A. Schmelzle, B. Lindemann and F.-J. Methner

Sensory Descriptive Analysis and Investigation of Consumer Acceptance of German Pilsner

To derive differences between German pilsner beers which have effects on acceptance, sensory description is linked to consumer acceptance. The sensory perception of pilsner beer is described by sensorily-trained consumers. For the pilsner type of beer, an appropriate number of representative and characteristic attributes are compiled for the precise description of sensory perceptions. By investigating acceptance by untrained consumers (n=142) in blind and open product tests, estimations of pilsner beers are measured. The results can highlight promising pilsner varieties and identify those which are sensorily unconvincing. In addition, split analyses are performed concerning consumers' objectives and sensory expectations. In the blind test, it was confirmed that consumers' acceptance of bitter pilsner (> 34 Bitterness Units, BU), leaving a coating mouthfeel, is lower than that of pilsner which is less bitter. If the brand name is known to consumers, they rate bitter pilsner (> 34 BU) with high acceptance. Additionally, pilsner varieties with an intense hop aroma and bitter pilsners (> 34 BU) are rated significantly better by consumers who drink beer for enjoyment. Consumers who state that they enjoy drinking a more bitter pilsner rate mild pilsners (< 20 BU) significantly lower. If consumers expect a hop aromatic pilsner, they also prefer these pilsner beers in blind taste tests.

Descriptors: pilsner, sensory evaluation, descriptive analysis, acceptance testing, bitter taste, hop aroma

1 Introduction

Pilsner is by far and away the variety of beer most loved by Germans. Pilsner beer has a market share of 55.5 %, which decreased 2.8 % in comparison to the previous year [1]. Overall, the demand for beer in Germany in terms of quantity has been continually decreasing since 1994. In 2010, the amount of beer per person was 102.1 litres [2]. The reasons for this development in beer consumption are the demographic factor on the one hand and changes in consumer behaviour on the other. Being increasingly price-oriented while at the same time showing a stronger appreciation of pleasure and quality, increased awareness of health, changing leisure behaviour and quest for individuality and exclusivity can all be observed in consumers. These trends pose a challenge to German breweries which they are taking on with innovations [3, 4].

The question arises as to which aspects are important to consumers of pilsner beer, and whether there are attributes of pilsner beer which have a greater bearing on consumer acceptance. These liking drivers are sensory attributes and can cause great changes in acceptance by small modifications. An accurate sensory description can reveal product differences and similarities and be used for pilsner brand positioning strategies. With the help of nuanced sensory profiles, a brewery can decide to set their pilsner as far apart from their competitors as possible or to imitate them [5].

The taste of pilsner is characterised by a strong bitterness caused primarily by the iso-alpha acids of the hops [6]. However, it is not only iso-alpha acid of hops which give the beer its bitter taste. Polyphenols from malt and hops, yeast autolysis, water quality, protein bitters or the aging of the beer can also influence its taste [7].

The bitter taste is considerably influenced by the real extract. At the same level of bitterness, highly fermented beers taste more bitter than those which are low fermented [8].

The perception of bitterness and the aftertaste associated with it can be described by the qualified and quantified taste, the intensity of the aftertaste and the persistence.

The aftertaste is an olfactory-gustatory stimulus, which is perceived after the product has been swallowed. Aftertaste is not limited to the taste alone. It can contain aromas, taste components and trigeminal perceptions in the oral cavity. The lasting effect of the aftertaste can be described as persistence. Persistence gives information about the chronological progress of the olfactory-gustatory perception. The perception that is to be determined chronologically appears when the food has been in the mouth and the stimulus remains for a measurable amount of time [9].

Apart from aromatic substances from malt and from the yeast metabolism, hops aromatic substances contribute to the smell and aroma of pilsner. Several hundred volatile components are identified in hops. The composition depends on the type [10]. *Schönberger* proposes an extensive collection of attributes for the description of hop aroma [11]. Individual sensory attributes can be assigned to

Authors

Dipl.-Ing. (FH) Annette Schmelzle, Prof. Dr.-Ing. Bernd Lindemann, Hochschule RheinMain, Fachbereich Geisenheim, Geisenheim, Germany; Prof. Dr.-Ing. Frank-Jürgen Methner, Technische Universität Berlin, Fachgebiet Brauwesen, Berlin; corresponding author: Annette.Schmelzle@hs-rm.de;

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Tables and figures see Appendix

particular hop aromas. A grassy and green smell is perceived from 1-Hexanal, (Z)-3-hexenal, (Z)-3-Hexen-1-ol amongst others. In particular, linalool and geraniol contribute to a flowery character. A citrus-like smell is provided by linalool and ethyl 3-methylbutanoate, ethyl 2-methylpropanoate amongst other compounds [12]. Myrcene, with a geranium-like smell, is a dominant component, in terms of quantity, in hop oil [13]. However, during boiling of the wort, myrcene is quantitatively removed [14].

Linalool is mentioned as an indicator substance for the hop aroma in beer [15]. Late addition of hops in the brew house quantitatively bring linalool and other aromatic substances to the beer [16].

Types of ester contribute to a fruity aroma. During fermentation, ester forms from organic acids and alcohols such as ethyl acetate (fruity, solvent-like), isoamyl acetate (banana, pear), phenyl ethyl acetate (roses, honey), ethyl caproate and ethyl caprylate (apple) [17].

Synergy effects with other aromatic substances may occur with hop aromas and esters. The sensory perception of dimethyl sulfide and diacetyl can be changed with linalool and ester [18]. The sensory effect of dimethyl sulfide (DMS) is described with the attribute of "boiled cabbage". DMS forms from S-methylmethionine, an amino acid in malt, and is largely eliminated during drying and boiling of the wort [19]. Additionally, dimethyl sulfoxide is reduced to DMS during fermentation with the involvement of proteins [20].

