

New German Hop Varieties – A Comparison to Established Varieties

by Adrian Forster

Introduction:

There are fewer topics in brewing technology that are more controversially discussed than the evaluation of hops and their usage. The minimum standard for hopping is the generation of a bitter flavour in the form of iso-alpha acids without a specific definition of an additional sensory value. If any, the only requirements mentioned are stability against a light-struck aroma and flavor for certain types of bottles or foam stability. This minimum standard is valid for the majority of the world's beer range.

Hops, however, should be viewed as a flavoring ingredient / component of beer which, within the broad range of available varieties and different process parameters, is an essential factor for determining the character of a beer. The result can be an inimitable and unique taste experience. Within this spectrum, the potential of usage is manifold, for instance by using various hop varieties to make the most of this raw material in order to not only add bitterness, but also flavor and aroma.

Part of this paper is to introduce a procedure/method for evaluating hop varieties in an easier way. The hop range is continually expanding through ongoing breeding and research. 50 years ago, there were four varieties in Germany, today there are seven aroma and 6 bitter hop varieties that are grown on a large scale. Apart from that, three promising aroma varieties are waiting in the wings, vying for brewers' attention. A part of this range will be described and brewing trials will be discussed.

The Three Categories of Hop Components

Hops contain three categories of components, of which only bitter compounds and especially alpha acids are indispensable. A large part of the world's beer range is completely or almost completely free of hop aroma components and/or hop polyphenols. Brewers only interested in a defined bitter flavor in beer rarely take an interest in the characteristics of different hop varieties. They mostly satisfy their needs with low-priced alpha-acids in the form of high-alpha varieties.

Hop bitter components can be analysed by HPLC. Through sophisticated methods, they can be broken down into as many as 50 substances. Routine analyses are limited to four peaks that are quantified as cohumulone, n- plus adhumulone, colupulone and n- plus adlupulone. The sum of the first two are alpha acid, the latter two are beta acids. From these, defining numbers may be derived, i.e. the cohumulone- content in % of alpha acids. A low cohumulone content can be seen as positive. There is still some disagreement whether coisohumulone creates a harsher bitterness in beer than n- and adisohumulon, though it is a quality criterion for many brewers. There is no doubt that the more polar coisohumulon results in lower foam stability than n- and adisohumulon. Furthermore, the decrease of n- and adisohumulone in beer is fractionally slower than in coisohumulone. This means that a low cohumulone content is a favorable quality criterion. The ratio of alpha to beta acids indicates how many

bitter compounds apart from alpha acids are contained in hop resin. While many technologists consider these accompanying bitter compounds unimportant, there are others who see them enhancing quality of beer bitterness.

Hop aroma components are fractionated through gas chromatography in up to 400 separate substances. Routine analyses yield as many as 100 components already. It is extremely difficult, however, to derive a practically-oriented evaluation of hop aromas. In this presentation the following key data for the evaluation of hop varieties are shown:

- The content of linalool is an important factor as linalool is a positive indicator for imparting hop aroma to beers.
- Sum of monoterpenes, sum of sesquiterpenes: these two add up to the hydrocarbon fraction and from that we can calculate the share of sesquiterpenes in the hydrocarbon fraction. Due to their lower volatility, sesquiterpenes, as epoxides or alcohols, can better contribute to the aroma of beers.
- The sum of all substances with a built-in oxygen atom results in the oxygen fraction. From that, three ester, i.e. isobutyl- and isoamylisobutyrate as well as methylhexanoate can be determined. These have an invasive aroma and are expressed as ester content in % of the oxygen fraction.

The third important group of substances in hops are the polyphenols. Polyphenols in general are secondary metabolites of many plants. For the last 30 years, there has been a lot of research on the composition and effect of polyphenols. In vitro tests showed anti-oxidative properties of several polyphenols, and furthermore, some also exhibit anti-carcinogenic, estrogenic, and anti-inflammatory effects. Interpretation of these results in the media lead to statements that some polyphenols could provide a positive effect on human health. Examples are soy, wine, tea and coffee. Polyphenolic extracts are added to some food to create food supplements or functional food. Hops are a natural source of different types of polyphenols. While research, publications, and articles on positive plant polyphenols increased greatly in the last 30 years, the dosage of hop polyphenols in beer decreased significantly. Regarding the existing positive and promising reputation of polyphenols, it is the question if hop polyphenols are really unimportant? The positive influence of hop polyphenols on beer flavor shall encourage making use of these substances.

There exist two types of methods to analyse the polyphenols in hops. The first one is a non-specific colouring method. HPLC is the alternative to this method and provides the separation, identification, and calibration of more than 100 individual low-molecular components. Values vary between 0.5 and 3 % [ww] as a sum of all HPLC components which is the relevant figure in this paper.

