



Alpha acids content in Czech hops from harvest 2022 – forecasts, reality and trends

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Abstract

From the brewing and commercial point of view, the content of alpha acids is the most important quality parameter of hops, which is subject to significant annual fluctuations. The established system for evaluating the content of alpha acids in Czech hops consists of pre-harvest and harvest predictions and a detailed analysis of reality based on the analysis of all purchasing lots of raw hops. It is differentiated according to varieties and hop growing areas. This article presents the results of the 2022 harvest, discusses the influence of weather conditions, the age of hop gardens and virus-free seedlings on the harvest results, and the relationship of predictions to reality. The average content of alpha acids in the majority Saaz variety in the Saaz, Auscha and Tirschitz hop growing regions was 2.88, 2.80 and 2.63% by weight in the original respectively. In all areas, the alpha acid content has been significantly affected by the age of the hop growths. Hybrid varieties coped with adverse weather conditions much better than most aromatic hops. The total production of alpha acids in Czech hops from the harvest of 2022 was 182.9 tons, one of the lowest in the last 15 years. It is due to the concurrence of two factors: the low yield per hectare and the content of alpha acids in Saaz hops. The cause was, similarly to Germany, an extreme deficit of precipitation and high temperatures during the vegetation season.

Keywords: hops; alpha acids; Saaz hops; hybrid varieties; weather conditions

1 Introduction

The content of alpha acids is the most important quality parameter of hops from a brewing point of view. Hopping doses in breweries and a total consumption for the planned production of beer depend on bittering ability of hops and hop products. Timely and as accurate as possible information about this hop crop parameter is annually expected by the hop growers, trade companies and brewers. This is especially true in years when weather conditions can cause a harvest with a low alpha acid production. The year 2022 belongs to such years. The Hop Research Institute (HRI) in Žatec (Saaz), Research Institute of Brewing and Malting (RIBM) in Prague together with significant participation of Chmelařství, Cooperative Žatec and V. F. HUMULUS Hořesedly have been sys-

tematically evaluating the content of alpha acids in Czech hops from annual crop harvests for more than 20 years. The entire process consists of several follow-up stages whose implementation is divided among four workplaces (Krofta et al., 2022).

Until the late 1990s, the process involved only the Saaz aroma hops. With the onset of hybrid varieties in the years 1995 to 2000, the evaluation expanded to include Premium, Sládek and after 2000 other varieties such as Agnus, Kazbek, Saaz Late, Saaz Special, etc. The alpha acid contents are assessed for all hop growing areas in the Czech Republic, i.e. the Saaz (Žatec) region, Auscha (Ústětek) region and the Tirschitz (Tršice) region in Moravia. In harvest parameters (yield, alpha acid content) there may

be significant differences among hop growing regions because the distance between them is about 300 km in a bee line. The community is continuously informed about the results on the website (www.chizatec.cz) and in professional journals. During the vegetation, data on selected weather parameters are continuously collected, as the weather significantly affects the alpha acid content in hops (Forster and Shüll, 2020).

The purpose of this article is to provide summarised information about the content of alpha acids in Czech hop varieties from the 2022 harvest in the context of weather conditions during vegetation season. It follows on from a similar assessment of the 2021 growing season (Krofta et al., 2022).

2 Materials and methods

2.1 Weather conditions

during the growing season

Weather conditions are evaluated on the basis of data from a network of weather stations operated by the Hop Research Institute in hop growing areas. The stations Žatec, Stekník, Tuhořice, Kněžves, Ročov and Petrohrad are located in the Saaz hop growing region, the stations Brozany, Liběšice and Tršice are situated in the Tirschiz region. The meteorological data are recorded in hourly intervals, stored in data loggers and from there they are transferred online to the data network. They are accessible on the HRI website (HRI, 2022). The stations measure the air temperature and humidity, the amount of rainfall, daylight intensity, wind direction and strength, and some also measure the soil temperature at depths of 20 and 50 cm.

