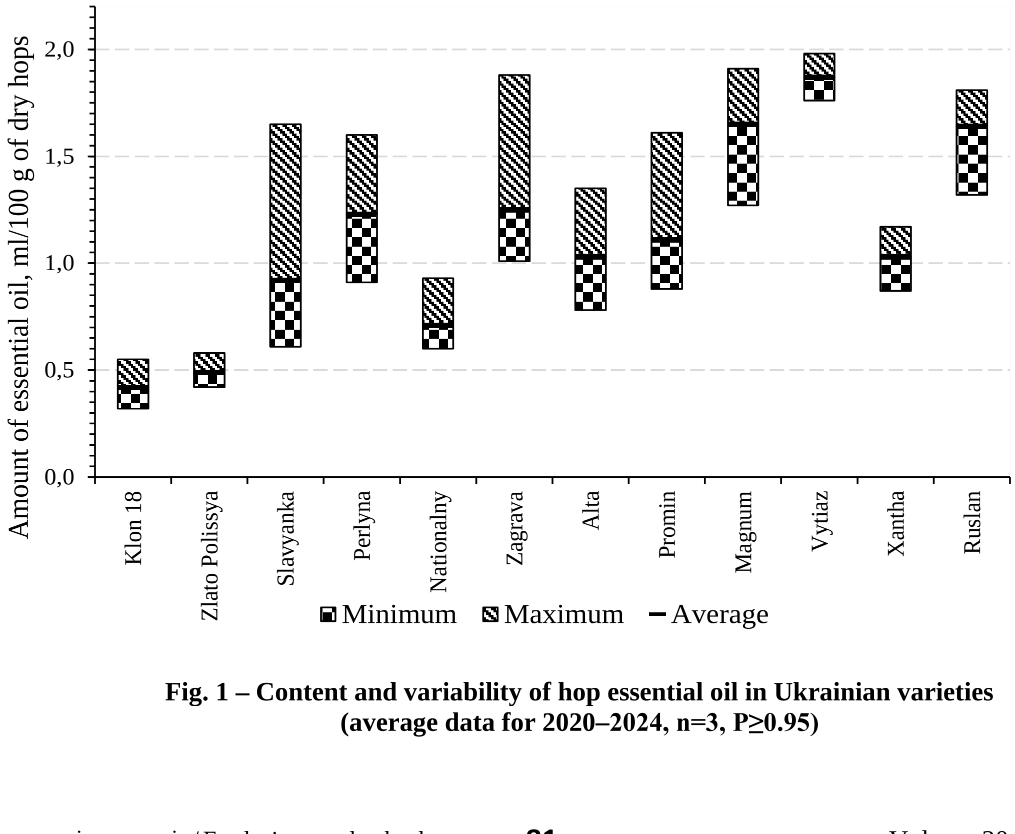

Fig. 1 – Content and variability of hop essential oil in Ukrainian varieties (average data for 2020–2024, n=3, P≥0.95)

The results of studies on the total accumulation of essential oil and its composition over the years of research are presented in Table 2. Analysis of the data in the table shows that most of the components of essential oil of Ukrainian hop varieties Ukrainian selection are hydrocarbons and are represented by terpenes: monoterpenoid – myrcene and sesquiterpenoids – caryophyllene, humulene and farnesene, which together account for 67.9–84.0 % of its total amount.

Thanks to the specific composition of the essential oil, each hop variety gives beer its own individual taste and aromatic properties. There are can be herbal, citrus, fruity and even berry notes, which greatly depends on the content of the hydrocarbon fraction of the essential oil, namely myrcene, caryophyllene, humulene and farnesene [8].

The main component among monoterpenes is myrcene ($C_{10}H_{15}$) but it proportion depending on the variety, ranges from 10 to 72 % [6]. Quantitatively, it is the most important component of hop oil [6] that is present in practically all varieties. Many American hop varieties, including Cascade, Amarillo, Citra and Simcoe, contain 50–70 % myrcene [14], while in European hop varieties its content is significantly lower, ranging from 20–40 % [6]. The aroma properties are extremely wide and can be described as green, hop, with slight pine and citrus notes. With modern brewing methods, in particular, the use of "dry hopping" technology, the aroma of "green" or fresh hops is usually formed [9,16].

