



Impartment of spicy, fruity and herbal aromas from the Czech hop varieties of Ceres, Pluto and Saturn to beer

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Abstract

The aim of the study is to evaluate the intensity and character of the beer aroma in selected hop varieties. In 2022 and 2023, new Czech Flavour hop varieties of Ceres, Pluto, and Saturn were registered. Ceres exhibits a mild citrusy and fruity hop aroma. Pluto has an intense fruity and herbal aroma, while Saturn has an intense fruity aroma with a milder citrus note. Differences in the intensity and character of the beer aroma were identified based on the hop variety used and the dry hopping dose. These varieties and their combinations were tested under dry hopping at 3 g/l and 6 g/l to assess the impartment of the aromas to beer. The combination of Pluto + Saturn shows the highest intensity of a spicy aroma, while Ceres exhibits the highest intensity of both the fruity and herbal aromas – all this at 6 g/l. The best character of the spicy aroma is observed with Ceres at 3 g/l. Ceres also demonstrates the best character of the fruity aroma, and Ceres + Pluto combination excels in the herbal aroma, both at the dose of 6 g/l. The popularity of beer is crucial, with the combination of Ceres + Pluto at 3 g/l proving to be the most popular. The results have practical applications in breweries producing ALE beers that utilize dry hopping. It is obvious which hop varieties or their combinations can be used to accentuate individual aroma profiles.

Keywords: hop; *Humulus lupulus* L.; beer; dry hopping; spicy aroma; fruity aroma; citrus aroma

1 Introduction

From a brewing perspective, hop breeding in the Czech Republic can be divided into three stages. From a historical standpoint, the first stage is quite extensive and involves refining of Saaz hops. Saaz is a mild aroma hop variety primarily cultivated in the Žatec and Rakovník regions. In the early 20th century, Karl Osvald registered the first Saaz clones, designated as Osvald clones 31, 72, and 114 (Nesvadba et al., 2020a). A crossbreeding method started to be used from the 1960s and by the end of the 20th century the first aromatic varieties Bor, Sládek, and Premiant were registered (Linhart and Nesvadba, 1994). From 1996 onwards, crossbreeding became the exclusive method in hop breeding in the Czech Republic (Rígr et al., 1997). Since the beginning of the 21st century, additional fine

aroma varieties such as Saaz, Late, Saaz Brilliant, Saaz Comfort, and Saaz Shine have been registered (Nesvadba and Charvátová, 2020b), as well as aroma varieties like Harmonie, Bohemie, Country, Jazz and Blues (HRI, 2022). Fine aroma Saaz varieties are characterized by an alpha acid content ranging from 2.5% to 6.0% w/w, a balanced alpha/beta acid ratio, Cohumulone content up to 27% rel., higher farnesene content, and, most importantly, a delicate hop aroma (Krofta, 2003). Aromatic hop varieties are characterized by the alpha acid content ranging between 3.5% and 9.0% w/w, an alpha/beta acid ratio of 1 to 2, and a higher intensity of the hop aroma (Krofta and Patzak, 2011). These varieties are most commonly used in lager-type beers for the second and third hopping.

The second stage was associated with breweries' demand for varieties with a higher alpha acid content. The first bitter variety, Agnus, was registered in 2001 (Nesvadba and Krofta, 2002). From 2007 to 2017, additional bitter varieties Rubín, Vital, Boomerang, and Gaia were registered. Bitter hop varieties (excluding Rubín) are characterized by a high beta acid content, resulting in the alpha/beta acid ratio of around 2 (Nesvadba et al., 2023a). Bitter varieties are predominantly used for the first and second hopping in lager beers but can also be well applied in top-fermented beers. The variety Vita is particularly interesting, as it was simultaneously registered for pharmaceutical purposes, having a high content of xanthohumol and desmethyloxanthohumol (Krofta et al., 2013).

