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Sensory Descriptive Analysis and Investigation of Consumer Acceptance of Bavarian Wheat Beer

The purpose of this research on wheat beer was to identify the most important acceptance-causing sensory attributes for wheat beer. For this reason, specific attributes were developed and 18 wheat beers were analysed in a sensorily descriptive format. The determination of acceptance was achieved by testing products in the target group (n=148). Twelve wheat beers were evaluated, which were chosen for their sensory properties. By linking sensory description and acceptance values, significant attributes for wheat beer that are responsible for acceptance were detected. Subsequently, split analyses based on gender, age and consumption intensity were performed. Wheat beers can be described using twenty sensory terms, which demonstrates that there is great product diversity. Wheat beers indicate different sensory qualities: fruity, non-fruity, bitter and mouth-coating, tingly or sweet and creamy. Wheat beers with a creamy mouthfeel were preferred by consumers, while bitter and non-fruity-smelling wheat beers were not well-liked. In investigating the acceptance of various sub-groups, it was discovered that women had a greater preference for wheat beers with a creamy mouthfeel than did men. In comparison to younger beer consumers, consumers over the age of 40 showed no differentiation in their acceptance of wheat beers. On the other hand, beer drinkers under 40 years preferred “creamy” wheat beers with a banana-like odour. Wheat beers with an above-average rating for the attribute “banana” were significantly more often preferred amongst consumers who drink wheat beer two to three times a month or more than by consumers who drink wheat beer only once a month or less.

Descriptors: wheat beer, sensory descriptive analysis, acceptance testing, mouthfeel, ester, creaminess

1 Introduction

In Germany, wheat beer is produced with at least 50% wheat malt and is a top-fermented beer with an original gravity between 11 and 13%. Cited as important acceptance characteristics for wheat beer are a high carbon dioxide content (more than 6 g/L) and the typical wheat beer flavour. A typical wheat beer flavour is expressed by a high content of esters and higher alcohols (fusel alcohols) and phenolic compounds [1]. With wheat beers different flavour types are described: estery, phenolic, yeasty, and neutral [2].

Types of esters contribute to a fruity aroma. During fermentation, esters are formed from organic acids and alcohols such as ethyl acetate (fruity ore solvent-like odour), isopentyl acetate (banana or pear odour), phenyl ethyl acetate (roses or honey odour), ethyl caproate and ethyl caprylate (apple odour) [3]. Isopentyl acetate is mentioned as an indicator substance for a pleasant fruity odour in wheat beer [4].

A hoppy flavour is usually not pronounced in wheat beer. Individual sensory attributes can be assigned to particular hop aromas. In particular, linalool and geraniol contribute to a flowery odour. A citrus-like odour is provided by linalool, ethyl 3-methylbutanoate and ethyl 2-methylpropanoate amongst other compounds [5]. Linalool is mentioned as an indicator substance for the hop aroma in beer [6]. Late addition of hops in the brewing process increase linalool and other aromatic substances in beer [7].

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 esters [8]. The sensory effect of dimethyl sulfide (DMS) is described with the attribute of “boiled cabbage”. DMS is produced from S-methylmethionine, an amino acid in malt, and is largely eliminated during kilning of malt and boiling of the wort [1]. Additionally, with the involvement of pro-

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teins, dimethyl sulfoxide may be reduced to DMS during fermentation by certain yeast strains [9].

Diacetyl has a buttery smell and is produced by beer yeast from the intermediate metabolism product acetolactate. Diacetyl is responsible among other things, for the aroma of young beer. Its concentration drops during maturation [1].

During the primary fermentation and in small batches, during the storage phase, higher aliphatic alcohols such as isoamyl alcohols (3-methylbutanol and 2-methylbutanol), 2-methyl-propanol and 1-propanol are formed. Approximately only 15% of the higher alcohols make up the aromatic alcohols. An important representative of this is 2-phenylethanol, which at a concentration of 15 mg/L gives off a rose-like odour [10]. Among the higher aliphatic alcohols, the isoamyl alcohols emanate a malty odour; 2-methyl-propanol smells like alcohol and the sensory sensation of 1-propanol is described as “numbing”. High concentrations of higher aliphatic alcohols have a strong pungent and fusel like odour, while low concentrations cause a fruity odour [11].

The phenolic compounds are produced by top-fermenting yeast strains, which are able to decarboxylate phenolic acids, derived from malt. The clove-like smelling 2-methoxy-4-vinylphenol (4-vinylguaiacol) is formed from ferulic acid, the phenolic, medicinal, astringent and bitter 4-vinylphenol is formed from p-coumaric acid and the sweet-smelling styrene is formed from cinnamic acid [12, 13, 14, 15]. A longer mashing process and temperatures between 45 to 50 °C help to dissolve the phenolic compounds. Cinnamic acid can be minimized through an acidification of mash (pH-value: 5.2-5.4) [16]. In the aging process of wheat beer, the content of isopentyl acetate and 2-methoxy-4-vinylphenol, inter alia, decreases [17].

