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Relationships between the Chemical-Physical Composition and the Sensory Evaluation of Bavarian Wheat Beer

In order to be able to determine which chemical and physical components contribute in any quantity to a high level of user acceptance, sensory descriptive analysis and the identification of consumer acceptance of 16 wheat beers was conducted in addition to instrumental analyses. By linking the profile test and the acceptance values, significant attributes that are responsible for acceptance could be detected.

The content of phenols (2-methoxy-4-vinylphenol and 4-vinylphenol), esters (isopentyl acetate and ethyl acetate) and higher aliphatic alcohols as well as other chemical and physical analysis data were compared against the sensory descriptive characteristics used for the wheat beers.

The high acceptance of a banana-like odour and a creamy and tingling mouthfeel in the wheat beer can be confirmed. The level of esters correlates with the intensity of the banana-like odour of wheat beer. The preferred banana-like smelling wheat beers show isopentyl acetate levels between 5.5 to 6.0 mg/L. The ratio of the ester to the sum of the higher aliphatic alcohols in the preferred wheat beers is 1:2.5–1:3.5. The sum of the higher aliphatic alcohols correlates with the intensity of sour taste. The 1-propanol content is associated with a fruity odour. There is a connection between the content of phenols (2-methoxy-4-vinylphenol and 4-vinylphenol) and the intensity of the clove-like odour.

Descriptors: wheat beer, sensory analysis, acceptance testing, esters, aliphatic alcohols, phenols

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 flavours. Typical wheat beer flavours are expressed by a high content of esters and higher alcohols (fusel alcohols) and phenolic compounds [1]. In addition to a banana-like odour, the creamy mouthfeel is an important attribute for creating acceptance in wheat beer. In particular, beer consumers under 40 prefer “creamy” and banana-scented wheat beer. Women prefer the creamy mouthfeel in wheat beer significantly more than do men [2]. Lynch and Bamforth [3] 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.

Types of ester contribute to a fruity aroma. During fermentation, ester forms from organic acids and alcohols such as ethyl acetate (fruity or solvent-like odour), isopentyl acetate (banana or pear odour), phenyl ethyl acetate (roses or honey odour), ethyl capro-

ate and ethyl caprylate (apple odour) [4]. The odour threshold for ethyl acetate in wheat beer is 30 mg/L and for isopentyl acetate 2.0 mg/L [5]. In wheat beer, the level of ethyl acetate is 10 to 50 mg/L and of isopentyl acetate 0.5 to 8.0 mg/L [6].

In wheat beer, after a level of isopentyl acetate of 4.5 to 6.0 mg/L, it is no longer described as pleasantly fruity. The odour at this concentration is designated as an off-flavour. Ethyl acetate, by its solvent-like odour, can suppress fruity odour sensations in wheat beer. Up to a content of 40 mg/L of ethyl acetate, no effect on the fruity odour is observed. Wheat beers with an isopentyl acetate content of > 6 mg/L and an ethyl acetate content of > 50 mg/L are also described as “flavourless” [5].

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. Only about 15 % of the higher alcohols make up to 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 [6]. 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 [7]. With top-fermented beers, the content of higher alcohols is between 90–180 mg/L [6]. If the total concentration of higher alcohols increases past a total concentration of more than 100 mg/L, it can negatively impact on the beer’s character [8]. In addition, higher alcohols and esters can cause a “broad” bitter

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taste [9]. If the esters are at a ratio between 1:3 to 1:4 to the sum of higher alcohols, a “balanced flavour” can be expected [1]. With a very high content of higher alcohols, the beers are described as “flavourless” and “hard” [10].

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 the ferulic acid and the phenolic, medicinal, astringent and bitter 4-vinylphenol is formed from the *p*-coumaric acid. For the spicy clove odour, 2-methoxy-4-vinylphenol concentrations of 1.5–2 mg/L are recommended. Wheat beers with 2-methoxy-4-vinylphenol concentrations of less than 0.7 mg/L are considered to be neutral and greater than 3 mg/L described as too phenolic [6]. If the values of 2-methoxy-4-vinylphenol go beyond 4 mg/L, the odour of this wheat beer is described as medicinal or pharmacy-like [8]. In wheat beer concentrations of 0.2 to 4.4 mg/L are identified [6]. During aging of wheat beer decreases inter alia, the content of isopentyl acetate and 2-methoxy-4-vinylphenol [5].