Ukrainian aromatic hop varieties contain myrcene in their essential oil, ranging from 25.9 % in the cones of the Klon 18 variety to 37.3 % in the Zagrava variety, which is characteristic of European varieties. Stably, the lowest content of this compound over the years of observation was determined in the finely aromatic hop varieties Klon 18 and Zlato Polissya, with average values of 25.9 % and 26.6 %, respectively that is characteristic of the finely aromatic Zatecky type of hop.

Among the bitter varieties, the highest myrcene content was found in the Promin variety – 41.1 %. Consistently high myrcene content values over the years of research, exceeding the values of other varieties, were found in the cones of the Ruslan variety, which amounted to 39.8–56.2 %, with average values of 46.3 %. As we can see, among Ukrainian selections, there are currently no varieties that genotypes determine a myrcene content of up to 70 % that was found in plants of American varieties [14].

Humulene ($C_{15}H_{24}$) is traditionally a component of hop oil and has a spicy, herbaceous aroma associated with European fine-aroma hops. Ukrainian hop varieties have relatively high humulene content in their essential oil, ranging from 15.5 % to 27.7 %, which classifies them as varieties with a delicate aroma. In the aromatic group of varieties, the highest humulene content is found in the Klon 18 and Zlato Polissya varieties, which are characterized by the lowest content of myrcene in their essential oil and a high proportion of farnesene. However, the highest humulene content is found in the cones of the Alta, Xantha and Magnum varieties.

Table 2 – The amount of essential oil and its qualitative composition in the cones of the studied hop varieties for 2020-2024 (average at n=3, P≥0.95± SD)

Hop varieties	Amount of essential oil, ml/100 g of dry hop	% to total content			
		myrcene $C_{10}H_{15}$	humulene $C_{15}H_{24}$	caryophyllene $C_{15}H_{24}$	farnesene $C_{15}H_{24}$
Fine aromatic varieties					
Klon 18	0.42*±0.11	25.9±3.87	24.3±6.21	7.8±1.25	19.8±3.65
Zlato Polissya	0.49±0.08	26.6±3.81	25.7±3.73	8.9±1.16	18.7±2.44
Slavyanka	0.92±0.22	35.8±6.87	17.3±4.54	7.7±1.13	16.8±3.16
Perlyna	1.23±0.30	32.5±3.13	16.4±2.17	7.3±1.43	14.7±1.09
Aromatic varieties					
Nationalny	0.71±0.13	30.7±7.19	15.5±3.45	6.3±1.53	19.7±3.88
Zagrava	1.25±0.35	37.3±8.66	18.8±4.53	5.7±1.89	14.5±5.65
Bitter varieties					
Alta	1.03±0.25	32.8±5.16	27.7±4.77	10.9±1.76	0.3±0.08
Promin	1.11±0.26	41.1±5.78	18.6±3.87	7.5±1.54	16.8±3.76
Vytiaz	1.87±0.07	37.7±1.43	22.7±1.22	10.9±1.08	0.4±0.07
Magnum	1.65±0.24	31.1±6.77	26.3±5.43	6.6±1.38	0.5±0.08
Bitter-aromatic varieties with a special aroma					
Xantha	1.03±0.12	37.6±4.22	26.7±5.54	12.6±1.71	0.7±0.14
Ruslan	1.64±0.17	46.3±5.66	17.9±2.55	9.9±1.33	0.8±0.16

Note:* average values of indicator X for 2020-2024 studies ± SD

Caryophyllene ($C_{15}H_{24}$) is the opposite of humulene in terms of taste and aroma characteristics, with woody, peppery, spicy and earthy aromas [9, 16]. Although this compound is not a significant characteristic component of European hops, caryophyllene is the main aromatic component of many traditional English varieties, such as Golding and Northdown, as well as American varieties, such as Mount Hood [14]. Caryophyllene gives beer a strong aroma of dry wood, pepper, spicy and earthy aftertaste. Sometimes it can create a citrus taste [8, 9].

Caryophyllene in Ukrainian aromatic varieties is within the range of 5.7–8.9%, which is also characteristic of European varieties [6]. The lowest caryophyllene content was found in the Zagrava hop variety – 5.7 %. The highest content of this compound (12.6 %) is consistently found in the bitter-aromatic hop variety with a special aroma called Xantha.

Farnesene ($C_{15}H_{24}$) is a “hallmark” of noble hop varieties [9]. It was getting a green apple taste, as well as floral, citrus and fruity aromas [9, 16]. In most European and American varieties, farnesene ranks last among the components of hop oil in terms of quantity, usually less than 1% [9]. However, in European fine-aroma hop varieties such as Zatecky, Lublin, Tettnanger, Spalt Select [6] and in all aromatic Ukrainian varieties, as well as in the bitter Ukrainian variety Promin, its content is significantly higher and may be exceed 20 %.

