



# Alpha acids content in Czech hops from the harvest of 2021 – forecast, reality, trends

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## Abstract

From the brewing and commercial point of view, the content of alpha acids is one of 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 2021 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 Žatec, Úštěk and Tršice areas was 4.45, 4.20 and 3.36% by weight in the original respectively. In all areas, the alpha acids content has been significantly affected by the age of the hop growths. The total production of alpha acids in hops harvested in the Czech Republic in 2021 was 414.5 tons. The harvest is the highest in the last 25 years; the result is due to the combination of two factors, both high yield per hectare and high alpha acids content.

**Keywords:** hops, alpha acids, Saaz hops, hybrid varieties, weather conditions

## 1 Introduction

From the brewing point of view, the alpha acids content is one of the most important quality parameters of hops. The hopping doses in the breweries, and therefore the total consumption of this raw material for the planned beer production, are derived from it. Timely information on this parameter is expected annually by the hop and brewing community. This is especially true in years when weather conditions during vegetation can cause low alpha acids harvests. The Hop Research Institute in Žatec (HRI) and the Research Institute of Brewing and Malting (RIBM) in Prague have been systematically evaluating the content of alpha acids in Czech hops from annual harvests for several decades, with significant participation from Chmelařství, Cooperative Žatec (CHD) and V.F. Humulus Hořesedly (VFH). The whole process consists

of several consecutive stages, the implementation of which is divided between several workplaces (Table 1). 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 Agnus, Kazbek, Saaz Late, Saaz Special, etc. The alpha acids content is also evaluated differently for individual hop-growing areas, because there can be significant differences between the Czech hop-growing areas and the Moravian area of Tršice in this respect. The community is continuously informed about the results on the website (HRI, 2022). The results of the harvest forecast and the results of the entire harvest are usually published in the journals *Kvasný průmysl* and *Chmelařství* respectively. This arti-

cle summarizes the results of the 2021 harvest in all three stages of monitoring alpha acids. Information on hop yields is collected and subsequently published by the Central Institute for Super- vising and Testing in Agriculture (CISTA, 2022).

**Table 1** Evaluation system of annual alpha acids contents in Czech hops (Krofta et al., 2012)

Variety	Pre-harvest forecast		Harvest forecast		Fact	
	Institution	Analytical method	Institution	Analytical method	Institution	Analytical method
Saaz	HRI	EBC 7.4	RIBM	EBC 7.7	HRI, VFH, CHD	EBC 7.4
Hybrid varieties	–	–	RIBM	EBC 7.7	HRI, VFH, CHD	EBC 7.4

CHD – Chmelařství, Cooperative Žatec; HRI – Hop Research Institute in Žatec; RIBM – Research Institute of Brewing and Malting; VFH – V.F. Humulus Hořesedly

## 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 meteorological stations operated by the Hop Research Institute in hop-growing areas. They are accessible on the HRI website (HRI 1, 2022). The station measures air temperature and its humidity, the amount of rainfall, the intensity of daylight, the direction and strength of the wind, and some also measure the soil temperature at depths of 20 and 50 cm. Meteorological data are scanned at hourly intervals, stored in data loggers and transferred online to the data network.

### 2.2 Hop samples

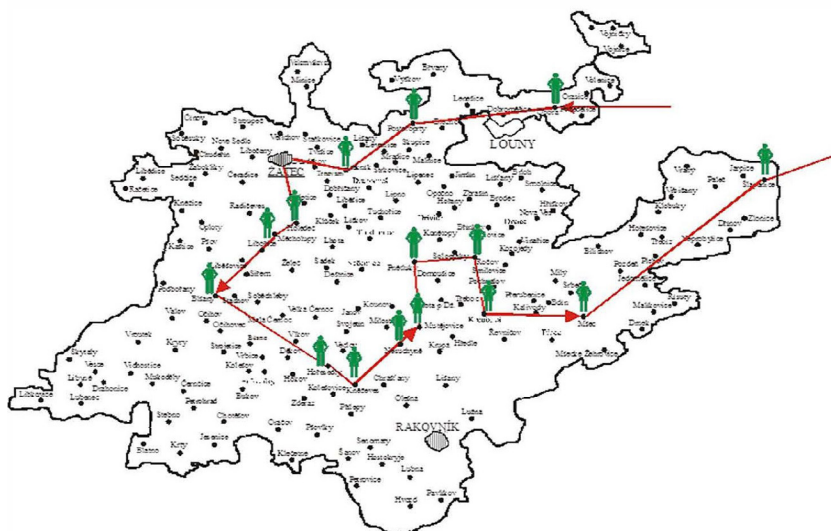
Pre-harvest predictions are made only for the Saaz variety on the basis of evaluation of the alpha acids content in hop cones collected directly in hop gardens during the 3 to 4 weeks before the expected start of harvest in selected localities of the Žatec and Úštěk hop-growing areas. The sampling points are selected to include most of the important and typical hop-growing locations – Ohře-river basin, Golden