2.2 Hop samples

Pre-harvest predictions are only carried out for the Saaz aroma variety based on the assessment of the content of the alpha acids in hop cones. They are taken directly from the hop yards in the course of 3 to 4 weeks before the expected start of harvest in selected locations in the Saaz and Auscha hop growing regions. The collection sites are selected to include most of the important and typical hop growing locations. For Saaz they are the Ohře-river basin, Údolí Zlatého potoka, Rakovník region, Podlesí and Polepská blata. For Auscha they are located in the surroundings of Ústěšk (Auscha) and Libochovice (Figure 1). The route is chosen to manage sampling in both areas within one working day. Samples of hop cones are taken from 5–10 plants in heights of 4–6 meters by means of telescopic rod in the same place of selected hop gardens.

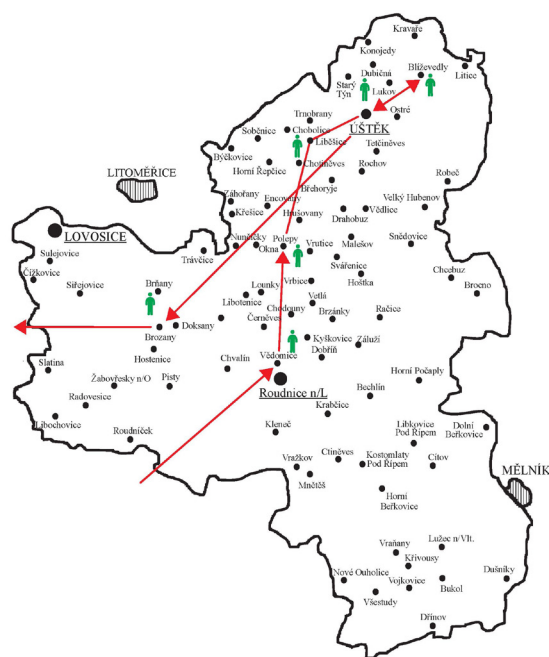


Figure 1 Sampling locations of hop plants as part of processing pre-harvest forecasts for Saaz hops in the Auscha growing region

Samples of hybrid varieties are only taken at random and they are not systematically evaluated. The results of the analyses are published on the HRI website (HRIa, 2022).

When evaluating the alpha acid content of the Saaz aroma hops, it must be taken into account that new hop yards planted with a virus-free planting stock (plants that are freed from plant viruses and viroids using biotechnological methods) have a significantly higher alpha acid content than the hops from older stands (Pethybridge et al., 2008). The effect of the recovery process is significantly manifested mainly within 5 years of planting. Due to re-infection with the latent hop viroid, which progresses relatively quickly, the content of alpha acids gradually decreases to the level of untreated hops (Donner et al., 2020).

For this reason, pre-harvest forecasts for Saaz are also carried out in hop gardens older than five years. At the same time, however, the content of alpha acids is significantly influenced by the course of weather conditions during the vegetation period, especially in the June–August period (Kučera and Krofta, 2009). In order to be able to separately evaluate the effect of recovery (virus-free process) and weather on the annual content of alpha acids in Saaz hops, it is necessary to separate the primary analytical data for the Saaz-standard and Saaz-VF (virus-free) categories.

Harvest prognoses for both Saaz and the hybrid varieties are based on analyses of selected commercial hop samples from all hop growing regions during the harvest.

The samples are collected by the Chmelařství laboratory (Cooperative Žatec) and are gradually handed over to the RIBM, where the final selection of samples as well as the analyses are carried out. Approximately 150 to 170 hop samples are tested in this way every year. Finally average values for Saaz variety (80–100 samples), Sládek and Premiant (25 samples of each variety) are calculated for all varieties and each growing area.

The actual harvest contents of alpha acids are determined for both Saaz and the hybrid varieties based on the processing of the analysis results of all purchased and farmers hop samples. The largest number of samples goes to Saaz. The total number of evaluated samples is most often in the range of 2,000 to 4,000 depending on the harvest year. Samples and results are differentiated according to varieties and hop growing regions (Saaz, Auscha, Tirschitz).