The third stage involves the development of flavour type Czech hop varieties. After 2010, the construction of craft breweries began in the Czech Republic. These breweries distinguish themselves from larger breweries by producing top-fermented beer. Flavour type hop varieties are used for these beers and they are characterized by non-hoppy aromas (fruity, citrusy, herbal, spicy, woody, etc.). The first Czech variety of this type was Kazbek, known for its citrusy aroma (Krofta et al., 2019). In 2019, another flavour type variety, Mimosa, was registered, featuring a delicate citrusy aroma. This variety is characterized by a low alpha/beta acid ratio (0.3), attributed to the high beta acid content, up to 7% w/w, with the alpha acid content starting from 2% w/w. In 2022 and 2023, a new generation of the Czech flavour hop varieties (Juno, Ceres, Saturn, Jupiter, Eris, and Pluto) was registered, distinguished by intense aromas with characteristics of fruit, citrus, spice, wood, herbs, etc. However, impartment of these aromas to the beer is crucial (Olšovská et al., 2020; Dresel et al., 2015). It is essential to note that hop varieties must exhibit a high resistance to fungal diseases (Trefilová et al., 2021). Additionally, these varieties are included in a drought resistance testing, with Juno and Ceres showing good resistance, and Saturn exhibiting moderate resistance to drought (Nesvadba et al., 2023b).

The main objective of this study is to evaluate individual types of hop aroma in beer, both depending on the variety and the amount of hops. At the same time, whether it is appropriate to use single hop or a combination of two selected hop varieties.

2 Materials and methods

Three flavour hop varieties were selected for testing from the collection of the hop genetic resources (MZE 6.2.1 62216/2022-13113):

Ceres was registered in 2023. The variety was obtained through crossbreeding with Kazbek and the paternal plant 11/12 from the European breeding. The hop aroma is characterized by delicate citrusy notes (lemon, lime, orange, grapefruit) and fruity undertones (apricot).

Pluto was registered in 2022. It was obtained through inbred crossbreeding of Harmonie varieties and a paternal plant originating from Saaz. The hop aroma is intense and features fruity notes (banana, pineapple, lemon) and herbal undertones (mint, basil, chamomile, green tea).

Saturn was registered in 2022 and obtained through crossbreeding with Kazbek and the paternal plant 11/08 from the European breeding. The hop aroma is characterized by intense fruity notes (apricot, peach, melon, mango) and a milder citrusy scent (lemon, lime, tangerine, grapefruit, orange).

2.1 Sensory evaluation of hops and their main parameters

After harvest, dry hop samples were evaluated for hop aroma. The intensity of individual aromas (scored on a scale of 0 to 10 points) was assessed, including hoppy, spicy, fruity, woody, citrusy, grassy, and floral aromas.

A total of 42 individuals participated in the hop evaluations. All evaluators were informed in advance about the evaluation of the samples. Dry hop heads were split between the fingers and rubbed together several times. This released more hop oils. Then the intensity and character of the hop aroma was evaluated. Each evaluator worked independently and scored each sample according to a point scale.

The alpha acid content was determined using liquid chromatography (EBC 7.7, 1998). The content and composition of hop essential oils were determined through liquid chromatography from dried hop cones (Krofta, 2008). The results of hop analyses are presented in Tables 1 and 2.

2.2 Brewing experiments

All experimental batches were conducted in the 50-l mini-brewery at the Hops Research Institute Ltd., Žatec. The batches of hops were selected based on consultations with craft breweries.

The varieties were tested in the ALE beer style, which was hopped three times with the Sládek hop variety (1st hopping at the beginning of boiling, 2nd hopping after 40 minutes, 3rd hopping at the end of boiling). After the primary fermentation (using Fermentis 05 yeast), the young beer was transferred to 5-liter kegs and dry-hopped with pellets. The dry hopping lasted 3 days at a temperature of 10°C, followed by an additional 8 days at 2°C. The dry hopping was performed in two doses: 3 g/l and 6 g/l. Six combinations were applied for each dose:

- 100% dry hopping with Ceres
- 100% dry hopping with Pluto
- 100% dry hopping with Saturn
- 50% dry hopping with Ceres and 50% dry hopping with Pluto (C+P)
- 50% dry hopping with Ceres and 50% dry hopping with Saturn (C+S)
- 50% dry hopping with Pluto and 50% dry hopping with Saturn (P+S)

All beers were filtered using a plate filter and bottled into 0.33-liter bottles. Bottling took place 2 days before the tastings. Beers were stored at 2 °C throughout and tastings were conducted at a temperature of 7–9 °C. The beers had an EPM of 12.5 and IBU of 29.