Creek Valley, Rakovnick region, Woodlands, Polepy Marshes, the surroundings of Úštěk and Libochovice (Figure 1). The route is chosen so that sampling in both areas is completed within one working day. Samples of hop cones are taken from 5–10 plants on heights of 4–6 meters using a telescopic rod always in the same place of the selected hop gardens.

When assessing the alpha acids content of Saaz, account must be taken of the fact that new hop yards planted virus-free seedlings (plants that are deprived of plant viruses and viroids by biotechnological methods) have a significantly higher alpha acids content than hops from older ones (Patzak et al., 2021). The effect of recovery process is significantly manifested mainly within 5 years of planting (Donner et al., 2020). Due to reinfection with hop latent viroid, which progresses relatively quickly, the alpha acids content gradually decreases to the level of standard non-virus-free seedlings (Donner et al., 2020). For this reason, pre-harvest forecasts for Saaz are also made in hop gardens older than five years. However, the content of alpha acids is also significantly affected by the weather conditions during

the vegetation, especially in the period June–August, i.e. in the period of flowering, cone-forming and ripening (Kučera and Krofta, 2009). In order to be able to independently evaluate the effect of recovery (virus-free) and weather on the annual alpha acids content of the Saaz variety, it is necessary to first divide primary analytical data for the Saaz-ST (standard) and Saaz-VF (virus-free) categories.

Harvest forecasts for Saaz and other Czech hop varieties are made on the basis of analyses of selected purchase samples of hops from all hop-growing areas during the post-harvest period. The samples are collected by the laboratory of the company



**Figure 1** Hop sampling sites within the processing of pre-harvest forecasts for Saaz in the Žatec region

**Table 2** Average monthly temperatures (°C) in the growing months in 2021

Month/Locality	Stekník	Žatec	Kněževs	Ročov	Petrohrad	Liběšice	Brozany	Tuchořice	Tršice
April	7.2	6.7	5.8	5.8	6.3	6.4	7.4	6.6	6.9
May	12.1	11.8	10.8	10.7	11.6	11.1	12.5	11.7	12.3
June	20.7	20.3	19.4	19.8	20.1	20.2	21.5	20.3	20.3
July	20.0	19.9	18.8	18.7	19.6	19.6	20.5	19.8	20.7
August	17.8	17.5	16.6	16.2	17.1	17.0	17.7	17.4	17.2
September	16.2	15.5	15.1	15.2	15.0	15.7	16.1	15.8	14.8

**Table 3** Monthly precipitation totals (mm) in the growing months in 2021

Month/Locality	Stekník	Žatec	Kněževs	Ročov	Petrohrad	Liběšice	Brozany	Tuchořice	Tršice
April	6.8	6.8	17.0	17.0	14.2	14.0	13.2	14.0	28.0
May	97.4	78.4	70.0	111.4	82.4	69.2	75.0	79.0	69.7
June	76.0	64.6	131.0	110.0	45.6	110.4	38.8	108.6	58.9
July	123.2	101.0	68.8	81.8	93.2	84.6	100.0	116.4	58.9
August	93.8	56.6	70.6	76.0	77.2	51.0	63.0	46.8	132.8
September	8.4	20.6	9.6	24.0	20.6	0.4	8.4	2.2	25.4
<b>Total</b>	<b>405.6</b>	<b>328.0</b>	<b>367.0</b>	<b>420.2</b>	<b>333.2</b>	<b>329.6</b>	<b>298.4</b>	<b>367.0</b>	<b>373.7</b>

Chmelařství, cooperative Žatec and gradually handed over to RIBM, where the final selection is made, taking into account coverage of growing areas and the analysis of hops. Every year, 150 to 180 hop samples are tested in this way. For Saaz (100 samples), Sladek and Premiant (25 samples from each variety), harvest values as well as values by growing area are calculated.

