



Alpha acids content in Czech hops from the 2023 harvest – forecasts, reality and trends

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Abstract

The most important weather factor for the hop growing season in 2023 was the rainy period in the last decade of July and the first decade of August, which replaced the previously warm and dry weather. Heavy rainfall with a total of 60–100 mm of water and temperatures in the range of 20–25 °C saved the annual hop harvest from the yield decline that occurred in 2022. However, the above-average harvest of nearly 7000 tonnes and a yield of 1.44 t/ha was achieved at the expense of the bitter compound content of most varieties. The alpha acid content of Saaz hops was well below 3.0% w/w in all hop-growing regions, one of the lowest levels for the last 10 years. It is even lower than the extremely hot and dry year 2022 and comparable to 2015. Lower levels of alpha acids were also found in Sládek (4.8–6.7% w/w), Premiant (6.9–7.9% w/w) and Saaz Special (4.3% w/w). The varieties Agnus, Rubín and Vital contained stable amounts of alpha acids in the range of 11–13% w/w, which is about the same as in previous years. The total production of alpha acids in Czech hops from the 2023 harvest was 253 tons, which is average in a longer-term comparison. Saaz hops accounted for only 55% of the total production, although they are grown on 83.3% of the harvest area.

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. Hop-ping doses and total consumption of hops depend on bitter vigour of hops and hop products for the planned beer production. Timely and as accurate as possible information about this quality parameter is expected annually by the professional public (trade, breweries). This is especially important in years when weather conditions cause harvest with low alpha acids production. Global climate change also has an impact on the hop cultivation in the form of more frequent warm and dry periods (Sedlmaier et al., 2018). Their impact on

the yield and content of bitter substances depends on the development stage in which the hop plants are at that moment.

The Hop Research Institute (HRI) in Žatec (Saaz) and the Research Institute of Brewing and Malting (RIBM) in Prague, with significant participation of Chmelařství, Cooperative Žatec and V.F. HUMULUS Hořesedly, have been systematically evaluating the content of alpha acids in Czech hops gained from annual crop harvest 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 Saaz aroma hops. With the onset of hybrid varieties in the years 1995 to 2000, the evaluation expanded to include Premiant, Sládek and after 2000 other varieties as Agnus, Kazbek, Saaz Late, Saaz Special, etc. The alpha acid contents are assessed for all hop growing areas in the Czech Republic, the Žatec (Saaz) region, the Úštěk (Auscha) region and the Tršice (Tirschitz) region in Moravia. In harvest parameters (yield, alpha acid content), there may be significant differences among the 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 (HRI, 2024) and in professional journals. During the vegetation, data on selected weather parameters are continuously collected, as the weather significantly affects the content of alpha acids content in hops (Forster and Gahr, 2021; Donner et al., 2020; Forster and Shüll, 2020).

The purpose of this article is to provide summary information about the content of alpha acids in Czech hop varieties from the 2023 harvest in the context of weather conditions during the vegetation season. It follows on a similar assessment of the 2021 and 2022 crop seasons (Mikyška et al., 2023; 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 Stekník, Žatec, Ročov, Kněževy, Tuhořice and Petrohrad are located in the Žatec hop growing region, the stations in Brozany and Liběšice are situated in the Úštěk region. The meteorological data recorded in hourly intervals are accessible on the HRI website. The stations measure air temperature and humidity, amount of rainfall, daylight intensity, wind direction and strength, some also measure soil temperature at depths of 20 and 50 cm. The weather monitoring in the locations of Žatec, Tuhořice, Petrohrad and Brozany was affected by the outage of the SIGFOX network at the end of April 2023 and it was not restored until the end of the year. The Hop Research Institute, in cooperation with the manufacturer of the weather stations, ensures their reconstruction for data transmission in the GSM network. The meteorological data for the Žatec location for the year 2023 was taken from the database of the Czech Hydrometeorological Institute.