Table 1 Content and composition of hop resins.

Variety	Alpha acid (% w/w)	Beta acid (% w/w)	Ratio Alpha/beta	Cohumulone (% rel.)
Ceres	6.61	3.43	1.93	36.10
Pluto	7.39	4.54	1.63	22.90
Saturn	6.62	3.00	2.21	46.90

Table 2 Content and composition of hop essential oils.

Variety	Weight (% w/w)	Myrcene (% rel.)	Caryophyllene (% rel.)	Farnesene (% rel.)	Humulene (% rel.)	Selinenes (% rel.)
Ceres	1.09	23.60	12.50	0.51	24.10	3.34
Pluto	1.08	19.91	8.04	< 0.5	17.00	2.70
Saturn	1.30	22.40	10.89	< 0.5	20.20	3.06

2.3 Sensory evaluation of beers

The testing took place during a workshop at the Hops Research Institute Ltd., Žatec, with the participation of 26 samplers from small and medium-sized breweries (each evaluated all samples). The evaluation focused on the intensity and the character of aroma, its pleasantness and influence on the beer's drinkability. The main three types of aromas, i.e. spicy, fruity, and herbal were monitored. The aroma evaluation for beer was directed at an intensity of the aroma on a scale of 1 (very weak) to 10 (very strong) points, a character of the aroma on a scale of 1 (very unpleasant) to 10 (very pleasant) points, and liking/impression after tasting on a scale of 1 (worst) to 10 (best) points. Each evaluator worked independently and assigned points to each sample according to a scoring scale. The results were statistically processed.

2.4 Statistical evaluation of data

Basic statistics were processed using the mean (\bar{x}). The significance of differences between varieties was determined using a t-test ($\alpha = 0,05$). The difference between sets was established based on the significance level α , indicating the probability of differentiation between tested sets (Meloun and Militký, 1994).

3 Results and discussion

3.1 Hop aroma evaluation

The harvested samples were assessed olfactorily for the intensity and character of their aroma. Figure 1 indicates that the highest point ratings for all observed aromas be-

long to the Ceres variety. Clearly, Ceres has a significantly higher intensity of the fruity aroma (5.9 points) compared to Pluto (5.8 points) and Saturn (5.0 points). Ceres also exhibits a higher intensity in the spicy aroma (5.3 points) and, conversely, a lower intensity in the herbal aroma (4.8 points). Pluto has the lowest intensity in the herbal aroma (3.9 points). Saturn shows nearly identical intensities of aromas ranging from 4.4 (herbal) to 5.0 (fruity). The aroma assessment determined that Saturn exhibits a rougher spicy aroma (with faint undertones of garlic). On the other hand, Pluto displays the highest variability of aromas, ranging from 3.9 (herbal) to 5.8 (fruity).

3.2 Evaluation of aroma intensity in beer

All beer samples were tasted on a single day with the necessary time intervals as required by the tasters. The aroma evaluation for the beer focused on its intensity, ranging

from 1 (very weak) to 10 (very strong) points. Figure 2 depicts the intensity of the spicy aroma in the beer with dry hopping doses of 3 g/l and 6 g/l. From the results it can be observed that the Ceres variety and Ceres + Saturn variant exhibit a nearly identical intensity. A higher intensity of the spicy aroma at the 6 g/l of a dry hopping dose is noted in the Pluto, Saturn, and Ceres + Pluto variant. Significantly, the highest difference in the intensity of the spicy aroma is seen in the Pluto + Saturn variant, where the average value increased from 4.41 points (3 g/l) to 5.88 points (6 g/l). From a practical perspective, the higher dry hopping dose does not impact the increase in the spicy aroma for the Ceres variety and Ceres + Saturn variant. For the other variants, the higher dry hopping dose consistently led to an increased intensity of the spicy aroma.