The yeast flavour 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 (billy goat-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 [8].

In respect of the variety “Hefeweizen”, yeast autolysis is another step in the ageing 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 [5]. Other acids involved in this process include medium-chain fatty acids such as, octanoic acid, which has a billy goat odour and decanoic acid, which has a rancid smell [11, 12].

The bitter-tasting compound content of wheat beer is characteristically listed with 10–14 Bitter Units (BU) [9] and 10–20 BU [6]. 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 decanoic acids. Likewise, some esters and higher alcohols may create a bitter taste sensation [9].

2 Materials and methods

2.1 Sensory descriptive analysis

The sensory perception of wheat beer was described by 15 sensorily-trained consumers. The eligibility criteria were sensory sensitivity according to DIN 10961 [13] 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. Nineteen attributes were selected for the profile testing developed for wheat beer attributes [2] (Table 3).

The profile test of the 16 wheat beer varieties was carried out in the sensory analysis laboratory. The test room was designed in

Table 1 Chemical and physical analysis data of wheat beer samples

Product no.	Original gravity	Alcohol	Alcohol	Extract, real	Extract, apparent	Apparent attenuation	Density	Bitterness Units	pH	Colour	Carbon dioxide	Viscosity
	% by wt	% by wt	% by v	% by wt	% by wt	%, % by v	sL20/20	BU		EBC	g/L	mPa s
Mean [2, 3]	12.20	4.12	5.26	4.22	2.33	–	–	17.0	4.32	10.9	5.5–9.0	–
meanW19-34	12.49	4.23	5.40	4.27	2.31	82.13	1.00904	12.5	4.29	13.5	6.6	1.75
minima	11.51	3.84	4.90	3.80	1.94	78.30	1.00757	8.2	4.06	9.3	5.8	1.54
maxima	13.21	4.54	5.78	4.93	2.97	85.30	1.01162	19.2	4.56	19.5	7.2	2.01
W19	13.03	4.46	5.69	4.44	2.39	82.40	1.00935	8.2	4.13	16.0	7.2	1.72
W20	11.60	4.02	5.12	3.80	1.94	83.90	1.00757	11.2	4.32	13.3	7.1	1.54
W21	11.51	3.91	4.98	3.92	2.11	82.40	1.00823	19.2	4.23	16.5	6.2	1.66
W22	12.48	4.17	5.33	4.41	2.48	80.90	1.00970	14.6	4.22	15.3	6.6	1.79
W23	12.66	4.39	5.60	4.18	2.16	83.60	1.00843	10.8	4.06	10.5	6.8	1.82
W24	13.21	4.25	5.51	4.32	2.27	82.70	1.00885	9.5	4.30	16.7	7.1	1.73
W25	12.74	4.19	5.36	4.64	2.71	79.50	1.01060	10.5	4.34	10.5	7.0	1.76
W26	12.99	4.51	5.75	4.30	2.23	83.50	1.00871	13.5	4.46	11.3	7.1	1.69
W27	12.66	4.47	5.70	4.02	1.96	85.10	1.00766	13.2	4.30	12.5	6.5	1.70
W28	11.58	3.87	4.94	4.06	2.27	81.10	1.00885	10.0	4.15	12.0	5.8	1.59
W29	12.55	4.39	5.60	4.06	2.04	84.40	1.00797	9.5	4.56	11.3	6.4	2.00
W30	12.62	4.20	5.36	4.52	2.58	80.30	1.01010	12.7	4.52	10.2	7.0	1.81
W31	12.80	4.54	5.78	4.05	1.97	85.30	1.00768	13.0	4.21	18.4	6.5	1.68
W32	12.57	4.20	5.36	4.46	2.53	80.70	1.00989	15.0	4.28	19.5	5.9	1.91
W33	11.65	3.84	4.90	4.20	2.42	80.00	1.00944	12.0	4.17	12.4	5.9	1.64
W34	13.13	4.26	5.45	4.93	2.97	78.30	1.01162	16.5	4.37	9.3	6.0	2.01

