The influence of hopping on beer quality

SINGULAR SENSORY EXPERIENCE | Few topics in brewing science are as controversially discussed as the evaluation and usage of hops. A minimum goal of hopping is the generation of a slight bitter flavour without requirement of any additional sensory properties, though positive side-effects such as light stability for certain bottle types or improved head retention are often noted as desirable characteristics. Hops are also considered to be a spice and the vast range of available hop varieties and possible hopping technologies allow them to contribute significantly to the character and flavour of a beer. The ultimate goal would thus be to strive for an inimitable and singular sensory experience.

THERE ARE INNUMERABLE POSSIBILITIES for expressing aromas and flavours in addition to bitterness and the costs of hopping are as a result extremely variable. The hopping costs for a beer with 20 bitterness units generated solely through the use of low-priced pre-isomerised products are around 0.25 EUR per hectolitre; using aroma hops in several doses (without dry-hopping) generates additional costs in the range of 0.10 EUR to 1.50 EUR per hectolitre.

Project definition

The initial question was of whether or not the quality of a beer is related to the method and costs of hopping, and to what degree. Figure 1 schematically depicts how beer quality and costs of hopping could be related, though it is not clear which type of function can be expected. A simple test series presented at the First German Hop Congress in Tettnang on August 21 and 22, 2009 was an attempt to seek an answer to this question. Congress participants evaluated 5 beers brewed at the research brewery in St. Johann, Hallertau, in a blind tasting.

Design of the test series

Due to plant size and geometry of the 2 hectolitre experimental brewery in St. Johann, intense sedimentary processes during wort boiling, fermentation, and maturation, as well as an intense separation during filtration are typical, and this in turn guarantees highly consistent and reliable results from sensory panels.

The base beer was a finely filtered adjunct lager with the following general characteristics:

- non-assertive character;
- comparable to an international “mainstream lager beer”;
- long shelf life;
- internationally typical bitterness of 15 mg of iso-alpha-acid per litre.

Particulars in the brew house:

- 70 percent pilsner malt;
- 30 percent adjunct (corn and rice 1:1);
- single-decoction mash with adjunct boil;
- internal boiler, 75 min boiling time;
- whirlpool with 20 min rest followed by 45 min wort cooling.

Additional characteristics:

- cold primary fermentation at 8.5 °C;
- warm conditioning at 14 °C;
- cold conditioning at 0 to 1 °C;
- filtration with diatomaceous earth and membrane (1.2 and 0.45 µm);
- filling ($O_2 < 0.15$ mg/l).

The beer for comparison (zero beer or 0-beer) was hopped using only pre-isomerised extract for bittering and the four test

Authors: Dr Adrian Forster, Consultant of the German Hop Growers Association, Fürsteneck and Andreas Gahr, Hopfenveredlung St. Johann GmbH & Co. KG, Research Brewery, St. Johann; both Germany

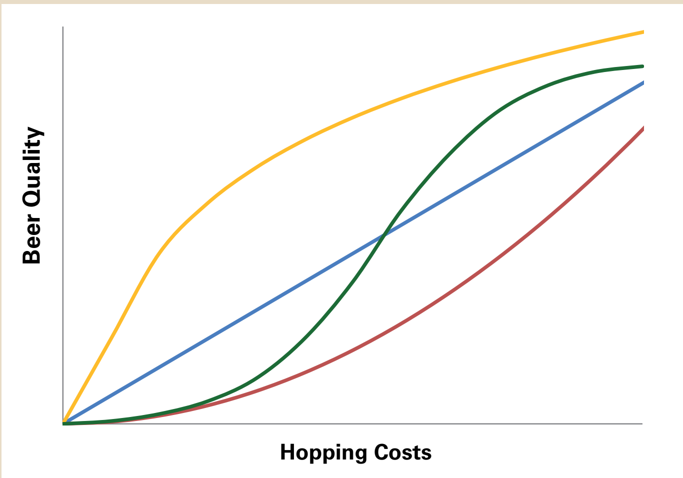


Fig. 1 Possible changes in beer quality as a function of hopping costs (schematic depiction)