From the results (Figure 3), it is evident that the variants Ceres + Pluto and Ceres + Saturn exhibit a nearly identical intensity of the fruity aroma. No statistical difference was determined for these variants. A higher average value by 0.76 points is observed in the Pluto + Saturn variant. Interestingly, a higher difference in the fruity aroma with an increase in the dry hopping dose is noted in the single hopping variants. For the Saturn variety, there was an increase of 1.07 points, for the Ceres variety by 1.26 points, and notably, for Pluto by 2.08 points at a 6 g/l dry hopping dose. The single hopping consistently shows a significantly higher intensity of the fruity aroma at the higher dose compared to the 3 g/l dose. Ceres exhibits the highest intensity of the fruity aroma (6.14 points), while the other variants are below the 6-point threshold.

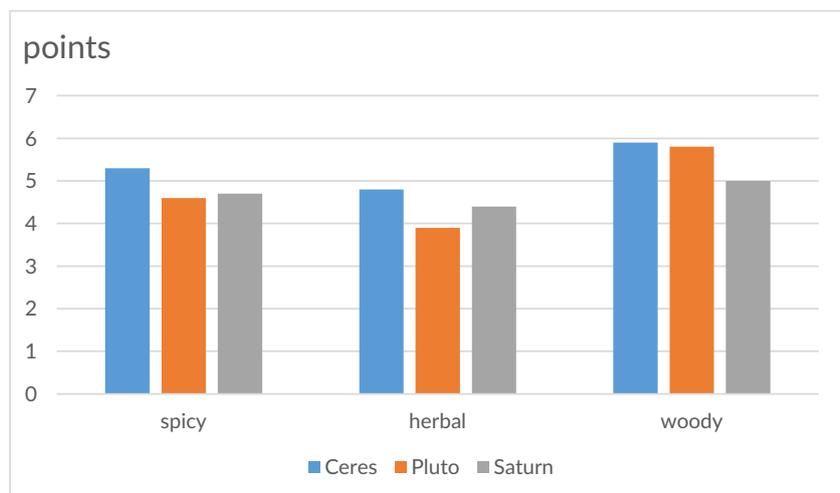


Figure 1 Intensity of the spicy, herbal, and fruity aromas in the hop cones of Ceres, Pluto, and Saturn varieties (Žatec, 2022)