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 taken directly in the hop yards in the course of 3 to 4 weeks before the expected start of harvest in selected locations in Saaz and Auscha hop growing regions. The collection sites are selected to include most of the important and typical hop growing locations – the Ohře-river basin, Golden Creek Valley, the Rakovník region, Podlesí, Polepská blata, the surroundings of Úštěk (Auscha) and Libochovice. Samples of hop cones are taken from 5–10 plants in heights of 3–6 meters by means of telescopic rod in the same place of selected hop gardens (Figure 1). Samples of hybrid varieties are only taken at random and are not systematically evaluated.

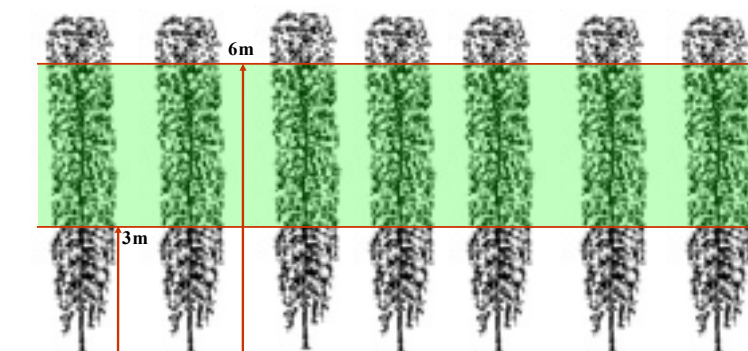


Figure 1 Taking samples of hop cones in pre-harvest period

Harvest prognosis for both Saaz and hybrid varieties are made on the basis of analyses of selected purchase samples of hops 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. In 2023, 70 samples of Saaz, 15 samples each of Sládek and Premiant and 10 samples of other varieties were tested.

The actual harvest contents of alpha acids are determined for both Saaz and hybrid varieties once the analysis of all purchase and farmers hop samples was processed. The largest number of samples goes to Saaz. The total number of the evaluated samples is most often between 2,000 to 4,000 depending on the vintage harvest. The samples and results are differentiated according to the varieties and hop growing regions (Žatec, Úštěk, Tršice).

2.3 Analytical and statistical evaluation

Two methods for determining the content of alpha acids were used for the analytical evaluation of the hop samples. Pre-harvest forecasts and analysis of the purchased samples for final harvest data were conducted using

a modified conductometric method according to EBC 7.4 (Krofta et al., 2022; EBC Analysis Committee, 2010). Hop samples selected for determination of harvest forecasts were analysed by liquid chromatography according to the EBC 7.7 method (EBC Analysis Committee, 2010). The statistical evaluation of the experimental data was performed using the statistical software Statistica 12 (StatSoft, CZ). The mean value was evaluated using the arithmetic mean and median.

3 Results and discussion

3.1 Weather conditions in the year 2023

The year 2023 will be listed as one of the warmest in historical surveys. Already the winter has been unusually warm. Compared to long-term averages, not even two-thirds of the usual snow cover fell in the Czech Republic. The warmest month was July, when hop growers were also suffering from a significant drought. Unusually high temperatures also prevailed in the autumn months of September and October. However, 2023 will not be the driest year. The first third of the year and heavy rains at the end of July and the beginning of August ensured water. The average monthly temperatures and precipitation totals during the growing months (April–September) in selected locations of the hop-growing regions are shown in Table 1 and Table 2.

Almost every hop growing season is characterised by weather conditions that have a major impact on the economics of the vintage, i.e. especially yield and alpha acid content. While in 2022 there was a major drought and high temperatures during the hop cones formation and ripening period, in 2023 two factors can be considered decisive. Unlike previous years, there was no tropical and dry wave in June with temperatures exceeding 35 °C. The tropical waves occurring during this period are particularly damaging because the hop plants usually do not reach the top of trellis. The second aspect was the already mentioned rainfall-rich last decade of July and first decade of August. This brought a cooling down of 20 to 25 °C and heavy rainfall with a total of 60–100 mm of water. It was at the time when the hops were blooming and beginning to form cones. This relatively short period essentially saved the annual hop harvest from the yield losses that had occurred the previous year. Nearly 7,000 tonnes of hops were harvested.

