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Pilot brewery tests of Czech flavour hop varieties registered in 2022

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Abstract

Seven new Czech "flavour hop" varieties were tested in pilot brewing trials (50 l), in which samples of Ale-style beer were prepared using dry hopping. Essential oils in the beer were determined by fluidized-bed extraction combined with gas chromatography–mass spectrometry. Hop-derived aromas in beer were evaluated by descriptive method. Comparison of terpene essential oils in samples showed differences between hop genotypes and only a partial relationship with the sensory profile of beer. A cluster analysis of hop aromas in beer revealed the relationship between the pairs of Saturn and Pluto; N and Eris; Ceres and Jupiter hop varieties. The submitted results present the sensory properties of these new varieties and are useful for further study of the relationship between chemical and sensory profile of dry hopped beers.

Keywords: hop varieties; dry hopping; beer sensory profile; hop volatiles

1 Introduction

Hops are undoubtedly a brewing raw material that creates or completes the sensory character of beers of all styles and the specific character of beer brands. Approximately 150 hop varieties have been bred and registered worldwide, and even more are added each year (Patzak and Henychová, 2018). Hop breeding in the Czech Republic has a long tradition; currently 28 Czech varieties are registered by the Central Institute for Supervising and Testing in Agriculture (CISTA), including the traditional Saaz (CISTA, 2022).

The breeding of a new hop variety takes many years. The newly bred genotypes are targeted for various uses, be it for a high content of alpha acids, basic hopping and bittering of beer, or a typical hop aroma, and recently also for new unusual aromas ("flavour hops varieties"). Traditional aromatic hop varieties hold their place on the market, but changes in consumer preferences and the need for innovation, the development of new beer brands are the reason for breeding and using new varieties with interesting aroma and bitterness profiles.

The brewing value of hops depends primarily on the content and composition of bitter acids and essential oils. These brewing-important substances are formed in the lupulin glands of hop cones (*Humulus lupulus* L.). Hop resins (bitter acids) give beer its bitterness, while volatiles from the group of hop essential oils provide aroma and flavour (Almaguer et al., 2014).

The majority of beer bitterness comes from alpha acids, their isomerised products, iso-alpha acids (Jaskula et al., 2010; Almaguer et al., 2014; Oladokun et al., 2015), bitterness is also shown by hulupones, oxidation products of beta acids (Dušek et al., 2014; Algazzali and Shellhammer, 2016; Krofta et al., 2019) and humulinones, oxidation products of alpha-acids (Algazzali and Shellhammer, 2016). These oxidation products contribute significantly to the bitterness of beer only during dry hopping (Algazzali and Shellhammer, 2016). Some polyphenols have bitter or bitterness-modifying properties (Goiris et al., 2014; Oladokun et al., 2016).

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Bitterness is one of the key attributes used to assess the sensory quality of beer. Sensory bitterness of beer includes various aspects of bitter perception, such as intensity, quality (pleasantness) and the rate at which bitterness fades after drinking (Mikyška et al., 2015). The perception of organoleptic bitterness is highly individual and depends on the beer matrix (He et al., 2014).

The specific aroma that hops impart to beer depends on the hopping technology used during the brewing process. The composition of hop essential oils is very diverse, more than 450 volatile substances have been identified (Inui et al., 2013). Volatiles in hops typically represent 0.5–3.0% of the weight of dried hop cones (Dresel et al., 2016). The aroma of hops is created rather by a synergistic action of individual compounds than by the effect of a single compound.

The components of hop essential oils are generally divided into three chemical groups: hydrocarbons, oxygenated compounds and sulphur compounds. These groups represent 60–80%, 20–40% and less than 1% of the total essential oils in hops, respectively. The main components of essential oils are hydrocarbon terpenes, the most widespread of which are the monoterpene myrcene and the sesquiterpenes β-caryophyllene, α-humulene, β-farnesene and selinenes. Oxygenated compounds include alcohols, ketones, and esters. The group of terpenic alcohols, which includes, for example, linalool, geraniol, terpineol and farnesol, is very important for the sensory profile of beer.