2.3 Analytical and statistical evaluation

Two methods were used to determine the content of alpha acids for the analytical evaluation of the hop samples. Pre-harvest forecasts and analysis of the purchased samples for final harvest data were assessed using a modified conductometric method according to EBC 7.4 (Krofta et al., 2022). The hop samples intended for the determination of the harvest forecasts were analysed by liquid chromatography according to the EBC 7.7 method. The statistical evaluation of the experimental data was performed using the statistical software QC-Expert 2.5 (TriloByte Pardubice, CZ). For large files, the mean value was evaluated using the arithmetic mean and median, for small files of up to 20 data, the mean value was determined using the method of small selections according to Horn (Meloun and Militký, 1995).

3 Results and discussion

3.1 Weather conditions in the year 2022

The year 2022 will go down in history as one of the driest and warmest in the last 30 years. The precipitation deficit gradually accumulated since the winter months and it in-

creased dramatically during the summer due to high temperatures. The winter period of 2022 was relatively warm and poor in precipitation. Temperatures in January and February were 2 to 4 °C above the long-term averages. In February, temperatures were in the range of 10–15 °C on some days. The alternation of warm and cold fronts was accompanied by frequent, but precipitation-weak showers. During January and February, only 25 mm of rain or snow fell, which is 40–50% of the long-term average. The hottest months of the growing season were June and August, with average temperatures in the 20–21 °C range, which is 2–3 °C above the long-term averages. Twenty-nine tropical days were also recorded in the June–August period. Precipitation was mostly not very abundant, rarely more than 10 mm of water fell. The Saaz variety began to bloom in the second half of June. At that time, however, the bines on a number of hop farms did not reach the top of trellis, which subsequently resulted in a very low yield. Intervals between heavier rainfall events (i.e., more than 10 mm) were longer than 7 days and were also highly variable locally. This was not nearly enough to cover the potential evaporation, which was greater than 100 mm/month in the summer. Thanks to the warm and dry nature of the weather, the infection pressure of downy mildew was not as strong as in previous years. The relatively strong infection pressure of the hop aphid during May and June was managed with proven chemical preparations. The last decade of August and the first decade of September brought temperature drops and abundant rainfall. At that time, however, the hop harvest was in full swing and the water in the hop gardens rather complicated the situation. Average monthly temperatures and precipitation totals in the growing months of the year 2022 are summarized in Tables 1 and 2.

Some growers started harvesting hops already on August 13–14, the majority a few days later. In 2022, the precipitation balance in the Tirschitz region was not as critical as in Bohemia, because several rain-rich fronts were moving from the southwest to the northeast. During their movement, they hit Southwest Bohemia, Vysočina and Northern Moravia, but the hop growing areas in Bo-

Table 1 Average monthly temperatures (°C) in the vegetation months in 2022

Month/Locality	Žatec	Stekník	Tuchořice	Kněžves	Ročov	Petrohrad	Brozany	Liběšice	Tršice
April	7.7	7.9	7.6	6.8	6.9	7.0	8.4	7.6	7.5
May	15.7	16.2	16.1	15.1	15.4	15.5	16.5	15.5	15.3
June	20.3	20.3	20.4	19.4	19.4	20.2	20.8	19.8	19.9
July	20.0	20.2	20.0	19.0	19.4	19.4	20.0	19.7	20.1
August	20.5	20.8	20.5	19.7	19.9	19.7	20.7	21.0	21.0
September	13.7	13.9	14.7	14.1	14.0	14.1	13.8	13.3	3.2