Table 2 Phenols, esters and higher alcohols of wheat beer samples

Product no.	2-Methoxy-4-vinyl-phenol mg/L	4-Vinyl-phenol mg/L	Acetaldehyde mg/L	Ethyl acetate mg/L	Isopentyl acetate mg/L	Methyl acetate mg/L	I-Amyl alcohol mg/L	2-Methyl-1-propanol mg/L	1-Propanol mg/L	total higher alcohols mg/L
Mean [4]	0.2–4.4	0.02–2.7	5.5	10–50	0.5–8.0	–	58–94	26–43	0.0–18.8	90–180
meanW19-34	2.17	0.98	2.86	35.46	4.04	0.2	81.07	33.54	18.54	133.15
minima	0.10	0.02	1.00	12.50	0.90	0.0	56.10	15.00	12.60	95.50
maxima	3.60	1.70	7.70	52.40	6.00	0.4	108.70	54.80	25.70	182.50
W19	2.28	1.07	2.8	38.9	5.8	0.2	80.4	54.8	19.9	155.1
W20	2.63	0.99	4.0	42.6	5.5	0.2	70.3	26.2	18.2	114.7
W21	1.08	0.42	2.2	21.9	3.8	0.2	91.3	46.5	18.8	156.6
W22	1.68	0.71	2.7	32.3	5.9	0.2	95.3	38.0	19.1	152.4
W23	2.87	1.13	3.4	52.4	4.8	0.3	103.5	46.0	18.5	168.0
W24	1.71	0.63	4.5	41.9	3.6	0.3	85.9	46.6	21.0	153.5
W25	0.10	0.02	4.6	31.9	2.6	0.2	56.1	15.4	25.7	97.2
W26	3.60	1.66	1.0	38.8	3.4	0.3	58.2	24.9	17.4	100.5
W27	1.70	0.61	3.3	47.8	5.9	0.2	71.2	34.3	17.3	122.8
W28	1.47	0.65	1.0	36.2	6.0	0.0	79.3	30.8	17.2	127.3
W29	2.62	1.70	2.5	23.6	2.3	0.3	60.7	23.4	12.6	96.7
W30	2.86	1.67	2.1	17.1	2.1	0.3	79.4	18.9	15.8	114.1
W31	3.41	1.33	1.1	51.1	3.5	0.0	108.7	52.1	21.7	182.5
W32	2.86	1.43	1.8	32.9	4.3	0.2	103.5	29.7	16.8	150.0
W33	0.43	0.21	1.1	12.5	0.9	0.2	63.0	15.0	17.5	95.5
W34	3.34	1.41	7.7	45.4	4.3	0.4	90.3	34.0	19.2	143.5

accordance with DIN 10962 [14]. For the sessions, tulip-shaped tasting glasses were used according to ISO 3591 [15]. The glasses were filled with 50 ml of beer for sensory assessments. The beer samples were brought to a drinking temperature of 12 °C.

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 intensity of the 19 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 [16].

2.2 Investigation of consumer acceptance

For the acceptance investigation, 73 consumers, who represented the target group, were recruited via telephone from a database. The target group was made up of beer consumers who drink wheat beer once a month or more often. Since older consumers of wheat

beers do not differ in acceptance [2], only beer consumers up to 50 years of age were invited. The average age was 29.6 years. In correlation to consumption, more men than women were invited to the test. Of those who took part in the test, 33 % (n = 24) were female and 67 % (n = 49) were male.

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, a nine-point scale is used to make distinctions.

For the investigation of acceptance, average values for each individual product were initially generated and investigated for significant differences.

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

2.3 Chemical and physical analysis

A beer analyser (Anton Paar) was used to analyse original gravity, alcohol, real extract, apparent extract, density and apparent attenuation. Bitter Units (BU) were analysed by extraction of bitter constituents with 2,2,4-trimethylpentane from the acidified sample and spectrophotometrically determination. Dissolved carbon dioxide content of bottles was determined using manometric method according to Haffmans. The beer colour (EBC) was analysed by