Table 1 shows the most important groups of polyphenols and the typical variation of contents in different hop varieties.

Table 1: Polyphenol Groups in Hops; Contents depend on the variety

Substance	Contents in mg/100 g
Hydroxy benzoic acids	1 – 10
Hydroxy cinnamic acids	100 – 450
Proanthocyanidins	100 – 600
Flavanols	30 – 200
Flavonols	1 – 10
Quercetin flavonoids	50 – 250
Camphorol flavonoids	50 – 300
Prenyl flavonoids	1,000 – 10,000

For the evaluation of polyphenols in various hop varieties, the total content of low-molecular HPLC-substances is determined and in addition, their ratio to the level of alpha acids is calculated. The lower the resulting figure, the more pronounced is the polyphenolic character of a hop variety.

Xanthohumol is the most important representative of the prenyl flavonoids and is a unique polyphenol which is only found in hops. It is considered to be the polyphenol with the greatest potential for human health benefits. In vitro tests show clear anti-inflammatory, anti-oxidative, and anti-carcinogenic effects. In vivo research is considered to be very promising.

The prenyl flavonoides – the most eminent amongst them being xanthohumol – are listed separately. The ratio of alpha acids to xanthohumol is comparable to the quality criterion of polyphenols.

For the four previously mentioned criteria – bitter compounds, aroma components, polyphenols and prenyl flavonoids – quality points from 1 – 3 are given (table 2 shows the ranges). 1 point means a rating with a typical bitter character, 2 points mean a medium rating, 3 points are the maximum with a typical aroma hop character. The total of quality points of all four criteria can be 4 as a minimum and 12 at the most.

Table 2: Classification of Quality Points**1 = bitter hop character ; 2 = medium rating; 3 = aroma hop character**

HCF = Hydrocarbon Fraction

		1	2	3
Cohumulone content	% rel	> 30	25-30	< 25
humulone : lupolone		> 2-0	1 – 2.0	< 1.5
linalool	mg/100g	< 6	6 - 8	> 8
humulone : linalool	% [ww] : mg/100 g	> 2	1 - 2	< 1
Ester content in oxygen fraction	% rel	> 20	5 - 20	< 5
Sesquiterpene content in HCF	% rel	< 40	40 - 50	> 50
Sum of HPLC-polyphenols	% [ww]	< 0.6	0.6 – 1.2	> 1.2
Humulone : Polyphenols		> 10	5 - 10	< 5
Xanthohumol	% [ww]	< 0.3	0.3 – 0.5	> 0.5
Humulone: Xanthohumol		> 20	10 - 20	< 10

Evaluation of 10 Hop Varieties

From the range of hops grown in Germany, the following varieties are selected for comparison:

Established or traditional aroma hop varieties (noble aroma hops) are Tettnanger, Hallertauer Mittelfrueh and Hersbrucker. Hallertauer Tradition is a breed from the Hop Research Institute in Huell. Four new aroma breeds are the varieties Saphir, Select, Smaragd and Opal. Of these, Saphir and Select have already been introduced into the market, whereas Smaragd and Opal have only a limited availability.

In the high-alpha/bitter hop sector, the Hop Research Institute in Huell has had significant success with new varieties like Taurus and Herkules which show promising yields.

There are two factors responsible for the success of a variety: Yields and resistance to pests and diseases. The economic success of a variety mainly relies on the interaction of good yields with high alpha acids. The uncritical fixation on alpha acid contents in bitter hops that disregards other important characteristics has unfortunately already been adapted for aroma hops as well. Table 3 shows the yields per hectare (kg/ha), alpha acid contents and the resulting yields in alpha acid (kg alpha/ha). Generally, the numbers are based on long-term averages; for the newer varieties, there are no long-term data available.

Table 3: Yields of 10 Hop Varieties in kg/ha and kg alpha/ha

Variety	Yield kg/ha	α -value % [ww]	α -yield kg- α / ha
Tettnanger	1300	4.0	52
Hallertauer mfr.	1250	3.9	49
Hersbrucker	1700	2.8	48
Hall. Tradition	1800	6.0	108
Saphir*	1950	4.1	80
Select	1900	4.8	91
Smaragd*	1850	6.1	113
Opal*	1850	7.4	137
Taurus	1850	15.5	287
Herkules	2300	16.0	368

* preliminary data

Table 3 shows the yields. Traditional varieties yield approx. 50 kg of alpha acid per hectare, new breeds (e.g. Saphir) yield approx. 70 kg, and some even deliver yields of more than 100 kg alpha per hectare.

