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Evaluation of variability in alpha and beta acid content in European hop varieties (*Humulus lupulus* L.)

Vladimír Nesvadba[1*], Jitka Charvátová[1], Jana Olšovská[2] and Sabina Trnková[1]

[1] *Hop Research Institute, Kadaňská 2525, 438 01 Žatec, Czech Republic*

[2] *Research Institute of Brewing and Malting, Lípová 511/15, 120 00 Prague, Czech Republic*

**corresponding author: nesvadba@chizatec.cz*

Abstract

Between 2009 and 2023, European hop varieties were evaluated within genetic resources in the Czech Republic. The objective of this paper was to determine the variability of hop alpha and beta acid contents in the monitored varieties at a single site over the period of fifteen years. At the same time, the trend in which the observed substances decrease or increase was assessed. The lowest average alpha acid content was detected in Strisselspalter (2.96% w/w), while the highest content was found in Herkules (14.03% w/w). The lowest variability in alpha acid content was measured in Vital (14.59%) and Herkules (16.48%). Unlike the aforementioned varieties, Golding exhibits the highest variability (46.28%). All varieties showed a decreasing trend in alpha acid content over the fifteen years of cultivation. Lubelski had the highest decrease in alpha acid content and also showed a high correlation (r^2 = 0.664). The varieties with the lowest average beta acid content were Celeia (2.77% w/w) and Golding (2.97% w/w). The variety with the highest average beta acid content was Vital (7.30% w/w). All varieties displaied a decreasing trend in beta acid content. Perle had the lowest trend of decrease in beta acid content, while Tradition had the highest trend of decrease. The varieties Strisselspalter, Saaz, Tettnang, Sládek, and Bobek had an alpha/beta acid ratio below 1. However, the variety Bobek showed the highest variability at 32.18%. Herkules had the highest alpha/beta acid ratio (3.20). The most stable alpha/beta acid ratio was found in Marynka (8.41%).

Keywords: hop; *Humulus lupulus* L.; alpha and beta acids; ratio alpha/beta; variability

1 Introduction

Genetic resources of hops in the Czech Republic are part of the National Programme for the Conservation and Utilization of Plant Genetic Resources and Biodiversity. Hop collections are preserved in a field *ex situ* collection, and all genotypes are evaluated annually (Charvátová et al., 2017). The main part consists of hop varieties from around the world. Currently, the hop collection in the Czech Republic includes 386 different genotypes. The hop gene pool serves as the basis for breeding, not only as parent plants for crossing but also for evaluating their traits and variability during cultivation at a single site. Assessing trait variability is crucial, as varieties with low variability are most frequently used for hop breeding (Nesvadba et al., 2023). It can be assumed that their progeny will also exhibit low variability in a given environment. Therefore, evaluating foreign hop varieties under the conditions of Žatec expands the genetic variability for breeding. On the other hand, variability indicates the performance stability for hop buyers. It is presumed that more stable varieties do not show high variability in hop production during their cultivation.

Currently, all world hop varieties are listed in the "*Hop Variety List*" (IHGC, 2024). Hop varieties are divided into aroma, bitter, and other categories. Each country decides which category individual varieties belong to. There are ongoing efforts to divide the category of aroma hops fur-

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ther into Fine Aroma and Aroma (Forster et al., 2022). Additionally, there is a proposal to create a new category called "Flavour Hops," which includes hops with specific aromas (citrus, fruity, etc.). Hop breeding is clearly focused on this group of hops as well (Nesvadba et al., 2020a). The newly proposed division provides a better clarity for breweries. The current group of aroma varieties includes, for example, Saaz, Spalt, Tettnag (with a lower alpha acid content, balanced alpha/beta acid ratios, and a pleasant, delicate hop aroma), as well as varieties such as Perle, Marynka, Premiant, Boadicea (which have a higher alpha acid content and higher alpha/beta acid ratios, also their hop aroma ranges from a more intense, sharp hop aroma to a spicy one). The group of aroma hops like Citra, Amarillo, Mosaic, Huell Melon, Saturn, etc., with non-hop scents, should not be overlooked.