Table 3 Attributes and References

Sensory dimensions	Attribute	Comp. F	Sig. p	References
Odour and aroma	Banana	3.54	< 0.0001	Isopentyl acetate
	Apple	2.10	0.0112	Ethyl hexanoate
	Lemon	1.92	0.0225	Linalool
	Artificial fruit	1.21	0.2670	Isopentyl acetate
	Clove	2.84	0.0005	2-Methoxy-4-vinylphenol
	Rose	1.88	0.0265	Geraniol
	Yeast	1.07	0.3822	Yeast
	Butter	1.22	0.2619	Diacetyl
	Lactic acid	1.44	0.1323	D,L-Lactic acid
	Boiled Cabbage	2.93	0.0003	Dimethyl sulfide
	Sweat/Billy goat	3.96	< 0.0001	Isovaleric acid/Caprylic acid
Taste	Sour	2.04	0.0144	Citric acid
	Sweet	2.10	0.0110	Sucrose
	Bitter	4.92	< 0.0001	Iso-alpha-acids
Mouthfeel	Tingly	1.87	0.0277	
	Thick	0.88	0.5821	
	Smooth	2.04	0.0140	
	Creamy	2.02	0.0151	
	Mouthcoating	2.23	0.0064	

spectrophotometrically determination. Viscosity of beers was performed using a capillary viscometer. The analyses of the phenols 2-methoxy-4-vinylphenol and 4-vinylphenol were determined using reversed-phase chromatography and HPLC with UV detection. Higher alcohols and esters were analysed by gas chromatography without NaCl [17].

The correlation analysis records the connection between the data of the chemical-physical analysis and sensory attributes of the profile test.

3 Results

3.1 Chemical and physical analysis

Table 1 and 2 show the chemical and physical analysis data. Wheat beer no. 34 is notable with a higher extract. The contents of bitter substances are between 8.2 to 19.2 BU. Sample nos. 21 (19.2 BU) and 34 (16.5 BU) shows the highest bitter substance content. In wheat beers, the carbon dioxide content is in the range of 6 g/L [6]. The samples present a normal carbon dioxide concentration from 5.8 to 7.2 g/L.

The phenols, esters and higher alcohols of the wheat beer samples are shown in table 2. While sample nos. 25 and 33 present a very low content of 2-methoxy-4-vinylphenol, sample nos. 26, 31 and 34, present the highest values among the samples examined. None of the wheat beers, however, have a higher concentration of 2-methoxy-4-vinylphenol than 4 mg/L, which can create a medicinal or pharmacy-like odour [8]. With high ethyl acetate content, the

wheat beer nos. 23, 27, 31 and 34 are notable. These samples show a concentration higher than 45 mg/L, which can lead, according to *Hermann* [5] to a suppression of the fruity odour. Sample nos. 30 and 33 have low ethyl acetate content.

As to isopentyl acetate, wheat beers nos. 19, 20, 22, 27 and 28 present a value between 5.5 and 6.0 mg/L and therefore exceed the recommended value of 4.5 mg/L, beyond which the odour is no longer described as "pleasantly" fruity [5]. Sample no. 33 shows a very low content of isopentyl acetate as it also does for other fermentation by-products.

As for the higher aliphatic alcohols, the beers show values from 95.5 to 182.5 mg/L. Sample nos. 25, 26, 29 and 33 present 100 mg/L and less. Wheat beer no. 31 has the highest content of higher alcohols at 182.5 mg/L. Fifty percent of the samples show a value greater than 130 mg/L. Looking at the ratio of esters and higher alcohols, beers nos. 20, 26 and 27 show a ratio of 1:2.5. Wheat beers nos. 21, 30 and 33 show a very high content of higher alcohols in comparison to the esters; the two last-mentioned essentially present very little ester.

3.2 Sensory descriptive analysis

The results of the sensory descriptive analysis are summarized in table 3 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 the attributes „banana“, „apple“, „lemon“, „clove“, „rose“, „boiled cabbage“, „sweat“, „sour“, „sweet“, „bitter“, „tingly“, „smooth“, „creamy“ and „mouthcoating“ and can