The yeasty odour of wheat beer should be neutral and without sulphury or yeast autolysis-notes or bitter aftertaste [1]. Various esters and sulphur compounds are among the pleasant-smelling yeast flavour components. Medium-chain fatty acids (billygoat-like or rancid odour), short-chain fatty acids (cheesy or sweaty odour) and higher alcohols such as heptanol (earthy odour) play a role in the odour of autolysed yeast [2].

In respect of the variety “Hefeweizen”, yeast autolysis is another step in the aging process. The presence of the short-chain fatty acid, isovaleric acid, is an indicator of yeast autolysis, during which a sweaty, cheesy odour is released [17]. Other acids involved in this process include medium-chain fatty acids such as octanoic acid, which has a billygoat odour and decanoic acid, which has a rancid smell [18, 19].

The bitter-tasting compound content of wheat beer is characteristically listed as having 10-14 Bitter Units (BU) [20] and 10-20 BU [10]. In yeast containing wheat beers, after a certain aging, a “yeasty bitterness” may occur. This is accompanied by increased levels of fatty acids such as hexanoic, octanoic and particularly of

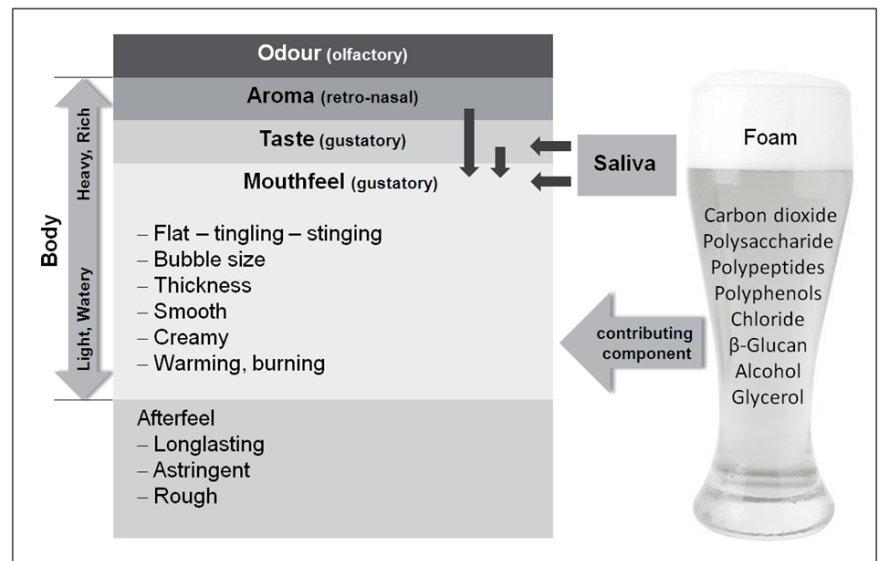


Fig. 1 Mouthfeel of beer

decanoic acids. Likewise, some esters and higher alcohols may create a bitter taste sensation [20, 21].

Wheat beer is commercially offered as filtered or unfiltered (cloudy). Among the wheat beers studied, only unfiltered products were analysed. Yeast with a particle size of 5-8 µm temporarily contribute to a beer's cloudiness through shaking. Substances such as proteins, polyphenols, and starch fragments with a particle size below 1 µm produce a stable haze [1].

The mouthfeel of beer makes an important contribution to the overall sensory perception. In particular, cloudy wheat beer offers more mechanical stimuli for tactile sensation through its high CO₂ content and its particles. The mouthfeel of beverages can be described with a variety of sensory attributes. Szczesniak [22] classifies 35 mouthful attributes into 11 categories in this context. The attributes “smooth” and “creamy”, for example, are assigned to the “feel of soft tissue surfaces” group. Lynch and Bamforth [23] define creamy mouthfeel with CO₂ bubble formation, which also continues during the consumption of beer. The activity of the bubble formation, the surface tension, the density and CO₂ concentration affect the intensity of this creamy mouthfeel. Langstaff et al. [24] defined nine sensory attributes which make up the mouthfeel of beer: sting, bubble size, foam volume, total CO₂, density, viscosity, oily mouthcoat, astringency and stickiness. With reference to viscosity, humans can perceive differences of 1 mPa*s and particles smaller than 5 µm can be sensed if they are hard and edged. For soft and round particles, particles of 80 µm are discernable [25]. At 20 °C, beer viscosity is between 1.5 to 2.2 mPa*s [20].