Most of the components of hop essential oils undergo significant changes during the wort boiling and at the same time, their large losses occur. Only a few polar terpenoid compounds, such as linalool, geraniol and humulene epoxides, can partially survive this process, these compounds impart the hop flavour to the final beer (Mitter et al., 2001; Fritsch and Schieberle, 2003; Kaltner and Mitter, 2009; Praet et al., 2016).

Further, the essential oils go through a thermal/oxidative transformation and biotransformation by the yeast action (Praet et al., 2012; Takoi et al., 2017) during fermentation. Moreover, sorption of some of the essential oils, especially myrcene, to the yeast cells accompanies the fermentation process (Haslbeck et al., 2017). During dry hopping, essential oil components are extracted into a slightly alcoholic beer solution, and partially sorbed or changed by the yeast present (Kaltner and Mitter, 2009; Forster and Gahr, 2013).

Sensory perceptions of essential oils in beer are usually described as floral, citrusy, fruity, spicy or herbal aromas. Terpene alcohols such as linalool and geraniol are important components of the floral character of hop essential oils and beer. The contribution of hop essential oils is particularly pronounced when dry hopping is applied. The typical hop flavour and aroma of kettle hopped beers is mainly formed by oxidized sesquiterpenes (Praet et al., 2016). It is known that the aroma of raw hops is often not comparable to the hop aroma in the final beer (Praet et al., 2012; Hanke et al., 2015).

This article focuses on pilot brewing trials with six new Czech hop varieties bred for special aromas and intended for dry-hopping of beer. Breweries need to know what to expect from these new varieties therefore chemical as well as sensory parameters were determined for both the hop cones of newly bred genotypes and for experimental beers produced as part of testing.

2 Materials and methods

Brewing tests of seven new genotypes of the hop (*Humulus lupulus* L.) intended for dry hopping were carried out in a pilot brewery of the Research Institute of Brewing and Malting (RIBM). Top-fermented beers with dry hopping were produced. The tested genotypes were bred in Hop Research Institute Žatec (HRI) and were the following: Juno, Ceres, Saturn, Jupiter, Eris and Pluto, registered in 2022; and genotype 5551 (N) currently in the registration process.

Wort was prepared from Pilsen malt of the Bojos variety using the infusion mashing. The brew was hopped with CO_2 hop extract of the Herkules variety to a target beer bitterness of 30 IBU. After a hot trub separation in a whirlpool, the wort was cooled down to the fermentation temperature of 10 °C and aerated to a dissolved oxygen content of 7.5 mg/l.

The primary fermentation was carried out in cylindroconical tanks (CCT), using Lallemand's Essential series ALE yeast, which does not form large amounts of esters. The maximum temperature was set at 13 °C ± 0.1 °C. The green beer was cooled down to a temperature of 3–4 °C within 24 hours and transferred to the following CCT. The maturation took place for three weeks at a temperature of 2 °C. 50-Liter aliquots of beer were taken five days before the end of aging in order to perform dry hopping of the tested hop genotypes using a static procedure with a uniform dose of 2.5 g hops/1 liter. The hop pressed cones were applied in a net bag fixed above the bottom of the CCT.

The beers were filtered with a plate filter and bottled on a machine filler with double evacuation and pre-filling of the bottles with carbon dioxide and then pasteurized to the level of 20 PU.

Analysis of hops for bitter acids and essential oils, as well as analyses of beers, were performed according to Analytica EBC (Analytica EBC, 2010). Essential oils in beer were measured by a previously developed gas chromatography method coupled with mass spectrometry detection (Štěrba et al., 2015). Consequently, a trained twelve-member panel of RIBM evaluators performed a sensory analysis of the beer including a detailed assessment of hop aromas. Both, the basic sensory profile of the beer and the hop aroma profile of the beer were evaluated. The intensity of bitterness after swallowing, the culmination of bitterness (after 15 s), the bitterness lingering (after 40 s), the bitterness character, as well as astringency, sweetness and sourness were rated on an ascending scale from 0 to 5 (not perceptible to very strong). The overall sensory impression was evaluated on a descending scale from 9 to 1. The intensity of the hop aroma and the intensity of individual components of the hop aroma were evaluated on an ascending scale from 0 to 5.