Table 4 Mean Values of Acceptance

Product no.	Overall impression		Physical appearance		Odour and Aroma		Taste	
	Mean	Duncan 5 %	Mean	Duncan 5 %	Mean	Duncan 5 %	Mean	Duncan 5 %
W19	5.94	AB	6.27	ABC	5.85	AB	5.72	AB
W20	5.94	AB	5.86	BCDEF	5.68	ABC	5.74	AB
W21	4.93	DEFG	6.11	BCD	5.17	BCDE	4.53	DE
W22	4.91	DEFG	6.03	BCDE	4.29	GH	4.77	CDE
W23	4.56	FG	5.84	BCDEF	4.25	H	4.56	DE
W24	5.18	CDEF	5.41	EF	4.95	DEFG	5.34	ABC
W25	5.39	BCD	5.73	BCDEF	5.00	CDEF	5.23	ABCD
W26	6.03	A	6.01	BCDE	5.80	AB	5.91	A
W27	5.95	AB	6.39	AB	5.93	A	5.70	AB
W28	5.41	ABCD	5.24	F	5.64	ABCD	5.47	ABC
W29	4.74	EFG	5.64	CDEF	4.35	FGH	4.85	CDE
W30	5.14	CDEF	5.83	BCDEF	4.98	CDEF	5.03	BCDE
W31	5.27	CDE	5.51	DEF	5.51	ABCD	5.18	BCD
W32	5.60	ABC	6.73	A	5.23	BCDE	5.38	ABC
W33	4.32	G	5.83	BCDEF	3.55	I	4.36	E
W34	4.94	DEFG	5.23	F	4.73	EFGH	4.77	CDE
Comp. F	11,06		4.14		9.78		4.94	
Sig. p	< 0.0001		< 0.0001		< 0.0001		< 0.0001	

be repeatedly described with these attributes.

The values of the individual wheat beers are presented in a biplot (Fig. 1) 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: fruity varieties, bitter and mouth coating varieties, non-fruity varieties and sweet and creamy varieties.

Wheat beer no. 21 (19.2 BU), which has already been noted for its bitter substances also shows a bitter and mouth-coating taste in the sensory description. Sample nos. 26, 31 and 34 with a high content of 2-methoxy-4-vinylphenol are classified in the lower half of the biplot in the direction of the attribute "clove" as are their other sensory properties accordingly. Up until sample no. 22, all beers having a very high content of isopentyl acetate (nos. 19, 20, 27 and 28) were also described as fruity. Sample no. 22 also received