Diacetyl has a buttery smell and is produced by beer yeast from the intermediate metabolism product acetolactate. Diacetyl is responsible for the aroma of newly-fermented beer, amongst others. Its concentration drops during maturing [19].

Kaneda determined emotional changes during the olfactory perception of hop aroma and ester via brainwave measurements. He was able to prove that linalool and geraniol produce a relaxing effect. This also applies to a mixture of esters from ethyl acetate and isoamyl acetate [21].

In Germany, bitterness units of pilsner beer are generally between 21 and 42 BU. *Kunze* assumes that bitterness units of pilsner have decreased due to consumer preferences [19]. Investigations have shown that bitterness units of pilsner in Germany have, on average, not changed in decades [22, 23]. *Thalacker* disagrees with this. He arrives at the conclusion that bitterness in pilsner has decreased and that pilsner varieties which contain more than 30 BU have reduced [24]. If the quantity of sales of pilsner is incorporated into the investigation, a statement can be made regarding the iso-alpha acids which are actually consumed.

A consumer study in which pilsner and lager beers were rated demonstrates that bitter beers are not preferred in any region in Germany. Moreover, every sixth consumer disliked a long-lasting aftertaste. Concerning the preference of hop aroma, consumers are divided [25].

Despite this, the intensity of consumption of beer, alcohol and other bitter substances has no effect on the perception and acceptance of bitter tastes [26].

Behrendt und Sommer account for men's preference for bitter beers as a need to express their masculinity. Should men prefer a less-bitter beer, they become conflicted, as they do not want to be branded as softies [27].

If consumers rate not only the basic product but also the complete product with the factors of marketing, packaging, price and communication, judgement of the total quality may interfere with perception of individual characteristics. Here, individual product characteristics such as taste are rated as being better because of the brand's image [28].

In particular, multi-sensual brand communication in which several senses are appealed to may augment consumers' perception of the value of the brand [29].

The brand image of strong brands is frequently characterised by emotional impressions and images. *Esch* demonstrated in a study that well-known and powerful brands activate regions of the brain which signify positive emotions. By contrast, unknown or weak brand names stimulate brain regions which evoke negative emotions [30].

The purchase decision nevertheless takes place neither rationally nor emotionally, but rather on the basis of goals. Consumers make their decision on the basis of anticipated rewards or desired conditions. The fundamental and obvious basic features are to connect with and communicate the exciting features which distinguish a product from the competition [31].

First and foremost, pilsner beer must taste good. Beyond this, other basic objectives of consumers must be fulfilled. Pilsner beer acts as a thirst quencher and an intoxicant and is drunk for pleasure and relaxation.

2 Materials and methods

2.1 Sensory descriptive analysis

12 panel members are selected from a group of 30 for the sensory descriptive analysis of pilsner varieties. The eligibility criteria are expressive linguistic abilities, sensory sensitivity according to DIN 10961 [32] and the recognition of sensory attributes. The panel members are trained consumers. Their training is conducted with smell- and taste-recognition tests, threshold tests, simple descriptive tests and the scaling of different sensory attributes.

For the development of language for describing pilsner, meaningful sensory attributes with corresponding reference substances are compiled, using individual descriptions of 21 samples. 18 attributes (Table 1) are selected for the profile test according to frequency distribution and after consultation with the panel.

The profile test of the 21 pilsner varieties is carried out in the sensory analysis laboratory of the Geisenheim Research Centre. The test room is designed in accordance with DIN 10962 [33]. For the sessions, tulip-shaped tasting glasses were used according to ISO 3591 [34]. The glasses are filled with 50 ml of beer for

sensory assessments. The beer samples were brought to a drinking temperature of 10 °C.

For the profile tests, the beers are coded and tasted according to a randomised test plan. The tests are administered monadically in sequence, i.e., the tester evaluates only one beer and has no direct comparison. Before each succeeding beer, bread and water are consumed to neutralise the taste. The profile tests are repeated three times on different days and the beer tests coded with new numbers. The intensity of the 18 specified attributes is assessed on a verbally-based 11-point scale from „not noticeable“ to „very strong“.

The 21 pilsner beers (Table 2) are beers which are commercially declared with the description „pilsener“, „pilsner“ or „pils“. The pilsner varieties which are studied exhibit bitterness units of 18.3 to 36.2 BU. The real extract content of the beers which are studied is between 3.43% and 5.32 % by wt.

The evaluation of the profile tests takes place using statistical evaluation procedures, such as analysis of variance, multiple average comparisons and principal component analysis. In this way, a sensory profile is compiled for each product which reveals the objectively-existing intensities of all sensory characteristics and is reproducible at any time. The results are represented as a biplot of the principal component analysis because of the large number of attributes and tests. The biplot of the principal component analysis illustrates sensory similarities and differences between the individual pilsner varieties and provides an overview of the sensory perceptions of the beer samples tested [35]. Additionally, the connection between sensory attributes is established in order to determine which expressions are used by the tasters in parallel or independent of one another. Attributes which are in direct proximity to one another correlate with each other. If the attributes are presented in opposite directions in the biplot, then a negative correlation exists [36].

Additionally, the connection between the sensory perception of bitter taste and the bitterness units of the pilsner varieties is investigated.

2.2 Investigation of consumer acceptance

For the investigation of acceptance, eight products are selected to represent the sensory groups from the 21 pilsner varieties. For the acceptance investigation, 142 consumers who correspond to the target group are recruited via telephone from a databank. The target group are beer consumers. In order to make a statement regarding the preferences of women and men as well as older and younger consumers, attention is paid to an even distribution of genders and age groups during recruitment.

Additionally, during the consumer test the coded beer samples are administered monadically in sequence according to a randomised test plan in sampling glasses, in order to avoid context effects.