Langstaff and Lewis [26] cite a number of substances that may contribute to the mouthfeel of beer: foam, carbon dioxide, polypeptides, polyphenols, dextrans, chlorides, β-glucan, glycerine and alcohol. In addition, arabinoxylan is cited as a substance that has an impact on the mouthfeel [27]. Diacetyl from 0.6 mg/L and dextrin from 50 g/L contribute to the mouthfeel, however, these are higher levels than those usually found in beer. [26]. Odour and taste substances also contribute to the perception of texture [29]. For example, a creamy mouthfeel influences a sweet taste [30]. In addition, the flow

of saliva alters the sensory properties of foods and beverages [22]. A beverage's body is described by the dipolar attributes of light/heavy or watery/rich. Besides the haptic sensation, body includes the smell and taste sensation. Figure 1 shows an overview of the sensory attributes for the mouthfeel and substances that may contribute to the mouthfeel of beer.

The average age of wheat beer consumers in Germany is 44.9 years. By comparison, consumers of Pilsner beer are on average 47.8 years. Of the wheat beer consumers, 6% are under the age of 20 and the group of 20-39 year-olds wheat beer consumers is 33%. The proportion of 40-49 year-olds is 24%; for consumers aged 50 and older, 37%. Of wheat beer consumers, 25% are female and 75% male [31]. The frequently encountered assertion that women prefer sweeter beers could not be confirmed in a qualitative study by Birklbauer [32].

In particular, the sensitivity to the sour and bitter taste qualities diminishes with age [33, 34]. In addition, the olfactory sense in terms of odour detection decreases at an advanced age. More than half of adults 65 to 80 years-old, indicate a clear weakness in their olfactory sensory function. In those over 80 years of age, this impairment is observed in approximately 75% [35]. The influence of age on the identification, differentiation, and the stimulus threshold for fragrances is confirmed by Markovic et al. [36]. In addition, people over 60 show a differentiated assessment of the intensity and acceptance of different fragrances, as compared to younger adults. Age also has an influence on the evaluation of texture. Younger people in general and women in particular perceive the texture of foods more intensely [37, 38].

2 Materials and methods

2.1 Sensory descriptive analysis

The sensory perception of wheat beer was described by 19 sensorily-trained consumers. The eligibility criteria were sensory sensitivity according to DIN 10961 [39] and the recognition of sensory attributes. Their training was conducted with smell- and taste-recognition tests, taste-threshold tests, simple descriptive tests and the scaling of different sensory attributes.

For the development of language to describe wheat beer, meaningful sensory attributes with corresponding reference substances were compiled, using individual descriptions of 18 samples. 20 attributes (Table 1) were selected for the profile test according to frequency distribution and after consultation with the panel.

Table 1 Attributes and references

Sensory Dimension	Attribute	Comp. F	Sig. p	References
Odour and Aroma	Banana	4.84	<0.0001***	Isopentyl acetate
	Apple	2.71	<0.0001***	Ethyl hexanoate
	Lemon	3.35	<0.0001***	Linalool
	Artificial fruit	4.30	<0.0001***	Isopentyl acetate
	Clove	5.34	<0.0001***	2-Methoxy-4-vinylphenol
	Rose	2.24	0.0015**	Geraniol
	Yeast	2.60	<0.0001***	Yeast
	Butter	2.80	<0.0001***	Diacetyl
	Lactic acid	2.54	<0.0001***	D,L-Lactic acid
	Boiled Cabbage	4.41	<0.0001***	Dimethyl sulfide
Taste	Sweat/Billygoat	3.37	<0.0001***	Isovaleric acid, Caprylic acid
	Sour	2.99	<0.0001***	Citric acid
	Sweet	6.50	<0.0001***	Sucrose
Mouthfeel	Bitter	6.57	<0.0001***	Iso- α -acid
	Tingly	8.32	<0.0001***	
	Bubble size	1.72	0.039*	
	Thick	2.85	<0.0001***	
	Smooth	2.42	0.0011**	
	Creamy	3.05	<0.0001***	
	Mouthcoating	3.47	<0.0001***	

The profile test of the 18 wheat beer varieties was carried out in a sensory analysis laboratory. The test room was designed in accordance with DIN 10962 [40]. For the sessions, tulip-shaped tasting glasses were used according to ISO 3591 [41]. The glasses were filled with 50 ml of beer. The beer samples were then brought to a drinking temperature of 12 °C and the beers were tasted without foam.

During the profile tests, the beers were coded and tasted according to a randomised test plan. The tests were administered monadically in sequence, i.e., the tester evaluates only one beer and has no direct comparison. The profile tests were repeated three times on different days and the beer tests were coded with new numbers. The intensity of the 20 specified attributes was assessed on a verbally-based eleven-point scale ranging from "not noticeable" to "very strong".