In the Portfolio you can also find data on the classification of hop varieties regarding the resistance against pests and diseases, such as the wilt disease, downy and powdery mildew. The description from low (0) to medium (1) to good (2) is included in table 4. In this context, I have to point out that even a good resistance to pests and diseases is not equivalent to a complete resistance.

Table 4: Resistance to Diseases
0 = low ; 1 = medium ; 2 = good

Variety	Wilt disease	Downy mildey	Powdery mildew
Tettnanger	2	0	1
Hallertauer mfr.	0	0	1
Hersbrucker	1	0	0
Hall. Tradition	2	2	1
Saphir	2	1	2
Select	2	2	1
Smaragd	2	2	0
Opal	2	2	2
Taurus	2	1	0
Herkules	2	2	1

Experience shows that traditional aroma hops have little resistance to pests and diseases; therefore pesticides have to be used more often. New breeds show much more resistance, which is one of the major purposes of breeding. Table 4 shows the classification of pest resistances.

Table 5 contains the relevant key figures and quality points for bitter compounds; here almost all aroma hops get the highest marks with the

exception of the variety Tradition. Bitter varieties inevitably get lower marks. The new aroma varieties Saphir, Smaragd, and Opal have particularly low cohumulone levels.

Table 5: Key Data of Bitter Compounds with Quality Points (Qp)
Alpha : Beta = Alpha-Acids : Beta-Acids

Variety	Cohumulone ratio %rel	Alpa : Beta	Qp
Tettnanger	25	0.76	3
Hallertauer mfr.	22	0.80	3
Hersbrucker	21	0.38	3
Hall. Tradition	27	1.19	2
Saphir	17	0.57	3
Select	23	0.96	3
Smaragd	18	1.13	3
Opal	16	1.34	3
Taurus	24	3.04	2
Herkules	35	3.09	1

Regarding aroma data and quality points (see table 6), the new varieties Saphir and Select reach the same level as traditional aroma hops. In spite of the low content of linalool, Hersbrucker gets 3 points, because of the ratio of humulone to linalool. The variety Tradition shows a higher level of esters. The high level of linalool in Opal is striking; in spite of the low level of sesquiterpene, this nevertheless merits 3 points. Sensory analyses demonstrate that especially new breeding varieties reveal interesting and unique flavors.

Table 6: Key Data of Aroma Components with Quality Points (Qp)

Variety	linaloole mg/100g	alpha:linaloole %[ww]:mg/100g	Ester %rel.	Sesquit. %rel.	Qp
Tettnanger	6	0.67	1.5	55	3
Hallertauer mfr.	9	0.43	6.0	58	3
Hersbrucker	5	0.56	2.0	67	3
Hall. Tradition	9	0.68	15.0	45	2
Saphir	6	0.67	3.0	58	3
Select	9	0.53	4.5	60	3
Smaragd	8	0.76	4.0	47	2
Opal	12	0.62	4.0	42	3
Taurus	15	1.00	8.0	49	2
Herkules	6	2.70	30.0	37	1

Taurus gets as many as 2 points. Herkules is a typical bitter variety with a low linalool level and a correspondingly high alpha:linalool ratio as well as a low sesquiterpene ratio with a high level of esters. One cannot find any faults in both bitter hop varieties regarding their sensory values, however.

Table 7 shows the absolute polyphenol levels and the ratio of alpha acids : polyphenols. Classic aroma varieties are especially rich in polyphenols, though

aroma breeds like Tradition as well as Select and – coming in a distant third – Saphir come close. Smaragd and Opal have slightly lower polyphenol levels. Inevitably, bitter varieties have considerably lower polyphenol contents. It is interesting, however, that Herkules with 16 % alpha acid has a relatively high level of 0.8 % by weight.

Table 7: Key Data of Polyphenols with 7 Quality Points (Qp)

Variety	HPLC-polyph. %[ww]	Alpha : Polyph. %[ww] : %[ww]	Qp
Tettnanger	2.3	1.7	3
Hallertauer mfr.	1.4	2.9	3
Hersbrucker	1.8	1.6	3
Hall. Tradition	1.3	5.0	2
Saphir	1.0	4.1	3
Select	1.7	2.8	3
Smaragd	1.0	6.1	2
Opal	0.8	9.0	2
Taurus	0.5	31.0	1
Herkules	0.8	20.0	2

In table 8, the key figures for prenylflavonides are shown. Xanthohumol is the only type of polyphenol that is present in the lupulin glands together with bitter acids and hop oils. All other polyphenols can be found in the bracteoles. Thus, the biogenesis of xanthohumol and bitter compounds are linked. In this way, a low alpha acid content can be linked with high polyphenol levels.