Table 2 Monthly precipitation totals (mm) in the vegetation months in 2022

Month/Locality	Žatec	Stekník	Tuchořice	Kněževs	Ročov	Petrohrad	Brozany	Liběšice	Tršice
April	38.0	43.0	–	46.6	51.0	54.8	44.2	41.0	30.1
May	19.2	21.8	25.0	20.0	24.2	30.0	13.8	18.0	45.4
June	40.0	47.2	47.8	58.2	94.2	–	30.8	79.0	76.4
July	25.6	31.0	51.4	39.4	42.6	55.8	30.0	26.0	67.3
August	37.4	38.6	36.0	32.4	75.8	26.0	56.8	115.2	56.6
September	57.8	68.8	38.4	46.6	47.8	53.0	37.8	65.6	60.9
Total	218.0	250.4	198.6	243.2	335.6	219.6	213.4	344.8	336.7

hemia remained without rain. Therefore, the average hectare yield of Saaz hops in the Tirschitz region (0.97 t/ha) is significantly greater than in the Saaz and Auscha regions (0.72; 0.78 t/ha). The extremely unfavourable weather conditions resulted in the lowest hop harvest in the history of Czech hop farming, this means 4,452 tonnes.

3.2 Alpha acids content

3.2.1 Evaluation of the difference in analytical data between EBC 7.4 and EBC 7.7 methods

Since two fundamentally different analytical methods were used to evaluate hop samples (EBC 7.4 – lead conductance value, EBC 7.7 – HPLC), the difference in the results of the mentioned methods was determined. Data from the AHA's international round robin tests were used for the evaluation. A comparison of the data showed that the result of the analysis by the conductometric method EBC 7.4 is usually higher than the result of the chroma-

tographic method EBC 7.7, but the opposite differences are not an exception. The average difference of analytical results in the absolute value is 3.7% rel. (EBC Analysis Committee, 2010; Krofta et al., 2022)

3.2.2 Saaz variety – forecasts and reality

Table 3 shows the results of the pre-harvest forecasts of the alpha acid content in the Saaz aroma variety from the Saaz and Auscha growing areas. The content of alpha acids in both areas showed a slow increase from a level of approx. 2.2–2.3% by weight at the beginning of August up to the level of 2.4 to 2.5% wt. in the third decade of August, when the harvest of this variety was in full swing. The pre-harvest forecasts as well as the harvest forecasts were, in contrast to the year 2021 (Krofta et al., 2022) quite accurate. The actual contents in the “standard” Saaz category were 2.68% for the Saaz region, 2.75% for the Auscha region, but only 2.47% by weight for the Tirschitz growing region.

Table 3 Alpha acids content in Saaz variety from the harvest 2022, forecasts and reality

Saaz standard		Saaz	Auscha	Tirschitz
Pre-harvest forecast	arithmetic mean	2.83	2.54	–
	median	2.47	2.5	–
	small selections	2.46	2.57	–
Harvest forecast	arithmetic mean	2.65	2.44	2.41
	median	2.57	2.32	2.58
Reality	arithmetic mean	2.68	2.75	2.47
	median	2.65	2.67	2.59
Saaz – virus free				
Harvest forecast	arithmetic mean	3.22	3.33	3.05
	median	3.14	2.92	2.81
Reality	arithmetic mean	3.72	4.31	2.94
	median	3.68	4.47	2.88
Saaz – total				
Harvest forecast	arithmetic mean	2.88	2.89	2.69
	median	2.79	2.82	2.51
Reality	arithmetic mean	3.14	3.27	2.72
	median	2.88	2.80	2.63

The content of alpha acids in the Saaz category VF is, as expected, significantly higher, by 30 to 40% rel. in Saaz and Auscha regions, in the Tirschitz area by a slightly more than 10% rel. The harvest forecasts for the Saaz and Auscha areas were lower than the reality. With a small number of samples, the influence of the hop plants age and local weather conditions can be more pronounced. The strong influence of plant age on the alpha acids content in Saaz aromatic hops is evident from the data in Table 4. Despite of the unfavourable weather in 2022, the content of alpha acids in hops harvested from the hop gardens established in 2020 and 2021 normally reached values of 6 to 7%. A restoration of overgrown hop gardens is thus one of the

effective tools for solving problems associated with the effects of climate change on hop cultivation.