The content and composition of hop resins, particularly alpha and beta acids, are of great importance to the brewing industry. One of the factors influencing the popularity of beer is its specific pleasant bitterness, primarily caused by the presence of a group of substances known as iso-alpha-bitter acids, which originate from hops (Opletal et al., 2007). Alpha acids are the fundamental precursors of iso-alpha-bitter acids formed during the brewing process (Karabín et al., 2009). The content of alpha-bitter acids in hops (*Humulus lupulus* L.) is significantly dependent not only on growing conditions but especially on the variety, so hop varieties are classified based on the content of these substances for their technological utilization (Verzele and Keukeleire, 1993). From this perspective, the alpha acid content in individual hop varieties is closely monitored. Although beta acids have a lower bitterness potential than alpha acids, they have very positive bioactive effects in beer (Krofta and Mikyška, 2014). The beta acid content in hop cones is lower than the alpha acid content. The alpha acid content in bitter varieties can exceed 15% by weight, while the beta acid content reaches a maximum of about 10% by weight (Krofa and Mikyška, 2013).

This paper aims to determine the variability of hop alpha and beta acid content over a fifteen year-long cultivation period of the monitored varieties at a single location. Additionally, it evaluates the trend of decrease or increase in the monitored substances. The results are intended for breweries, traders, and hop growers, enabling them to influence the demand for quality hops based on the age of the hop stand for those varieties that may change the content or ratio of the monitored substances due to the age of the stand. Conversely, long-term contracts can be safely signed for varieties with good stability during cultivation without risking a decrease in hop quality. The data obtained is also used for breeding hops for resistance to abiotic factors. Varieties with low variability and a non-declining trend in content substances are further used for breeding hops for tolerance to drought and high temperatures (Nesvadba et al., 2011).

2 Materials and methods

The evaluation was conducted between 2009 and 2023 within the hop genetic resources collection of the Czech Republic, which is located in Stekník near Žatec (GPS 50.334958N, 13.621461E). Agronomy, nutrition, and protection were carried out according to the hop cultivation methodology.

2.1 Hop varieties

The selected foreign varieties are of aroma and bitter types. The selection was based on a larger cultivation area in the respective country and on the complete time series of evaluated traits over fifteen years. The varieties include:

Czech Republic:	Saaz, Sládek, Premiant, Agnus and Vital
Germany:	Tettnang, Perle, Tradition (Hallertauer Tradition), Magnum (Hallertauer Magnum) and Herkules
Slovenia:	Aurora, Bobek, Celeia
Poland:	Lubelski, Marynka, Sybilla
England:	Golding, Fuggle, Target (Wye Target), Pioneer
France:	Strisselspalter

2.2 Growing conditions

The evaluated genotypes were cultivated under the following conditions:

The hop garden was located at an altitude of 215 meters in the Žatec hop-growing region and the hop-growing area of central Poohří. It was situated in a warm and dry region, with a sum of temperatures above 10 °C ranging from 2,600 to 2,800 °C per year. The evaluation presented does not include the impact of weather conditions in individual years for two reasons:

1. The hop garden had drip irrigation, which was used during water deficit in the soil. This factor can be influenced during hop cultivation.
2. The goal was to evaluate the variability that the temperature course over fifteen years could influence, but growers could not control. The result showed the stability of performance traits during cultivation at a single location.

2.3 Soil characteristics

Pedologically, the soil was classified as alluvial soil, light with colluvial and alluvial sediments. The soil slope – it was completely flat without signs of surface water erosion, and the land's exposure is omnidirectional. The soil was free of skeletons and was over 60 cm deep.