In 2023, the weather in the Tršice hop-growing region was different from that in the Žatec and Ústěck regions, especially in terms of the amount and timing of rainfall. Many rain-rich fronts coming into Bohemia from the southwest avoided the Žatec and Ústěck hop-growing areas. As they moved northeast, they crossed the Highlands into Moravia and often hit the Tršice hop-growing region and included extreme weather events (hail, strong winds, torrential rainfall).

Table 1 Average monthly temperatures (°C) in the vegetation months in 2023

Month/Locality	Stekník	Žatec	Kněžves	Ročov	Liběšice	Tršice
April	7.9	7.4	6.8	6.9	7.7	8.0
May	14.0	13.8	13.0	13.2	14.0	14.0
June	18.8	18.5	17.5	18.0	18.5	18.4
July	20.9	20.1	20.2	19.8	20.3	20.0
August	20.4	19.7	19.5	19.2	19.7	20.1
September	17.5	16.0	17.0	17.6	17.9	18.3

Table 2 Monthly precipitation totals (mm) in the vegetation months in 2023

Month/Locality	Stekník	Žatec	Kněžves	Ročov	Liběšice	Tršice
April	–	32.9	34.0	43.4	28.0	58.7
May	–	7.2	4.0	5.6	14.0	64.4
June	–	58.0	59.2	87.0	67.2	49.6
July	–	66.4	34.6	57.4	45.2	54.9
August	–	66.7	57.0	78.0	100.0	150.8
September	–	20.4	6.8	8.0	11.4	63.2
Total	–	251.6	195.6	279.4	265.8	441.6

3.2 Alpha acids content

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

Since two fundamentally different analytical methods were used to evaluate the hop samples (EBC 7.4 – lead conductance value, EBC 7.7 – HPLC), the difference in the results of the above-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 chromatographic 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. (Krofta et al., 2022).

3.2.2 Saaz variety – forecasts and reality

The results from the pre-harvest forecasts of the alpha acids content in the Saaz aroma variety for the Žatec and Ústěk growing areas are shown in Table 3. Samples are taken from hop gardens more than 5 years old. The alpha acid content in the pre-harvest period of 2023 in the Saaz region showed a very small increase from a level of about 1.4 to 1.6% w/w at the beginning of the month, rising to 2.5 to 2.6% in mid-August. At the third decade of August, the amount of bitter substances had stagnated or even decreased slightly to a level of 2.3 to 2.4% w/w. The forecasts for the Ústěk region were more favourable. The alpha acid content gradually increased from 2.1% w/w at the beginning of the month to 3.0% w/w at harvest time (Table 3).

The actual contents, based on analyses of several thousand purchased samples of raw hops, were determined to be 2.58% w/w (2.54% median) for Žatec and 2.72% w/w (2.73% median) for the Ústěk regions. The pre-harvest forecasts for the Žatec area proved to be accurate, while for the Ústěk region they were overestimated by around 0.30%. In Tršice region, the alpha acid content of the Saaz hops was also very low, only 2.39% w/w (2.41% median). Many samples from this area contained less than 2.0% alpha acids.

The harvest estimates that are available in the fourth quarter of the calendar year are generally underestimated compared to the reality by 0.3% w/w for Žatec and 0.50% w/w for Ústěk growing regions. The best agreement between the forecast and the reality was achieved for the Tršice region due to the low level of alpha acids across the entire area (Table 3). The reason for the different results lies in the limited number of evaluated samples, especially in the Ústěk area (ten samples). An increase in the number of analyses would undoubtedly bring better precision to the results. However, there are time constraints and increased economic costs that play a role as well.

The content of alpha acids in Saaz category VF is, as expected, significantly higher, by 30 to 40% rel. in the Žatec and Ústěk regions. In the Tršice region, the increase in the content of alpha acids in hops of the VF category practically did not manifest itself. This is due to the age of the stands with a small proportion of regeneration. The influence of the age of hop plants of Saaz hops on the content of alpha acids is well known (Donner et al., 2020; Krofta 2002). The content of alpha acids in Saaz hops harvested from hop gardens established in 2021 and 2022 normally reached values of 5 to 7%. The 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.