3 Results and discussion

The resulting sensory effect of dry hopping beer depends on a number of raw material and technological factors, hop variety, hop dose, hop contact time with beer, method of hop application (static batch or dynamic flow process), technological operation (application to young beer, filtered beer) and last but not least, the type of beer and the matrix of sensory active substances derived and not derived from hops in the starting beer before dry hopping (Steenackers et al., 2015; Algazzali and Shellhammer, 2016; Hauser et al., 2019; von Heynitz et al., 2020; Bandelt Riess et al., 2020).

During dry hopping, the essential oils contained in hops have a sensory effect, but derivatives of hop resins and polyphenolic substances can have a non-negligible effect on the intensity and profile of bitterness (Algazzali and Shellhammer, 2016; Oladokun et al., 2016). In our study, for the characterization and comparison of newly registered varieties, we applied a batch procedure with a contact time of 5 days before the end of maturation and dosing per hop weight (3 g/l), which has proven itself in many cases of developing specific recipes for dry hopped beers, and is used by a number of authors (Takoi et al., 2016; Dresel et al., 2015). Dosing by hop weight is common in brewing practice and fits the chosen goal of experiments, characterization and comparison of tested varieties. CO_2 extract of the Herkules bitter variety with a low relative content of essential oils was used for kettle hopping.

3.1 Hop samples

Varieties designated as "flavour hops", intended for dry hopping, are bred for a specific profile of hop aromas, therefore the content and composition of bitter acids in the hops of these varieties is quite different, and the spectrum of these varieties includes both aromatic and bitter hops (Krofta et al., 2019a). The content of alpha acids in the tested samples of Ceres, Saturn, N and Eris hops was 5.8 to 6.3%, the content of alpha acids in Juno, Jupiter and Pluto hops was lower, 2.8 to 4.8%. A low proportion of cohumulone in alpha-acids, typical for aromatic varieties, was found in N and Pluto hops (21%), and on the contrary, a high value typical for bitter hops was found in Saturn and Eris hops (50 and 51%). The ratio of alpha/beta-acids close to one, typical for traditional European varieties, was for Jupiter hops, for other hops it was in the range of 1.27 to 2.33 (Saturn), see Table 1.

The content of total polyphenols was from about 2.0 to 3.5%. The total essential oils were in the range of 1.0% w/w (Jupiter, Pluto) up to 1.7% w/w (N). Farnesene was not represented in the obtained profile of essential oils and the share of myrcene, the majority hop essential oil, was from 24% (Pluto) to 51% (Jupiter). The chemical composition of the tested samples was consistent with

Table 1 *Chemical profile of hop samples*

Hop parameter/ Tested genotype	Units	Juno	Ceres	Saturn	Jupiter	Eris	Pluto	N
Alpha acids	% w.	3.46	5.78	6.29	2.79	5.65	4.83	6.14
Cohumulone	% rel.	42	39	51	29	50	21	21
Beta acids	% w.	2.72	3.07	2.70	2.56	4.08	3.04	2.85
Alpha/beta ratio		1.27	1.88	2.33	1.09	1.38	1.59	2.15
Total polyphenols	% w.	3.21	1.98	2.26	2.35	2.29	2.07	3.61
Hop oils	% w.	1.29	1.38	1.52	1.00	1.36	1.10	1.73
Myrcene	% rel.	47.1	42.4	35.7	51.0	30.4	24.4	28.4
β-Caryophylene	% rel.	9.3	9.6	8.3	10.2	10.5	9.4	11.2
trans-β-Farnesene	% rel.	0.17	0.34	0.14	0.19	< 0.1	< 0.1	0.1
α-Humulene	% rel.	3.8	26.0	23.5	4.7	23.2	27.3	31.9
Selinens	% rel.	4.8	1.2	1.7	5.8	2.9	1.9	1.8

the chemical profile of the varieties. The origin, chemotaxonomic and sensory characteristics of the tested varieties are as follows:

Juno was bred in 2012 from Kazbek and wild Canadian hops. The intensity of the aroma of hop cones is medium, fruity sweet (mango, banana, melon), with the flavour of apple, orange, citrus fruits, and herbs. The content of alpha acids ranges from 4 to 6% w/w, the content of beta acids is 3 to 5% w/w, the presence of cohumulone is 35 to 45% rel. and essential oil content of 0.6 and 1.2% w/w.

