# Description of two Hüll aroma breeding strains

**AROMA POTENTIAL** | Currently more than 200 hop varieties are registered worldwide and every year these are joined by 10 to 20 new varieties. Hop breeding has been given an enormous boost especially by the craft beer wave. In breeding, there is currently a significant emphasis on hops with special aromas (special flavor hops) which are suitable for dry hopping. The evaluation of new varieties is becoming ever more important, but also much more difficult. Taking the example of two breeds from Hüll this article shows how hop strains yet to be discovered might be described, evaluated and classified.

**THE AIM IS** to examine breeds for their potential and to recognize promising varieties in time. We have chosen two aroma hops designated for late addition during wort boil.

The varieties currently grown in Germany for this purpose are as follows:

- 5 classic aroma hops, also known as landrace varieties: Tettnanger, Spalter, Hersbrucker and recently Saazer in the Elbe-Saale region;
- 6 Hüll breeding varieties: Perle, Hallertauer Tradition, Spalter Select, Saphir, Opal and Smaragd.

The last registration of a "normal" aroma variety goes back quite some time (Smaragd in 2003). We understand "normal" aroma hops to be varieties that are added to the wort – often at the end of boiling – and are only rarely used for dry hopping.

## Main focus of hop breeding

The essential requirements are listed below:

- High yield (kg/ha);
- good growing characteristics like low susceptibility to crown rot and good climbing properties;
- tolerance/resistance against/to fungal diseases like wilt, powdery mildew and downy mildew;
- insensitivity to insect pests like hop aphids and spider mites;
- tolerance of climate change, especially concerning high summer temperatures (= hot days > 30 °C) and dry periods;
- economic efficiency in application: high α-acid content and high α-acid yields (kg/ha) are sought after in bitter hops while α-acid content plays a minor role with aroma hops. Here, however, high yields in the transfer of polyphenols and more particularly aroma substances are required.

With Polaris and its α-acid content of up to 22 % a reasonable optimum has been reached. The processability of hops with even more α-acids in pellet and extract plants has its limitations because all the equipment quickly clogs.

In breeding, hops with special aromas (special flavor hops) which are suitable for dry hopping are currently preferred. The fruitier, more exotic and more untypical for hops, the more interesting and popular these varieties are. Of the 20 most recent newly approved varieties in the USA, Germany and Australia, 18 are special flavor hops.

"Normal" aroma hops have dropped somewhat into the background due to the hype around special flavor hops, but they still play a major role in brewing beer. However, evaluating aroma hops based on the criterion of α-acids can be misleading. We will explain this using a comparison between Perle and Saphir. Here, the aroma substance linalool serves as an indicator of the hop bouquet. The threshold value of linalool is set at 15-20 µg/l (lowest content in the beer that still can be perceived) [1]. The transfer rate of linalool with a late hop addition is at least 30 %.

Table 1 shows the comparison of Perle and Saphir with a hopping of 100 g/hl as a last addition. The values of α-acid and linalool content are average according to [2, p. 146]. Perle yields up to 7.4 mg/l iso-α-acids in beer, Saphir only 4.1 mg/l, assuming an