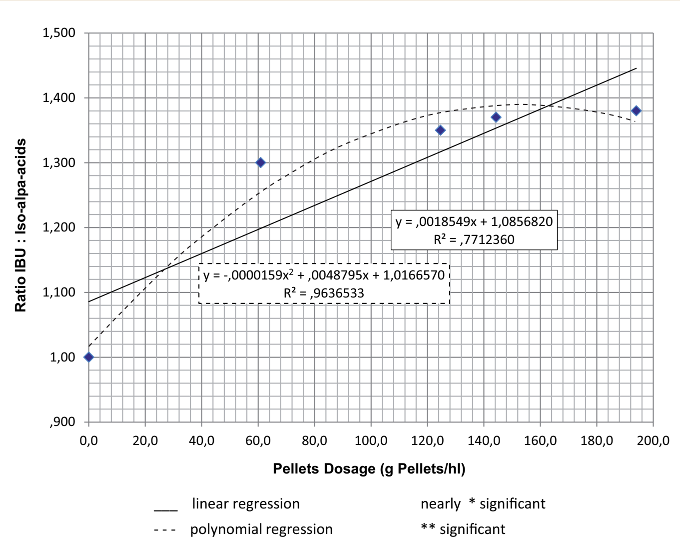


Fig. 2 Ratio IBU: Iso-alpha-acids in the beers as a function of pellets dosage

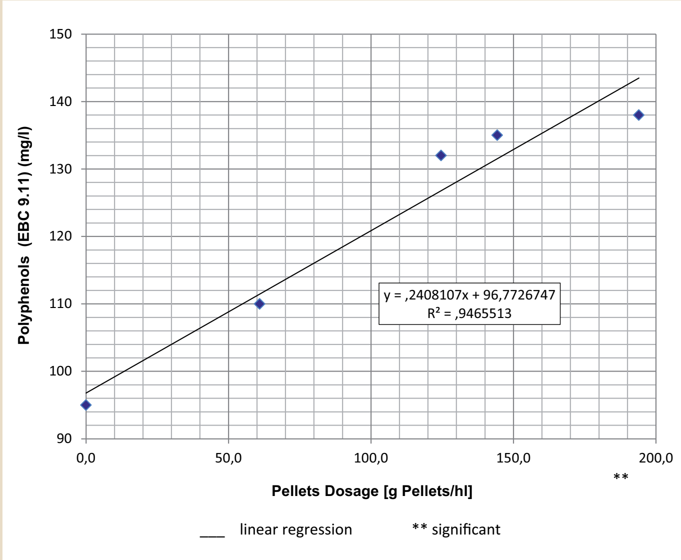


Fig. 3 Total polyphenols (EBC 9.11) in the beers as a function of pellets dosage

beers were hopped according to the following considerations:

- the hop doses at the end of boil (EB) or in the whirlpool (WP) are calculated based on the desired amount of linalool in the final beer (30 µg/l);
- hop doses at mid-boil (MB 1 = 30 min after begin boil, MB 2 = 30 min before end of boil) are calculated based on the desired levels of polyphenols in the final beer (20 mg/l);
- the required amount of additional bitterness results in the dosage of alpha-acids at the beginning of the boil (BB).

The following hop varieties and products were employed:

- Pre-isomerised extract (ISO);
- Herkules / pellets 90 (HHS);
- Hallertauer Tradition / pellets 90 (HHT);
- Tettnanger / pellets 90 (TTE);
- Saphir / pellets 90 (HSR).

The hopping of the 5 beers was carried out as depicted in table 1.

The costs for hopping are based on the current forward contract prices for the 2010 harvest and are given below in Euros per hectolitre:

- 0-Beer: 0.35 EUR/hl;
- Beer 1: 0.47 EUR/hl;
- Beer 2: 0.80 EUR/hl;
- Beer 3: 1.13 EUR/hl;
- Beer 4: 1.24 EUR/hl.

The hopping costs using solely pre-isomerised extract for bittering in the zero beer were 0.35 EUR/hl. If instead using Herkules pellets for bittering at begin boil, the cost is 0.38 EUR/hl at the current forward contract price or 0.20 EUR/hl at the current spot market price. This clearly demonstrates that pre-isomerised products do not necessarily reduce costs.