Ceres was bred in 2012 from Kazbek and breeding material of European origin. The intensity of the hop aroma of cones is medium, mixed fruity (apple, pear, orange, grapefruit, lime), woody (bark, tobacco) and green (tomato leaves, grass, nettle and herbs). The content of alpha acids ranges from 4 to 7% w/w, the content of beta acids is 3 to 5% w/w, the representation of cohumulone is 32 to 42% rel. and an essential oil content of 0.7 to 1.3% w/w.

Saturn was bred in 2012 from Kazbek. Intense aroma of citrus (lemon, lime peel, tangerine, grapefruit, orange, ginger), sweet and tropical fruit (apricot, peach, melon, mango) is mixed with floral (citrus, rose), spicy (chilli, black pepper, anise), vegetable (garlic, green parsley) and woody (pine, conifer) notes. The content of alpha acids ranges from 6.0 to 8.5% w/w, the content of beta acids is 3.5 to 4.5% w/w, the representation of cohumulone is 40 to 52% rel. and the content of essential oils is 2.0 to 3.0% w/w.

Jupiter was bred in 2013. It is the result of a cross between Kazbek and breeding material of world origin. The intensity of the aroma of the hop cones is medium, a mixture of floral (jasmine, rose), herbal (mint, lemon peel), spicy and fruity (apple, peach) aromas. The content of alpha acids ranges from 3 to 7% w/w, the content of beta acids is 2 to 4% w/w, the proportion of cohumulone is 27 to 34% rel. and the content of essential oils is 0.4 to 0.9% w/w.

Eris was bred in 2013 from Kazbek and Fuggle selection. The intensity of the aroma of the hop cones is very intense, citrus (lime, grapefruit, tangerine, orange, citrus peel), floral, herbal and blackcurrant. The content of alpha acids ranges from 5 to 8% w/w, the content of beta acids is 4 to 6% w/w, the proportion of cohumulone is 30 to 44% rel. and the content of essential oils is 0.7 to 1.3% w/w.

Pluto was bred in 2013. It is a cross between Harmonie and ŽPČ. It is characterised by highly intense fruity (green fruit, lemon, pineapple, banana), sweet (yogurt, almond, vanilla) and woody (coniferous) aromas are complemented with herbal (mint, menthol, basil, chamomile, green tea) and vegetable (root vegetables, asparagus) aroma. The content of alpha acids is in the range from 5.5 to 6.5% w/w, the content of beta acids is 4.5 to 5.5% w/w, the representation of cohumulone is 19.0 to 25.0% rel. and the content of essential oils is 0.9 to 1.2% w/w.

3.2 Experimental beers

The basic chemical parameters of the beers, attenuation, pH and colour were very similar, the beer for the fifty-liter experiments was from two 250-liter pilot brews, and these parameters were not significantly affected by dry hopping (Table 2). The bitterness of the dry-hopped beers ranged from 26 to 32 IBU and, with the exception of Juno and Ceres, was higher than the bitterness of the non-dry-hopped beer. The concentration of iso-alpha acids in beers, with the exception of Saturn beer, was lower or, within the measurement uncertainty, the same as the original beer. During dry hopping with hop cones or pellets, depending on the applied dose, iso-alpha acids may be lost by sorption on the hop matrix (Hauser et al., 2019a; Forster and

Table 2 *Chemical parameters of beer samples*

Hop parameter/ Tested genotype	Units	Juno	Ceres	Saturn	Jupiter	Eris	Pluto	N	Zero
Original extract	% w.	12.88	12.88	12.39	12.4	12.51	12.52	12.41	12.44
Alcohol by volume	% v.	5.92	5.92	5.62	5.61	5.67	5.67	5.61	5.66
Attenuation apparent	%	86.1	86.2	85.2	85	85.1	85.1	85	85.5
pH		4.15	4.17	4.19	4.15	4.13	4.1	4.16	4.06
Colour	EBC	13.7	12.7	12.8	12.8	12.7	12.7	12.8	12.4
Total polyphenols	mg/L	190	177	171	176	178	181	185	165
Bitterness	IBU	26	27	34	32	32	32	32	27
Iso-alpha-acids	mg/L	25	25	32	30	27	26	30	29
Alpha acids	mg/L	1.73	0.96	1.09	0.9	0.6	0.41	0.86	0.56