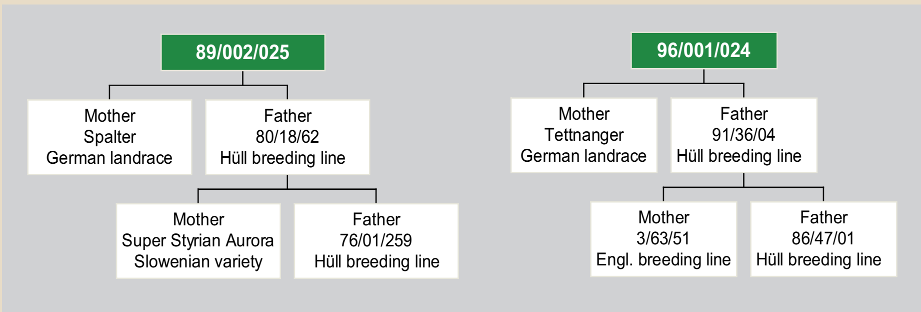


**Fig. 1 Pedigrees of the two breeding lines 89/002/25 and 96/001/24**

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## COMPARISON OF THE AROMA POTENTIAL OF PERLE AND SAPHIR

| | | Perle | Saphir |
|---|---|---|---|
| Alpha acids | % w/w | 7.4 | 4.1 |
| Alpha acids dosed | mg/l | 74 | 41 |
| Iso-alpha acids in beer | mg/l | 7.4 | 4.1 |
| Linalool content | mg/100 g | 4 | 10 |
| Linalool dosed | µg/l | 40 | 100 |
| Linalool in beer | µg/l | 12 | 30 |
| Aroma potential | | no | yes |

*Table 1*

## ANALYSIS RESULTS OF THE 5 HOP VARIETIES:

α-acids, β : α, and cohumulone ratio, total oil, total polyphenols (TPP), sum of low-molecular polyphenols (lmPP) and ratio lmPP : TPP

| | | 89 | 96 | SSP | TTE | HSR |
|---|---|---|---|---|---|---|
| Alpha acids | % w/w | 5.3 | 4.1 | 3.7 | 3.3 | 2.8 |
| Ratio β : α | | 0.89 | 1 | 1.86 | 1.55 | 2.11 |
| Cohumulone ratio | % rel. | 22 | 23 | 26 | 25 | 14 |
| Hop oil | ml/100 g | 1.70 | 1.75 | 0.70 | 0.60 | 0.95 |
| Total polyphenols (TPP) | % w/w | 5.7 | 5.7 | 6,4 | 6.5 | 6.7 |
| Low mol. polyphenols (lmPP) | % w/w | 1.18 | 1.01 | 1.78 | 1.76 | 1.84 |
| lmPP : TPP | % rel. | 21 | 18 | 28 | 27 | 27 |

*Table 2*

isomerization rate of 10 %. In the case of linalool, Perle gets 12 µg/l and Saphir 30 µg/l. If the aim of the dosage is to have a hop aroma in the beer, this is achieved with Saphir but not with Perle, unless you add at least double the amount of Perle. From these observations we can derive the terms “aroma potential” or “aroma capacity” of a hop variety. In assessing the efficiency of an aroma variety, it should therefore logically be the aroma potential that stands in the foreground and not the α-acids. A lower iso-α-acid content in the last addition can be easily compensated at no great cost in an earlier addition.

## Observed breeds

Two breeds from Hüll with the numbers 89/002/25 and 96/001/24 are subject of this study. In the following we will use the abbreviated identification number 89 for breed number 89/002/25 and 96 for breed number 96/001/24. Figure 1 shows the pedigrees of both varieties. The mother of 89 is a Spalter, the mother of 96 a Tettnanger.

The selection of the mothers shows the aim of creating crossings with properties of the Saaz group of varieties. The fathers are of Hüll breeding material that differs especially in their mothers. Breed 89 also includes a hop from the Saaz hop family with Super Styrian, and breed 96 is related to an English breeding line.

96 has slightly better agronomic properties than 89. The two breeds yield approx. 1900 kg/ha, compared to 1300 kg/ha with their mothers.

## Material and methods

In parallel to the two breeding lines 89 and 96, their mothers, Spalter (SSP) and Tettnanger (TTE), as well as Saphir (HSR) were examined in form of pellets type 90, crop 2015. Saphir meanwhile has become a leading aroma variety for providing a hop bouquet through late hopping. Spalter and Tettnanger were obtained from their respective growing areas, Saphir and the breeds from the Hallertau.

The examination of the five hop samples was based on the following characteristics:

- Bitter substances determined by HPLC acc. to EBC 7.7, including α-acids, the ratio β:α and cohumulone content according to [2, p. 136] and [4];
- total polyphenols (TPP) determined by the spectro method EBC 7.14;
- low-molecular polyphenols (lmPP) determined by HPLC according to a NATE-$CO_2$ method [5]. HPLC permits the separation of about 50 substances. In this article, only the sums of the individual components are considered;
- total hop oil (volumetric, according to EBC 7.10);
- analysis of the aroma substances using the gas chromatographic method EBC 7.12 which covers more than 100 different compounds. The data shown are limited to a few selected components and key figures.