However, this does not change the fact that the Saaz aroma variety is very sensitive to weather conditions during the growing season. The climate factor value defined for this variety by Forster is 5.1 (Forster and Schüll, 2020; Forster and Gahr, 2020). This is significantly higher than varieties that are more tolerant to weather fluctuations. However, a more detailed analysis of this issue would deserve more space and is not the goal of this article.

In the past five years (2017–2021), more than 1,000 ha of new hop gardens were restored in the Czech Republic with seedlings free of viral and viroid pathogens (Chromý,

Table 4 The effect of age of hop plants on alpha acid contents in 2022 crop harvest

Age of hop plants	Locality 1	Locality 2	Locality 3	Locality 4	Locality 5	Locality 6	Locality 7
1–2 years	4.1	4.3	4.9	5.1	6.7	7.1	4.5
> 5 years	2.9	2.5	2.8	2.5	3.6	3.8	2.6

Table 5 Alpha acid content, Czech hybrid varieties from the 2022 crop harvest, forecasts and reality

Variety		Statistics	Saaz	Auscha	Tirschitz
Sládek	harvest forecast	arithmetic mean	6.12	5.97	4.44
		median	5.99	5.90	4.21
	reality	arithmetic mean	6.94	6.70	4.85
		median	6.88	6.50	4.77
Premiant	harvest forecast	arithmetic mean	8.25	7.81	7.84
		median	8.58	7.75	7.62
	reality	arithmetic mean	8.45	8.09	7.68
		median	8.59	8.22	7.61
Agnus	harvest forecast	arithmetic mean	11.86	–	–
		median	11.94	–	–
	reality	arithmetic mean	12.07	13.15	10.20
		median	12.33	13.49	10.20
Kazbek	harvest forecast	arithmetic mean	–	–	5.19
		median	–	–	5.12
	reality	arithmetic mean	6.17	6.36	5.50
		median	6.32	6.62	5.60
Saaz Late	harvest forecast	arithmetic mean	2.47	–	–
		median	2.52	–	–
	reality	arithmetic mean	2.72	–	1.59
		median	2.59	–	1.59
Saaz Special	reality	arithmetic mean	6.60	–	–
		median	6.67	–	–
Harmonie	reality	arithmetic mean	6.63	–	–
		median	6.50	–	–
Vital	reality	arithmetic mean	12.77	10.59	–
		median	12.62	10.59	–

2022). The rate at which hop yards are renewed is about 200 ha every year, which makes 4.5% of the cultivated area.

The average content of alpha acids in Saaz, calculated for all harvest samples, regardless of the age of the growths and the type of planting, shows the median values ranging between 2.6–2.8% wt. The median values and quantitative harvest data were used to calculate the total production of alpha acids in the harvest year, which is shown in Table 5. The harvest forecasts were in good agreement with reality, due to the smaller representation of samples of the VF category (approx. 1/3) in the set of samples, the lower forecast values for this category did not significantly affect the overall rating.

3.2.3 Other Czech hop varieties – forecasts and reality

Currently, 27 Czech hop varieties are registered (Nesvadba et al., 2022); except for most Saaz hops, only a few are grown in significant quantities. Nowadays, Sládek, Premiant, Agnus, Kazbek, Saaz Late and Saaz Special belong to the Czech majority hybrid varieties with a cultivation area of over 20 ha. Their cultivation is gradually expanding to all hop-growing areas of the Czech Republic, even though the cultivation area is stagnant for some varieties (Saaz Late, Kazbek). In 2022, they were harvested from the area of 776.2 ha (Sládek 397.4 ha; Premiant 212.8 ha; Agnus 70.5 ha; Saaz Special 41.2 ha; Saaz Late 32.1 ha and Kazbek 22.2 ha) and their total harvest was 1286.5 tons. The contents of alpha acids in Czech hybrid varieties from the 2022 harvest are shown in Table 5.