Table 8: Key Data of Prenylfavonoids (Xanthohumol = XN) with Quality Points (Qp)

Variety	xanthohumol %[ww]	Alpha : XN %[ww]:%[ww]	Qp
Tettnanger	0.35	11	2
Hallertauer mfr.	0.32	12	2
Hersbrucker	0.28	9	3
Hall. Tradition	0.51	14	2
Saphir	0.43	9	3
Select	0.45	11	2
Smaragd	0.32	19	2
Opal	0.43	18	2
Taurus	1.0	17	2
Herkules	0.8	21	1

Table 9 gives a summary of the criteria shown in this presentation. The economic potential is expressed by alpha acids per hectare. The ecological evaluation is defined by the classification of the resistance to 3 diseases. Thus,

the range can go from 0 to 6. Furthermore, the overview includes the total of all quality points received (minimum 4, maximum 12). 4 quality points for bitter hops is average. Any value above 4 is an indicator for higher quality.

Table 9: Overview of all 10 Hop Varieties with Alpha Yields (kg alpha / ha), Resistance and Quality Points
Resistance Points: min = 0; max = 6
Quality Points: min = 4; max = 12

Variety	alpha-yields kg alpha / ha	Resistance points	Quality points
Tettnanger	52	3	11
Hallertauer mfr.	49	1	11
Hersbrucker	48	1	12
Hall. Tradition	108	5	8
Saphir	72	5	12
Select	91	5	11
Smaragd	113	4	9
Opal	137	6	10
Taurus	287	3	7
Herkules	368	5	5

As extensive and selective HPLC and GC-analyses are necessary for the evaluation of the key figures, there exist substantial data on all three substance groups. The evaluation also includes a sensory analysis, which can spawn new ideas, especially for new beers.

Brewing trials

The CMA (Central Marketing Association of German Agriculture) has compiled the major German hop varieties in a portfolio. Furthermore, the results of brewing trials that were done in the 2 hl research brewery in Sankt Johann are also published in the above-mentioned portfolio. 60 % of the alpha acids were added to the brewing process in the form of pellets at the beginning of boiling, 40 % were added into the whirlpool. Trial brews were meant to contain approx. 25 bittering units. Aroma as well as bitter hops, were dosed equally. The beer sample for comparison was hopped with one dose at the beginning of boil with a neutral CO₂-extract of the variety Magnum.

Table 10 shows analysis results, i.e. iso-alpha acids, bittering units, iso-xanthohumol- and linalool contents, as well as total polyphenols, analysed by an unspecific method.

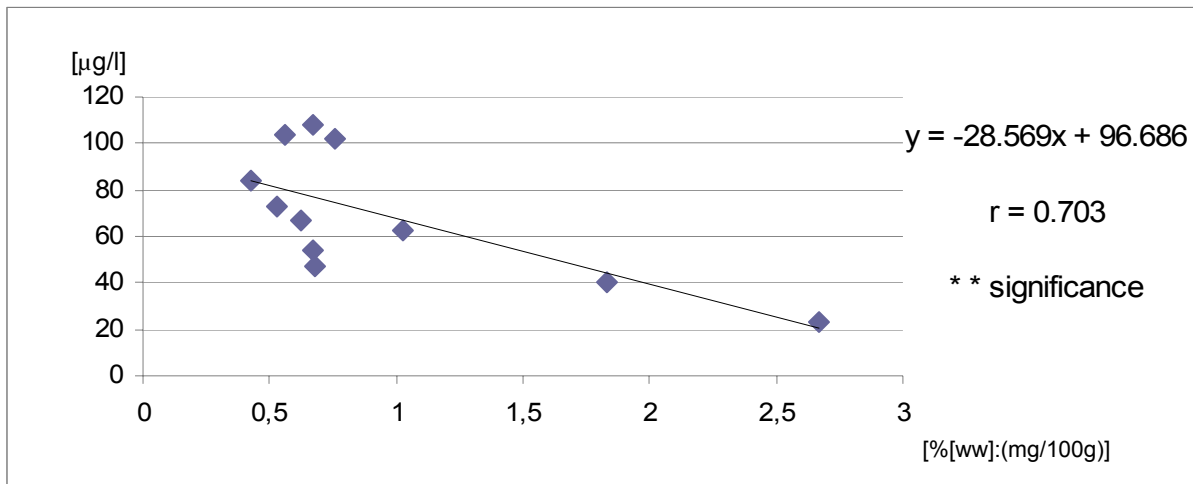
Table 10: Analysis Data of the Beers
1) IX = xanthohumul 2) unspecific method