The evaluation of the profile tests took 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. 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 wheat beer varieties and provides an overview of the sensory perceptions of the beer samples tested [42]. Additionally, the connection between sensory attributes was examined in order to determine which expressions were used by tasters in parallel or independent of one another. Attributes which are in direct proximity to one another correlate with

Table 2 Instrumental analysis of wheat beer samples

Product	Original gravity	Alcohol	Alcohol	Extract, real	Extract, apparent	Final attenuation	Density	Bitter Units	pH
No.	% by wt	% by wt	% by v	% by wt	% by wt	%, % by v	sL20/20	BU	
Mean [1,9]	12.20	4.12	5.26	4.22	2.33	80-85		17.0	4.32
Mean _{W1-18}	12.38	4.19	5.35	4.28	2.34	81.80	1.00916	13.2	4.41
Min.	11.81	3.51	4.50	3.83	1.80	69.62	1.00702	7.4	4.27
Max.	12.97	4.59	5.84	5.48	3.85	86.38	1.01511	19.5	4.75
W1	12.69	4.46	5.69	4.07	2.02	84.76	1.00787	15.7	4.25
W2	12.97	4.38	5.59	4.53	2.52	81.35	1.00985	9.5	4.25
W3	11.67	3.96	5.05	3.98	2.15	82.28	1.00838	11.9	4.52
W4	11.57	3.84	4.90	4.11	2.33	80.60	1.00909	12.7	4.44
W5	12.77	4.59	5.84	3.92	1.82	86.38	1.00709	10.5	4.67
W6	11.59	4.02	5.12	3.78	1.92	84.06	1.00749	19.3	4.17
W7	12.87	4.51	5.75	4.18	2.11	84.31	1.00823	14.5	4.50
W8	12.50	4.10	5.25	4.58	2.69	79.32	1.01050	10.0	4.38
W9	12.80	4.14	5.29	4.82	2.91	78.12	1.01139	19.5	4.42
W10	12.61	4.24	5.41	4.43	2.48	81.12	1.00968	11.0	4.29
W11	12.48	4.40	5.61	3.97	1.95	85.03	1.00760	14.0	4.43
W12	12.60	4.24	5.41	4.41	2.46	81.22	1.00962	14.7	4.34
W13	12.72	4.15	5.31	4.70	2.78	78.94	1.01089	13.0	4.75
W14	12.35	4.40	5.61	3.83	1.80	86.02	1.00702	14.8	4.49
W15	12.61	4.39	5.60	4.13	2.11	83.95	1.00824	16.0	4.60
W16	12.26	3.51	4.50	5.48	3.85	69.62	1.01511	7.4	4.29
W17	11.98	4.14	5.28	3.96	2.04	83.61	1.00797	11.3	4.27
W18	11.81	3.98	5.08	4.09	2.25	81.69	1.00877	11.5	4.35

each other. If the attributes are presented in opposite directions in the biplot, then a negative correlation exists [43].

Additionally, the connection between the sensory perception of bitter taste and the bitterness units of the wheat beer was investigated.

2.2 Investigation of consumer acceptance

For the study of acceptance, 12 products were selected to represent the different sensory groups from the 18 wheat beer varieties. For the acceptance investigation, 148 consumers, who represented the target group, were recruited via telephone from a database. The target group was made up of beer consumers. To examine the preferences of women and men as well as older and younger consumers, attention was paid during recruitment, to having an even distribution of participants in terms of gender and age.

Additionally, in order to avoid context effects during the consumer test, the coded beer samples were given to participants monadically in sequence, according to a randomised test plan.

The initial sensory impressions were used to investigate acceptance. The consumers were asked about their overall impression.

To quantify the acceptance parameters, a nine-point scale was used to make distinctions.

To perform split analyses, data concerning age, gender and intensity of consumption was gathered.

To investigate acceptance, average values for each individual product were initially generated and examined for significant differences with the factor analysis of variance and the Duncan Test. Furthermore, split analyses for particular sub-groups (gender, age, intensity of consumption) were performed with the single-factor analysis of variance [42].

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

2.3 Wheat beers used in this study

Table 2 shows the chemical-physical analysis of the data for the 18 wheat beers used in this study. It also shows the normal average values of the chemical-physical analysis for wheat beers [1, 9]. The samples have an original gravity ranging from 11.81 to 12.97% by weight and are within normal values for wheat beer. The alcohol content of the wheat beer samples is between 4.5 to 5.8 ABV. This also corresponds to the normal values for this beer