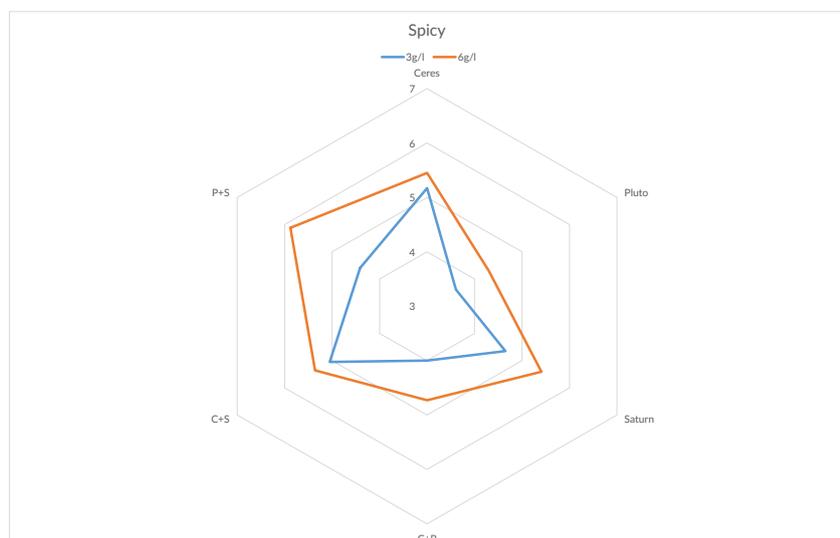


Figure 2 Intensity of the spicy aroma at dry hopping doses of 3 g/l and 6 g/l

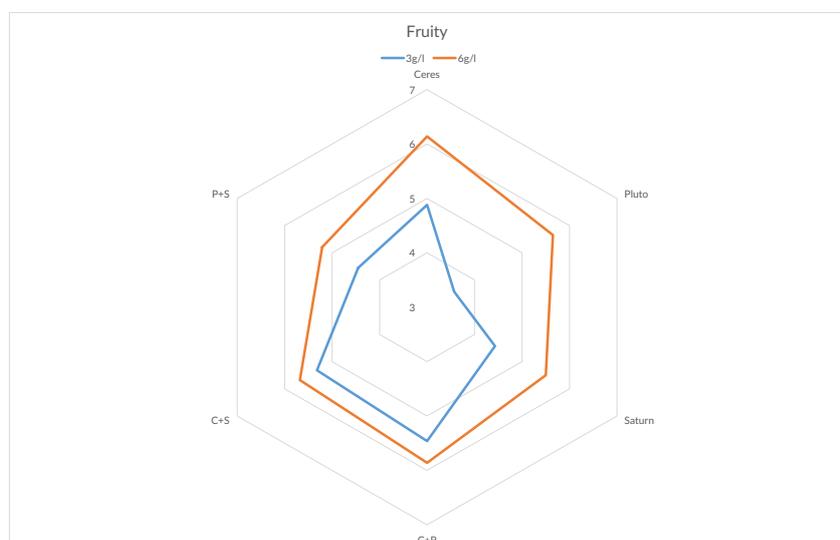


Figure 3 Intensity of fruity aroma at dry hopping doses of 3 g/l and 6 g/l

A very interesting evaluation can be observed for herbal aroma (Figure 4). Single hopping with the varieties Ceres, Pluto, and Saturn consistently shows a significantly higher intensity of the herbal aroma compared to the combinations with other varieties. Interestingly, even the Ceres + Saturn dry hopping exhibits a slightly higher intensity of herbal aroma than at the 6 g/l dose. The highest floral aroma is observed at the 6 g/l dose for the Ceres (5.59 points) and Saturn (5.45 points) varieties, followed by the combination of Ceres + Saturn at the 3 g/l dose (5.32 points).

3.3 Evaluation

of aroma characters in beer

The aroma character is a crucial attribute from the consumers' perspective. A pleasant aroma enhances the drinkability of beer while being vital for various beer styles. The aroma character is once again assessed by the average score ranging from 1 (very unpleasant) to 10 (very pleasant). The evaluation results are presented in Figure 5. For the Ceres variety, the increased dose does not alter the aroma character, as the average is 5.88 points at the 3 g/l dose and 5.82 points at the 6 g/l dose. Pluto exhibits a more pleasant aroma character at a higher dry hopping dose, while the Saturn variety shows a better aroma character at a lower dry hopping dose. Ceres + Pluto has a better aroma character at a higher better hopping dose, whereas Ceres + Saturn have slightly unpleasant aroma tones at a higher dry hopping dose. The results show that concerning the character of the spicy aroma, the Saturn variety has the lowest rating. Saturn has an average score above 5 points only in combination with the Ceres