2.4 Sample preparation and chemical analysis

In the hop genetic resources collection, each variety was cultivated according to the methodology, with 8 plants per variety. At technological maturity, all plants were harvested, and an average sample for chemical analyses was dried at 55°C to a moisture content of 7%. The content and composition of hop resins were determined by liquid chromatography (EBC 7.7) in the accredited laboratory of the Hop Research Institute in Žatec (Krofta and Patzak, 2011).

2.5 Statistical analysis

Basic statistical methods were used for evaluation across the entire set of varieties: mean, standard deviation, and variability expressed as a percentage (the coefficient of variation multiplied by 100). To determine the trend of trait dependence over fifteen years of cultivation, linear regression was used, and the tightness of the dependence was determined by the coefficient of determination (r^2) and correlation coefficient (r). The coefficient of determination multiplied by 100 expresses the percentage by which the trend of decrease or increase is influenced by the time series (Meloun and Militký, 1994).

3 Results and discussion

Alpha and beta acids are of great importance to breweries. Therefore, hop farmers harvest hops at the optimal maturity time to ensure that the levels of these compounds match the declared values for each hop variety. It is very important that these parameters are consistent for hop varieties throughout their growing period.

3.1 Alpha acids

Table 1 shows that only the Strisselspalter variety reached an average content below the 3% (w/w) threshold when grown for 15 years. The low content was also observed in the Saaz, Celeia, and Tettnang varieties, which aligns with their characteristics. Alpha acid contents of the other aroma varieties ranged from 4.06% w/w (Sládek) to 7.81% w/w (Marynka). Among the bitter varieties, Magnum had the lowest content (9.21% w/w), whereas Herkules showed the highest content (14.03% w/w). The Herkules variety displayed the alpha acid content below 10% w/w only once, but this content exceeded 14% w/w eight times. The Vital variety had an alpha acid content below 10% w/w only once, but it exceeded 14% w/w only twice. Vital never had an alpha acid content over 15% w/w. Conversely, Herkules had an alpha acid content above 17% w/w in 2013 and 2014. Among the bitter varieties, this variety would likely be the most suitable for the lowland conditions of the Žatec area. Other bitter varieties showed alpha acid contents above the 10% threshold only six times (Agnus and Taurus) or five times (Magnum). The lowest variability in alpha acid content was observed in Vital (14.59%) and Herkules (16.48%). A variability below 20% was also seen in Aurora, Agnus, Premiant, and Target varieties. Interestingly, all the bitter hop varieties fell into this low variability category. Conversely, the highest variability was found in Golding (46.28%). A variability above 30% was observed in Celeia, Bobek, and Tradition. The varieties with a lower variability will be more suitable for current climate changes.

Forster et al. (2024) evaluated German hop varieties between 2013 and 2022. The Perle variety displayed an average alpha acid content of 6.20% w/w, which is by 0.73% w/w higher than the results obtained in the Czech Republic. The Tradition variety had an average alpha acid content of 5.20% w/w, which is by 0.55% w/w higher than the results obtained in the Czech Republic. Nesvadba et al. (2020b) monitored a time series of Czech hop varieties as part of hop breeding maintenance. Their results showed lower average alpha acid values for Saaz (2.87% w/w) and higher values for Sládek (5.94% w/w), Premiant (7.54% w/w), Agnus (10.69% w/w), and Vital (12.31% w/w). The authors also assessed the variability of alpha acid content, which did not differ significantly. The greatest difference was found in Agnus (with 5.05% lower variability), and the smallest difference was recorded in Saaz (with 1.86% higher variability).