Table 3 Component loading and communality of attributes / rotated component matrix

rotated component matrix					
component					
Attribute	1	2	3	4	5
Banana	0.531	0.390	-0.010	0.272	-0.181
Apple	0.709	0.240	0.030	0.174	0.130
Lemon	0.695	0.131	-0.023	0.062	0.277
Artificial fruit	0.744	0.046	-0.069	-0.058	0.075
Clove	0.123	0.409	0.022	0.535	0.038
Rose	0.678	0.118	0.078	0.152	0.001
Yeast	0.331	0.439	0.265	0.369	0.139
Butter	0.178	0.203	0.595	0.045	-0.108
Lactic acid	0.024	0.040	0.717	-0.003	0.187
Boiled cabbage	-0.090	0.091	0.784	0.059	0.104
Sweat/billygoat	-0.154	0.156	0.726	0.157	0.153
Sour	0.106	0.099	0.022	0.471	0.443
Sweet	0.319	0.578	0.292	0.274	-0.232
Bitter	0.259	-0.096	0.424	-0.019	0.517
Tingly	0.131	0.010	-0.032	0.655	0.224
Bubble size	0.044	-0.194	0.257	0.689	-0.128
Thick	0.091	0.575	0.028	0.329	0.433
Smooth	0.234	0.778	0.250	-0.066	0.082
Creamy	0.134	0.791	0.085	-0.164	0.162
Mouthcoating	0.132	0.258	0.277	0.142	0.682

KMO-Value: 0.8249

Table 4 Age distribution of test participants

Age group* Gender Contingency table				
Age group		Gender		
		Female	Masculine	Total
16-25 years	Number	9	20	29
	% of total number	6.1%	13.5%	19.6%
26-39 years	Number	21	32	53
	% of total number	14.2%	21.6%	35.8%
40-55 years	Number	25	22	47
	% of total number	16.9%	14.9%	31.8%
56+ years	Number	7	12	19
	% of total number	4.7%	8.1%	12.8%
Total	Number	62	86	148
	% of total number	41.9%	58.1%	100.0%

type. Sample no. 16 is striking because of its high real extract and a low final attenuation. Additionally, it also displays a very low level of bitter substances. By contrast wheat beers nos. 6 and 9 show a high level of bitter substances.

3 Results

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 wheat beers demonstrate a significant difference in 11 attributes for odour and aroma, in 3 attributes for taste and 6 attributes for mouthfeel.

Table 3 shows the effect relationship between the wheat beer attributes. With the help of a principal component analysis, the variety of attributes can be combined and can contribute to the discovery of descriptive variables which amongst themselves are independent. The rotated component matrix is a matrix of the component loadings for each variable onto each component. Component loadings more than 0.4 are printed in bold letters.

In this way, the panel members used the attributes "banana", "apple", "lemon", "artificial fruit" and "rose" to describe a fruity and bloomy aroma. The attributes "sweat", "billygoat", "boiled cabbage", and "lactic acid" show another component. In connection with these attributes, bitter taste sensation and the attribute "butter" were used. A bitter taste and a coating mouthfeel go together with a sour taste. The sweet taste and the smooth, creamy and thick mouthfeel form another component. The sensation "thick" was perceived in both bitter and mouthcoating beers as well as in sweet and creamy beers. The attribute "clove" was used with the attribute "yeast" and also with the attributes "sweet", "creamy", "smooth" and "thick". Sometimes it was used with the sour and tingling sensations.

The values of the individual wheat beers are presented in a biplot (Figure 2) according to the descriptive variables formed. The closer the wheat beer varieties are positioned towards the attributes, the stronger these products are marked by these attributes. Wheat beers which are positioned in direct proximity to each other exhibit similar sensory characteristics. The individual wheat beer varieties can be assigned to four different sensory trends: bitter and mouthcoating, sweet and creamy, fruity and non-fruity varieties.

Wheat beers nos. 7 and 17, and in particular no. 1, were characterised by their fruity odour and thick mouthfeel. In addition, all three wheat beers have a clove odour. Wheat beer no. 1 was judged more intense in the attributes "apple", "lemon" and "rose".

Wheat beer no. 9 was also judged with fruity attributes and the attribute "clove" similar to the fruity wheat beers. The taste however is sourer and bitterer by comparison.

In terms of odour, sample no. 10 has low values for the attributes "banana" and "clove". The panellists strongly assessed it for the attributes "lemon", "apple" and "rose". These attributes describe a hoppy odour such as the panellists for Pilsner beers are familiar with [44]. The panellists also detected a slight lactic acid and sweaty odour. For that reason, sample no. 10 assumes a position in the biplot between the fruity and non-fruity wheat beers.

Wheat beers nos. 2 and 8 have a creamy mouthfeel. Moreover,

wheat beer no. 2 has an intense banana and yeast odour. The taste is sweet and the mouthfeel, in addition to being described as creamy, is also described as thick and smooth. Wheat beer no. 16 in comparison to all other samples is very sweet.

The position of wheat beer no. 3 is due to strong ratings for the attributes "banana", "yeast", "lactic acid", "butter", "thick" and "tingly". In terms of odour, beer no. 18 presents characteristics in line with the average. Rated as below average are its bitter taste and tingly sensation.