Trial brews were made in the 2-hl St. Johann Research Brewery.


**Fig. 2 Content of hop-based low-molecular polyphenols in the five beers**


**Fig. 3 Content of total linalool in the five beers**

### CONTENT OF SELECTED MONOTERPENES AND SESQUITERPENES ...

... in 5 hop varieties (mg/100 g)

| | 89 | 96 | SSP | TTE | HSR |
|---|---|---|---|---|---|
| Myrcene | 719 | 644 | 331 | 242 | 330 |
| β-caryophyllene | 61 | 94 | 27 | 25 | 35 |
| Farnesene | 83 | 14 | 55 | 56 | 9 |
| α-humulene | 145 | 266 | 99 | 96 | 100 |
| α- and β-selinene | 8 | 9 | 3 | 3 | 15 |

*Table 3*

### CONTENT OF SOME OXYGENOUS AROMA COMPONENTS ...

... as well as the sum of 6 esters and total of the oxygen fraction (mg/100 g)

| | 89 | 96 | SSP | TTE | HSR |
|---|---|---|---|---|---|
| Linalool | 17 | 12 | 6 | 5 | 7 |
| Geraniol | 2 | 2 | 6 | 4 | 2 |
| Sum of 6 esters | 54 | 18 | 12 | 5 | 27 |
| Oxygen fraction | 129 | 95 | 71 | 54 | 132 |

*Table 4*

The main characteristics of the brews are as below:

- 100 % Pilsner malt;
- infusion mashing to achieve an original extract of 12 %;
- bottom-fermenting yeast W34/70;
- fermentation at 8 °C, maturation at 14 °C, storage at 0 °C;
- kieselguhr filtration, bottling with low residual oxygen.

In the series described here, the hopping at the end of wort boiling is based on the hop oil content of the samples with 6 ml/hl hop oil, in equal doses of 3 ml/hl at end of boil and in the whirlpool. The expected bitter substance content through the late addition was supplemented by an addition of pellets of the variety Herkules at begin of boil in order to obtain 20 IBU.

## Analysis of the hop samples

Table 2 presents the α-acid data with key figures, the total polyphenols and the sum of the HPLC polyphenols with the key figure "lmPP : TPP", which shows the portion of low-molecular polyphenols in a percentage of the total polyphenols. The volumetric total hop oil content is also given.

The breeding lines, especially breed 89, have a higher content but a significantly lower cohumulone ratio than their mothers; Saphir has a particularly low level (14 %) anyway. The hop oil of the breeding lines more than doubles that of the mother varieties and is about 80 % more than Saphir. The total polyphenol content is a little lower than that of the two established varieties. The portion of the valuable low-molecular polyphenols drops from 27-28 % to 18-21 % in the breeding lines.

Table 3 lists the content of important monoterpenes and sesquiterpenes. The two breeding lines are at the top with myrcene, β-caryophyllene and α-humulene, and Saphir leads with the selinenes. It is striking that breed 89 with 83 mg/100 g has significantly more farnesene than the two classics SSP and TTE, but breed 96 has only a fraction of this with 14 mg/100 g. As already mentioned above, a grandmother of breed 89 is also an offspring of the Saaz group of varieties, which could well be responsible for the more pronounced Saaz character.

Table 4 shows the contents of some aroma components containing oxygen, the sum of six esters (isobutyl isobutyrate, 2-methylbutyl propanoate, 3-methylbutyl 2-methylpropanoate, 2-methylbutyl 2-methylpropanoate, 2-methylbutyl 3-methylbutanoate and 2-methylbutyl 2-methylbutanoate) and the sum of all substances with oxygen content (= oxygen fraction). Breed 89 in particular produced significantly higher contents of esters, linalool and the oxygen fraction, components that are responsible for a hoppy aroma in beer. Their solubility in wort and beer is decisive for classifying the efficiency of aroma components. Thus, the nonpolar monoterpenes and sesquiterpenes are only poorly soluble, the polar esters, terpene alcohols and epoxides on the other hand are much more soluble. Even intensive late hop additions do not produce a monoterpene or sesquiterpene concentration in beer that in any way approaches their sensory threshold values. It is the more soluble oxygenated substances that survive the brewing process in late dosing. The yields through to the finished beer range from about 10 to 50 %.