Results of the trials

Analytical results

Table 2 contains common beer analyses as well as some hop-relevant data. A standard HPLC-method (EBC, soon to be published) separates specific alpha- and iso-alpha-acids. The EBC method number 9.8 for bittering units is unspecific and results include, in addition to alpha- and iso-alpha-acids, other bittering compounds, that are hereafter referred to as accompanying bittering compounds. The ratio of bittering units (IBU) to iso-alpha-acids (HPLC) serves then as an indicator for the amount of accompanying bittering compounds that have been added. This ratio increases with the amount of pellets added, especially with aroma hop

HOPPING (IN G/HL)

	BB	MB 1	MB 2	EB	WP
0-Beer				ISO/10.4	
Beer 1	HHS/28.9			HHT/16.0	HHT/16.0
Beer 2	HHS/12.0	HHT/62.6		HSR/25.0	HSR/25.0
Beer 3	HHS/18.3	TTE/76.0		HSR/25.0	HSR/25.0
Beer 4	HHT/40.0	HHT/30.0	TTE/50.0		HSR/50.0

Table 1

BEER ANALYSES

		0-beer	Beer 1	Beer 2	Beer 3	Beer 4
Original Gravity	GG %	11.7	11.8	11.8	11.6	11.8
Apparent attenuation	%	80	75	80	76	79
pH		4.22	4.35	4.32	4.30	4.36
Colour	EBC	3.3	3.3	3.6	3.4	3.6
Iso-alpha-acids	mg/l	15.2	13.1	15.5	13.9	15.2
Alpha acids	mg/l	–	1.4	1.4	1.5	1.4
IBU (EBC)		15	17	21	19	21
IBU:Iso-alpha-acids		0.99	1.30	1.35	1.37	1.38
Polyphenols (EBC)	mg/l	95	110	132	135	138
Linalool	µg/l	6	30	54	58	72

Table 2

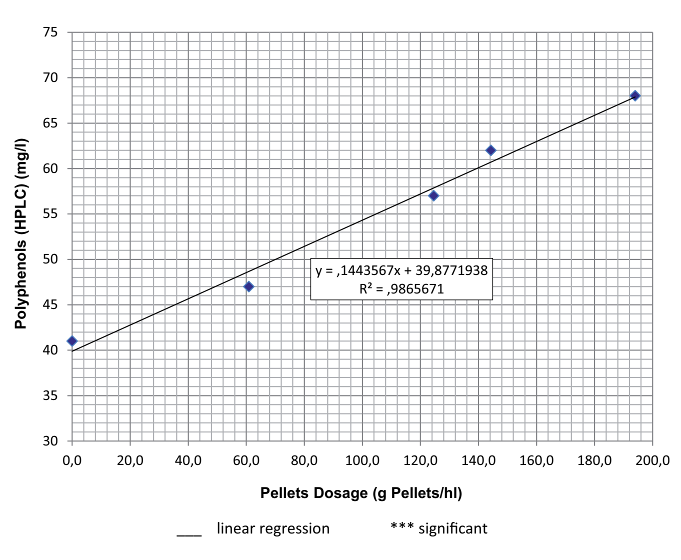


Fig. 4 HPLC-polyphenols in the beers as a function of pellets dosage

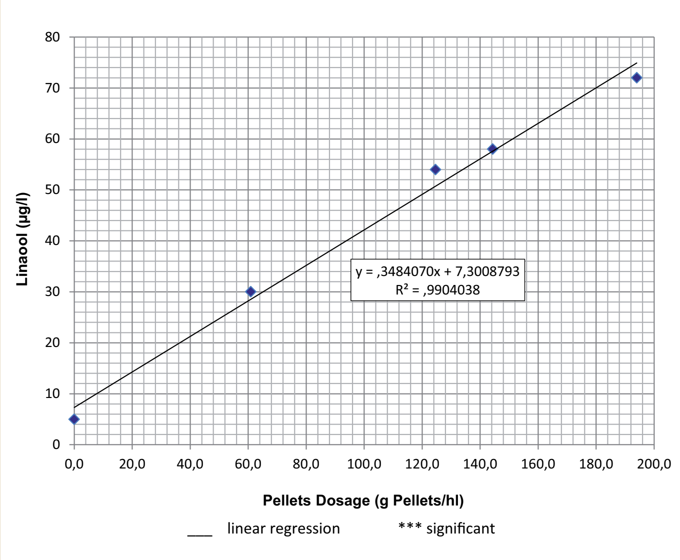


Fig. 5 Linalool content in the beers as a function of pellets dosage

pellets. Since aged hops are also responsible for an increase in accompanying bittering compounds, it is necessary to ensure a similar degree of freshness among different pellets when comparisons are being made. Two recent research projects (*Mitter* et al 2009, *Forster* 2009) determined a correlation between the amount of accompanying bittering compounds, expressed as the ratio IBU : iso-alpha-acids, and the quality and harmony of bitterness in different beers.