The samples studied show significant variability in the farnesene content of essential oil, with average values ranging from 0.3 % (Alta) to 19.8 % in hop cones of the Klon 18 variety. The Ukrainian hop varieties studied can be divided into two groups based on the minimum and maximum percentage of farnesene in the essential oil: varieties with high farnesene content from 12 % to 20 % and varieties with a farnesene content of up to 1 %. All delicate and aromatic varieties have a relatively high content of farnesene in their essential oil, ranging from 14.5 % in Zagrava cones to 19.8 % in Klon 18 cones, which is a Zatecky-type hop variety. This compound is also present in significant quantities (16.8 %) in the cones of the Promin variety, which is the only representative among the bitter varieties of both Ukrainian and European and American varieties with farnesene-type essential oil [9]. The ratio of beta acids and alpha acids is 0.5–0.6, which characterises the variety as a bitter type of hop. However, as evidenced by our previous studies [34], the low content of cohumulone in the alpha acids (26–30 %) and the presence of farnesene essential oil compounds, which is a characteristic feature of aromatic varieties, determine the high brewing qualities of this variety.

The National variety has a high content of farnesene in its essential oil, which is 14.6–20.5 %, with an average value of 19.7 %. Thanks to the low content of caryophyllene and the high content of farnesene in the essential oil, in combination with other components, the National variety has a high technological rating.

The Slavyanka variety of Zatecky-type hops has similar characteristics. The quantity and composition of essential oil, combined with the unique composition of bitter substances, characterize this variety as a particularly valuable, delicately aromatic type of hop for brewing. The Alta, Vytiaz, Magnum, Ruslan and Xantha hop varieties have less than 1.0 % farnesene in their essential oil.

Thus, the results of the studies confirm that the qualitative composition of the components of essential oil and their ratio in hop cones does not depend on the group belonging of the variety and its chemical composition, is a varietals characteristic, i.e. it is controlled at the genome level and is one of the biochemical criteria for the identification of breeding hop varieties.

As noted above, the qualitative composition of essential oil depends on the hop variety, i.e. it has a genetic basis [35], while its quantitative content may vary depending on cultivation techniques, fertilizer application, weather conditions, etc. Higher temperatures during the synthesis of bitter substances, essential oil and the absence of precipitation are, of course, important parameters that affect the stability of the variety's characteristics. Thus, Czech scientists [6] noted that increased temperatures and the absence of precipitation in the last decade have negatively affected the quality of hop varieties [36, 37]. As a result, in the Czech Republic, in particular, in 2021, the QK21010136 research project was started to study and apply new hop genotypes resistant to drought in brewing, called «Application of new hop varieties and genotypes resistant to drought in hop growing and beer brewing» [6]. After all, assessing the stability of the technological characteristics of a hop variety is a necessary criterion for obtaining stable beer quality.

An analysis of the research results of leading Czech hop scientists [6] shows that the delicately aromatic hop varieties of the Zatecky type, Saaz, Saaz Brilliant, Saaz Late, Saaz Shine and Saaz Comfort, have the lowest content of essential oil (0.43–0.83 ml/100 g of dry hops), which corresponds to the results of our research on the lowest oil content in the Zatecky type hop varieties Klon 18 and Zlato Polissya, the content of which ranges from 0.32 to 0.58 ml/100 g of dry hops. The average results obtained for these varieties (0.42 and 0.49 ml/100 g of dry hops) are closer to the lower limit compared to the passport data for these varieties [31], according to which the oil content is in the range of 0.4–0.9 ml/100 g of dry hops. According to the Atlas of Czech Hop Varieties [38], the essential oil content in Saaz ranges from 0.4 to 0.8 ml/100 g of dry hops. The results obtained for these varieties by Czech scientists are also at the lower limit of the passport data [6]. Also, these varieties contain the most valuable farnesene for brewers, which determined to be 20 % and more and the least myrcene [6], which also corresponds to the results of our research.

As can be seen from the results, the quantitative content of essential oil during long-term cultivation in some of the hop varieties studied was subject to change. It is well known that weather conditions during the formation of hop cones have a significant impact on their technological qualities, so such changes may be associated with changes in climatic factors. In today's conditions, when global climate change is observed, this issue is becoming increasingly relevant. The degree of influence of stressful weather factors on the formation of the brewing qualities of hops in Ukraine under changing climatic conditions has not been sufficiently studied and covered in the literature that explains the relevance of further research.