Table 5 shows a sample evaluation of the aroma capacity of the substances myrcene and linalool and includes the volumes of hops, transfer rates in the beer, resulting volumes in the beer and the taste threshold values in beer. Even though myrcene is 100 times stronger in hops, the 15 times higher threshold value in conjunction with the much lower transfer rate of less than 1 % leads to a clear classification: Compared with linalool, myrcene has practically no aroma capacity.

## Analytical results of the trial brews

The general beer analyses like alcohol, original extract and pH show only very slight variation coefficients between 0.8 and 1.9 %. The bitterness units vary in a range of 18 to 22 IBU, similar to the iso-α-acids with values between 12.7 and 15.2 mg/l.

Figure 2 shows the sums of the low-molecular polyphenols that derive exclusively from the hops. The two breeding lines are significantly lower. This is partly due to the fact that their share of these substances is lower than in the classics (see table 2). But the decisive factor is that the dosage of the breeding varieties was much lower thanks to their high oil content and their improved aroma potential.

Of particular interest is the content of hop aroma substances in the beers. Neither monoterpenes nor sesquiterpenes could be

### EXAMPLE OF THE AROMA POTENTIAL OF MYRCENE AND LINALOOL ...

... with a hop dosage of 100 g/hl

| | Unit | Myrcene | Linalool |
|---|---|---|---|
| Amount in hops | mg/100g | 1000 | 10 |
| Transfer rate into beer | % rel. | < 0.1 | > 30 |
| Amount in beer | µg/l | < 10 | 30 |
| Threshold in beer | µg/l | > 150 | > 10 |

*Table 5*

detected in reliable volumes. This confirms the previous assumption that even with substantial late hop additions these substances do not leave any sensory-relevant traces because of their low solubility and volatility. Figure 3 illustrates the total linalool content in the 5 beers, which lies between 134 µg/l in the TTE beer and 215 µg/l in the 89 beer. The perception threshold at 10 to 20 µg/l was significantly exceeded in all of the beers. Correspondingly, the comparatively high linalool content in the 89 hops leads to the highest value in the beer.

Of the esters dosed with hops, 6 could be detected in the beers (fig. 4). The 89 beer shows the highest concentration of these aroma components followed by Saphir. The other 3 beers have a much lower concentration and it is questionable whether these esters exceed the perception threshold at this low level.

## Sensory results of thetrial brews

The tasters of the research brewery awarded without exception above-average points for all characteristics according to DLG. As the differences were minimal, these results are not presented here. The 89 beer has been preferred significantly to the other beers though.

Additionally, the beers were tasted according to the CMA variety portfolio [6] and produced results about hop-relevant characteristics. Figure 5 shows the assessments for the intensity and quality of the hop aroma. Figure 6 displays the results for intensity and harmony of the bitterness. No clear differences could be established. The beers with Spalter and 89 tend to have the edge over the other three beers. Dosage based on hop oil content led to beers with a comparable intensity of hop aroma. Weaknesses of the strains regarding the harmony of the bitterness could also not be detected; the 89 breed is taking the lead here.

Another panel compared the 89 beer with the SSP beer and the TTE beer. The results of the tastings in pairs are given in table 6. The aroma intensity of the 89 beer was judged to be slightly better. The fact that the beers brewed with the classic aroma hops came across as having more body can be put down to the significantly higher polyphenol content thanks to the higher hop dosages [2, p. 305]. In bitterness and personal preference the 89 beer ranked slightly higher than the SSP beer and significantly higher than the TTE beer.

On the occasion of the 3rd German Hops Conference in October 2016, the participants compared four beers with similar recipes. Among other things, the tasters were asked to express their preferences. Table 7 shows the results. In the test acc. to Kramer [4] the 89 beer ranked first with a 2-star significance. There is hardly any difference between the three other beers (SSP, 96 and TTE).