With wheat beers nos. 4, 5 and 12, fruity attributes were less perceived by the panellists. Sample no. 4 has a below average rating in the attributes "rose", "clove" and "artificial fruit" and is characterised by a slight sweaty note. The odour of beer no. 12 is characterised by the attributes "lactic acid", "boiled cabbage" and "sweat". Sample no. 5 has an intense odour of yeast and boiled cabbage. Wheat beers nos. 6, 11, 13, 14 and 15 are characterised by their bitter or sour taste.

A strong connection exists between the bitter units analysed and the bitter taste. The greater the number of bitter units of the wheat beer, the more intense is the bitter taste ($p=0,000$, $R=0,870$, $R^2=0,757$). Sensorily-perceived bitterness is determined up to 75.7% by the bitter units measured (Figure 3).

3.2 Consumer acceptance

148 beer consumers were invited to the test. Of those who took part in the test, 42% ($n=62$) were female and 58% ($n=86$) were male. The age distribution of the beer consumers who took part in the study is presented in Table 4.

The 12 wheat beers which were selected and evaluated by the consumers represent the individual sensory groups which were investigated by the sensory description. Figure 4 shows the average values of acceptance of the wheat beer varieties from all consumers who took part in the test, as well as the results of the pair comparisons of averages (Duncan Test 5%). The Duncan Test measures which product groups differ in the consumer acceptance (identification with letters).

The creamy wheat beer varieties nos. 2 and 8 were preferred. With its additional fruity odour, sample no. 2 was furthermore unanimously favoured by the test participants. Very fruity wheat beers with a hop aroma, bitter wheat beers and wheat beers with an odour of yeast autolysis were not favoured by consumers.

Table 5 shows the connection between consumer acceptance and the sensory features. A connection exists between consumer acceptance and the sensory features of the sweet taste, the creamy mouthfeel and the odour of fresh yeast. With higher intensity of perceived sweetness, creaminess and yeasty odour, evaluations by the test participants were more favourable. The consumers'