Variety	Iso- α - Acids mg/l	IBU units	IX 1) mg/l	Linalool μ g/l	Polyphenols mg/l 2)
Tettnanger	21,9	25	0,73	54	251
Hallertauer mfr.	22,5	28	0,62	84	247
Hersbrucker	21,8	26	0,49	104	272
Hall. Tradition	22,5	24	0,51	47	208
Saphir	21,0	28	0,85	108	283
Select	23,0	24	0,72	73	264
Smaragd	21,0	23	0,51	102	205
Opal	20,5	23	0,47	67	172
Taurus	18,5	20	0,62	63	179
Herkules	21,4	22	0,49	23	165
Corresponding	26,1	25	n.d.	trace	159

The following observations were of interest:

- The difference between bittering units and iso-alpha acids in the 8 aroma varieties averages + 16%, whereas in the two bitter hops, it is merely + 5%. While the results of the pellet beers with two hop dosages show higher bittering units than iso-alpha acids, this ratio for the Magnum extract beer has the inverse relation. Pellets, aroma pellets in particular, add components to the beer which can be described as secondary or accompanying bittering compounds.
- It is well known that, similar to alpha acids, xanthohumul dosed with hops will be isomerised during wort boiling. Iso-xanthohumul levels in the 8 aroma beers show an average of 0,61 mg/l, in the 2 bitter beers 0,56 mg/l. This difference is lower than one could have expected from the xanthohumul dosages.
- Linalool levels in the beers correlate with dosage. In Fig. 1, the relation between linalool in beer and the ratio of humulone and linalool in hops is shown. This results in a two star significance.
- The polyphenols in beer were analysed by an unspecific method. As the hops were analysed by HPLC, which provides much more specific information, a direct comparison does not make sense. Compared to the corresponding Magnum beer, however, polyphenol levels in aroma hop beers show an average relative increase of 50 %, in bitter hop beers a mere 9%. Especially through the use of aroma varieties, the polyphenolic character of beers can be effectively emphasized.
- The iso-cohumulone content in beers is approx. 6% above the co-humulone content of hops. The reason for this is a better solubility compared to n- and ad-isohumulone.

Figure 1: Linalool in Beer (µg/l) in Relation to Alpha-Acids/Linalool in Hops (%[ww]:(mg/100g))



The beers for the CMA program were tested in 4 sessions with a panel consisting of 22 to 28 persons each time. In this context, only the results associated with hopping are relevant.

Participants were asked for 5 specific characteristics, i.e. hoppy, fruity, floral, citrusy and herbal. The intensity of these 5 characteristics had to be classified by aroma as well as flavor and ranged from 0 (not perceptible) to 7 (clearly perceptible). For easier comparison, the points given for aroma and flavor are averaged and listed in table 11. The new aroma varieties Saphir, Select and Opal have higher marks for hoppy and fruity notes than traditional aroma hops. Most outstanding is the variety Saphir with top results in all categories. At the same time, the table shows that specific objectives can be achieved with different varieties, thus arousing the brewer's interest.

**Table 11: Specific Sensory Characteristics of the Beers brewed
Evaluation from 0 (not perceptible) to 7 (clearly perceptible); Average from
Aroma and Flavor**

Variety	hoppy	fruity	floral	citrusy	herbal
Tettnanger	5,0	4,3	3,0	3,3	3,0
Hallertauer mfr.	5,3	4,8	5,8	2,8	2,8
Hersbrucker	5,3	4,0	4,3	2,8	3,0
Hall. Tradition	5,0	4,0	4,3	1,8	5,0
Saphir	6,5	6,3	6,3	3,5	3,8
Select	5,8	4,8	3,8	2,8	2,5
Smaragd	5,0	5,0	4,0	2,3	3,8
Opal	5,8	4,8	3,8	2,8	2,5
Taurus	4,3	3,3	2,0	2,0	2,0
Herkules	4,5	3,5	3,3	1,8	1,5
Corresponding	2,2	1,7	0,5	0,5	0,4