**Fig. 4 Content of the sum of six esters in the five beers**

## Discussion of the results

A comparison of the two breeding lines 89 and 96 with their Spalter and Tettnanger mothers as well as with Saphir showed a significantly higher content of hop oil and aroma-relevant substance groups. The 89 breed is particularly prominent in its aroma potential, not least because of its high linalool content. The following quantities are required for late addition dosing of the five hops in form of 6 ml hop oil per hl:

- 89 353 g/hl;
- 96 343 g/hl;
- Spalter 857 g/hl;
- Tettnanger 1000 g/hl;
- Saphir 632 g/hl.

The beers differ in the content of the key aroma compound linalool with 134 and 140 µg/l for TTE and SSP to 152 µg/l for the 96 and 170 µg/l for Saphir to 215 µg/l for the 89. The 89 is also ahead with the ester values followed by Saphir and – after quite a gap – the three other beers.

Sensorily the 89 beer was considered best; there were no statistically relevant differences in the preferences shown for the remaining four beers. Still the following conclusions can be drawn: In comparison to the classics the high aroma potential of the breeding lines permits a significantly lower dosage, which will have an effect on the costs. If the hop aroma in beer with the "normally" used varieties is rather subdued or not even perceivable, using the 89, for example, in similar quantities achieves a much clearer result in the form of an undeniable hop bouquet.

## Summary

Worldwide the breeding of hops with special aromas (= special flavor hops) is the big trend. Hüll alone has had six new varieties registered in the last five years. In contrast, since 2003 no aroma hop for wort boiling (= "normal" aroma hop) has been approved in Hüll.