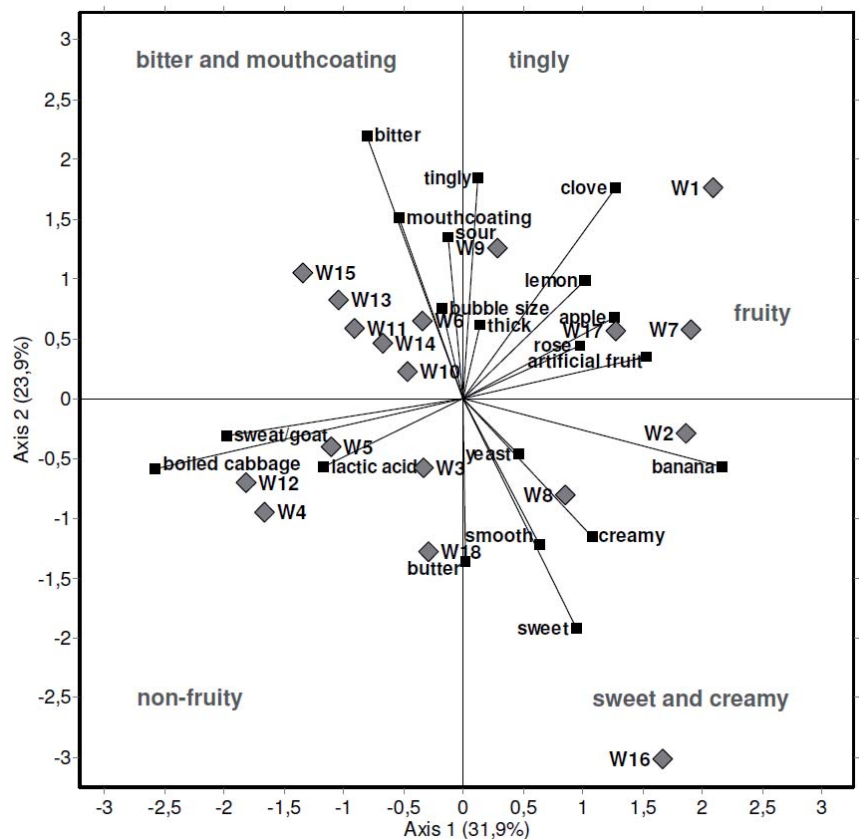


Fig. 2 Bi-plot of the principal component analysis of means products/attribute

Table 5 Pearson's correlation between acceptance and sensory terms

Attribute	Explained variation R^2	Sig. p	Coefficient R
Banana	0.085	0.358	0.291
Apple	0.000	0.951	0.020
Lemon	0.023	0.637	-0.152
Artificial fruit	0.081	0.369	0.285
Clove	0.038	0.545	0.194
Rose	0.028	0.600	-0.169
Yeast	0.486	0.012	0.697
Butter	0.006	0.804	0.080
Lactic acid	0.009	0.772	-0.094
Boiled Cabbage	0.012	0.733	-0.110
Sweat/billygoat	0.149	0.216	-0.386
Sour	0.121	0.268	-0.348
Sweet	0.376	0.034	0.613
Bitter	0.231	0.114	-0.481
Tingly	0.052	0.475	0.228
Bubble size	0.000	0.966	0.014
Thick	0.094	0.332	0.307
Smooth	0.273	0.082	0.522
Creamy	0.689	0.001	0.830
Mouthcoating	0.207	0.137	-0.455

Table 6 Split analyses for gender, age group and consumption

Product No.	Mean value Gender		Sig.	Mean value Age group		Sig.	Mean value Consumption		Sig.
	Female	Masculine	p	16-39 years	40 years and older	p	≥ 2-3 times a month	≤ once a month	p
W1	5.35	5.13	0.557	4.80	5.68	0.017	5.48	4.93	0.138
W2	5.85	6.22	0.239	6.33	5.79	0.073	6.41	5.66	0.014
W3	5.63	5.55	0.833	5.78	5.36	0.217	5.94	5.15	0.021
W4	5.23	5.28	0.894	5.00	5.54	0.148	5.11	5.43	0.386
W5	5.79	5.76	0.936	5.78	5.77	0.963	5.67	5.91	0.470
W6	5.44	5.65	0.567	5.77	5.34	0.235	5.65	5.45	0.584
W7	5.69	5.85	0.643	5.84	5.69	0.666	6.05	5.50	0.112
W8	6.42	5.72	0.025	6.38	5.65	0.021	6.33	5.78	0.076
W9	5.45	5.52	0.843	5.69	5.25	0.215	5.86	5.12	0.034
W10	5.73	5.61	0.736	5.81	5.48	0.355	5.67	5.66	0.961
W11	5.16	5.48	0.349	5.17	5.52	0.299	5.41	5.24	0.605
W12	5.84	5.21	0.088	5.52	5.50	0.966	5.60	5.41	0.605
Number	62	86		82	66		80	68	
% of total number	42	58		55	45		54	46	