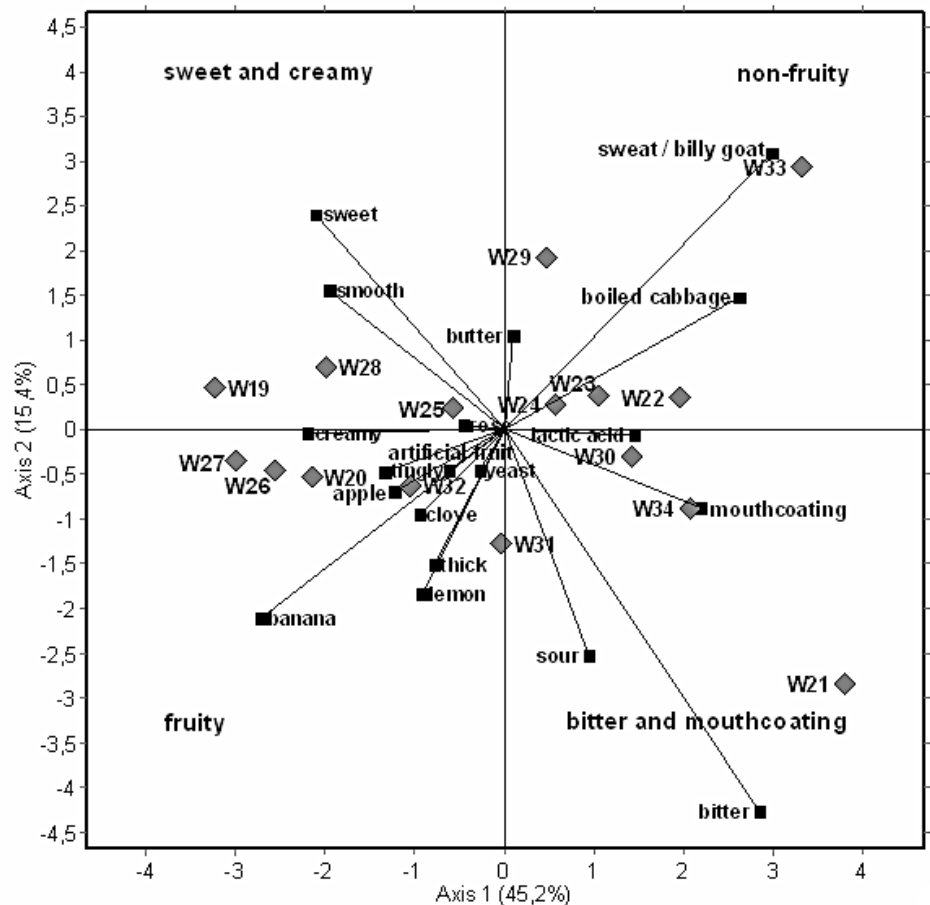


Fig. 1 Biplot of the principal component analysis of means products/attributes

Table 5 Correlation between acceptance and sensory terms

Attribute	Explained variation	Sig.	Coefficient
	R ²	p	R
Banana	0.71	0.000	0.841
Apple	0.24	0.028	0.486
Lemon	0.34	0.009	0.582
Artificial fruit	0.10	0.120	0.312
Clove	0.17	0.059	0.406
Rose	0.08	0.146	0.281
Yeast	0.04	0.220	0.208
Butter	0.01	0.345	-0.108
Lactic acid	0.42	0.003	-0.651
Boiled Cabbage	0.79	0.000	-0.888
Sweat/Billy goat	0.72	0.000	-0.846
Sour	0.02	0.306	-0.138
Sweet	0.25	0.024	0.500
Bitter	0.15	0.069	-0.387
Tingly	0.57	0.000	0.758
Thick	0.30	0.014	0.549
Smooth	0.26	0.021	0.514
Creamy	0.52	0.001	0.720
Mouthcoating	0.33	0.010	0.574

a high rating in the intensity of the odour of sweat and lactic acid. Beer no. 33, having an overall low content of fermentation by-products, also stands in a negative correlation to these sensory attributes.

3.3 Consumer acceptance

Table 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).

Wheat beers nos. 19, 20, 26 and 27 were preferred, followed by beers nos. 28 and 32. Clearly not preferred were wheat beers nos. 23 and 33. Similarly, beers nos. 21, 22, 29 and 34 on average receive a rating below the midpoint of the 9-point scale.

The preferred wheat beers all have a fruity odour and a sweet taste with a thick, smooth and creamy mouthfeel. Wheat beer no. 26 furthermore has a stronger clove-like odour.

The not preferred wheat beer no. 33 has no fruity odour and was judged with the attribute "sweat" higher than any of the other wheat beers. It additionally has an odour of boiled cabbage. This odour is also shown by the non-preferred beer no. 23, which in addition to the attribute "tingling" receives a low mark. Beers nos. 21 and 34 were not favoured, partly because of their bitter and mouthcoating taste. What consumers least favoured in wheat beers nos. 22 and 29 in particular was the odour.

Table 5 show the connection between consumer acceptance and the sensory features. A connection exists between consumer acceptance and the sensory features of the tingly and creamy mouthfeel and the odour of banana, sweat and boiled cabbage. The higher the wheat beer was evaluated by the test participants, the more intense the tingly and creamy mouthfeel and odour of banana were. The worse the wheat beer was evaluated by the test participants, the more intense the odour of sweat and boiled cabbage were.

3.4 Correlation with the chemical and physical composition

The correlation matrix of the chemical and physical analyses and sensory description is shown in table 6.

The content of 2-methoxy-4-vinylphenol shows a correlation with the intensity of its "clove" odour sensation ($r = 0.668$). Similarly, the 4-vinylphenol content correlates with the intensity of the clove-like odour ($r = 0.694$). Both substances show at the attribute "thick" a significance level of ≤ 0.05 .

The ethyl ester ($r = 0.613$) and isopentyl acetate ($r = 0.686$) correlates with the intensity of the "banana" odour. Both Esters have an effect on the sensory attributes "boiled cabbage" and "sweat" or "billygoat". Similarly, the isopentyl acetate content also correlates with the strength of the yeasty odour ($r = 0.602$).

The concentration of acetaldehyde is associated with the attribute "artificial fruit" ($r = 0.621$).

The content of 1-propanol shows a correlation with the intensity of the sensory features "apple" ($r = 0.635$) and "lemon" ($r = 0.668$).

The sum of the higher alcohols correlates with the intensity of sour taste ($r = 0.616$).

The alcohol content is associated with the intensity of the clove-like odour ($r = 0.703$) and the thick mouthfeel ($r = 0.679$).