Acceptance is compiled first without and then with knowledge of the brands. The time difference between the tests amounts to one week. In the second meeting the test subjects receive information about the brands, packaging and price which they would normally encounter at the point of sale (Figure 1). Four well-known and four unknown brands from different price ranges (Table 3) are used.

In both tests, initial sensory impressions are used to investigate acceptance. The consumers are asked about their overall impression. To quantify the acceptance parameters, a nine-point scale is used to make distinctions. For compiling the intensity of the bitter taste, a five-point „just about right“ scale is employed.

For performing split analyses, data concerning age, gender and intensity of consumption is gathered. The consumers are asked about the objectives of their beer consumption. Here, they must provide information concerning whether they like drinking pilsner beer as a thirst quencher, for pleasure or for relaxation, and whether they enjoy the feeling of being intoxicated. Additionally, the test subjects are asked to indicate whether a pilsner must be bitter for them and whether they expect an intensive hop aroma.

For the investigation of acceptance, average values for each individual product are initially generated and investigated for significant differences. Furthermore, split analyses for particular sub-groups (gender, age, intensity of consumption, consumption objectives and sensory expectations) and the comparison of the average acceptance values of the blind test and of the aggregate product test with the single-factor analysis of variance (ANOVA) are performed [35].

To ascertain whether there are certain sub-groups within the complete random sample of test participants who differ distinctly in their acceptance behaviour, k-means cluster analysis is used. With this method, potential market niches for heavily-accepted products can be identified for particular target groups [35].

The evaluation of the bitterness using the five-point „just about right“ scale is made with the corresponding frequency of the five possible designations. A penalty analysis supplies additional information as to whether the bitterness influences the acceptance rating and, if so, to what extent [5, 35].

The correlation analysis records the connection between the sensory consumer acceptance and sensory attributes of the profile test.

3 Results and discussion

3.1 Sensory descriptive analysis

The results of the sensory descriptive analysis are summarized in table 1 and show the product's F-value and the significance level which demonstrates whether the products differ significantly from each other ($p < 0.05$). The pilsner beers demonstrate a significant difference in the attributes “lemon”, “apple”, “rose”, “onion”, “boiled cabbage”, “vanilla”, “smoky”, “butter”, “bitter”, “sweet”, “umami”, “aftertaste” and “persistence” and can be repeatedly described with these attributes.

Table 4 shows the effect relationship between the pilsner attributes. With help of factor analysis, the variety of attributes can

be combined and can contribute to the discovery of descriptive variables which amongst themselves are independent. In this way, the panel members use the attributes „lemon“, „apple“ and „rose“ to describe the hop aroma. The attributes „boiled cabbage“, „onion“, „smoky“ and „umami“ correlate negatively. The strong combination of the bitter taste, the intensity of the aftertaste and of the persistence shows that the panel members also evaluate bitter beers similarly in terms of the effect of the aftertaste. The attribute „sweet“ correlates negatively to this. The Attributes “vanilla” and “butter” are combined with the sweet taste.

The values of the individual pilsner beers are presented in a biplot (Figure 2) in regard to the descriptive variables formed. The closer the pilsner varieties are positioned towards the attributes, the stronger these products are marked by these attributes. Pilsner beers which are positioned in direct proximity to each other exhibit similar sensory characteristics. The pilsner varieties can be assigned to four different sensory groups: very bitter pilsner varieties, mild pilsner varieties, pilsner varieties with hop aroma and pilsner varieties without hop aroma.

Pilsner beers no. 13 (27.8 BU) and no. 18 (29.2 BU) and particularly samples no. 3 (36.2 BU) and 4 (33.9 BU) are distinguished by a very bitter taste and an intense and long-lasting aftertaste. Pilsner no. 4 is, however, hoppier in its smell and aroma compared to sample no. 3.

In contrast, the pilsner varieties no. 6 (18.3 BU) no. 14 (24.6 BU) and no. 15 (21.6 BU) demonstrate a lower intensity in bitter taste and aftertaste. The smell and aroma are similarly unpronounced.

The pilsner beers no. 1, no. 11, no. 16 and no. 20 and especially no. 5, no. 7 and no. 19 are marked by hop aroma. Of the pilsner beers with an intense hop aroma, pilsner no. 5 (27.8 BU) exhibits a bitter taste and pilsner no. 7 exhibits a sweet taste.

In contrast, samples no. 2, no. 8, no. 9, no. 10, no. 12, no. 17 and no. 21 are assigned to the sensory group of „pilsner varieties without hop aroma“.

A strong connection exists between the bitterness units analysed and the sensorily-quantified bitter taste. The greater the number of bitterness units of the pilsner, the more intense the bitter taste is. The sensorily-perceived bitterness is determined up to 70 % by the bitterness units measured (Table 5).

3.2 Investigation of consumer acceptance

142 beer consumers were invited to the test. Of those who took part in the test, 44 % (n = 63) were female and 56 % (n = 79) were male. The age distribution of the beer consumers who took part in the study is presented in table 6. 71 % of the consumers came from (Western) Central Germany, 15 % from Southern Germany, 7 % from Eastern Germany and 7 % from Northern Germany. 74 % of the participating consumers drink pilsner once a week or more. 26 % of the participants consume pilsner once a month or less.

The pilsner beers which were selected and evaluated by the consumers represent the individual sensory groups which were investigated by the sensory description. The following products are tasted in the consumer test:

- Very bitter pilsner varieties: no. 3 and no. 4 (with intense hop aroma);
- Mild Pilsner varieties with little aftertaste and little flavour and smell: no. 6;
- Pilsner varieties without hop aroma: no. 2 and no. 8;
- Pilsner varieties with hop aroma: no. 1;
- Pilsner varieties with intense hop aroma: no. 5 (bitter) and no. 7 (not bitter).