Table 1 also lists the values of the trend in alpha acid content over a 15-year cultivation period, using linear regression. All varieties exhibited a decreasing trend in alpha acid content over the fifteen years of cultivation. Sládek was characterized by a very low trend of alpha acid reduction, which was only 0.036% w/w per year. Importantly, this decline was not due to the age of the crop but to year-to-year variability (Figure 1). A similar trend pattern was observed in the Tettnang, Strisselspalter, and Saaz varieties. The highest reduction in alpha acid content was seen in the Lubelski variety (Figure 2), which also showed a high coefficient of determination (r^2 = 0.6638). This means that 66.38% of this decline was due to the age of the crop. Results indicated that similar negative trends were seen in the Fuggle, Marynka, and Target varieties, whose r^2 exceeded 0.40. Between 2010 and 2022, bitter hop varieties

Table 1 *Alpha acid content, coefficient of variability (CV), dependency trend (y), and coefficient of determination (r^2) for evaluated hop varieties (Stekník, 2009–2023)*

Hop variety	Alpha acids (% w/w)	CV (%)	y	r^2
Strisselspalter	2.96	21.53	-0.0399x + 3.2762	0.0783
Saaz	3.03	23.52	-0.0435x + 3.3816	0.0745
Celeia	3.09	32.84	-0.0815x + 3.7430	0.1288
Tettnang	3.39	20.71	-0.0257x + 3.6067	0.0249
Sládek	4.06	22.99	-0.0362x + 4.3460	0.0302
Golding	4.19	46.28	-0.2732x + 6.3734	0.3974
Fuggle	4.37	27.27	-0.1889x + 5.8851	0.5015
Tradition	4.65	30.86	-0.1472x + 5.7968	0.2402
Bobek	4.98	31.89	-0.1312x + 6.0264	0.1367
Perle	5.47	29.95	-0.0971x + 6.2511	0.0702
Sybilla	6.34	29.40	-0.2433x + 8.2138	0.3414
Lubelski	6.70	24.27	-0.2964x + 9.0742	0.6638
Premiant	6.73	19.65	-0.1086x + 7.6747	0.1308
Aurora	7.34	19.25	-0.2053x + 8.8819	0.3693
Pioneer	7.61	27.65	-0.2352x + 9.6586	0.3052
Marynka	7.81	20.83	-0.2382x + 9.7170	0.4286
Magnum	9.21	21.42	-0.1204 + 10.1690	0.0746
Agnus	9.25	19.42	-0.2071x + 11.112	0.3872
Target	9.35	19.71	-0.2701x + 11.514	0.4291
Vital	11.77	14.59	-0.1707x + 13.221	0.1727
Herkules	14.03	16.48	-0.1869x + 15.5280	0.1306

were assessed in the Czech Republic (Nesvadba et al., 2023), and these results confirmed a decreasing trend in alpha acid content for the Agnus and Vital varieties. Agnus displayed a lower rate of decline (y = -0.1777x + 368.58) and a lower coefficient of determination (r^2 = 0.3872). The Vital variety reached almost identical parameters:

$y = -0.1316x + 276.73$ and $r^2 = 0.1727$.

From the obtained results it is apparent that the evaluation of alpha acid content stability over the period of 15 years provided us with numerous important parameters. They displayed good parameters among the aromatic varieties.

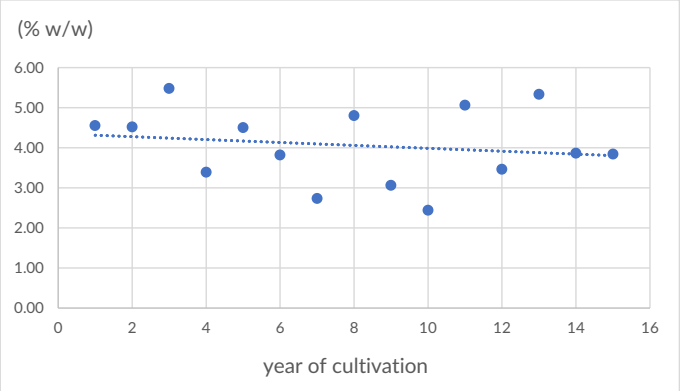

Figure 1 *Trend in alpha acid content for the Sládek variety (Stekník, 2009–2023)*