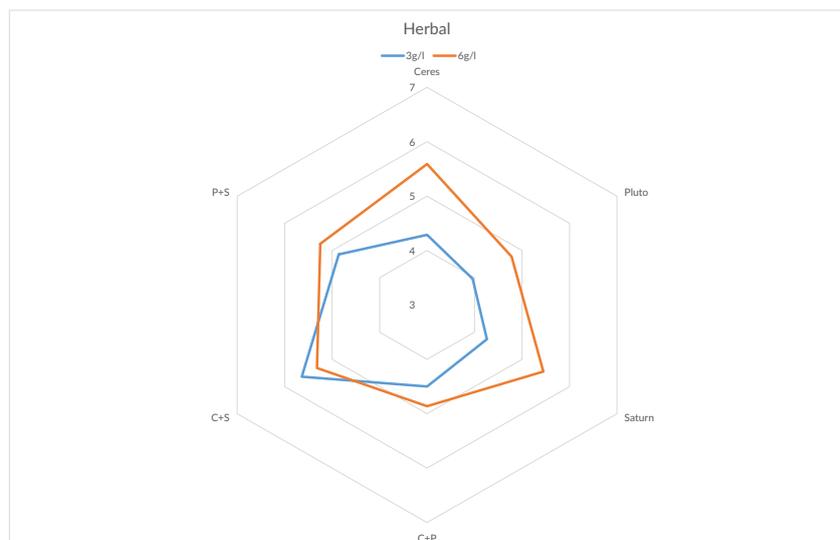


Figure 4 Intensity of the herbal aroma at the dry hopping doses of 3 g/l and 6 g/l

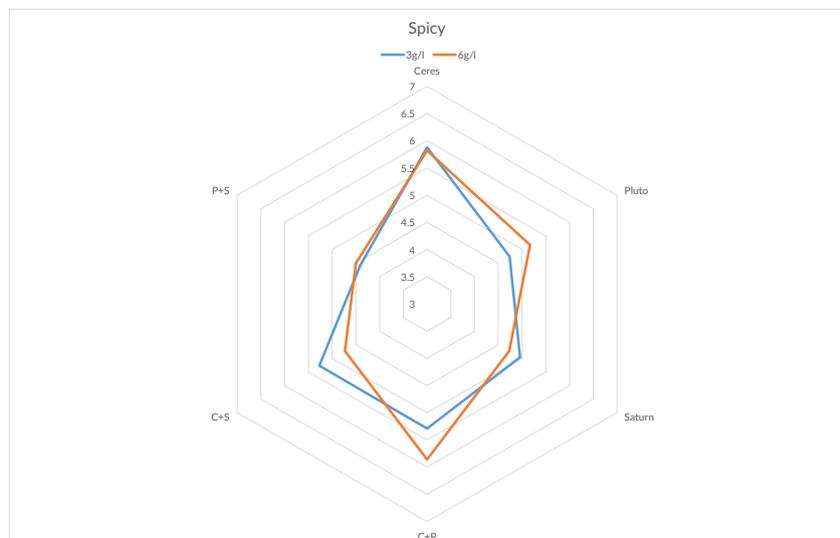


Figure 5 Character of the spicy aroma at the dry hopping doses of 3 g/l and 6 g/l

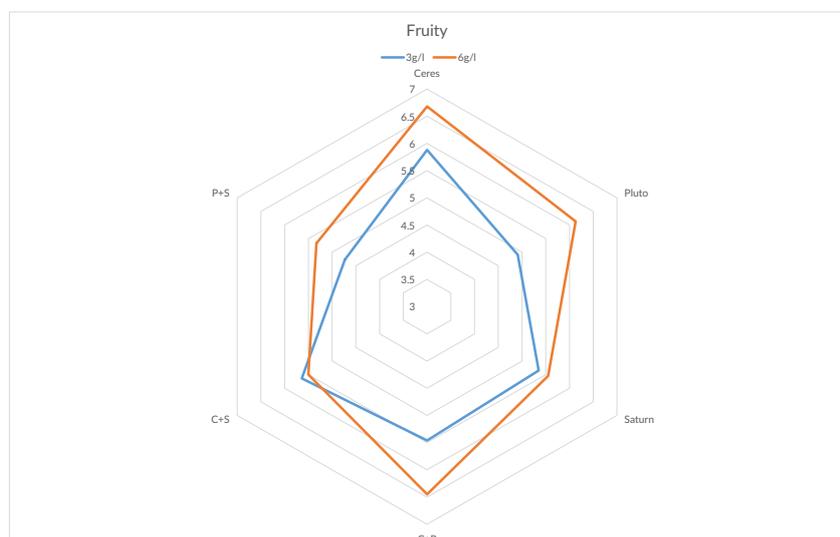


Figure 6 Character of the fruity aroma at the dry hopping doses of 3 g/l and 6 g/l

variety at the 3 g/l dose. The character of the spicy aroma is below the average for the other variants.