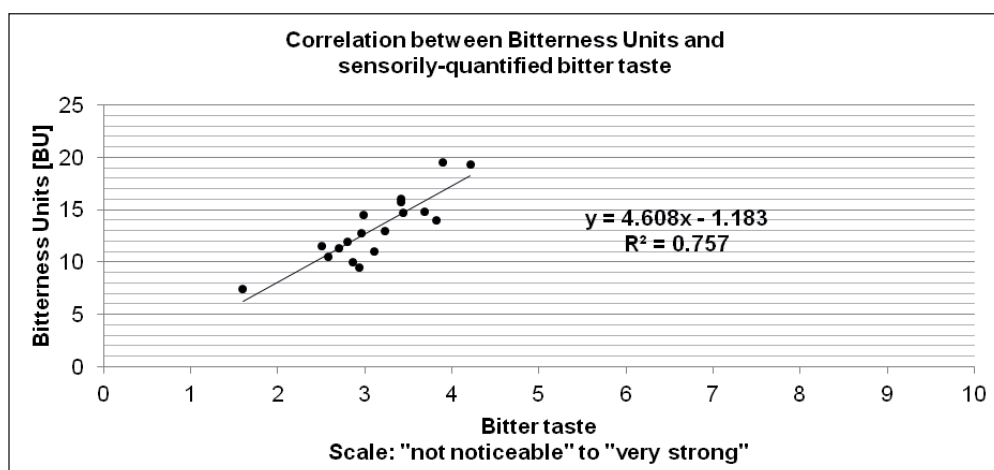


Fig. 3 Correlation between Bitter Units and sensorily-quantified bitter taste

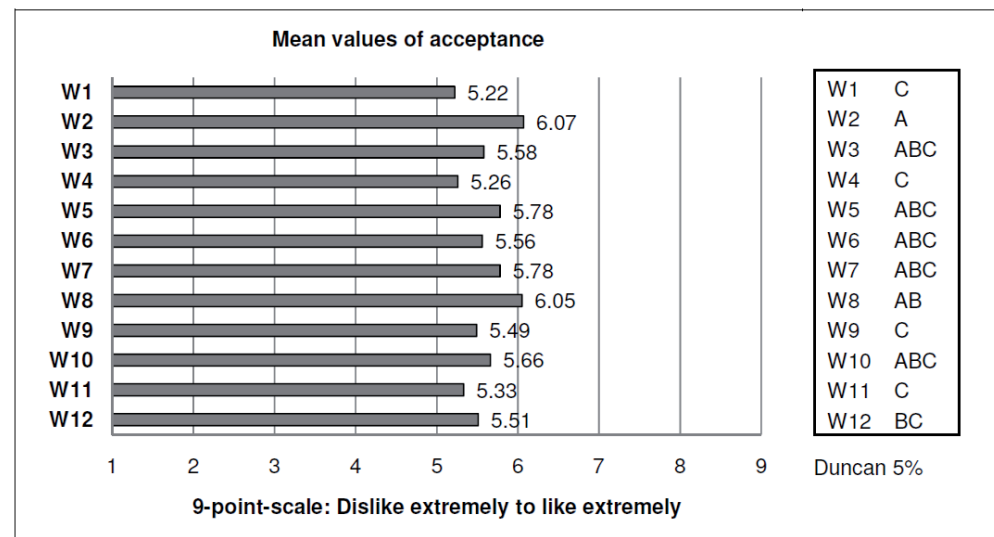


Fig. 4 Mean Values of Acceptance and Duncan Test

acceptance is determined up to 69% by the creamy mouthfeel. The term “smooth” shows a trend of correlation with acceptance.

Regarding the gender, age and intensity of consumption of the participants, different assessments of acceptance were shown by the consumer groups (Table 6). Data on wheat beer no. 8 reveals that there is a significant difference on acceptance among men and women in regard to wheat beers (p=0,025). Wheat beer no. 8 is characterised by a creamy and smooth mouthfeel, which is particularly favoured by women.

Consumers under 40 accepted the wheat beers significantly different (p=0.0001) in contrast to the older wheat beer consumers (p=0.9028) which do not differ.

The different age groups (16-39 years and 40 years and older) show significant differences with samples nos. 8 (p=0.021) and 1 (p=0.017). Beer consumers under 40 prefer “creamy” and banana-smelling wheat beers (nos. 2 and 8). Beer consumers over 40 valued the strongly fruity wheat beer with a hop aroma (no. 1) less than did younger ones.

Table 6 shows a significant difference between the valuation of wheat beers nos. 9 ($p=0,034$), 3 ($p=0,021$) and 2 ($p=0,014$) among users with occasional consumption and those with frequent consumption. These 3 samples, which were preferred by heavy users, all show an above-average rating in the sensory description for the attribute "banana".

4 Discussion

Wheat beers which were investigated represent a selection of products offered on the market. The sensory descriptive analysis shows a sensory diversity of Bavarian wheat beers. Nuanced profiles can be created with the attributes compiled for wheat beers. Wheat beers demonstrate a significant difference in 11 attributes for smell and aroma, 3 attributes for taste and 6 attributes for mouthfeel. Additionally, individual wheat beer varieties can be assigned to four different sensory trends: fruity varieties, bitter and mouthcoating varieties, non-fruity varieties, and sweet and creamy varieties.

A clear grouping of wheat beers according to the flavour types named by Back [2] (estery, phenolic, yeasty, and neutral) cannot be discerned. Fruity wheat beers in some cases simultaneously present a clove-like odour. The odour of yeast is not associated with yeast autolysis by consumers. The short- and medium-chained fatty acids are described by them with the attributes "sweat" and "billygoat". The more neutral-smelling wheat beers generally have a bitter and sour taste. It is possible that the different sensory description is the result of the distinct panels: consumers and experts.

The significant difference in six attributes of mouthfeel shows how important the description of this dimension is, especially for cloudy wheat beers that have higher carbon dioxide content than other beer varieties and due to their cloudiness, offer more detectable substances. A detailed description of the mouthfeel rather than collective terms such as body and palate fullness is able to uncover some positive attributes for the mouthfeel.

Wheat beers with a sweet taste and creamy mouthfeel were favoured more by consumers. Bitter wheat beer varieties, beers with smell of yeast autolysis or very fruity beers with a strong hop aroma were preferred less in this study.

In examining the acceptance by various sub-groups it was determined that women have a considerably more pronounced preference for a wheat beer with creamy mouthfeel than do men. Although women strongly prefer a slightly sweet taste in wheat beer, distinctly sweeter samples however, were not rated significantly better by them.

Just as women rate bitter beers no worse than do men [44], they also do not evaluate the sweeter beers better.

The fact that in terms of acceptance consumers over 40 do not differ in comparison to the younger wheat beer consumers is due to two reasons. Either they perceive the sensory properties in which the wheat beers differ less strongly, or they prefer the sensory properties less than do beer consumers under 40.

The preference for wheat beers with a banana-like odour by the heavy users confirms the assertion by Kunze [1] and Back et al. [4] that a high content of esters is an important feature for acceptance.

The majority of the wheat beer varieties exhibit a bitter taste with a mouthcoating aftertaste. Only a few products have a sweet taste and a creamy mouthfeel.

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