Table 7 shows the average values of acceptance of the pilsner varieties from all consumers who took part in the test, as well as the results of the pair comparisons of averages (Duncan Test 5 %) of the blind and open taste tests. The Duncan Test measures which product groups differ in the consumer acceptance (identification with letters).

Pilsner varieties no. 3 and 4 were preferred less in the blind taste test, i.e., pilsner beers with > 34 BU were not favoured by consumers compared to pilsner varieties with < 28 BU. However, consumers do not prefer a particular smell for pilsner in blind taste tests.

When consumers evaluate the complete product, acceptance of pilsner beers no. 3, 4 and 8 differs significantly from the values in the blind taste test. Pilsner varieties no. 3 and 4 were evaluated significantly better according to their extrinsic features than in the blind taste test. The low price of product no. 8 led to consumers evaluating this pilsner variety with a low product quality. Acceptance of pilsner no. 2 tended to improve because of its extrinsic features.

A very strong connection exists between consumer acceptance and the sensory features of bitter taste, aftertaste and persistence. The worse the pilsner was evaluated by the test participants, the more intense the bitterness, the aftertaste and the persistence were. Consumer acceptance is determined up to 69 % by these sensory features (Table 8).

Figures 3 and 4 show the investigation of the complete random sampling of certain sub-groups who differ markedly in their acceptance behaviour. In the blind taste test, pilsner varieties no. 4 and 7 are preferred markedly less by cluster 1 than by cluster 2. For pilsner 1, the opposite effect can be noticed. These pilsner varieties were accepted quite differently within the consumer group because of their sensory characteristics. Pilsner varieties no. 4 and 7 have a very intense hop aroma.

If the consumers know the brand, cluster 2 rate the strong well-known brands better than the unknown and well-known weak brands.

Figures 5 and 6 show the evaluation of the bitter taste. The consumers perceive the intensity of the bitter taste. In the blind test, the pilsner varieties which had 34-36 BU (no. 3 and 4) were largely evaluated in their bitterness as much too strong. The consumers

repeatedly evaluated the bitterness of pilsner no. 6 (18 BE) as „too weak“. Nevertheless, this pilsner was preferred. The penalty analysis revealed a significant difference between the acceptance average of the test participants who rated pilsner no. 4 as „just right“ and that of the test participants who rated the product as „too bitter“ or „much too bitter“ (Table 9). For Pilsner no. 3 and in the open taste test, the bitterness did not significantly influence the acceptance rating.

Regarding intensity of consumption and gender, there is no significant difference in the acceptance of pilsner beer.

The individual age groups rate the pilsner beers in the blind taste test similarly. If older consumers (age 40 and older) knew the brand, they rated pilsner no. 3 in their acceptance significantly better than 16- to 39-year-old consumers.

Regarding the objectives associated with pilsner beer, different assessments of acceptance were shown by the consumer groups (Table 10).

Consumers who drink pilsner beer for pleasure rated products no. 3, 4, 5 and 7 in the blind taste test significantly better than consumers who do not do this. These beers were pilsner varieties with an intense hop aroma or pilsner with a very bitter taste.

If consumers like drinking beer for relaxation, they rated the very bitter pilsner no. 3 and the pilsner no. 7 with an intense hop aroma and a high real extract significantly better.

Consumers who enjoy the effect of intoxication in pilsner beer rate the pilsner varieties no. 4 and 7 significantly better than consumers who state that they do not do this.

There is no difference in evaluating acceptance between consumer groups who declare that they drink pilsner beer in order to quench their thirst and those who do not do this.

Consumers who are of the opinion that a pilsner beer must taste bitter did not rate the bitter pilsner varieties (> 34 BU) better than those consumers who did not agree with that statement. Pilsner varieties with hop aroma, however, are rated significantly better by this consumer group. The mild pilsner beer, no. 6, was rated significantly worse by consumers who claim to prefer bitter pilsner varieties (Table 11). If this consumer group evaluated the beers with knowledge of the brand, they rated the bitter pilsner varieties no. 3 and 4 significantly better. Both pilsner varieties were known to the consumers as bitter.

If the consumers stated that they expected an intense hop aroma from pilsner beer, they rated the pilsner varieties no. 1, 3, 4 and 7 in the blind taste test significantly better than consumers who did not desire this. The pilsner beers no. 1, 4 and 7 also possess this sensory feature. By contrast, beer no. 3 has a strongly bitter taste and less of a hop aroma. Nonetheless, it can be assumed that the consumer does not distinguish between a bitter taste and a hop aroma. In the open taste test, this consumer group rated pilsner no. 3, known to be a very bitter beer, significantly better.

4 Conclusion – summary

4.1 Sensory description

The pilsner beers which were investigated represented a selection of products offered on the market. The sensory descriptive analysis, however, shows a sensory diversity of German pilsner beers. Nuanced profiles can be created with the attributes compiled for pilsner beers. Additionally, the individual pilsner varieties can be placed according to their sensory characteristics into groups of very bitter pilsner varieties, mild pilsner varieties, and pilsner varieties with and without hop aroma. The majority of the pilsner varieties exhibit a taste with a medium level of bitterness (approx. 25 BU +/–5). Only a few products demonstrate a distinctive hop aroma, a mild character or a very bitter taste (> 34 BU). These sensory characteristics permit the brand to be positioned far from its competitors instead of imitating them. The sensory description provides the basis for product development and the decision for a „points of difference“ or „points of parity“ strategy.