In general it can be stated that, in terms of alpha acid content, the hybrid varieties coped with the weather conditions of the 2022 harvest year much better than Saaz. But even among them there are more sensitive varieties, and on the contrary, very stable hop cultivars. Among the sensitive varieties is the Saaz Late variety, which in the Saaz region contained 2.6% wt. of alpha acids and in the Tirschitz area only 1.6% wt. The Sládek variety contained an average of 6.9% by weight of alpha acids in the Saaz region, 6.5% by weight in Auscha, but only 4.8% by weight in Tirschitz. The Premiant variety contained an average of 8.6% by weight of alpha acids in the Saaz region, in Auscha 8.2% wt. and Tirschitz only 7.6% wt. However, the new plantings of the hybrid varieties Premiant and Sládek contained 10 to 11% wt. of alpha acids. Similar to Saaz hops, a significantly lower content of alpha acids was found in hybrid varieties grown in the Tirschitz region than in those from the Bohemian growing areas.

The great stability of the content of alpha acids, basically independent of weather conditions, was confirmed for the Agnus variety. The content in the range of 11 to 13% was in all hop-growing areas, which is roughly at the level of previous harvest years. The value of the aforementioned climatic factor is only 1.3 (Forster and Schüll, 2020; Forster and Gahr, 2020) for this variety. The stable level of alpha acids between 6.0 to 7.0% wt. was also maintained in the Kazbek and Saaz Special varieties. The harvest forecasts for the hybrid varieties in the 2022 harvest were in very good agreement with reality, with the exception of the Sládek variety (forecast lower by approx. 10% rel.).

3.3 Production of alpha acids from the annual harvest

Annual alpha acids production in the Czech Republic was calculated from the final harvest balance published by the Central Institute for Supervising and Testing in Agriculture on its website (CISTA, 2022) at the end of 2022, and from the average alpha acids contents listed in Tables 3 and 5. Results differentiated by variety and growing area are summarized in Table 6. The total production also includes the contributions of minority varieties (Vital, Harmonie, Rubín), which are grown on an acreage of 11.7 hectares. For hops in the “other” category, the production of alpha acids was determined for an average content of 5% wt.

The total production of alpha acids in Czech hops from the 2022 harvest was 182.9 tons, and in a longer-term comparison it is among the lowest. The very low production is due to the concurrence of two factors, the low yield per hectare and the content of alpha acids in the Saaz hops, which is grown on 84% of the area of hop gardens and is therefore crucial for the production of alpha acids. At the same time, the volume of production deteriorated due to the extreme weather events and it was significantly smaller than in previous years.

Table 6 Production of alpha acids in the Czech Republic in 2022

Variety/Region	Žatec (Saaz)	Ústěk (Auscha)	Tršice (Tirschitz)	Total
Saaz	67.36	9.02	12.25	88.63
Sládek	30.40	7.58	7.90	45.88
Premiant	13.91	5.07	6.35	25.33
Agnus	8.70	3.65	0.39	12.74
Saaz Late	1.30	–	0.06	1.36
Saaz Special	3.33	–	–	3.33
Kazbek	1.74	0.87	0.54	3.15
Vital	0.41	0.22	–	0.63
Harmonie	0.52	–	–	0.52
Rubín	0.12	–	–	0.12
Other	1.17	–	–	1.17
Total	128.96	26.41	27.49	182.9

3.4 Long-term development of alpha acids content in Saaz hops in the period 1992–2022

Figure 2 shows the average harvest levels of alpha acids detected in the Saaz variety from all three hop-growing areas between 1992 and 2022. The data presented here result from the evaluation in which all purchased samples of hops from the annual harvest were analysed. The methodology is described in this paper. The content of alpha acids is usually ranges between 3–4% with large year-on-year fluctuations caused by the conditions of the given growing season. In 1996, 2000, 2004, 2010, 2011 and 2021, the average alpha acids content in Saaz variety was above 4.0% wt. These were always years, in which there were no long tropical periods with sufficient rainfall. The year 2022 will go down in history not only for the low content of alpha acids in Saaz, but also with the lowest yield per hectare of Saaz variety in the Saaz hop growing area of 0.72 t/ha. Even irrigation did not significantly improve the situation, as the available water could not compensate for the huge rainfall deficit.