3.2 Beta acids

Table 2 clearly showed that Celeia (2.77% w/w) and Golding (2.97% w/w) have the lowest average beta acid content. These varieties displayed the lowest beta acid content in 2020, which was under 2.00% w/w threshold. Contrary to that, Vital (7.30% w/w) reached the highest average beta acid content. In 2011, Vital had a beta acid content of up to 10.10% w/w. Other genotypes exhibited an average beta acid content ranging between 3.00 to 5.50% w/w. The varieties with the lowest variability in beta acid content were Strisselspalter (16.24% w/w), Magnum (16.59% w/w), and Saaz (19.04% w/w). Tradition, Pioneer, and Golding had a variability above 30% w/w. Other varieties showed beta acid content variability between 20 to 30% w/w. The results indicated that the average alpha acid content ranged from 2.96 to 14.03% w/w in the selected set of hop varieties, which was a broader scale compared to the average beta acid content (2.77 to 7.30% w/w).

When compared with the results of the evaluation of Czech hop varieties between 2010 and 2019 (Nesvadba et al., 2020b), the average beta acid contents were more varied than the average alpha acid contents. The achieved results were: Premiant 4.28% w/w, Saaz 2.87% w/w, Agnus 5.33% w/w, Sládek 5.72% w/w, and Vital 7.35% w/w. Except for the Saaz variety, all varieties showed a higher average beta acid content in the ten-year series than in the fifteen-year series. The authors also evaluated the variability of alpha acid content, which does not differ significantly. The highest difference was in the Vital variety (5.76% lower variability), and the lowest difference is in the Sládek variety (2.95% higher variability).

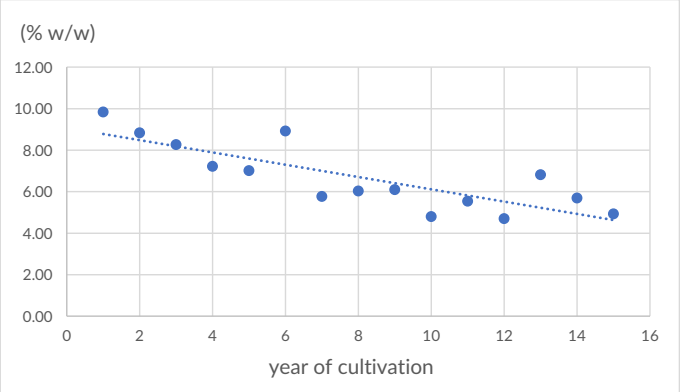

Figure 2 *Trend in alpha acid content for the Lubelski variety (Stekník, 2009–2023)*

Table 2 *Content, coefficient of variability (CV), dependence trend (y), and coefficient of determination (r^2) in beta acid content of the evaluated hop varieties (Stekník, 2009–2023)*

Hop variety	Beta acids (% w/w)	CV (%)	y	r^2
Celeia	2.77	25.78	-0.1066x + 3.6235	0.4457
Golding	2.97	30.80	-0.1536x + 4.2005	0.5637
Pioneer	3.18	31.47	-0.1239x + 4.2600	0.3741
Fuggle	3.26	29.16	-0.1453x + 4.4203	0.4677
Aurora	3.29	24.08	-0.1228x + 4.2148	0.4199
Perle	3.48	29.44	-0.0806x + 4.1226	0.1239
Tradition	3.48	32.77	-0.2026x + 5.0570	0.7199
Lubelski	3.57	27.33	-0.1620x + 4.8680	0.5509
Marynka	3.64	24.69	-0.1308x + 4.6899	0.4231
Premiant	3.93	27.74	-0.1531x + 5.2646	0.3818
Tettnang	4.24	21.67	-0.1293y + 5.3263	0.3683
Saaz	4.25	19.04	-0.0934x + 5.0595	0.3862
Sybilla	4.25	28.84	-0.1406x + 5.3310	0.2664
Strisselspalter	4.34	16.24	-0.1144x + 5,2555	0.5265
Herkules	4.49	22.01	-0.1194x + 5.4440	0.2922
Agnus	4.62	28.60	-0.2241x + 6.4338	0.5523
Target	4.72	23.14	-0.1862x + 6.2141	0.5802
Sládek	4.78	25.26	-0.1857x + 6.2637	0.4736
Bobek	5.24	25.45	-0.1748x + 6.6386	0.3436
Magnum	5.49	16.59	-0.1418x + 6.6270	0.4843
Vital	7.30	21.11	-0.2736x + 9.6288	0.5509