In the past five years (2017–2022), more than 1,000 ha of new hop gardens were restored in the Czech Republic with seedlings free of virus and viroid pathogens (Kršková, 2023). The rate of renewal of hop yards is 211,6 ha in 2023, which is 4.4% of the cultivated area.

Table 3 Alpha acids content in Saaz variety (% w/w) from the harvest 2023, forecasts and reality

Saaz standard		Žatec	Ústěk	Tršice
Pre-harvest forecast	arithmetic mean	2.42 ± 0.51	3.11 ± 0.82	–
	median	2.34	3.03	–
Harvest forecast	arithmetic mean	2.29 ± 0.80	2.17 ± 0.23	2.35 ± 0.51
	median	2.13	2.15	2.07
Reality	arithmetic mean	2.58 ± 0.54	2.72 ± 0.50	2.39 ± 0.51
	median	2.54	2.73	2.41
Saaz – virus free				
Harvest forecast	arithmetic mean	3.09 ± 1.31	–	–
	median	2.95	–	–
Reality	arithmetic mean	3.54 ± 1.16	3.84 ± 1.45	2.53 ± 0.94
	median	3.34	3.61	2.25
Saaz – total				
Harvest forecast	arithmetic mean	2.49 ± 1.03	2.12 ± 0.28	2.28 ± 0.52
	median	2.18	2.14	2.04
Reality	arithmetic mean	2.81 ± 0.84	2.95 ± 0.91	2.47 ± 0.77
	median	2.63	2.78	2.32

The alpha acid content of Saaz hops is one of the lowest in the last 10 years. It is even lower than the extremely hot and dry 2022 vintage and comparable to 2015. The reason for the overall low level of alpha acids in 2023 is most likely the above-average yield of hops, which was achieved thanks to very favourable weather conditions at the turn of July and August. The intense growth of the cones was faster than the formation of bitter acids, so the content of alpha acids stagnated during the ripening of the hops in many locations, and even declined slightly in others.

The levels of alpha acid content in Saaz hops vary depending on the altitude and location of the site, or soil type. The distribution of alpha acid levels of Saaz hops in the Saaz growing region in 2023 is shown in Figure 2. Alpha acid content is divided into three levels, greater than 3.0%, 2.5–3.0% range and less than 2.5%. In a large area of the Žatec region, the content of alpha acids was lower than 2.5% w/w. This applies to the central part of the area, for localities Tuchořice, Třeskonice, Pnětluky, Hořesedly, Solopysky, Konětopy, Domoušice, Hředle and a number of others. This also includes the entire hop-growing region of Woodlands (Ročov, Pochvátov, Kozojedy, Divice, Vinařice, Kroučová, Třeboc, Mšec, Milý, Smilovice). In Ohře river region, in the western and eastern parts of the area, the content of alpha acids was mainly in the range of 2.5–3.0% w/w (Čínov, Kněžice, Sedčice, Stekník, Holedč, Mradice, Strkovice, Postoloprty, Lenešice, Vraný, Zlonice). The highest contents of alpha acids above 3.0% were detected in hops from locations situated in the region of Golden Creek Valley (Siřem, Kryry, Vroutek, Mukoděly, Petrohrad, Běsno, Malá and Velká Černoc, Očihov, Blšany). The alpha acid content of the hops from Kněžves, Chrást'any, Nesuchyně, Přílepy and Olešná locations (Rakovník region) was comparable.

The average content of alpha acids in Saaz hops, calculated for all harvested samples, regardless of the age of the growths and the type of planting, is in the median and arithmetic mean values in the range of 2.6–2.8% w/w in the Žatec region, 2.8–3.0% w/w in the Úštěk area and 2.3–2.5% w/w in the Tršice region. 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.