The actual harvested alpha acids contents for Saaz and other Czech varieties are determined on the basis of processing the results of analyses of all purchase and farm samples of hops. Saaz variety has the largest number of samples. The total number of evaluated samples usually ranges from 2,000 to 4,000, depending on the amount of hops in the annual harvest, a larger quantity means a larger number of commercial lots of hops. Samples and results are differentiated according to varieties and hop-growing areas (Žatec, Úštěk, Tršice). For the purposes of processing annual balances, e.g. calculation of total alpha acids production, the average alpha acids content in all hop samples from a given area is further calculated, regardless of the age of the hop gardens and the type of seedling.

### 2.3 Analytical and statistical evaluation

Two methods for the determination of alpha acids have been used for the analytical evaluation of hop samples. Pre-harvest forecasts and analyses of purchasing samples for the final harvest data have been analysed by a modified conductometric method according to EBC 7.4. The modification consisted of adjusting the sample weight

(7.5 g), the volume of the extractant (50 ml of toluene) and the extraction time (90 minutes). Samples of hops intended for harvest forecasts have been analysed by liquid chromatography according to EBC method 7.7. Statistical evaluation of experimental data was performed using statistical software QC-Expert 2.5 (TriloByte Pardubice, Czech Republic). For large groups of samples, the mean value was evaluated using the arithmetic mean and median; for small sets of samples up to 20, the mean value of the sample was still determined by the method of small selections according to Horn (Meloun and Militký, 1994).

## 3 Results and discussion

### 3.1 Weather conditions in the year 2021

The weather conditions in 2021 were characterized by several important phases, which proved to be crucial from the perspective of harvest results. These were mainly precipitation-rich winter months, colder and drier spring, warm June, colder August and precipitation-rich months July-August.

The winter of 2021, unlike most of the previous ones, was abundant in terms of precipitation. During January and February, 55 to 85 mm of rain fell or snowed, which was 130 to 150% of the long-term average. The very warm end of March, when temperatures on some days ranged from 20 to 25 °C, was followed by cold April and May with numerous snow and rain showers. Average temperatures

in April were approximately 2 °C below the long-term average. The development of hop vegetation was delayed by 2 to 3 weeks at this time compared to previous years.

The second half of May was accompanied by cloudy weather with showers and maximum daily temperatures in the range of 15–20 °C. The tropical period of the week from June 14 to 20 was replaced by a rainy week, during which up to 70 mm of water rained down in some localities. On June 24, strong hailstorms hit the Žatec hop-growing area, which severely damaged or completely destroyed tens of hectares of hop gardens in the Petrohrad, Kolešov, Kněževy, Chrášťany, Hořesedly, Třeboc and Kroučová localities. Warm and rain-rich June, with an average temperature of 3.2 °C above the long-term average, helped to partially catch up with the delayed development of hop growths. Rain-rich July without longer tropical periods created a strong infectious pressure of downy mildew (*Pseudoperonospora humuli*) in hop gardens. Water-soaked soils in the hop gardens made it difficult to access the technique and complicated the treatment of hop plants with fungicides. Warm and humid weather with maximum daily temperatures of up to 30 °C with a rapid alternation of warm and sunny days with rain showers and rain-fall-rich fronts prevailed in August as well. Despite the favourable weather conditions in the second half of the vegetation, the hop plants did not fully catch up with

the developmental delays from the spring months. Most growers started harvesting during the 34<sup>th</sup> week (August 23–29, 2021).