Gahr, 2013), the bitterness value may, on the contrary, increase slightly due to the interference of extracted alpha acids, oxidation products of bitter acids (humulinones and hulupons) as well as some hop polyphenols (Algazzali and Shellhammer, 2016; Hauser et al., 2019a).

During dry hopping, in contrast to the significant thermal transformations and volatilisation of essential oils during wort boiling (Takoi et al., 2016; Dresel et al, 2015), the components of essential oils are extracted into a slightly alcoholic solution of young beer, and partially sorbed on or changed by the yeasts present (Kaltner and Mitter, 2009; Forster and Gahr, 2013). The concentration of the main components of terpenic oils (myrcene, limonene, linalool, alpha-terpineol, cis-geraniol, beta-caryophyllene epoxide) differed significantly in relation to the genotype and was many times higher in beers that were dry-hopped with the "planetary hops" compared to the original beer (Figure 1). The total concentration of analysed essential oils in beer correlated with the content of essential oils in hops (k=0.746; n=7).

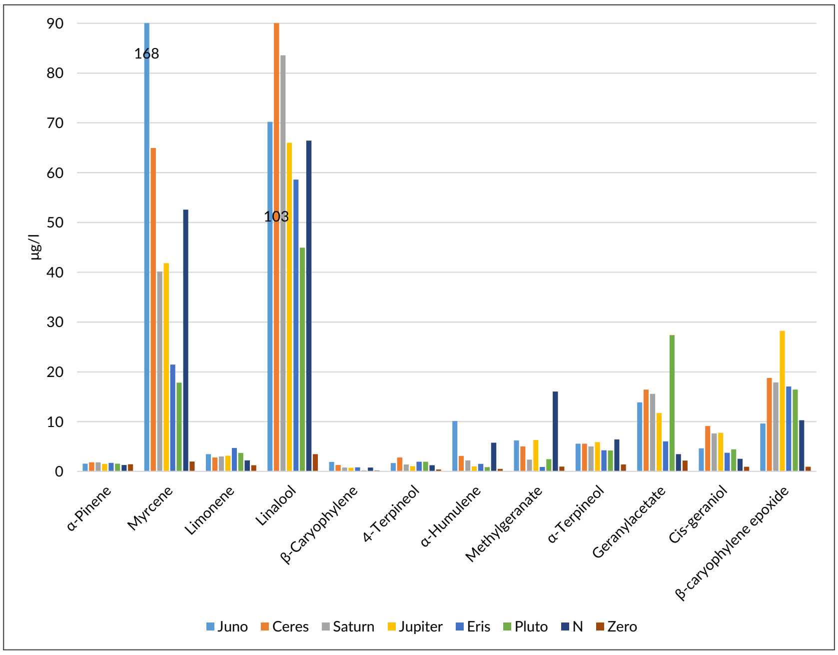


Figure 1 *Profile of terpene essential oils in experimental beers*
Zero: beer without dry hopping

Descriptive sensory analysis of beers showed balance of carbonation and fullness of beers (Table 3). All beers had weak to medium carbonation (2.4–2.7 points) and medium fullness (2.9–3.1 points), which corresponds to high degree of attenuation (apparent attenuation 85.0–86.2%).