The ratios IBU : iso-alpha-acids plotted against the amount of pellets employed – using the data analysis functions of MS Excel 2007 – demonstrate, despite the small amount of data points, a clear dependency with good significance (Sachs, Statistische Methoden, Springer-Verlag, 1993).

The increase in accompanying bittering compounds as a function of pellets dosage is demonstrated in figure 2 and the path of the curve indicates that this ratio tends toward a saturation point, though this is only valid for fresh, properly stored pellets. The linear regression results in a lower coefficient of correlation than the polynomial regression, which achieves a ** significance.

Hops are rich in polyphenols, so a greater amount of hop pellets dosed will inevitably result in higher polyphenol levels in the beer. Figure 3 demonstrates the correlation between pellets dosage and the level of unspecific polyphenols (EBC method 9.11) in the 5 beers. Although only 5 data points are available, the linear regression achieves a ** significance.

Using a HPLC method in addition to the EBC method to determine low-molecular polyphenols in beer, 51 peaks could be identified and quantified. Table 3 contains the amounts of 12 different substances, some of which are only found in either malt or hops, and some of which are found in both.

The table also contains the sum of all quantifiable polyphenol compounds in the beers. These values are analogue to the unspecific polyphenols plotted against the pellets dosages in figure 4. A calculated linear regression achieves a ***significance.

SELECTED LOW-MOLECULAR POLYPHENOLS IN THE BEERS ...

... with identification of their origin from raw materials (H = hops; M = malt) (in mg/l)

Substance	Origin	0-Beer	Beer 1	Beer 2	Beer 3	Beer 4
Hydroxy benzoic acid	M	21	22	22	22	23
Procyanidine B3	M/H	1.5	2.0	2.2	2.5	2.4
Coffeeoylchinic acid	H	0.0	0.5	1.4	1.6	2.1
Catechin	M/H	2.2	3.3	4.6	5.7	5.8
Procyanidine B2*	M	1.7	1.2	1.3	1.3	1.2
Epicatechin	M/H	0.6	0.8	1.0	1.2	1.3
Ferulic acid	M	1.2	1.4	1.4	1.4	1.5
Peak 193	H	0.0	1.2	2.6	2.8	3.7
Peak 197 *	M	2.9	0.9	1.3	1.1	0.8
Quercitrineglycoside	H	0.0	1.0	2.6	3.6	4.3
Campherolglycoside	H	0.0	0.4	1.1	1.4	1.7
Isoxanthohumole	H	0.0	0.7	0.7	0.8	0.9
Sum of all HPLC- Polyphenols		41	47	57	62	68

** Significant decrease in the pellet beers compared to the 0-beer*

Table 3

TASTING RESULTS OF THE 73 HOP CONGRESS PARTICIPANTS

	0-Beer	Beer 1	Beer 2	Beer 3	Beer 4
Intensity of hop aroma	1.9	4.2	5.4	5.9	5.8
Fullness of body	3.5	4.7	5.3	5.6	5.6
Harmony of bitterness	4.0	5.4	5.5	5.9	5.5
Average	3.13	4.77	5.40	5.80	5.63