Table 2 presents the values of the trend showing dependence of beta acid content during 15 years of cultivation using linear regression. All varieties exhibited a decreasing trend in beta acid content over the fifteen years of cultivation. The lowest trend of decline in beta acid content was observed in the Perle variety, with a decrease of 0.0806% w/w annually, representing a total decrease of 1.21% w/w over 15 years. A similar trend can be seen in the Saaz variety, with an annual decrease of 0.0934% w/w, amounting to 1.40% w/w over 15 years. Given that Saaz had an average beta acid content of 0.77% w/w, the decline trend was milder (Figure 3). On the other hand, considering the average beta acid content, the highest decline trend in beta acids was found in the Tradition

variety (Figure 4). This variety showed an annual decline trend of 0.2026% w/w, and the coefficient of determination was highest from all hop varieties (r^2 = 0.7199). The Perle variety reached the lowest the lowest coefficient of determination (r^2 = 0.1239), meaning that the decline was influenced by the age of the crop by only 12.39%.

3.3 Ratio of alfa and beta acids

A lot of breweries prefer a low ratio of alpha to beta acids. Generally, it can be stated that bitter varieties have higher alpha/beta acid ratio than the aroma ones. The varieties Strisselspalter, Saaz, Tettnang, Sládek, and Bobek had the alpha/beta acid ratio below 1. However, the Bobek variety showed the highest variability at 32.18%. The Herkules variety reached the highest alpha/beta acid ratio (3.20), and varieties Pioneer, Aurora, Agnus, Marynka, and Target exhibited ratios above 2. Due to its high beta acid content, it can be stated that the Vital variety (alpha/beta ratio = 1.65) belongs to the group of aroma hop varieties. The most stable alpha/beta acid ratio was found in the Marynka variety (CV = 8.41%). Overall, it can be summarised that the evaluated varieties showed a higher stability in the alpha/beta acid ratio than in the content of either alpha or beta acids.

Again, the obtained results can be compared with outputs from Germany (Forster et al., 2024). The Perle variety had an average alpha/beta acid ratio of 1.21% w/w, which is by 0.42% w/w lower than in the Czech Republic. The Tradition variety had an average alpha acid content of 1.13% w/w, which is by 0.26% w/w lower than in the Czech Republic. Nesvadba et al. (2020b) reported that between 2010 and 2019, Czech hop varieties exhibited the following average alpha/beta acid ratios: Saaz 0.77; Sládek 1.14; Vital 1.70; Premiant 1.84; and Agnus 2.07. Only Sládek showed a higher average alpha/beta acid ratio by 0.25. The other varieties had almost identical results.