4.2 Consumer acceptance

It was confirmed that consumers in blind tests do not prefer strongly bitter pilsner varieties (> 34 BU) with an intense aftertaste and long persistence. If the brand name is known to the consumers, they evaluate the bitter pilsner varieties (> 34 BU) accordingly with a high rate of acceptance. As such, the very bitter pilsner beers have succeeded in staking out a good position in the market with their distinction from competitors and the right communication of outstanding importance for consumers. The ideal situation is one in which as many consumers as possible regard their sensory perception of a variety of pilsner as being very good and in which the pilsner variety can score additional points with its extrinsic features. In what way the extrinsic features influence the hedonic evaluation of the sensory profile of a product is made clear by inexpensive pilsner beers. The low price suggests to the consumer a less-valuable product.

The observation by *Guinard* that the intensity of consumption has no influence on the acceptance of bitter taste was confirmed. Test participants who consume pilsner once a week or more did not rate the beer significantly differently than test participants who drink pilsner once a month or less.

Similarly, gender and age have no influence on the acceptance values.

By contrast, the sensory expectation of the product does have an influence on the evaluation of acceptance. Consumers who claim to enjoy drinking a bitter variety of pilsner evaluate mild pilsner varieties (< 20 BU) significantly less favourably. If the connoisseurs of bitter pilsner beer know the brand in the test, they evaluate the bitter pilsner varieties significantly better. Because of the communication of a bitter taste, the consumer can orient themselves.

Those consumers who expect a pilsner with hop aroma also prefer these pilsner beers in the blind taste test. Because of their product experiences with pilsner, consumers have developed a mindset towards pilsner. The test participants evaluate the pilsner

depending on how the comparison of the anticipated and actual satisfaction turns out.

Consumers also evaluate pilsner differently based on their goals. Pilsner varieties which are endowed with an intense hop aroma or a strong bitterness are rated significantly better by consumers who drink beer for pleasure. This demonstrates that certain sensory features aid certain customer goals.

Good consumer acceptance provides a good basis for reasoning in negotiations with sales agents. Because of changes in consumer behaviour, developments observed in acceptance must be checked in the course of time.

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Appendix

Table 1 Terms and References

Sensory Dimensions	Term	Comp. F	Sig. p	References
Odour and Aroma	**Lemon**	4.49	<0.0001***	Linalool
	Apple	3.24	<0.0001***	Ethyl 2-methyl butyrate
	Rose	5.43	<0.0001***	Geraniol
	Geranium	0.84	0.6671	Myrcen
	Freshly-cut grass	0.89	0.5983	(Z)-3-hexen-1-ol
	Onion	2.39	0.0006***	Onion
	Boiled Cabbage	4.29	<0.0001***	Dimethyl sulfide
	Vanilla	4.12	<0.0001***	Vanillin
	Malt	0.94	0.5325	Pilsner Malt
	Smoky	2.50	0.0003***	Guaiacol
	Butter	3.05	<0.0001***	Diacetyl
Taste	**bitter**	7.69	<0.0001***	Iso-α-acid
	sweet	3.11	<0.0001***	Saccharose
	sour	0.97	0.5014	Citric acid
	umami	2.65	0.0001***	Monosodium glutamate
Mouthfeel	**Aftertaste**	7.27	<0.0001***	
	Persistence	6.83	<0.0001***	

Table 2 Chemical-technical Analysis of Pilsner samples

Product No.	**Original gravity** % by wt	**Alcohol** % by wt	**Alcohol** % by v	**Extract, real** % by wt	**Extract, apparent** % by wt	**Final attenuation** %, % by v	**Density** sL20/20	**Bitter-units** BU	**pH**
1	11.89	4.10	5.23	3.93	2.03	83.55	1.00793	26.0	4.50
2	11.15	3.88	4.94	3.59	1.79	84.49	1.00700	23.6	4.33
3	11.39	3.97	5.06	3.67	1.83	84.57	1.00712	36.2	4.19
4	11.11	3.65	4.66	4.00	2.3	80.01	1.00898	33.9	4.45
5	11.89	3.97	5.07	4.18	2.35	80.99	1.00917	27.8	4.47
6	11.83	4.11	5.24	3.85	1.95	84.12	1.00762	18.3	4.41
7	11.48	3.17	4.07	5.32	3.84	72.72	1.01505	24.0	4.43
8	11.13	3.76	4.79	3.81	2.07	82.08	1.00807	23.7	4.55
9	11.33	3.97	5.06	3.6	1.76	85.08	1.00685	23.5	4.33
10	11.40	3.98	5.07	3.66	1.82	84.67	1.00708	27.6	4.45
11	11.38	4.09	5.2	3.43	1.54	86.99	1.00600	20.9	4.22
12	11.23	3.86	4.92	3.71	1.92	83.54	1.00748	27.5	4.37
13	11.24	4.03	5.13	3.39	1.52	86.99	1.00593	27.8	4.44
14	11.44	3.70	4.73	4.42	2.52	78.71	1.00986	24.6	4.67
15	11.35	3.91	4.98	3.75	1.94	83.56	1.00756	21.6	4.40
16	11.74	4.11	5.23	3.77	1.87	84.64	1.00731	27.0	4.44
17	11.68	3.48	4.46	4.90	3.3	72.64	1.01293	30.0	4.62
18	11.38	3.94	5.02	3.72	1.89	83.98	1.00739	29.2	4.40
19	11.04	3.91	5.89	3.44	1.71	84.53	1.00669	18.5	4.34
20	11.39	3.73	4.76	4.14	2.41	79.61	1.00940	21.3	4.24
21	11.14	3.69	4.71	3.95	2.23	80.66	1.00871	23.5	4.48

Table 3 Product information at the informed test

Product No.	Brand	Packaging Item * L	Price per Crate	Price per Liter
1	unknown	20 * 0.5	13.40 €	1.34 €
2	well-known	20 * 0.5	14.99 €	1.50 €
3	well-known	20 * 0.5	12.79 €	1.28 €
4	well-known	24 * 0.33	10.99 €	1.33 €
5	unknown	20 * 0.5	13.49 €	1.35 €
6	unknown	24 * 0.33	12.79 €	1.55 €
7	unknown	24 * 0.33	13.49 €	1.63 €
8	well-known	20 * 0.5	5.99 €	0.60 €