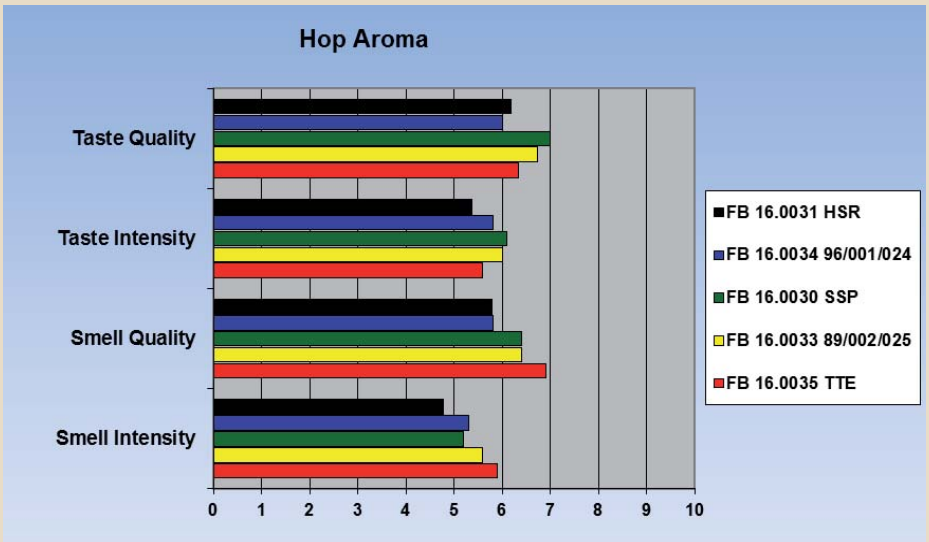


**Fig. 5 Hop-relevant characteristics of the tasting according to the CMA; intensity and quality of the hop aroma**

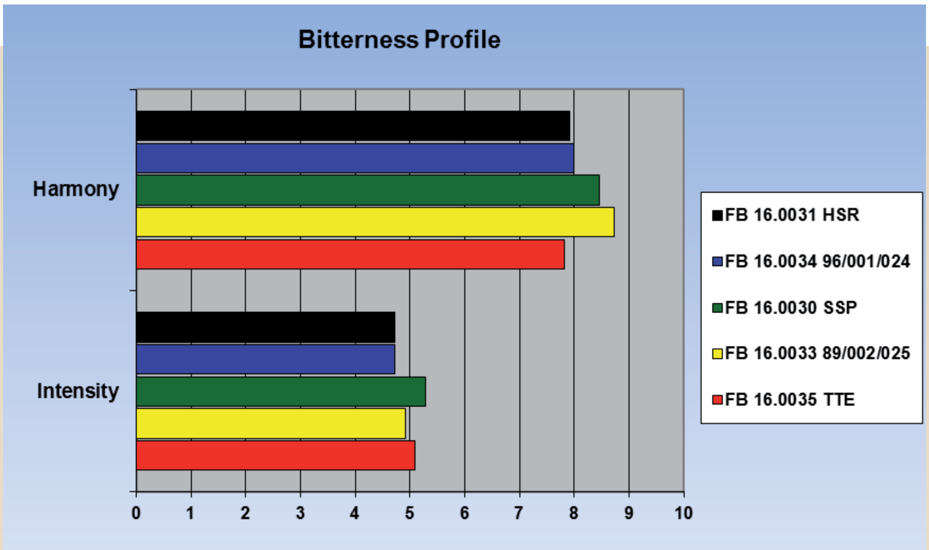


**Fig. 6 Intensity and harmony of the bitterness**

Above and beyond the special flavor hop hype there is certainly a need to breed aroma hops with the aim of higher yields and better resistance to diseases and climate change. The aroma potential should also be enhanced.

Two aroma breeds with the numbers 89/002/25 and 96/001/24 have long been under examination in Hüll. They are compared with their respective Spalter and Tettnanger mothers as well as with Saphir. Saphir is considered to be the variety with the highest aroma potential to date among the classic aroma hops. The results of analytical comparisons and trial brews can be summarized as follows:

- The α-acid content of both breeding lines is higher than that of the three other hops in the comparison, but with lower cohumulone levels than the mother varieties.
- Both breeding lines have slightly lower levels of low-molecular polyphenols and significantly higher hop oil content.
- The 89 shows the highest farnesene value of all five hops, which can be an indicator for its relationship with the Saaz group of varieties.
- In particular the 89 hop has a high aroma potential which is due to its high level of easily soluble esters and linalool.
- In trial brews with late-hopped, bottom-fermenting beers the five hops are dosed according to their hop oil content in a volume of 6 ml of oil/hl. The volumes of the breeding lines required for this are logically only 35 % of TTE, 41 % of SSP and 55 % of HSR.
- Nevertheless, the beers containing hops from the breeding lines can easily keep up with the other three beers in intensity and quality of the hop aroma.
- The 89 beer has the highest values for aroma-active substances like linalool and esters.
- The beers with the 89 breed were given significant preference in all the tastings.

The breeding lines, especially the 89, have a high aroma potential that either permits lower dosages or generates a distinctly more perceptible hop bouquet. Meanwhile both varieties have proven their suitability in late additions and also in blends with their mothers. Based on these promising aspects both breeding lines are being grown in a large-scale trial. ■

## Literature


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## TASTING IN PAIRS OF THE 89 BEER ...

... with the SSP beer and the TTE beer with significance levels (sig.) of the results

| | Pair 1 | | | Pair 2 | | |
|---|---|---|---|---|---|---|
| | 89 | SSP | Sig. | 89 | TTE | Sig. |
| Which of the beers is more aromatic? | 10 | 4 | - | 8 | 6 | - |
| Which of the beers has more body? | 4 | 10 | - | 6 | 8 | - |
| Which of the beers has a more pleasant bitterness? | 8 | 6 | - | 12 | 2 | ** |
| Preference | 10 | 4 | - | 12 | 2 | ** |

*Table 6*

## TASTING OF FOUR BEERS; ...

... specification of the rank sums according to Kramer [7], ranking and significance

| | 89 | 96 | SSP | TTE |
|---|---|---|---|---|
| Rank sum | 112 | 157 | 154 | 167 |
| Ranking | 1 | 3 | 2 | 4 |
| Significance | ** | - | - | - |

*Table 7*