The overall perspective on [Figure 6](#) indicates that the character of the fruity aroma is almost always better with a higher dose of dry hopping. Only the Saturn variety and the combination of Ceres + Saturn do not show a significant difference in the aroma character. A noticeable improvement in the character of the fruity aroma is observed in Pluto and Ceres + Pluto at a higher dry hopping dose. Interestingly, the Ceres variety consistently exhibits the best character of the fruity aroma at each hopping dose compared to other variants, scoring 5.88 (3 g/l) and 6.68 (6 g/l). Pluto also receives a high rating, with 6.13 points at the 6 g/l dose, and the combination of Pluto + Ceres scores 6.45 points at a 6 g/l dose. The results show that the Ceres and Pluto varieties have the best character of the fruity aroma. However, the Saturn variety (5.35 points) has a better rating at the lower dose than Pluto (4.91 points).

A distinctly more pleasant character of the herbal aroma is exhibited by the Ceres and Pluto varieties at the higher dry hopping dose ([Figure 7](#)). However, the combination of these varieties, specifically Ceres + Pluto, is very interesting because it consistently shows the best character of the herbal aroma at each dry hopping dose compared to the other variants, scoring 5.50 (3 g/l) and 5.86 (6 g/l). For the Saturn variety, either as by itself or in combination with another variety, increasing the dry hopping dose does not have a positive effect on the character of the herbal aroma. On the contrary, it shows a worse character of the herbal aroma in combination with the Ceres variety.

Numerous authors point to the fact that certain hop oils influence the hop aroma. For instance, [Nance and Setler \(2011\)](#) mention farnesene, contributing to a taste reminiscent of green apple, as well as of floral, citrusy, and fruity aromas. From the results in this study, it can be observed that all the mentioned varieties do not contain farnesene, yet they exhibit a pronounced fruity aroma. Similarly, caryophyllene, known for its woody, peppery, spicy, and earthy aroma ([Retberg et al., 2018](#)), or humulene, are usually associated with the European fine aroma hop varieties and recognized for their spicy and grassy aroma ([Iannone et al., 2022](#)). These findings could explain why the Pluto variety has a lower spicy aroma

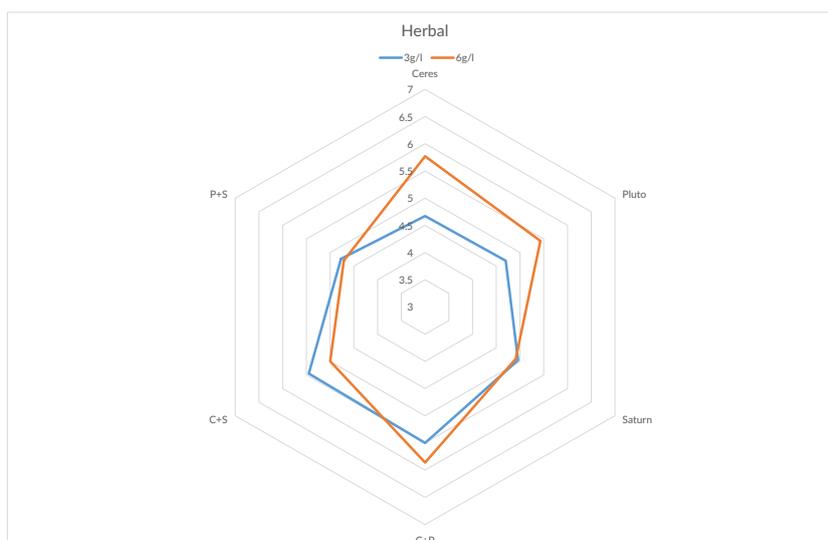


Figure 7 Character of the fruity aroma at the dry hopping doses of 3 g/l and 6 g/l

than the Ceres and Saturn varieties. The Pluto variety has a lower content of caryophyllene and humulene.