Table 4

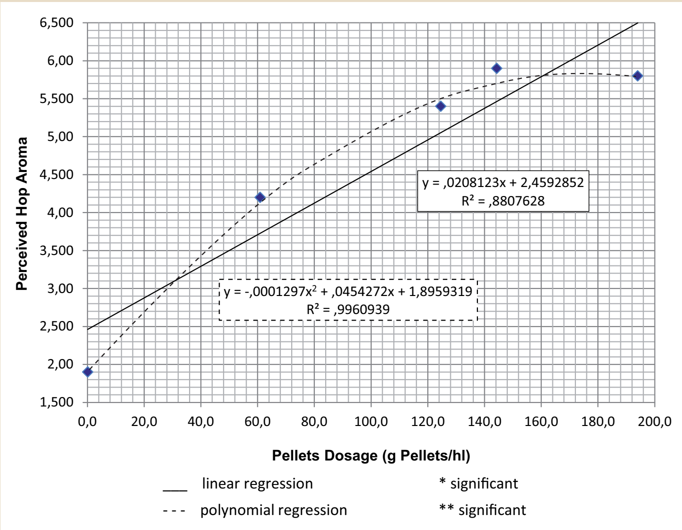


Fig. 6a
Perceived hop aroma as a function of pellets dosage

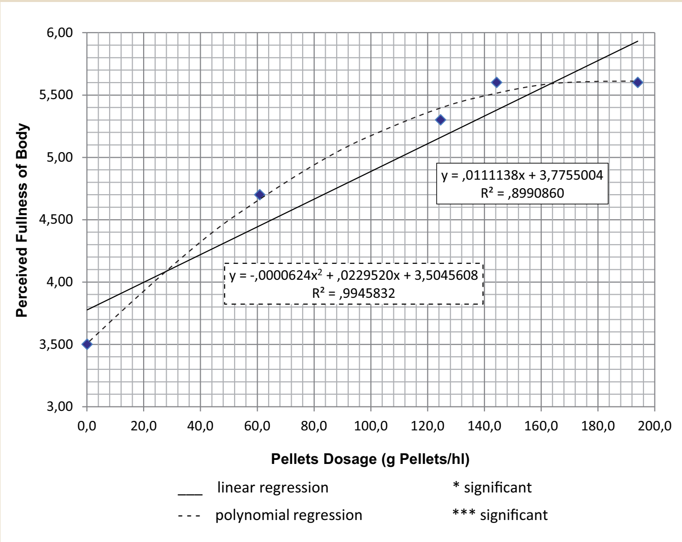


Fig. 6b
Perceived fullness of body as a function of pellets dosage

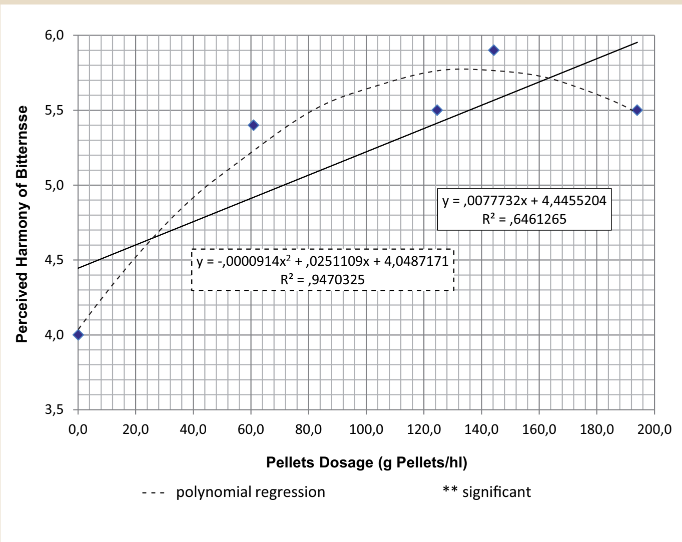


Fig. 6c
Perceived harmony of bitterness as a function of pellets dosage

Linalool is generally considered to be an indicator for perceivable hop aroma in beer. The 0-beer contains levels of 6 µg/l, which can be attributed to absorption from the yeast. The linalool levels in the 5 beers as a function of the amount of pellets dosed is depicted in figure 5 and demonstrates here also a clear ***significance.

Tasting results

All five beers were presented in a blind tasting to 73 participants at the hop congress in Tettnang, a heterogeneous group, among them schooled and experienced tasters as well as untrained, but critical and informed consumers. In light of this, the results are more interesting, perhaps even more valuable, than had the group been more homogeneous. Results of the tasting were evaluated immediately and presented to the group.

On a scale of 0 to 10 points (lowest to highest), tasters assessed the intensity of hop aroma, the fullness of the body of the beer, and the harmony of bitterness. Table 4 lists the average points for each of the characteristics and figures 6a, 6b, and 6c clearly demonstrate the relationship between the points for perceived aroma, fullness of body, and harmony of bitterness in the beers with respect to the pellets dosage.

In all three figures, the linear and polynomial functions of the three characteristics are plotted for comparison. Even if the polynomial calculations, under strict mathematical aspects, could give cause for some doubt, the results are quite compelling. The falling trends in the polynomial curves are a result of the calculations, though saturation without the drop is more probable. A linear regression demonstrates significance for both hop aroma and fullness of body despite the low number of data points. The significance that arises out of the polynomial regression is very clear.