Table 4 Factor loading and communality of terms rotated component matrix

Term	component			
	1	2	3	4
Lemon			.826	
Apple			.759	
Rose			.629	
Geranium	.620			
Freshly-cut grass	.699			
Onion	.670			
Boiled Cabbage	.564			
Vanilla				.661
Malt	.527			.522
Smoky	.702			
Butter				.761
bitter		.838		
sweet				.632
sour	.623			
umami	.535			
Aftertaste		.892		
Persistence		.820		

Table 5 Pearson's correlation between bitter units and sensorily-quantified bitter taste

Attribut	Explained variation R^2	Sig. p	Coefficient R
Bitter	0.70	0.000	0.835

Table 6 Age distribution of consumers at the blind test

Age group* Gender Contingency table

Age group		Gender		
		Female	Masculine	Total
16-25	Number	15	17	32
	% of total number	10.6 %	12.0 %	22.5 %
26-39	Number	18	25	43
	% of total number	12.7 %	17.6 %	30.3 %
40-55	Number	19	23	42
	% of total number	13.4 %	16.2 %	29.6 %
56+	Number	11	14	25
	% of total number	7.7 %	9.9 %	17.6 %
Total	Number	63	79	142
	% of total number	44.4 %	55.6 %	100.0 %

Table 7 Mean Values of Acceptance (brand unknown and known)

	Mean	Groups	Mean	Groups	Std. Dev.	Std. Dev.	Tests of Between-Subjects Effects	
Product	**brand unknown**	**Duncan 5%**	**brand known**	**Duncan 5%**	**brand unknown**	**brand known**	**Sig. p**	**Partial Eta-Quadrat**
Pilsner 1	5.91	A	5.61	BC	1.82	1.76	0.200	0.007
Pilsner 2	5.87	A	6.32	A	2.00	1.72	0.070	0.014
Pilsner 3	**4.92**	B	**5.92**	AB	1.91	1.72	**0.000**	**0.067**
Pilsner 4	**4.88**	B	**5.94**	AB	2.05	1.85	**0.000**	**0.066**
Pilsner 5	5.56	A	5.39	BC	1.86	1.97	0.497	0.002
Pilsner 6	5.94	A	5.66	BC	1.75	1.89	0.225	0.006
Pilsner 7	5.54	A	5.47	BC	2.10	1.99	0.822	0.000
Pilsner 8	5.79	A	**5.28**	C	1.95	1.85	**0.044**	**0.017**

Table 8 Pearson‘s correlation between acceptance and sensory terms

Attribut	Explained variation R^2	Sig. p	Coefficient R
Bitter	0.68	0.012	–0.822
Aftertaste	0.70	0.009	–0.837
Persistence	0.68	0.011	–0.826

Table 9 Data for penalty analysis, pilsner no. 4 (brand unknown)

Consumer`s reaction to bitter taste of pilsner no. 4	**% of sub-groups**	**Number of sub-groups**	**Mean value of acceptance**	**Sig. p**
very much too weak, too weak	10	14	4.93	-
just about right	32	46	6.13	0,05
too bitter, very much too bitter	58	82	4.17	
Total	100	142	4.88	

Table 10 Split analyses for consumption objectives

Product No.	**Mean value Relaxation**		**Sig.**	**Mean value Pleasure**		**Sig.**	**Mean value Intoxication**		**Sig.**
	No	**Yes**	**p**	**No**	**Yes**	**p**	**No**	**Yes**	**p**
1	5.65	6.06	0.207	5.94	5.90	0.919	5.90	5.94	0.926
2	6.10	5.74	0.314	5.91	5.86	0.916	5.83	6.03	0.618
3	**4.48**	**5.18**	**0.036**	**3.91**	**5.22**	**0.001**	4.88	5.06	0.641
4	4.62	5.03	0.243	**3.78**	**5.20**	**0.000**	**4.64**	**5.74**	**0.008**
5	5.38	5.67	0.384	**4.84**	**5.77**	**0.012**	5.51	5.74	0.546
6	5.87	5.99	0.686	6.06	5.91	0.663	5.99	5.77	0.543
7	**4.69**	**6.02**	**0.000**	**4.37**	**5.87**	**0.000**	**5.33**	**6.26**	**0.030**
8	5.60	5.90	0.373	5.13	5.98	0.058	5.77	5.87	0.792
Number	52	90		32	110		111	31	
% of total number	37	63		23	77		78	22	

Table 11 Split analyses for sensory expectations

Product No.	Mean value		Sig.	Mean value		Sig.
	Expected bitter taste			Expected hop aroma		
	No	Yes	p	No	Yes	p
Brand unknown						
1	5.73	6.28	0.090	**5.62**	**6.30**	**0.028**
2	6.01	5.60	0.246	5.91	5.82	0.783
3	4.79	5.19	0.239	**4.64**	**5.30**	**0.043**
4	4.72	5.21	0.174	**4.52**	**5.36**	**0.015**
5	5.37	5.96	0.075	5.33	5.87	0.089
6	**6.15**	**5.53**	**0.048**	5.85	6.07	0.472
7	**5.18**	**6.26**	**0.004**	**5.00**	**6.25**	**0.000**
8	5.75	5.87	0.721	5.81	5.75	0.855
Brand known						
1	5.70	5.43	0.461	5.49	5.78	0.435
2	6.25	6.46	0.569	6.10	6.65	0.120
3	**5.52**	**6.66**	**0.001**	**5.42**	**6.65**	**0.000**
4	5.69	6.40	0.660	5.71	6.28	0.137
5	5.39	5.40	0.982	5.51	5.23	0.485
6	5.83	5.34	0.223	5.64	5.68	0.937
7	5.50	5.43	0.865	5.42	5.55	0.758
8	5.34	5.17	0.659	5.39	5.13	0.487
Number	95	47		81	61	
% of total number	67	33		57	43	