### 3.2 Alpha acid content

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

AHA's international round robin tests, which are regularly attended by almost 40 laboratories from 17 countries around the world, are a good guide for evaluating differences in results measured by two analytical methods. 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. and the absolute difference in the results is in the range of ± 6.0% rel. The difference between the modified method 7.4 and the HPLC determination was even smaller (on average 1.3% rel.). But the absolute difference in the results ranged from -6.4% rel. up to +15% rel. (Krofta et al., 2017).

#### 3.2.2 Saaz variety – forecast and reality

The results of the pre-harvest forecasts of the alpha acids content in Saaz for the Žatec and Ústěk regions are shown in Table 4. The alpha acids content in both areas showed

**Table 4** Alpha acids content in Saaz variety from the harvest of 2021, forecasts and reality

Saaz standard		Žatec	Ústěk	Tršice
Pre-harvest forecast	Arithmetic mean	3.89	3.48	-
	Median	3.88	3.51	-
	Small selections	3.84	3.57	-
Harvest forecast	Arithmetic mean	<b>3.28</b>	<b>3.53</b>	*
	Median	3.01	3.42	*
Reality	Arithmetic mean	<b>4.24</b>	<b>4.02</b>	<b>2.83</b>
	Median	4.23	4.03	2.83
Saaz – virus free				
Harvest forecast	Arithmetic mean	<b>3.68</b>	*	<b>3.43</b>
	Median	3.42	*	3.39
Reality	Arithmetic mean	<b>4.97</b>	<b>4.91</b>	<b>4.24</b>
	Median	4.85	5.04	4.06
Saaz – total				
Harvest forecast	Arithmetic mean	<b>3.47</b>	<b>3.45</b>	<b>3.22</b>
	Median	3.26	3.36	3.15
Reality	Arithmetic mean	<b>4.68</b>	<b>4.2</b>	<b>3.36</b>
	Median	4.35	4.11	3.14

\* Insufficient number of samples

a gradual increase from a level of about 2.40% by weight in original at the beginning of August up to the level of 3.50 to 3.80% by weight in the third decade of August, when the harvest of this variety was in full swing. The value of the predicted alpha acids content in Saaz for the Žatec region was 3.89% by weight in original (median = 3.88%), for the Ústěck region 3.48% wt. in orig. (median = 3.51%). The data in Table 4 show that pre-harvest forecasts are 0.40 to 0.50% lower than reality. In the case of the harvest forecast for the Žatec region, the difference is even higher, 0.75% by weight. In other years, the difference between forecasts and reality is usually in the range of  $\pm 0.50\%$  by weight (Mikyška et al., 2021).

Unlike in previous years, pre-harvest forecasts turned out to be significantly underestimated. The reason is probably the increase in the content of alpha acids during the entire harvest, which, due to the delayed development of hop growths, lasted until the second half of September. Pre-harvest forecasts, which capture the situation during the third decade of August, could no longer capture this development. For the same reason, the harvest forecasts are also underestimated, because the samples came from the turn of August/September 2021, when the harvest was in the first third. The actual contents in the Saaz category “standard” were 4.24% in the Žatec region, 4.02% in the Ústěck region, but only 2.83% by weight in the Tršice region. While in the Czech hop-growing areas these are the highest values in the last 25 years, in the Tršice, Moravian region, the content of alpha acids in the Saaz variety is below average. The reason for such a low content is most likely the course of weather conditions during the vegetation, which in average monthly values does not show a significant difference from Žatec and Ústěck regions, but in the critical period of flowering and cone-forming there was a significant temperature fluctuation in the third decade of June and July disrupted and prolonged this phenophase.

As expected, the content of alpha acids in Saaz category VF is significantly higher, by 15 to 25% rel. in Žatec and Ústěck areas, and even by more than 40% rel. in Tršice area. In the past five years (2017–2021), 1,051 ha of new hop yards were planted in the Czech Republic with seedlings free of viral and viroid pathogens (Chromý, 2022). The rate of vegetation renewal is about 200 ha every year, which

represents 4.5% of the total cultivation area. The content of alpha acids in the hops established in 2019 and 2020 usually reached values of 6 to 8% by weight, which was reflected in the final evaluation.