A strong correlation exists between the bitter substance content and the intensity of the sensorially perceived bitter taste ($r = 0.835$). Also, the content of the bitter substances correlates with the mouthcoating afterfeel ($r = 0.597$).

The intensity of the rose-like odour correlates with the real extract ($r = 0.707$) and the density ($r = 0.655$).

The content of isopentyl acetate ($r = 0.497$) and carbon dioxide ($r = 0.416$) shows a correlation with the acceptance.

4 Discussion

Consumers who drink beer regularly, favour wheat beers that have a banana-like odour [2]. This is been demonstrated repeatedly. Likewise, this study confirms the positive correlation of acceptance and creamy mouthfeel.

Table 6 Correlation matrix of instrumental analysis data and sensory attributes (*significant at 5 %, **significant at 1 %, ***significant at 0.1 %)

	2-Methoxy-4-vinylphenol	4-Vinylphenol	Acetaldehyde	Ethyl acetate	Isopentyl acetate	Methyl acetate	1-Amyl alcohol	2-Methyl-1-propanol	1-Propanol	Total higher alcohols	Original gravity	Alcohol	Extract, real	Apparent attenuation	Density	Bitterness Units	pH	Carbon dioxide	Viscosity
Banana	0.432*	0.283	-0.132	0.613**	0.686**	-0.254	0.076	0.388	-0.047	0.218	0.139	0.492*	-0.382	0.653**	-0.535*	-0.131	-0.072	0.344	-0.277
Apple	-0.080	-0.266	0.005	0.539*	0.219	-0.531*	-0.095	0.067	0.635**	0.038	0.060	0.154	-0.079	0.157	-0.123	-0.262	-0.262	0.137	-0.423
Lemon	-0.289	-0.431*	0.187	0.257	0.317	-0.262	-0.155	0.144	0.668**	0.040	0.087	-0.032	0.166	-0.157	0.170	0.032	-0.153	0.273	-0.462*
Artificial Fruit	0.021	-0.138	0.621**	0.573*	0.389	0.309	0.057	0.345	0.539*	0.247	0.470*	0.322	0.372	-0.084	0.251	-0.269	-0.301	0.454*	0.096
Clove	0.668**	0.694**	-0.131	0.221	-0.021	0.244	-0.017	0.191	-0.097	0.067	0.611**	0.703**	0.118	0.376	-0.127	-0.115	0.484*	0.574*	0.219
Rose	0.287	0.339	0.281	-0.007	-0.138	0.401	-0.125	-0.354	0.214	-0.215	0.450*	0.188	0.707**	-0.499*	-0.499*	-0.128	0.309	0.391	0.315
Yeast	0.393	0.368	-0.067	0.160	0.602**	0.025	0.278	0.405	-0.443*	0.307	-0.085	0.048	-0.317	0.336	-0.344	-0.006	0.007	0.172	-0.048
Butter	-0.164	-0.065	0.083	-0.196	-0.077	0.290	-0.356	-0.225	-0.071	-0.324	0.000	-0.152	-0.055	-0.003	-0.043	-0.332	0.288	0.350	0.036
Lactic acid	-0.104	0.008	-0.179	-0.472*	-0.323	0.248	0.160	0.093	-0.169	0.122	-0.079	-0.140	0.048	-0.135	0.090	0.353	0.062	-0.015	0.174
Boiled Cabbage	-0.274	-0.153	0.057	-0.496*	-0.593**	0.386	0.041	-0.116	-0.069	-0.035	-0.087	-0.289	0.096	-0.250	0.168	0.124	0.071	-0.080	0.284
Sweat/ Billy Goat	-0.324	-0.181	0.009	-0.611**	-0.530*	0.316	0.004	-0.183	-0.127	-0.094	-0.121	-0.364	0.255	-0.459*	0.368	0.107	-0.052	-0.244	0.286
Sour	0.059	-0.065	0.114	0.080	0.273	0.084	0.537*	0.590	0.227	0.616**	-0.010	-0.031	0.047	-0.050	0.056	0.510*	-0.312	0.168	-0.095
Sweet	0.111	0.182	-0.214	0.165	-0.008	-0.131	-0.520*	-0.256	-0.055	-0.436*	0.290	0.465*	-0.019	0.292	-0.161	-0.721**	0.143	0.335	-0.074
Bitter	0.031	0.028	0.177	-0.276	-0.264	0.215	0.380	0.081	0.038	0.270	-0.181	-0.257	0.078	-0.227	0.172	0.835***	0.175	-0.250	0.230
Tingly	0.192	0.158	-0.161	0.027	0.112	-0.126	-0.267	-0.282	0.120	-0.277	0.065	0.052	0.095	-0.058	0.084	-0.136	0.219	0.416	-0.397
Thick	0.463*	0.509*	-0.056	0.212	0.052	0.218	0.013	0.147	-0.050*	0.070	0.559*	0.679**	0.124	0.344	-0.100	0.146	0.460*	0.363	0.325
Smooth	0.069	0.170	-0.473*	0.038	0.265	-0.269	-0.409	-0.136	-0.440	-0.353	-0.029	0.313	-0.332	0.447*	-0.410	-0.433*	0.067	0.073	-0.187
Creamy	0.274	0.333	-0.300	0.200	0.403*	-0.064	-0.122	0.113	-0.311	-0.054	0.301	0.455*	-0.150	0.436*	-0.311	-0.327	0.195	0.321	-0.039
Mouth-coating	0.035	0.060	-0.285	-0.337	-0.578*	0.000	0.372	0.002	-0.144	0.211	-0.131	-0.121	-0.064	-0.032	-0.021	0.597**	0.026	-0.479*	0.181
Ac-ceptance	0.249	0.155	-0.049	-0.397	0.497*	-0.197	-0.206	0.081	0.127	-0.074	0.193	0.336	-0.093	0.307	-0.202	-0.137	0.140	0.416*	-0.343