The bitterness of the beers immediately after swallowing was in the range of 1.6 points (Eris) to 2.2 points (Juno) on a scale of 0–5 points. The values of the bitterness culmination at the 15th second were balanced and moderate to strong in intensity (3.4–3.6 points). Sensory bitterness did not correlate with analytical bitterness, polyphenols and oxidized forms of alpha acids, humulinones, can in-

Table 3 *Results of descriptive sensory analysis of experimental beers*

Parameter/Used hop genotype	Juno	Ceres	Saturn	Jupiter	Eris	Pluto	N
Carbonation	2.6	2.5	2.6	2.4	2.5	2.4	2.7
Palate-fullness	3.0	3.0	2.9	3.1	2.9	3.0	2.9
Bitterness	1.9	2.2	2.0	2.1	1.6	1.9	1.8
Bitterness - culmination	3.6	3.4	3.6	3.5	3.4	3.4	3.4
Bitterness-lingering	2.0	2.1	2.2	2.3	2.1	2.1	1.9
Bitterness-character	2.5	2.6	3.2	2.9	2.6	2.5	2.4
Astringency	0.9	1.4	1.6	1.7	1.4	1.4	1.4
Sweetness	1.4	1.6	1.2	1.4	1.8	1.6	1.4
Sourness	2.1	2.1	2.4	2.7	2.4	2.4	2.2
Hoppy	2.9	2.9	2.6	3.1	2.9	2.9	2.6
Fruity-esteric	1.4	1.5	1.3	1.3	1.6	1.8	1.7
Overall impression	3.5	3.5	4.5	4.0	3.9	4.1	3.8

Descriptors 0 (no perception) – 5 (very strong); Overall impression 9–1 (descending scale) terfere with the determination of bitter substances in dry hopped beers (Algazzali and Shellhammer, 2016). Conversely, oxidation products of bitter acids, humulinones and hulupones with a bitterness intensity at the level of 66% and 84% of iso-alpha acids can contribute to the intensity and character of sensory heat (Algazzali and Shellhammer, 2016). Bitterness lingering (bitterness intensity after 40 seconds) was similar for all beer samples (1.9–2.3 points), with a weak trend towards a slower decline, as well as a less gentle character of bitterness for Jupiter and Saturn hops. The bitterness character of the beers was assessed as mild to moderate (2.4–3.2 points).

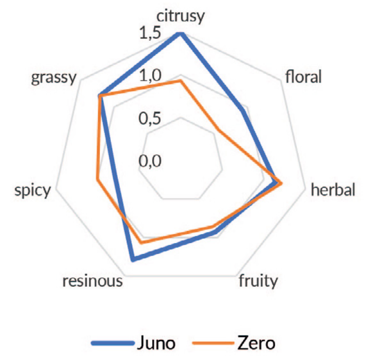
The astringency of the beers was very weak to weak (0.9–1.7 points), the values at the upper limit corresponded again to Jupiter and Saturn hops. Sweetness and sourness were fairly balanced for all beers and rated as mild to moderate. The overall sensory impression of the beers was good to moderate, ranging from 3.5 to 4.5 on a nine-point scale.

The profile of hop aromas in the beers from the individual tested hops differed, the intensity of the evaluated aromas and flavours derived from the hops was different for the individual tested genotypes, as already indicated by the analysis of terpenic oils in the beer. The hoppy aroma increased significantly for all dry hopped beers, the fruity aroma increased for Eris and Pluto beers, and the grassy, spicy and resinous aromas increased significantly for Saturn beer. Table 4 presents a detailed description of the aroma profile.

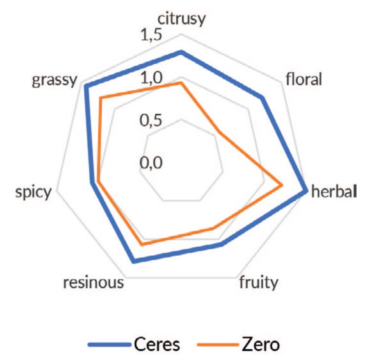
Hop aroma intensity was influenced by linalool, α-terpineol and ß-caryophyllene epoxide. Citrusy aroma correlated with ß-caryophyllene concentration and green aroma correlated with cis-geraniol concentration (Table 5). However, the found dependencies may not be causal due to the synergistic or antagonistic relationships of the sensory perception of the individual components of essential oils (Praet et al., 2016; Schmidt and Biendl, 2016; Takoi et al., 2016). Cluster analysis of the essential oils in the beer separated Juno on the first level. The profiles of pairs of varieties Eris and Pluto and Saturn and Jupiter were very close on the other levels (Figure 2).