Fig. 1 Product information at the informed test

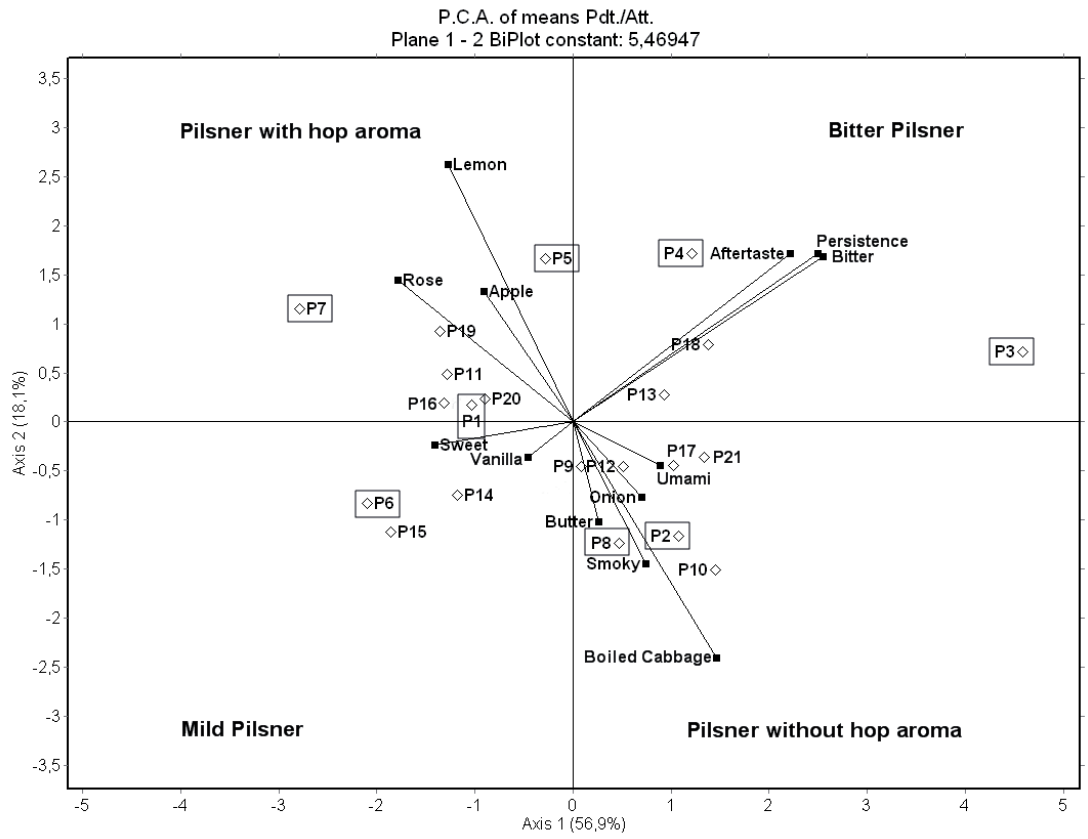

Fig. 2 Biplot of the principal component analysis

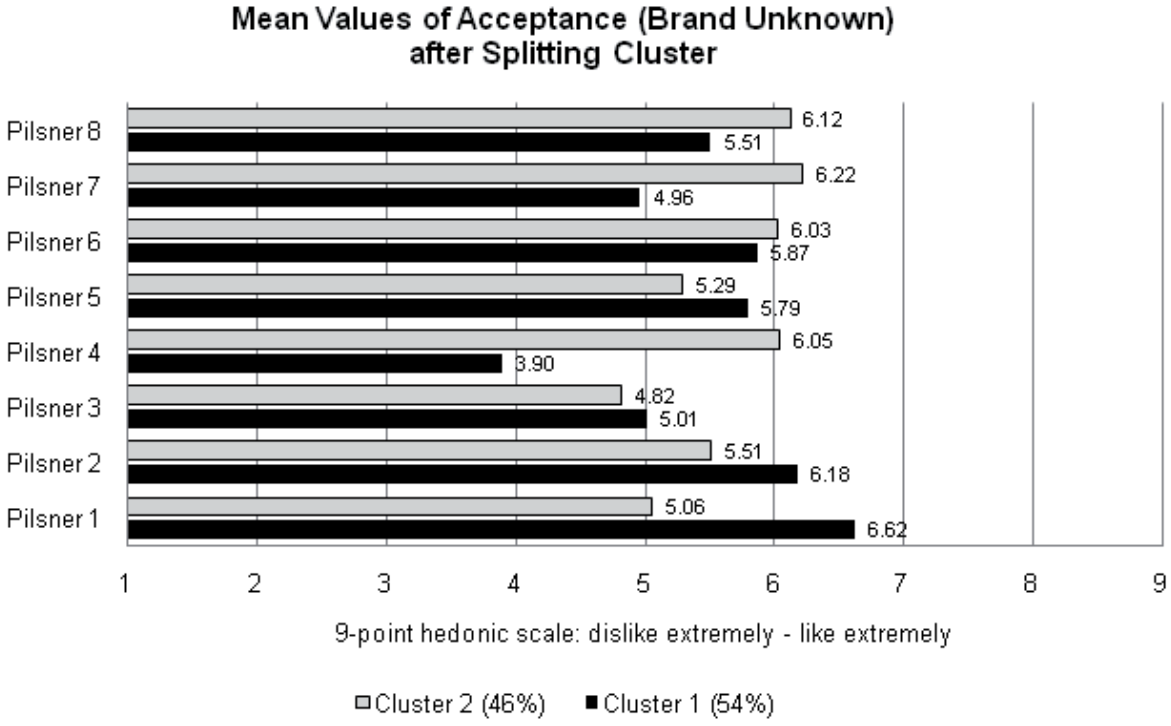

Fig. 3 K-means cluster analysis (brand unknown)