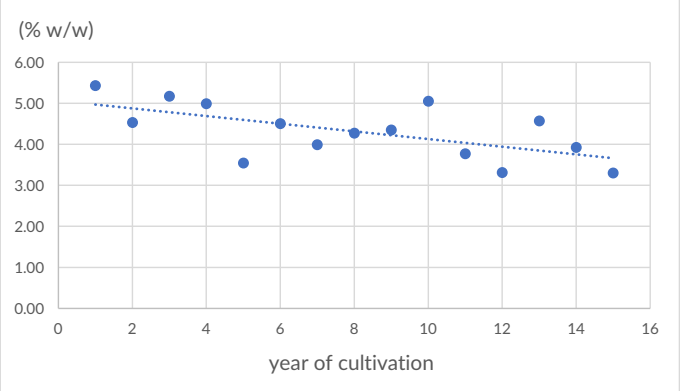

Figure 3 *Trend of beta acid content in the Saaz variety (Stekník, 2009–2023)*

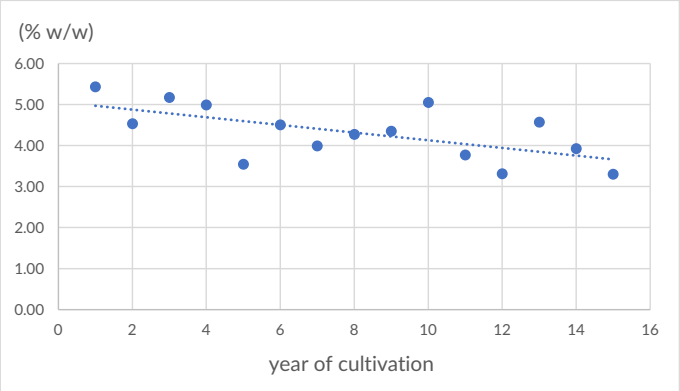

Figure 4 *Trend of beta acid content in the Tradition variety (Stekník, 2009–2023)*

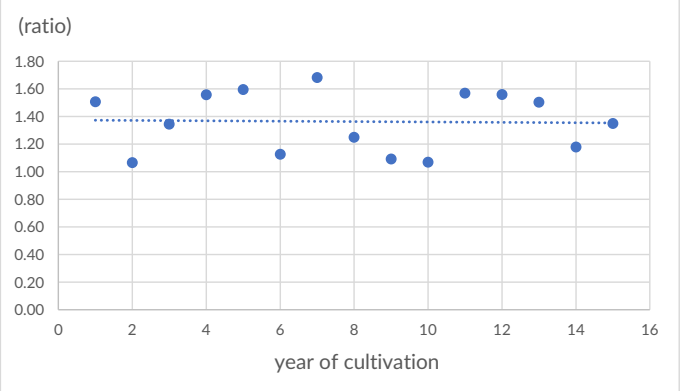

Figure 5 *Trend of beta acid content in the Fuggle variety (Stekník, 2009–2023)*

Table 3 presents the values showing dependence trend of ratio alpha/beta acid content during 15 years of growing using linear regression. Only three varieties (Fuggle, Golding and Sybilla) exhibited a decreasing trend in the alpha/beta acid ratio. Unfortunately, a growing trend in the alpha/beta ratio occurred in other hop varieties, even though it was negligible (e.g. Lubelski, Marynka and Pioneer). The lowest tightness of dependence was measured in Fuggle (r = 0.03), which demonstrated a good stability of alpha/beta acid ratio (Figure 5). The figure also shows that the range of alpha/beta acid ratio started at 0.09 in the 9th year of growing and increased up to 1.56 between the 4th and 12th year of growing. A more pronounced trend in alpha/beta acid ratio (Agnus, Tradition and Herkules) taked place in some varieties. Its development is interesting in Agnus in the 15th year of growing (Figure 6). As for the ratio of alpha/beta content in Agnus, it was between 2.16 and 2.75 in the 10th year of growing, but up to the 9th year of growing the

Table 3 *Alpha/beta acid ratio, coefficient of variability (CV), dependence trend (y), and coefficient of determination (r^2) of the alpha/beta acid ratio in the evaluated hop varieties (Stekník, 2009–2023)*