Beers hopped with Juno and Ceres varieties were rated the best in overall sensory impression, while beers hopped with genotypes N and Eris were rated somewhat worse. Saturn and Pluto beers were rated the worst of the tested genotypes (Table 3). However, the ranking test for acceptance did not show statistically significant differences between the beers, although the best places were the beers Juno, Ceres, N and Eris. Acceptance is a highly individual phenomenon and this result indicates that each of the tested hops can find its application in the recipes of new beer brands with the potential to gain popularity among consumers.

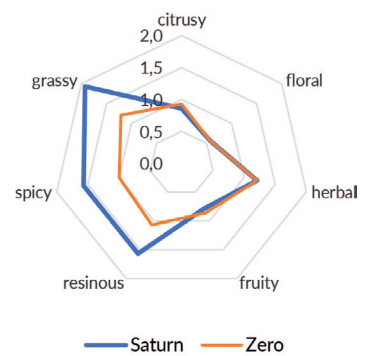
Table 4 *Profiles of hop-derived aromas in experimental beers*



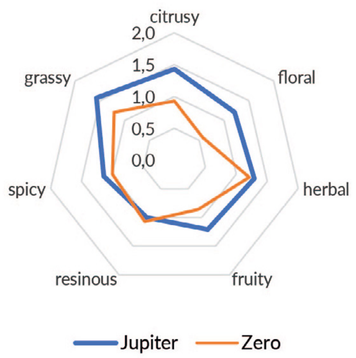
Juno
Fairly balanced aroma with components of citrusy (lemon, grapefruit), floral (beige, jasmine), herbal (chamomile, mint), fruity (red, green and tropical fruits), resinous (woody), spicy (pepper) and green (grass, leaves, hay) aroma.



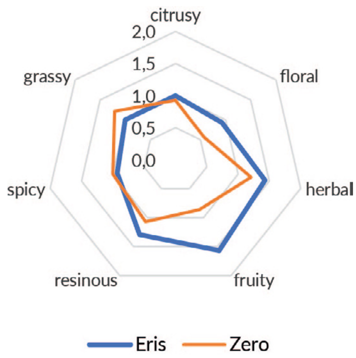
Ceres
Fairly balanced aroma with components of citrusy (lemon, bergamot), floral (elder, jasmine, rose), herbal (chamomile, mint, thyme), fruity (red, green, tropical fruit), resinous (woody), spicy (juniper, pepper), and green (grass, leaves, hay) aroma.



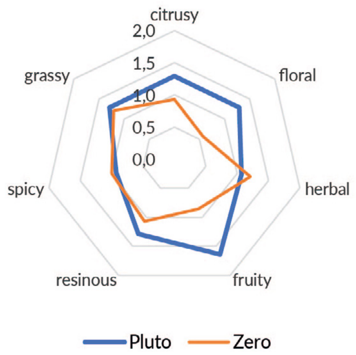
Saturn
Predominant intensity of green (grass, leaves, hay, stale grass), spicy (juniper, pepper) and resinous (woody) aromas. Citrusy (lemon, orange), floral (jasmine, rose), herbal (basil, chamomile, parsley), fruity (tropical fruit) and other (cannabis, smoky) aromas are also present.



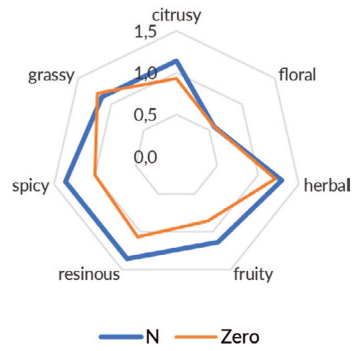
Jupiter
Fairly balanced intensity of hop aroma components consisting of citrusy (lemon, grapefruit, orange), floral (elder, jasmine, rose, lily of the valley), herbal (chamomile, parsley, mint, thyme), fruity (red, green, tropical fruit), resinous (woody), spicy (clove, juniper, pepper) and green (grass, leaves, hay, lemongrass) aroma.