3.4 Evaluation of beer popularity

From the brewing perspective, the evaluation of popularity (sometimes referred to as the impression after drinking) is a crucial characteristic. High popularity ensures increased consumption of a given beer. The harmonization of the intensity and character of the beer aroma, pleasantness of bitterness, fullness of beer, and other characteristics constitute the popularity of beer. All variants were also rated on a scale of 1 (worst) to 10 (best). The goal was to determine which dry hopping variant affects the likability of a particular beer sample. This part focused on assessing the impact of each variant.

[Figure 8](#), clearly shows that the Ceres variety exhibits a consistent likability at both dry hopping doses. This is likely due to the harmonization of the aroma intensity and character. The Pluto variety shows a significantly higher popularity at the 6 g/l dose compared to the dose of 3 g/l of dry hopping. In contrast, Saturn demonstrates a notably lower likability at the 6 g/l dose compared to that of 3 g/l of dry hopping. The low popularity of Saturn could be compared to that of the Boomerang variety, which also exhibits a harsh spicy aroma ([Nesvadba et al., 2021](#)). Among all the mentioned variants, the Ceres + Pluto variant has the highest likability, while the Pluto + Saturn variant the lowest one.

It is necessary to note that these are partial results of the observed hop varieties. Some insights suggest that the results of beer evaluation may vary within a single hop variety harvested from different locations ([Carbone et al., 2021](#)). Nevertheless, the achieved results illustrate how the tested varieties impart different aroma types to beer.

4 Conclusion

The set goal has been successfully achieved, as each variety, whether used by itself or in combination, exhibits a distinct influence on the intensity and character of the beer aroma. The results indicate that the Ceres variety received very favourable evaluations. A crucial observation is that, for this variety, the dry hopping dose of 3 g/l is likely sufficient, and the higher dose will not have a negative impact on the aroma or likability. Conversely, the Pluto variety requires the higher dose of dry hopping. A contrasting finding is observed with the Saturn variety, where the higher dose of dry hopping has a negative impact on both the aroma and likability of the beer. From the perspective of all variants, it can be concluded that the combination of Ceres + Pluto attains the highest aroma and beer likability ratings.

The obtained results have practical applications in breweries producing ALE beers that utilize dry hopping. These findings can enhance beer popularity with the right dose of dry hopping for a given variety or combination. At the same time, it can optimize beer production, as the higher dry hopping dose has a negative impact on beer character in some variants.

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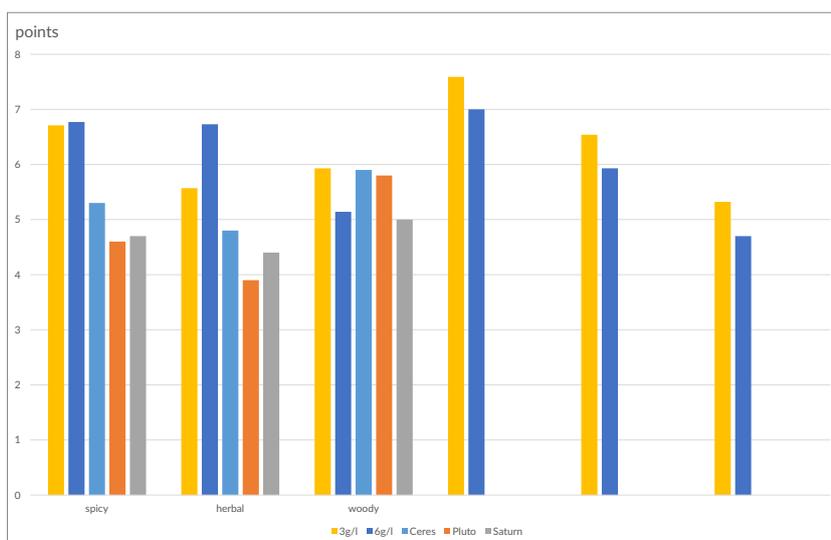


Figure 8 Beer popularity at the dose of 3 g/l and 6 g/l of dry hopping

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