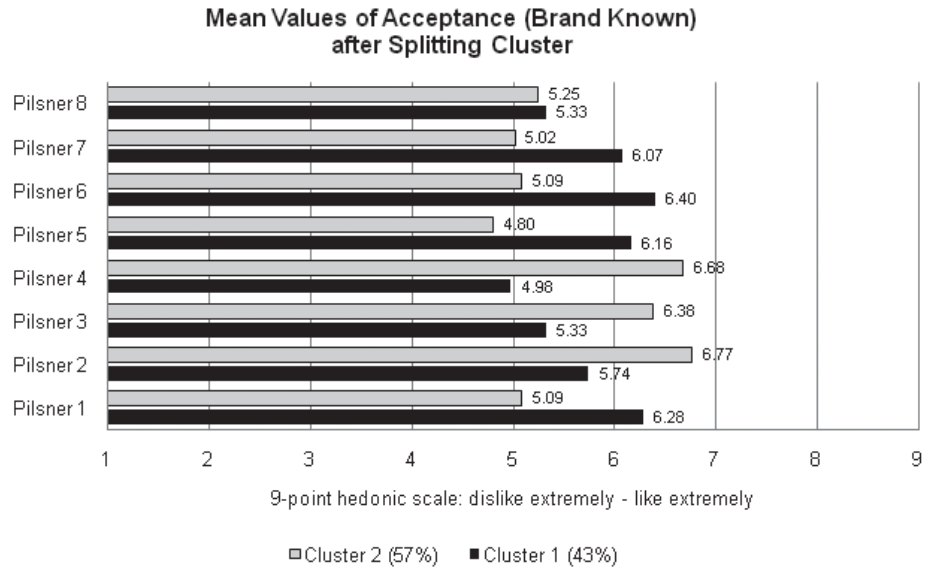

Fig. 4 K-means cluster analysis (brand known)

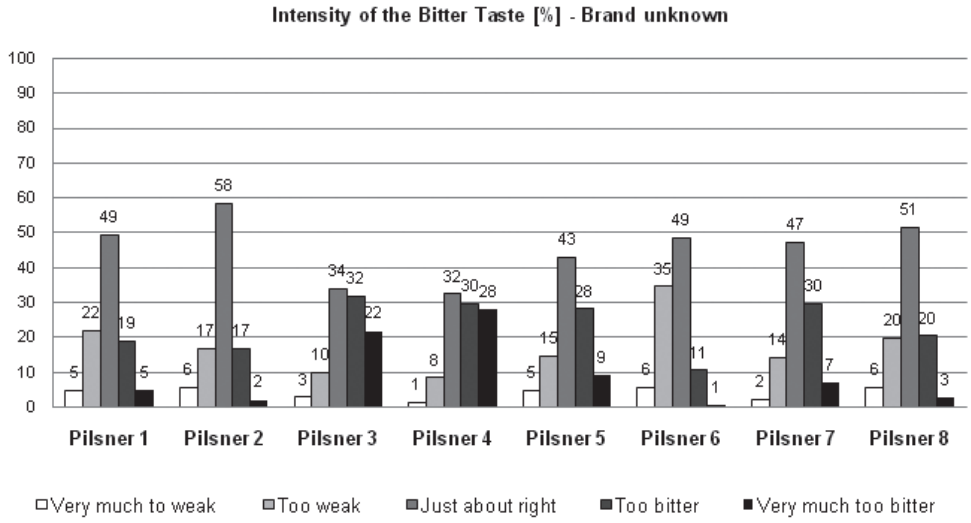

Fig. 5 Intensity of the bitter taste, brand unknown

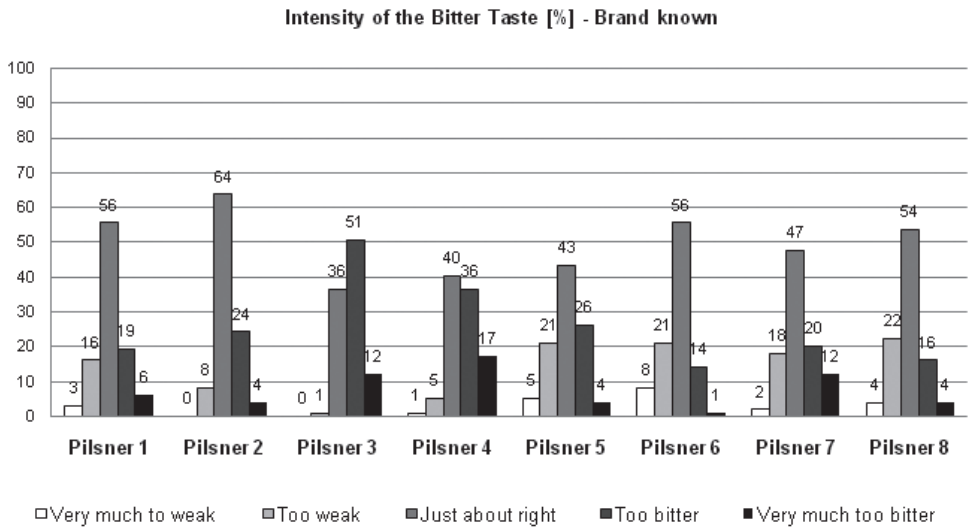

Fig. 6 Intensity of the bitter taste, brand unknown