For all 3 characteristics, there exist statistically sound differences between all pellet beers and the 0-beer as well as between beer 1 and all other pellet beers regarding hop aroma. Beers 3 and 4 set themselves apart from beer 1 in respect of hop aroma. One can only deduce tendencies between beer 2 and beers 3 and 4. In average points, beer 3 is somewhat better than beer 4, followed by beer 2. The difference between beer 3 and beer 1 is nearly one point, while the difference between beer 1 and the 0-beer is 1.64 points.

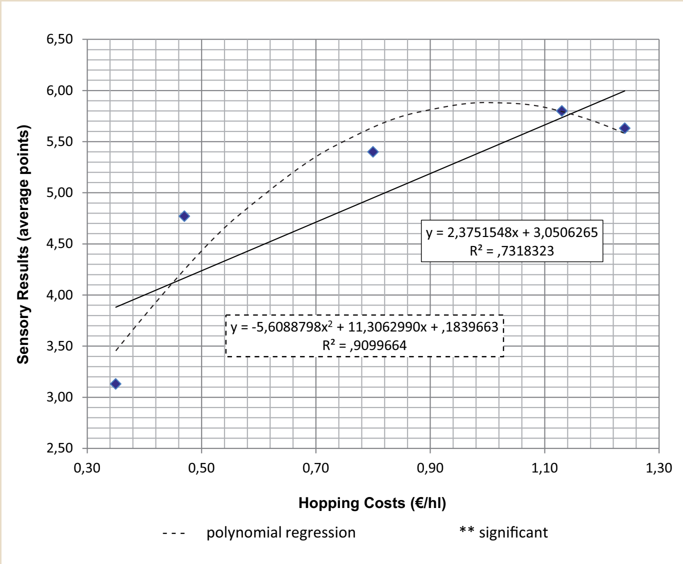
The results demonstrate that the seminar participants judged the use of aroma hop pellets to have a positive influence on the character of the beers. Figure 7 expands on this and displays the tasting results as a function of the hopping costs.

By using aroma hops, a flavour improvement can be attained even for a beer hopped for low bitterness, especially when used for middle and late dosages.

Interestingly, not only can the hop typical characteristics aroma and harmony of bitterness be improved, but also the fullness of body. Noteworthy is also the fact that, despite a bitterness 5 units higher than in the beers produced using pellets, the harmony of bitterness is judged to be better. Accompanying bittering compounds improve the quality of bitterness without increasing the intensity.

It is unavoidable that this little test series raises a number of additional questions, but the fact that middle and late aroma hop dosages can improve the flavour of a beer with low bitterness has been impressively demonstrated, though this effect is only clearly perceivable when large amounts of aroma hops are employed. Positive effects of aroma pellets added at begin boil could not be demonstrated in this series.

Fig. 7
Average points of sensory analysis of the beers as a function of hopping costs



Conclusion

The research brewery in St. Johann brewed 5 differently hopped beers with a neutral flavour base and low level of basic bitterness. Four of the beers were hopped using increasing amounts of aroma hop pellets. These beers were to be compared with a beer (0-beer) hopped using only small amounts of pre-isomerised extract. The amounts of total polyphenols (EBC method), low molecular polyphenols and linalool increased corresponding to the amounts of pellets dosed, as did the ratio of bittering units to iso-alpha-acids, a measure of positive accompanying bittering compounds. On August 21st, 2009, seventy-three participants of the First German Hop Congress in Tettnang assessed the 5 beers in a blind tasting, this chance mixed panel being composed of professional and experienced tasters as well as unschooled but critical consumers, a fact that lends more credence to the results.

The 0-beer for comparison was flawless, but through the addition of aroma hops, tasters found hop flavour characteristics such hop aroma and harmony of bitterness, as well as the atypical hop characteristic fullness of body to be markedly better. The professional sensory panel at the research brewery in St. Johann reached comparable conclusions. Again it must be noted that an atypical characteristic of hops, namely that of fullness of body, could be noticeably increased through the addition of aroma hops. It is also important to note that accompanying bittering compounds in aroma hops can raise the quality and the harmony of the bitterness without increasing its intensity.

A balance between aromatic and bittering compounds as well as polyphenols from aroma hops is consequently decisive in bringing about a higher sensory quality in beers, which is particularly valid when substantial rather than symbolic or homeopathic amounts of aroma hops are added. ■