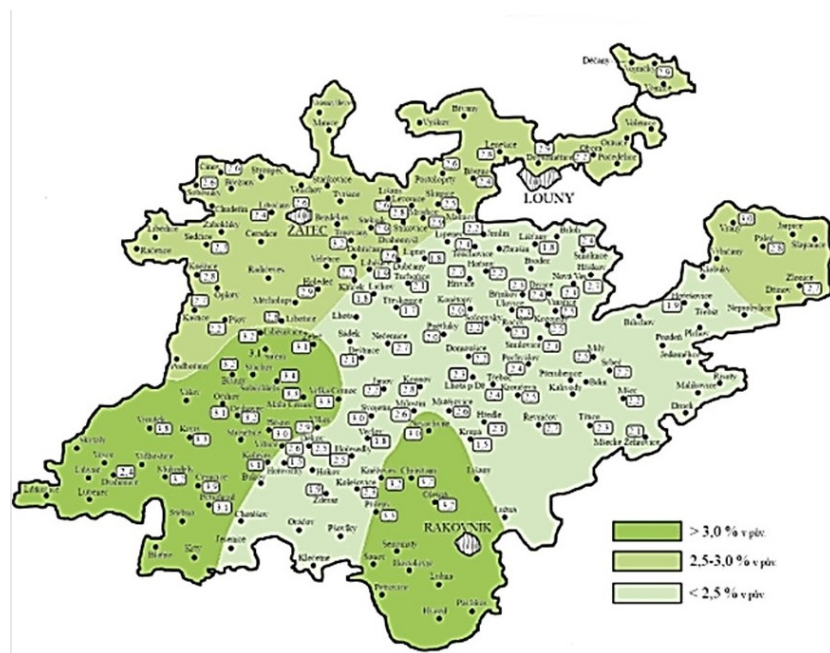


Figure 2 Distribution of alpha acid levels in Saaz hops in the Žatec growing region in 2023

3.2.3 Other Czech hop varieties – forecasts and reality

Currently, 28 Czech hop varieties are registered (Nesvadba et al., 2022), except for the majority Saaz hops, and only a few are grown in significant quantities. Currently, 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 if the cultivation area is stagnant in some (Saaz Late, Kazbek). The cultivation area of the new aromatic varieties Saaz Shine and Saaz Comfort is also gradually expanding. Their cultivation is currently concentrated in two locations, Stekník and Chrást'any.

In 2023, Czech hybrid varieties were harvested from an area of 780.6 ha (Sládek 410.2 ha; Premiant 196.9 ha; Agnus 78.0 ha; Saaz Special 41.2 ha; Saaz Late 32.1 ha and Kazbek 22.2 ha) and their total harvest was 1,611.5 tons. The contents of alpha acids in hybrid cultivars from the 2023 harvest are shown in Table 5.

The Sládek variety in Saaz region contained an average of 6.6% w/w of alpha acids, in the Úštěk region 6.5%, but in Tršice only 4.8%. These are values comparable to the previous year 2022 (Mikyška et al., 2023). The Premiant variety in the Žatec region contained an average of 7.1% w/w alpha acids, in Úštěk 8.0% w/w and Tršice region only 6.9% w/w. These are lower values compared to the year 2022, especially in the Žatec growing area. The reason for this is apparently the high yield (almost

2.5 t/ha) and the different dynamics of the increase in the weight of the hop cones and the formation of alpha acids during ripening, similar to what was observed in Saaz hops. A significantly lower content of alpha acids below 5% w/w was also found in the Kazbek and Saaz Special varieties in Saaz growing region. In contrast, the variety Saaz Late contained a somewhat surprisingly large amount of alpha acids (3.5% w/w), which in other years often reacts very negatively to adverse weather conditions. The content of alpha acids in the Saaz Comfort variety was 6.0% w/w on the Stekník farm, 5.4% w/w in Chrástany. The variety Saaz Shine contained 3.3% w/w alpha acids in Stekník and 3.1% w/w in Chrástany. The great stability of the content of alpha acids, practically independent of weather conditions, was confirmed by the varieties Agnus, Rubín and Vital. The content of alpha acids between 11 to 13% w/w in the Žatec and Ústěk growing regions was roughly at the level of previous years. Harvest forecasts match reality much better in the case of hybrid varieties than in the case of Saaz hops.