The average content of alpha acids in the Saaz variety, calculated for all harvest samples regardless of the age of the hop plants, was 4.45/4.35% by weight in the Žatec region (arithmetic mean, median) 4.20/4.11% wt. in the Ústěck region and in the Tršice region 3.36/3.14% wt. The median values and quantitative harvest data were used to calculate the total alpha acids production in the year shown in Table 6.

### 3.2.3 Other Czech hop varieties – forecast and reality

The results of harvest forecasts and actual alpha acids contents in Czech hybrid varieties are summarized for individual hop growing areas in Table 5. The differences between forecasts and reality for hybrid varieties are significantly smaller (Sládek) or the results are almost identical (Premiant). This is due to the fact that these hop varieties have a longer vegetation period and are harvested only after the Saaz variety. The Sládek, Saaz Late and Kazbek are clearly late varieties. They ripen in mid-September in the climatic conditions of the Czech hop-growing areas. Some of the differences found can also be attributed to different analytical methods.

Similar to Saaz variety, in some hybrid varieties grown in the Tršice region (Sládek, Premiant) a significantly lower content of alpha acids was found in 2021 than in Bohemia. However, in other varieties, Saaz Late, Kazbek and Agnus, there were no significant differences in alpha acids content among the regions. Even in hybrid varieties, the content of alpha acids is affected by the age of the plants. Hops from Premiant and Sládek varieties planted in the

**Table 6** Production of alpha acids in the Czech Republic in 2021

Variety/Region	Žatec	Ústěck	Tršice	Total
Saaz	228.18	28.5	22.73	279.41
Sládek	50.95	10.37	11.29	72.61
Premiant	21.2	8.15	5.83	35.18
Agnus	8.83	3.17	0.48	12.48
Saaz Late	2.73	–	0.15	2.88
Saaz Special	5.94	–	–	5.94
Kazbek	0.84	1.05	0.69	2.58
Vital	0.64	0.31	–	0.95
Harmonie	1.19	–	–	1.19
Rubín	0.17	–	–	0.17
Ostatní	1.09	–	–	1.09
<b>Total</b>	<b>321.76</b>	<b>51.55</b>	<b>41.17</b>	<b>414.48</b>

**Table 5** Alpha acids content in other Czech varieties from the harvest of 2021, forecasts and reality

Variety			Žatec	Ústěk	Tršice
Sládek	Harvest forecast	Arithmetic mean	8.19	7.97	5.76
		Median	8.28	7.91	5.35
	Reality	Arithmetic mean	8.65	8.40	6.65
		Median	8.52	8.13	6.40
Premiant	Harvest forecast	Arithmetic mean	8.73	9.72	7.53
		Median	8.38	10.10	7.71
	Reality	Arithmetic mean	9.11	9.54	7.77
		Median	9.02	9.48	7.50
Agnus	Harvest forecast	Arithmetic mean	11.13	*	*
		Median	11.35	*	*
	Reality	Arithmetic mean	11.29	12.04	11.73
		Median	11.29	12.19	11.73
Kazbek	Harvest forecast	Arithmetic mean	6.34	*	*
		Median	6.07	*	*
	Reality	Arithmetic mean	6.90	7.18	6.36
		Median	6.30	7.30	6.44
Saaz Late	Harvest forecast	Arithmetic mean	4.13	–	*
		Median	3.89	–	*
	Reality	Arithmetic mean	4.21	–	4.03
		Median	4.42	–	4.03
Saaz Special	Reality	Arithmetic mean	6.63	–	–
		Median	6.27	–	–
Harmonie	Reality	Arithmetic mean	8.24	–	–
		Median	8.07	–	–

\* Insufficient number of samples

period 2019–2020 contained 9–11% by weight last year, which is more than stated in the official atlases of hop varieties (7–10% by weight Premiant; 4.5–8.0% by weight Sládek) (Nesvadba et al., 2012). The Agnus variety is very robust in terms of alpha acids stability. The value of the regression dependence of yield of alpha acids per hectare on the climatic factor, which quantifies the dependence of alpha acids content on weather conditions during vegetation, is 1.3 (Forster and Schüll, 2020). For comparison, the value of this factor is 5.1 for the Saaz variety, for the German varieties Hercules and Perle the factor is 2.3 and 4.6, respectively (Gahr and Forster, 2021).