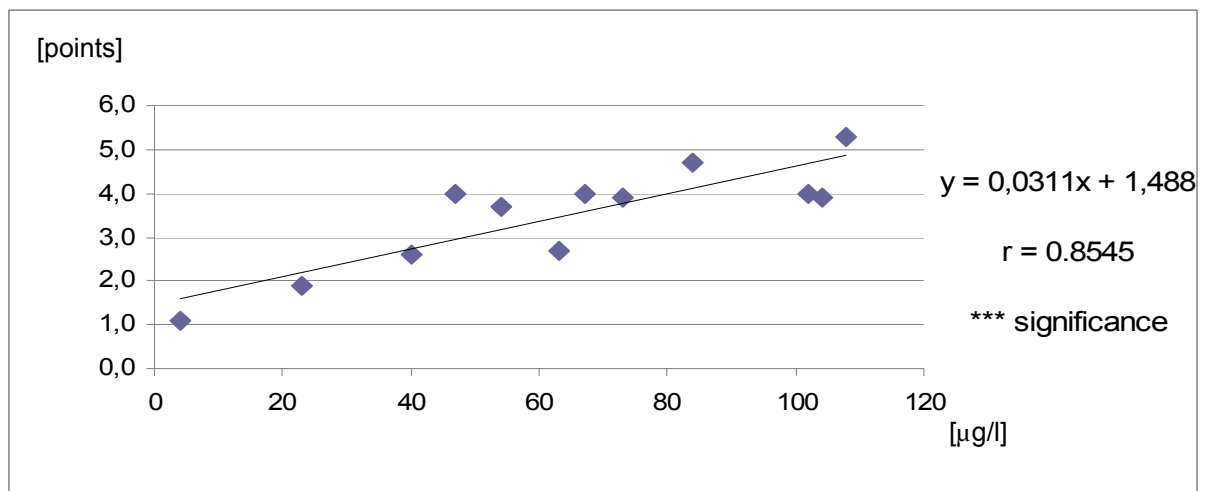
Table 12 includes the average of all 5 sensory characteristics as well as the harmony of bitterness.

Table 12: Average of all sensory Characteristics of Beers; Harmony of Bitterness ranging from 0 (unharmonious) to 10 (very harmonious)

Variety	Average of all sensory characteristics	Harmony of Bitterness
Tettnanger	3,7	6,8
Hallertauer mfr.	4,7	8,1
Hersbrucker	3,9	7,7
Hall. Tradition	4,0	6,8
Saphir	5,3	8,2
Select	3,9	8,0
Smaragd	4,0	7,0
Opal	4,0	7,0
Taurus	2,7	6,0

One interesting point is the correlation between the intensity of all sensory impressions (points) and the linalool content in the beers (mg/l). The 3-star-significance proves the correlation (see Fig. 2).

Figure 2: Intensity of sensory Impressions (in points) in Relation to Linalool Content in Beer



The participants in the beer tasting were also asked to evaluate the bitterness. On a scale ranging from 1 to 10 participants had to indicate intensity and harmony of the bitterness. One of the major criteria is the harmony of bitterness, which greatly influences the taste value and drinkability of a beer. This leads to the following conclusions:

- The harmony of bitterness in the corresponding beer sample is 6.3, goes up to 6.5 in both bitter pellet beers, with the average of the 8 aroma pellets beers being 7.5.
- The harmony can be offset against the co-isohumulone content of the beers (Fig. 3) as there is a one star significance. Considering the conditions of beer tasting (varying participants in several sessions), this is important evidence that the co-humulone content of hop varieties can have a sensory significance.

- The difference between bittering units and iso-alpha acids is an indication for accompanying bitter compounds in beers. In beers hopped with aroma hops, this relative difference was 16 %, in beers hopped with bitter hops merely 5 %. Offsetting the factor IBU:iso-alpha acids against the ratio of humulone : lupulone (alpha : beta acids) in the relevant hop varieties (see Table 5) provides a backed-up two star significance (Fig. 4).
- The most interesting question now is whether these accompanying bitter compounds have an influence on the harmony of the bitterness. Fig. 5 shows the relevant correlation which in this context entails a 2 star significance.

Figure 3: Harmony of Beer Bitterness (points) in Relation to Coisohumulone – Ratio (%relative)