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 pub-

lished by the Central Institute for Supervising and Testing in Agriculture on its website (Kršková, 2023) at the end of 2023, and from the average alpha acids contents listed in Tables 3 and 4. Results differentiated by variety and growing area are summarized in Table 5. The total production also includes the contributions of minor varieties (Vital, Harmonie, Rubín), which are grown on an area of 29.6 ha. Regarding the hops included in the “other” category (Bohemia, Magnum, Most, Perle, Country, Saaz Shine, etc.) the production of alpha acids was determined for an average content of 8% w/w. The total production of alpha acids in Czech hops from the 2023 harvest was 253 tons, and in a longer-term comparison, it belongs to the average ones. Saaz hops account for only 55% of the total production, although it is grown on 83.3% of the harvested area. In 2023, this was due to the very low content of alpha acids. The balance was partially improved by an above-average yield of 1.29 t/ha in Žatec and Tršice growing regions, and 1.59 t/ha in the Ústěk region respectively. The volume of production devalued as a result of extreme weather events is estimated at around 150 tons, out of which approximately 120 tons were in the Tršice growing region.

Table 4 Alpha acid content (% w/w), Czech hybrid varieties from the 2023 crop harvest, forecasts and reality

Variety		Statistics	Žatec	Ústěk	Tršice
Sládek	harvest forecast	arithmetic mean median	6.05 ± 0.57 6.09	5.64 ± 0.16 5.73	5.35 ± 0.44 5.58
	reality	arithmetic mean median	6.74 ± 1.33 6.57	6.52 ± 1.36 6.46	5.08 ± 0.97 4.79
Premiant	harvest forecast	arithmetic mean median	6.97 ± 0.53 7.04 ±	8.69 ± 0.22 8.82	7.27 ± 1.46 6.64
	reality	arithmetic mean median	7.08 ± 0.87 7.25	7.96 ± 0.57 7.95	6.97 ± 0.87 6.86
Agnus	harvest forecast	arithmetic mean median	11.58 ± 2.20 11.41	- -	- -
	reality	arithmetic mean median	11.93 ± 1.38 12.18	10.72 ± 1.64 11.01	8.85* 8.85*
Kazbek	harvest forecast	arithmetic mean median	5.31 ± 0.46 5.13	6.37 ± 0.25 6.28	5.36 ± 0.82 5.03
	reality	arithmetic mean median	4.84 ± 0.46 4.78	6.26 ± 0.51 6.27	5.38 ± 0.94 4.92
Saaz Late	reality	arithmetic mean median	3.56 ± 0.71 3.44	- -	2.92* 2.92*
Saaz Special	reality	arithmetic mean median	4.39 ± 0.64 4.39	- -	- -
Harmonie	reality	arithmetic mean median	5.86 ± 1.03 5.52	- -	- -
Vital	reality	arithmetic mean median	12.18 ± 1.27 11.62	11.84* 11.84*	- -

*the result of the evaluation of a single sample

3.4 Long-term development of alpha acids content in Saaz hops in the period 1992–2023

The average harvest levels of alpha acids in Saaz variety in the period from 1992 to 2023 for all three hop-growing areas are shown in Figure 3. The data presented are the result of an evaluation analysing all purchased samples of hops from the annual harvest by the system described in this publication. The content of alpha acids is usually in the range of 3–4% w/w with large year-on-year fluctuations caused by weather 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% w/w.

These were always the 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.

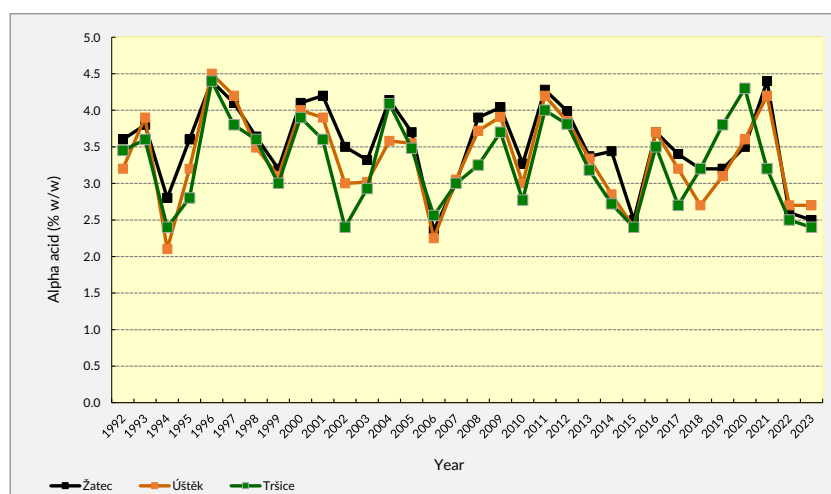


Figure 3 Alpha acid content of Saaz hops in the period 1992–2023

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% w/w and in the historical context they will also include the years 2022 and 2023.