### 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 2021, and from the average alpha acids contents listed in Tables 4 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 8% by weight. The total production of alpha acids in Czech hops from the 2021 harvest was 414.5 tons. This is the highest value in the last 25 years, when the cultivation area in the Czech Republic fell to the level of 5,000 hectares. The record production of alpha acids is given by the concurrence of two factors, the high yield per hectare and the content of alpha acids in Saaz variety, which is grown on 84% of the area of hop gardens and is thus crucial for the production of alpha acids. At the same time, part of the production deteriorated due to extreme weather events and a significant part of the harvest was also cut by hop downy mildew (*Pseudoperonospora humuli*), which damaged hop yards.

### 3.4 Long-term development of alpha acids content in Saaz hops in the period of 1992–2021

The average harvest levels of alpha acids in Saaz variety in the period 1992 to 2021 for all three hop-growing



areas are shown in Figure 2. The data presented are the result of an evaluation of the results of analyses of all purchase 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% 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% by weight. These were always years, in which there were no long tropical periods with sufficient rainfall. In addition, hops are a plant which is able to deal with a certain lack of water very well thanks to an extensive root system, which reaches depths of 1.5 to 2.0 meters (Brant et al., 2020). The year 2021 will go down in history not only with a high content of alpha acids, but at the same time also with the highest yield per hectare of Saaz variety, 1.59 t/ha.

In the past 30 years, three weather-critical years have also been recorded (1994, 2006, 2015), in which the average content of alpha acids in Saaz ranged from 2.0 to 2.5% by weight. These were years with high summer temperatures and low precipitation. For example, in July, average monthly temperatures were 3 to 4 °C above long-term values (Krofta et al., 2016). Extremely hot summer months and precipitation-poor years are usually not limited to the Czech Republic, but they cover the whole of Central Europe i.e. Germany, Poland, France and Slovenia.

## 4 Conclusion

Compared to previous years, the content of alpha acids in Czech hops from the 2021 harvest was very high, especially in the Žatec and Ústěck regions, but it was significantly lower in the Tršice region. Although the Moravian hop-growing region is only about 300 km in a beeline from the Bohemian regions, the weather conditions are so different in some years that they cause different harvesting results (yield of alpha acids). In all areas, the alpha acids content has been significantly affected by the age of the stands. Hops from young gardens up to 5 years after planting contained significantly more alpha acids than older ones. Therefore, regular regeneration of the hop gardens is necessary to maintain profitable hop cultivation.

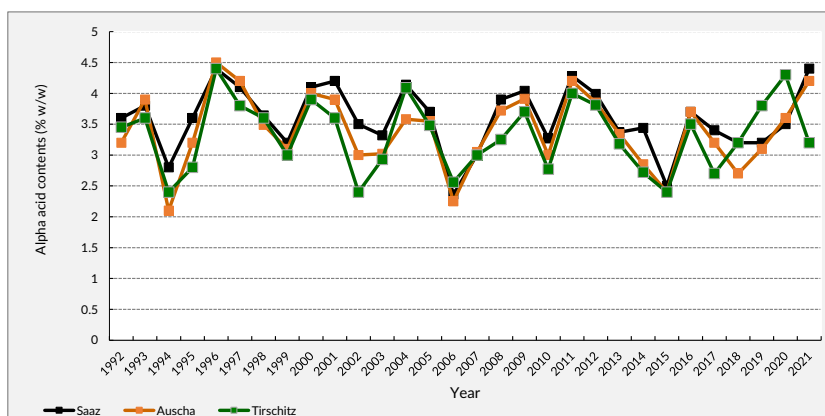


Figure 2 Alpha acids content in Saaz hops in the period of 1992–2021

## 5 Acknowledgement

The study was supported by the Ministry of Agriculture of the Czech Republic within the institutional support MZe-R01322 and MZE-R01922.

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