In the past 30 years, three weather-critical years 1994, 2006, 2015 have also been recorded, in which the average content of alpha acids in Saaz ranged from 2.0 to 2.5% wt. and in the historical context they will also include the year 2022. These have always been years with high summer temperatures and low total precipitation. Extremely hot and low-precipitation summers are usually not limited to the Czech Republic, but affect the entire area of Central Europe, i.e. Germany, Poland, France and Slovenia.

This is proven by the data presented in Table 7, which shows the average contents of alpha acids in selected German and Slovenian varieties in 2021 and 2022 (Anonym, 2022). Analogous trends can be observed from the data, as for Czech hops in the same period, i.e. varietal dependence in response to the manifestations of climate change. High content varieties are able to cope with stressful conditions in the form of limited access to water and high temperatures much better than most of aromatic hops.

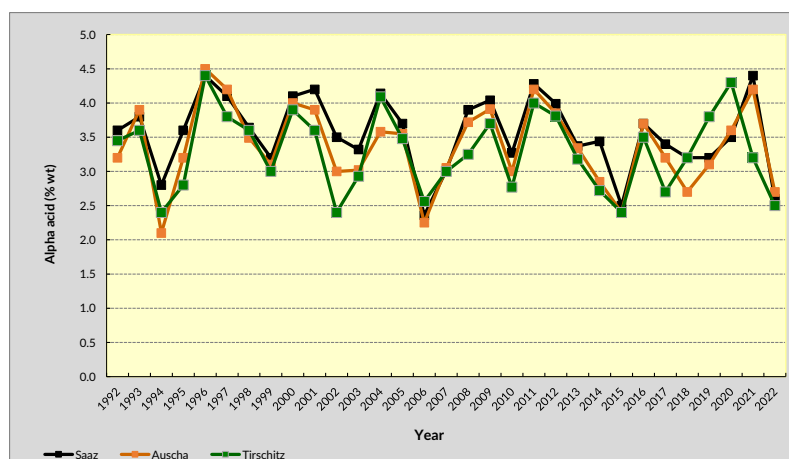


Figure 2 Alpha acid content of Saaz hops in the period 1992–2022

4 Conclusion

The weather fundamentally influenced the harvest results of the Czech hops in 2022. The characteristic weather parameters of the hop growing season in 2022 included a large precipitation deficit, which gradually accumulated from the winter months until the harvest, and high summer temperatures, especially in June and August. The content of alpha acids in Saaz from the 2022 harvest in the range of $2.5 \pm 0.3\%$ wt. was very low in all hop growing regions. Although the Bohemian regions and the Moravian hop region are separated by approx. 300 km in a beeline, the weather conditions are so different in some years that they cause different harvest results (yield, alpha acid content). The hybrid varieties coped with the 2022 weather conditions much better than Saaz in terms of alpha acid content and yield. But even among them, there are more sensitive varieties and, on the con-

Table 7 Alpha acid content (% wt.) in selected German (G) and Slovenian (S) hops in 2021 and 2022 (Anonym, 2022)

Variety/Region	2021	2022	10year mean
Hersbrucker (G)	4.6	1.9	2.6
Saphir (G)	4.3	2.6	3.4
Perle (G)	9.0	4.9	6.7
Spalter Select (G)	6.4	3.3	4.4
Hall. Tradition (G)	6.1	5.2	5.6
Magnum (G)	16.0	12.2	13.1
Herkules (G)	18.5	15.4	16.3
Polaris (G)	21.5	18.5	19.5
Aurora (S)	6.8	7.0	8.3
Savinjski Golding (S)	2.2	2.4	2.9
Celeia (S)	3.3	2.6	3.3

trary, very stable hop varieties. The great stability of the alpha acid content in the range of 11 to 13%, basically independent of weather conditions, is confirmed by the Agnus variety in the long term. The stable content of alpha acids at the level of 6.0 to 7.0% wt. is also maintained in the Kazbek and Saaz Special varieties. The age of the hop growth significantly influences the content of alpha acids which has been demonstrated in all hop growing areas of the Czech Republic. This applies not only to Saaz but also to the hybrid varieties.