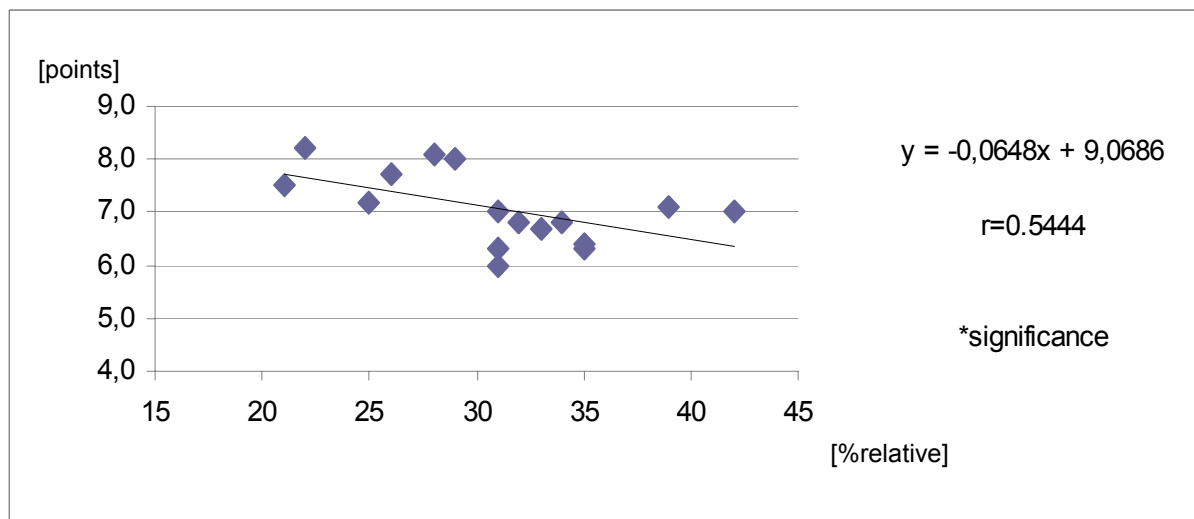


Figure 4: IBU/Iso-Alpha in Beer (%relative) in Relation to Alpha/Beta-Acids in Hops

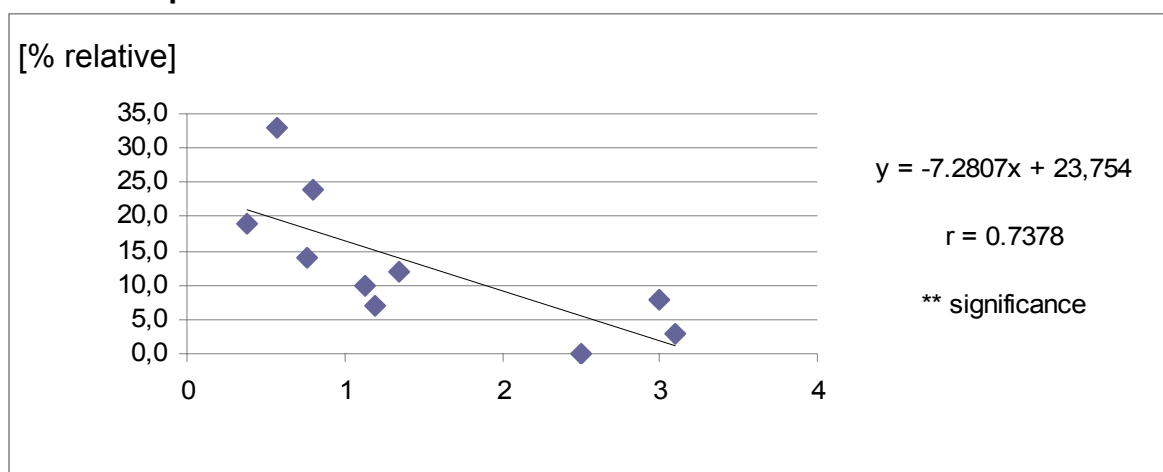
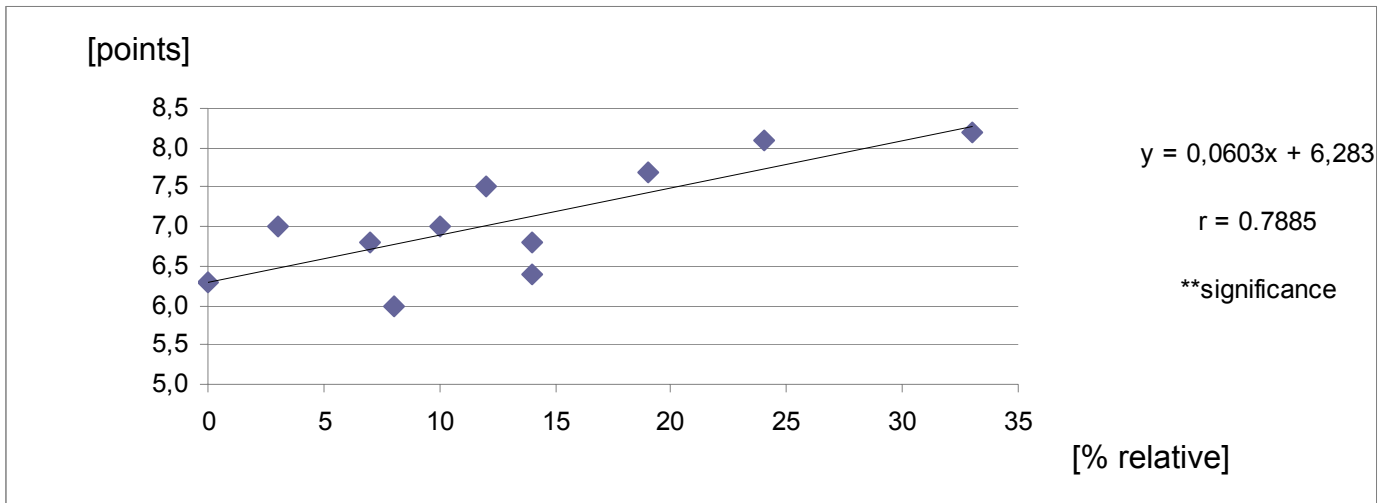