Hermann [5] describes isopentyl acetate beyond a content of 4.5 to 6.0 mg/L as no longer pleasantly fruity. It is found that the preferred wheat beers with a banana-like odour present isopentyl acetate content of 5.5 to 5.9 mg/L.

In addition, Back [8] notes that beyond 45 mg/L, ethyl acetate with its solvent-like odour suppresses pleasant fruity odour sensations. In the tests, wheat beers with an ethyl acetate content of > 45 mg/L demonstrate both a fruity and fruity-less odour. The fruity wheat beer that is highly rated for acceptance has an ethyl acetate content of 47.8 mg/L, but also has a very high isopentyl acetate content of 5.9 mg/L.

The ratio of ester to the sum of the higher aliphatic alcohols among the preferred wheat beers is 1:2.5–1:3.5 and thus within the range of the ratio specified by Kunze [1] of 1:3–1:4 for a “balanced flavour”.

Wheat beers with a higher proportion of higher alcohols are described as “flavourless” and “hard” [8]. In the studies, the sum of the higher aliphatic alcohols correlates with the intensity of sour taste. There is no negative correlation with thick mouthfeel.

The fact that at certain concentrations 1-propanol can smell fruity [7] is confirmed. The 1-propanol content is associated with the intensity of an apple and lemon-like odour.

Whether wheat beers with a 2-methoxy-4-vinylphenol content of > 3 mg/L are too phenolic [6] could not be confirmed. Wheat beers that have a 2-methoxy-4-vinylphenol content of > 3 mg/L are also preferred if they additionally have a fruity odour and a creamy mouthfeel.

It can be confirmed that a high carbon dioxide content is an important acceptance characteristic for wheat beers. In this context, Kunze [1] says that a content of > 6 g/L is typical for wheat beer. The preferred wheat beers show a carbon dioxide content of > 6.5 g/L

5 Conclusion

Rarely is the acceptance connected to a sensory attribute or an ingredient. Since a combination of several characteristics and the concentrations of ingredients are in play, they rarely correlate linearly with the sensory properties or with their acceptability. In some cases only the quantities of individual ingredients can explain the cause of a sensory characteristic. The reference to the acceptance requires a detour via the sensory description, since only in so doing can the overall sensation be perceived. It is also important that the acceptance identification be performed by consumers and not by experts. On the one hand, sensory impressions that consumers do not or hardly notice, but which an expert recognises through his/her long product experience and training are described in an intensified way. And on the other, sensory impressions that the consumer recognises and either does not prefer or strongly favours are not recognised the same way by the experts.

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