Hop variety	Ratio alpha/beta	CV (%)	y	r^2
Strisselspalter	0.69	19.25	0.0078x + 0.6254	0.0700
Saaz	0.72	20.05	0.0084x + 0.6549	0.0668
Tettnang	0.82	21.69	0.0183y + 5.3263	0.6692
Sládek	0.89	29.03	0.0312x + 0.6394	0.2927
Bobek	0.98	32.18	0.0113x + 0.8948	0.0253
Celeia	1.12	26.25	0.0148x + 1.0141	0.0530
Fuggle	1.36	16.01	-0.0014x + 1.3750	0.0009
Tradition	1.39	25.77	0.0450x + 1.0395	0.3612
Golding	1.39	22.94	-0.0169x + 1.5212	0.0565
Sybilla	1.52	22.01	-0.0113x + 1.6118	0.0230
Perle	1.63	26.26	0.0219x + 1.4561	0.0521
Vital	1.65	14.94	0.0386x + 1.3196	0.4294
Magnum	1.72	27.21	0.0311x + 1.4709	0.0881
Premiant	1.77	21.97	0.03450x + 1.472	0.1525
Lubelski	1.91	12.62	0.0025x + 1.8882	0.0022
Target	2.01	11.45	0.0227x + 1.8267	0.1953
Marynka	2.07	8.41	0.0102x + 2.0894	0.0618
Agnus	2.09	17.35	0.0574x + 1.6556	0.4401
Aurora	2.27	11.89	0.0205x + 2.1123	0.1013
Pioneer	2.43	10.94	0.0175x + 2.2786	0.1056
Herkules	3.20	16.28	0.0431x + 2.8556	0.1368

ratio was lower, i.e. between 1.54 and 2.22. This finding can be used by hop growers. It seems beneficial to grow this variety for maximum of 10 years to maintain a lower ratio of alpha/beta acids.

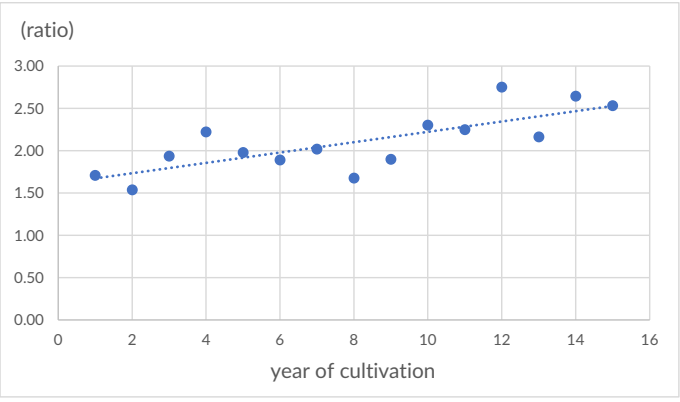

Figure 6 *Trend of beta acid content in the Agnus variety*

4 Conclusion

The results indicate that the selected set of hop varieties had a wider range of average alpha acid content (2.96 to 14.03% w/w) compared to the average beta acid content (2.77 to 7.30% w/w). All varieties exhibited a decreasing trend in the average content of both alpha and beta acids over the 15-year period. Interestingly, this decreasing trend was more dependent on the length of cultivation for the beta acid content. The average r^2 value for alpha acid content was 0.2436, meaning that 24.36% of the decrease in alpha acid content was due to the length of cultivation. The average r^2 value for beta acid content was 0.4444, indicating that 44.44% of the decrease in beta acid content was caused by the length of cultivation. The tightness of the dependence for the decline in beta acid content was almost twice that of alpha acids. It appears that the decline in beta acid content was more influenced by the age of the crop. This finding is very important for hop growers to consider how long they will cultivate a given hop variety to maintain its quality parameters.

The achieved results are significant for various fields. First are the breweries that use hop varieties. They need the supplied hop products to exhibit the same parameters each year, not only in terms of alpha acid content but also

beta acids, ensuring that the alpha/beta acid ratio will not change over the years. It can be assumed that this requirement for hop growers will be best communicated through the hop trade. Breweries are likely to demand the same quality of hops, which will probably be linked to the age of the crop. As it has been observed in many varieties, the alpha/beta acid ratio changes significantly with the crop age. This has the greatest impact on hop growers, who need to determine which hop varieties can be grown for 10 years and which even for 15 years.

The aims of this evaluation of European hop varieties have been met. The results have practical significance for growers and breweries, as well as for hop breeding. Stable varieties are likely to be used more as starting material for the development of new hop varieties that will be more resistant to climate changes and can be cultivated longer in one location.

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