Further research will focus on studying the impact of agroclimatic factors on the formation of the brewing qualities of hops in terms of aromatic and bitter varieties, as well as determining the relationship between weather factors and the commercial and technological quality indicators of the researching crop.

Conclusion

The eleven aromatic and bitter hop varieties studied show significant variability in essential oil content, which is crucial for brewing, with an average ranging from 0.42 (Klon 18) to 1.87 ml/100 g of dry hops (Vityaz). The maximum amount of essential oil is found in the cones of the new bitter hop variety Vytiaz and the minimum amount is found in the cones of the delicately aromatic Zatecky type of varieties Klon 18 and Zlato Polissya (from 0.32 to 0.58 ml/100 g). Among the aromatic varieties, the maximum amount of essential oil is found in the Zagrava variety of hops, with a range (R) from 1.01 to 1.88 ml/100 g of dry hops, with an average value of 1.25 ml/100 g.

Most of the components of hop essential oil are hydrocarbons and are represented by terpenes: monoterpenoids –myrcene and sesquiterpenoids – caryophyllene, humulene and farnesene, which together account for 67.9–84.0 % of its total amount.

In all hop varieties, a decrease in the amount of essential oil has been observed over the years of research. However, the range of variation in the content of essential oil and its composition for Ukrainian varieties over the years of research was within the range of the content of this compound according to the passport data of the studied varieties.

It has been confirmed that the qualitative composition of the components of essential oil and their ratio in hop cones does not depend on the group affiliation of the variety and its chemical composition but it is a varietals characteristic, i.e. it is controlled at the genome level and it is one of the biochemical criteria for the identification of selected hop varieties.

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ОЦІНЮВАННЯ ВМІСТУ ТА СКЛАДУ ЕФІРНОЇ ОЛІЇ ХМЕЛЮ АРОМАТИЧНИХ І ГІРКИХ СОРТІВ

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Анотація. Впродовж багатьох століть хміль, як основний компонент при варінні пива, надає напою не лише традиційної гіркоти, але і неповторний хмельовий аромат. Відбувається це завдяки різноманіттю ефірних олій і ароматичних речовин, що містяться в шишках хмелю і надають пиву своєрідного хмельового аромату. Метою нашої роботи було дослідити властивості та оцінити варіабельність вмісту і складу ефірної олії в одинадцяти ароматичних та гірких сортах хмелю з особливим акцентом на їхню генетичну стабільність та придатність для пивоваріння. У досліджуваних сортах хмелю спостерігається значна варіабельність вмісту ефірної олії, що має вирішальне значення для пивоваріння, середній показник якої коливається від 0,42 до 1,87 мл/100 г сухого хмелю. Максимальну кількість ефірної олії (1,98 мл/100 г сухого хмелю) визначили в шишках нового сорту хмелю гіркого типу Витязь, а мінімальна її кількість міститься в шишках тонкоароматичних сортів жатецького типу Клон 18 та Злато Полісся (від 0,32 до 0,58 мл/100 г). Серед ароматичних сортів максимальну кількість ефірної олії визначено у хмелі сорту Заграва з розмахом варіювання (*R*) від 1,01 до 1,88 мл/100г сухого хмелю, середнє значення показника 1,25 мл/100 г. Більшість компонентів ефірної олії хмелю є вуглеводнями і представлені терпенами: монотерпеноїдом – мірценом та сесквітерпеноїдами – каріофіленом, гумуленом та фарнезеном, що в сумі становлять 67,9-84,0 % від загальної її кількості. Ароматичні сорти демонстрували вміст мірцену, типовий для європейських сортів. Вміст фарнезену мав значні коливання – від 0,3 до 19,8 %, з найвищим вмістом у сортах Клон 18, Злато Полісся та Національний і гіркому сорті Промінь. Вміст гумулену коливався від 15,5 до 27,7 %. Дослідження показало, що, незважаючи на щорічні коливання, вміст та склад ефірної олії залишалися в межах паспортних даних, заявлених для сорту. Дослідження демонструє генетичну основу складу ефірної олії в хмелі, наголошуючи на його потенціалі як біохімічного критерію для ідентифікації сортів. Результати дослідження дають цінну інформацію про стале вирощування та оптимальне використання хмелю в пивоварній промисловості.

Ключові слова: ефірна олія хмелю, сорти хмелю, мінливість, стабільність, біохімічні критерії.

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