Eris
Fairly balanced intensity of hop aroma components with the highest intensity of fruity (tropical, red and green fruit) and the lowest intensity of spicy (clove, juniper, pepper) aroma. Citrusy (lemon, orange), floral (beech, jasmine, rose), herbal (basil), resinous (woody), green (leafy, hay) and other (chemical, earthy) aromas are also present.



Pluto
The highest intensity of resinous (woody), spicy (cloves, juniper, pepper) and herbal (chamomile, parsley, mint) aromas, the lowest intensity of floral (jasmine) aromas. Citrusy (lemon, grapefruit, orange), fruity (red and tropical fruits) and green (grass, leaves, hay, hop granules) aromas are also present.



N
Predominant intensity of fruity (tropical fruits, strawberries), herbal (mint, lemon balm) and resinous (woody) aromas. Citrusy (lemon, grapefruit, orange), floral (elder, jasmine), spicy (cloves, juniper, pepper), green (grass, leaves, hay, stale grass) and other (bread) aromas are also present.

Table 5 *Correlation of the intensity of hop-derived aromas with the concentration of terpene essential oils in experimental beers*

Essential oils/ Hop-derived aroma	Hoppy	Citrusy	Floral	Herbal	Fruity	Resinous	Spicy	Grassy	Astringency
α-Pinene	-0.23	-0.12	-0.06	-0.20	-0.41	-0.10	0.41	0.14	0.09
Myrcene	0.50	**0.65**	0.28	-0.05	-0.14	0.27	-0.39	0.12	**-0.68**
Limonene	0.27	0.34	0.29	-0.40	0.26	0.03	0.03	-0.04	-0.05
Linalool	**0.72**	0.50	0.55	0.47	0.16	0.49	0.15	0.52	0.14
β-Caryophylene	0.56	**0.72**	0.45	0.02	-0.07	0.31	-0.41	0.20	**-0.63**
α-Humulene	0.44	0.49	0.19	-0.03	0.03	0.30	-0.49	-0.04	**-0.72**
Methylgeranate	0.50	0.17	0.25	0.53	0.50	0.14	-0.35	-0.10	-0.02
α-Terpineol	**0.86**	0.57	0.56	0.47	0.40	0.42	-0.05	0.36	0.12
Geranylacetate	0.28	0.30	-0.04	0.27	-0.28	0.48	0.59	0.30	0.06
cis-Geraniol	0.58	0.47	0.46	0.46	-0.14	0.37	0.42	**0.71**	0.39
β-Caryophylene epoxide	**0.69**	0.51	0.59	0.34	0.24	0.23	0.34	0.59	0.61

Bold letters: significant at P=0.05

4 Conclusion

The newly registered varieties with specific aromas differ from each other both in the aroma of hop cones and in the profile of aromas after dry hopping of beer. Conducted comparative tests on a pilot scale as well as tests in microbreweries in the Czech Republic indicate their suitability for top-fermented beers and dry hopping. Partial results from microbreweries also point to a good IPL-style application. It is assumed that these new varieties will expand the variability of the portfolio of Czech hop varieties. In 2022, the planting of these hop varieties into growing practice continues in order to meet the current requirements of microbreweries.

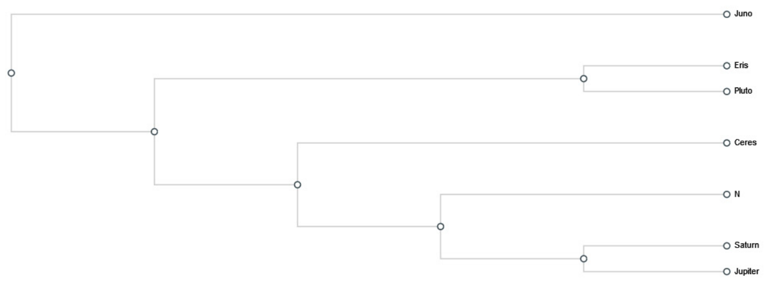


Figure 2 *Results of a cluster analysis of terpenic oils in experimental beers*

Figure 3 *Results of cluster analysis of hop-derived aromas in experimental beers*

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