The young plants, under 5 years since planting, contained significantly more alpha acids than older ones. Therefore, regular regeneration of hop gardens is necessary to maintain profitable hop cultivation.

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6 References

- Anonym (2022). Alpha-säurenwerte von Hopfen der Ernte 2022 und aktualisierte mehrjährige Durchschnittswerte – Teil 1. *Brauwelt*, 42, 1082.
- CISTA (2022). Úroda chmele je nejnižší za posledních 10 let. In: *eagri.cz* [online] [2023-01-30]. Retrieved from: <https://eagri.cz/public/web/ukzuz/portal/trvale-kultury/statisticke-vystupy/uroda-chmele-2022-nejnizsi.html>
- Donner, P., Pokorný, J., Ježek, J., Krofta, K., Patzak, J., Pulkrábek, J. (2020). Influence of weather conditions, irrigation and plant age on yield and alpha-acids content of Czech hop (*Humulus lupulus* L.) cultivars. *Plant, Soil and Environment*, 66(1), 31–46. <https://doi.org/10.17221/627/2019-PSE>
- EBC Analysis Committee (2010). *Analytica EBC, Methods 7.4, 7.7*, Fachverlag Hans Carl, Nürnberg. ISBN 978-3-418-00759-5.
- Forster, A., Schüll, F. (2020). The impact of climate change on hops. *Brauwelt International*, 40(3), 174–178.
- Forster, A., Gahr, A. (2020). The Saaz hop variety – how great is the influence of climate and growing region in the Czech republic? *Hopfen-Runhschau International*, 2020/2021, 38–44.
- HRI (2022). Počasí. Chmelařská oblast Žatecko. In: *chizatec.cz* [online] [2023-01-30]. Retrieved from <http://www.chizatec.cz/pocasi/?arc=163&sub=92>
- HRIa (2022). Dynamika tvorby alfa kyselin v hlávkách ŽPČ před sklizní. In: *chizatec.cz* [online] [2023-01-30]. <http://www.chizatec.cz/predskliznove-odbery/?arc=291>
- Chromý, Z. (2022). České chmelařství v přehledech ÚKZÚZ. Chmelařská ročenka 2022. VÚPS, Praha, 291–317. ISBN978-80-86576-95-4
- Krofta, K., Fritschová, G., Mikyška, A., Belešová, K., Vojtěchová, D., Tichá, J. (2022). Alpha acids content in Czech hops from harvest 2021 – forecasts, reality and trends. *Kvasny prumysl*, 68(1), 564–571. <https://doi.org/10.18832/kp2022.68.564>
- Kučera, J., Krofta, K. (2009). Mathematical model for prediction of yield and alpha acid contents from meteorological data for saaz aroma variety. *Acta Horticulturae*, 848, 131–139. <https://doi.org/10.17660/ActaHortic.2009.848.14>
- Meloun, M., Militký, J. (1995). *Statistical processing of experimental data*. Plus, Praha. ISBN 80-85297-56-6
- Nesvadba, V., Krofta, K., Patzak, J. (2022). *Czech hop varieties*. Chmelařský institut, Žatec. ISBN 978-80-86836-60-7.
- Pethybridge, S.J., Hay, F.S., Barbara, D.J., Eastwell, K.C., Wilson, C.R. (2008). Viruses and viroids infecting hop: significance, epidemiology, and management. *Plant Disease*, 92, 324–338. <https://doi.org/10.1094/PDIS-92-3-0324>