The data summarized in Table 6 show the average contents of alpha acids in selected German, Slovenian and Polish varieties in 2021, 2022 and 2023 (Anonym, 2023). Analogous trends can be observed from the data for Czech hops in the same period, i.e. varietal dependence in re-

Table 5 Production of alpha acids (tons) in the Czech Republic in 2023

Variety/Region	Žatec	Ústěk	Tršice	Total
Saaz	107.37	17.12	14.69	139.18
Sládek	36.94	9.26	5.94	52.14
Premiant	21.07	6.30	5.05	32.42
Agnus	13.52	3.41	0.28	17.21
Saaz Late	2.16	-	0.07	2.23
Saaz Special	2.87	-	-	2.87
Kazbek	1.52	0.85	0.36	2.73
Vital	0.69	0.21	-	0.90
Harmonie	0.85	-	-	0.85
Rubín	0.13	-	-	0.13
Others	2.37	-	-	2.37
Total	189.49	37.15	36.39	253.0

sponse to the manifestations of climate change. High alpha varieties are able to cope with stressful conditions in the form of limited access to water and high temperatures better than most of aromatic hops. The most favourable results in terms of alpha acid content in a year-on-year comparison were recorded in 2023 for the Slovenian varieties Aurora, Savinjski Golding and Celeia. This year Slovenia had enough precipitation throughout the growing season without extreme temperatures. The rainy season in July and August culminated in widespread flooding.

4 Conclusion

The alpha acid content of Saaz, the dominant variety in the Czech hop production, was well below 3.0% in 2023. This was similar to the previous year. Pre-harvest and harvest forecasts already indicated this. The content of alpha

acids in most hybrid varieties was average (Sládek, Premiant, Saaz Late) or slightly below average (Saaz Special), compared to the values given in the variety atlas. Only the varieties Agnus, Rubín, Vital remained at the level of previous vintages in terms of alpha acid content. The long-term development of alpha acids content in Saaz hops in the period 1992–2023 is characterized by significant interannual fluctuations as a response to the weather conditions of the given growing season. While the pre-harvest forecast accuracy for Saaz aroma hops is

acceptable, the harvest forecast accuracy for the same variety is generally worse. In 2023, the harvest forecasts for Saaz hops were significantly underestimated compared to reality due to the limited number of samples. An increase in the number of analyses would bring better precision to the results. However, there are time constraints and increased economic costs that play a role as well. A better match between harvest predictions and reality was achieved for hybrid varieties.

5 Acknowledgement

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Table 6 Alpha acid content (% w/w) in selected German (G), Slovenian (S) and Polish (P) hops in 2021, 2022, 2023 (Anonym, 2023)

Variety/Region	2021	2022	2023	5year mean	10year mean
Hersbrucker (G)	4.6	1.9	3.0	3.1	2.7
Saphir (G)	4.3	2.6	3.1	3.5	3.4
Perle (G)	9.0	4.9	6.0	6.8	6.7
Spalter Select (G)	6.4	3.3	4.7	4.8	4.5
Hall. Tradition (G)	6.1	5.2	4.9	5.6	5.6
Magnum (G)	16.0	12.2	11.8	13.3	13.1
Herkules (G)	18.5	15.4	13.9	16.1	16.1
Polaris (G)	21.5	18.5	18.0	19.6	19.5
Aurora (S)	6.8	7.0	9.7	8.5	8.6
Savinjski Golding (S)	2.2	2.4	3.1	3.1	3.0
Celeia (S)	3.3	2.6	4.1	3.5	3.4
Lubliner (P)	3.5	3.9	3.2	4.0	3.4
Marynka (P)	7.5	8.2	7.8	8.0	8.1

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