Figure 5: Harmony of Beer Bitterness (points) in Relation to IBU/Iso-Alpha-Acids (%relative)



For test beers, a few important results can be noted, as there are the following analytical correlations:

- The dosage of linalool correlates with the amount of linalool in the beer.
- It is logical that more polyphenols are dosed with aroma hops; consequently there are higher polyphenol quantities in the beer.
- The less alpha-accentuated the hop varieties are, i.e. the ratio of alpha : beta decreases, the more accompanying bitter compounds can be found in beers.

The major sensory results are as follows:

- Aroma hops have more intensive aroma and flavor characteristics than bitter hops. These characteristics differ from variety to variety. New varieties offer interesting aspects.
- The intensity of the flavor characteristics (hoppy, fruity, and floral) increases with the amount of linalool in the beer.
- The harmony of bitterness, which is a good indicator for drinkability, improves with the amount of accompanying bitter compounds in the beer. The latter increase with lower alpha : beta ratios, i.e. by using aroma hops.
- If the share of co-isohumulone falls, the harmony of bitterness gets higher. As co-humulone has a lower foam and storage stability in beer, a low co-humulone percentage in hop varieties is of advantage.

Summary

Progress in the breeding of hop varieties has been significant in the last 30 years. Until recently efforts were mainly concentrated on the breeding of high-alpha hops, whereas in the last couple of years new aroma varieties were increasingly launched. In order to facilitate the overview, this presentation first gives you an idea of how hops can be evaluated. The following three criteria are of importance:

- Yields (kg/ha) and alpha acid content (kg alpha/ha) are the decisive factor for the profitability of a variety.
- Growing hops without the use of pesticides would be ideal in an ecological sense, but is not realistic at the moment. Nevertheless, hops vary in their resistance against pests and diseases, leading to an ecological evaluation.
- In view of several hundred possible analytical results, a categorization regarding quality is difficult. Here 4 groups of components are included as follows:
 1. Bitter compounds with characteristics like co-humulone and the ratio alpha:beta acids.
 2. Aroma compounds with positive characteristics like linalool and sesquiterpene contents as well as the negative characteristics of three ester compounds.
 3. Low molecular polyphenols as the sum and the alpha:polyphenol ratio.
 4. Prenylflavonoids (xanthohumol) and the alpha:xanthohumol ratio. Low ratios emphasize the polyphenolic character of hop varieties.

The result of the above four characteristics give a total score for quality. New German aroma breedings are Saphir, Select, Smaragd and Opal. They are compared with classic aroma varieties like Tettnanger, Mittelfrueh and Hersbrucker as well as breeding Hallertau Tradition, which has been established for more than 10 years now.

Regarding yields and susceptibility to diseases new breedings are much better equipped than classic hop varieties; the same differentiation can be made for varieties like Saphir and Select regarding quality. Varieties Smaragd and Opal show interesting flavours in sensory evaluations.

This picture is further complemented by the two new high-alpha bitter varieties Taurus and Herkules, which show remarkable characteristics.

In the second part of this presentation, the results of brewing trials with the 8 aroma and 2 bitter varieties deserve a closer look. In the CMA portfolio one can find fundamental analysis data as well as sensory evaluations with interesting aroma diagrams which identify individual differences. From that, the following deductions can be made:

- Linalool and polyphenol contents of beers correspond with the amount of dosage via a variety.
- The more linalool there is in beer, the more pronounced odour and flavor impressions are, e.g. hoppy, floral or fruity.
- The difference of bittering units (IBU) and specific iso-alpha-acids increases with a decreasing alpha:beta acid ratio. As a consequence,

the lower the alpha character of a hop variety is, the more accompanying bitter compounds can be found in beer.

- The higher the difference of IBU to iso-alpha acids is, the more harmonious the bitterness of the beer.
- The lower the iso-cohumulone value is, the higher the harmony score for bitterness. A lower co-humulone value gives a better harmony of bitterness as well as more foam and storage stability of beers.

All observations as stated above allow the conclusion that aroma hops and especially also the new breedings improve the quality of beers.

Using aroma hops in later hop dosages in order to achieve a better beer quality results in a correspondingly higher quantity of hops needed. This could be up to several times the amount of the hop quantity, which – by using high alpha varieties dosed at the beginning of the boiling process – is needed to get the same level of bitterness in the beer.