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Sensory descriptive analysis and consumer acceptance of non-alcoholic beer

The purpose of this research on non-alcoholic beer was to identify the most important acceptance-causing sensory attributes for this product category. Sensory descriptive analysis was conducted on five non-alcoholic beers produced by ethanol removal and seven non-alcoholic beers produced by limiting alcohol formation or hybrid methods. Acceptance tests measured the popularity of nine samples, which were chosen for their sensory properties. The data of the descriptive analysis were combined with consumer test results and significant sensory attributes that are responsible for acceptance were detected. Subsequently, split analyses were carried out based on gender, age, consumption volume, consumers' motives and sensory expectations.

A significant difference can be described in non-alcoholic beers using 19 sensory attributes as a basic point of comparison. The products have a particular taste depending on the manufacturing process. If the alcohol is subsequently reduced, non-alcoholic beers have a bitter and sour taste. Non-alcoholic beers, which are produced by inhibited or reduced fermentation and mixed forms of various processes, have a sweet taste. Consumers preferred sweet non-alcoholic beers with a light fruity odour. They did not prefer products with a sour and bitter taste or with a malty odour or animality. Particularly men and consumers aged over 40 disliked the malty odour. Test participants did not rate beers highly with a strong hop aroma on average; 44.8 % of them, however, accepted products with a strong hop aroma very well while 55.2 % of them disliked this aroma.

Descriptors: non-alcoholic beer, dealcoholized beer, alcohol-free beer, sensory descriptive analysis, acceptance testing, methional

1 Introduction

The national laws for non-alcoholic beer vary. In the United States, beer containing less than 0.5% alcohol by volume (ABV) is labelled "non-alcoholic" [1]. In Germany, beer must contain no more than 0.5 % ABV if it is labelled "alcohol-free" [2; 3]. In this article, the term "non-alcoholic beer" is used.

A continual increase in sales of non-alcoholic beer has been observed for years [4], which is connected with its change of image from not "real" beer to a healthy natural drink [5]. In 2011, sales of the top 15 brands of non-alcoholic beers in Germany were up 10% on the previous year at around 328 million litres. The total output of non-alcoholic beer in 2011 was 376 million litres – an increase of 16% compared to 2010 [4]. These figures are based on non-alcoholic lager beers and non-alcoholic wheat beers.

Non-alcoholic beer is produced by the subsequent removal of alcohol from normally fermented original beer (a physical process) or the reduced formation of alcohol during fermentation (a biological process). Some breweries also apply both methods to a product to achieve the desired sensory properties. For example, either dealcoholized beer is blended with beer that is produced by inhibited or interrupted fermentation, or beer with reduced fermentation is dealcoholized afterwards.

The subsequent alcohol removal is caused by distillation or evaporation under vacuum and through semipermeable membranes. The sensory properties of these non-alcoholic beers are described as having a "neutral aroma and less palate fullness". Reverse osmosis and dialysis are used for the membrane separation process. The non-alcoholic beers produced by the dialysis method have a watery mouthfeel as well as a sour taste and no caramel-like aromas. To improve its sensory properties, a higher original gravity and higher fermentation temperature of the original beer are proposed. In addition, a return of a rectified aroma concentrate positively affects the odour, while the addition of lager beer or pilsner up to the acceptable alcohol content [6, 7] may also provide improvement.

Non-alcoholic beers, which are produced by inhibited or interrupted fermentation, have a strong wort-like odour and a sweet taste. A slight wort-like odour indicates partially fermented beer with subsequent removal of alcohol. This wort-like odour can be partially covered by the addition of aromatic hops [6, 7, 8].

Another way to suppress the formation of alcohol during fermentation is to use yeasts that are incapable of converting maltose or maltotriose to ethanol. In addition, yeast mutants that have a defect in the citrate cycle and cultures of *Lactobacillus* are also used [9, 10, 11].

The non-alcoholic beers from different production methods differ in their carbohydrate content. Non-alcoholic beers, which are

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Table 1 Results of the sensory descriptive analysis - average values, Duncan-test, product's F-value and the significance level (p < 0.05)

Attribute	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	Comp. F	Sig. p	References
Lemon	1.74 CD	1.69 CD	1.74 A	4.37 B	2.68 BCD	1.89 A	3.72 B	2.66 D	1.09 BC	2.28 BC	2.09 BC	2.00 BC	11.05	<0.0001	Linalool
Grapefruit	1.66 BC	1.34 C	1.51 BC	4.46 A	2.35 B	1.82 BC	4.06 A	1.89 BC	1.03 C	1.65 BC	2.32 B	1.43 BC	12.85	<0.0001	Grapefruit aroma
Herz	1.25 B	1.25 B	0.91 A	2.02 A	1.23 B	1.22 A	2.15 B	1.12 B	1.17 B	0.89 B	1.05 B	1.08 B	3.28	0.0002	Tree gum
Apple	1.51 CD	1.05 D	1.15 D	2.20 BC	2.97 A	1.51 CD	2.35 AB	2.20 BC	1.43 CD	1.82 BCD	2.11 BC	1.15 D	5.52	<0.0001	Ethyl-2-methylbutanoate
Rose	1.05 D	1.06 D	1.30 A	2.72 A	1.85 BC	1.00 D	2.42 CD	1.34 D	1.03 D	1.05 D	1.92 BC	1.14 D	6.58	<0.0001	Geraniol
Geranium	1.32 BC	1.66 BC	1.62 A	2.68 A	1.63 BC	1.82 A	2.69 BC	1.31 C	1.02 BC	1.52 BC	1.48 BC	1.69 BC	5.17	<0.0001	Myrcene
Malt	3.52 B	2.74 CD	1.83 EF	1.29 F	2.80 CD	3.18 BC	1.63 EF	1.83 EF	5.17 A	2.13 DE	2.34 DE	2.09 DE	18.13	<0.0001	Pilsner malt
Honey	3.11 A	2.02 BCD	1.25 CD	2.08 BCD	2.83 AB	2.14 BC	2.02 CD	1.49 CD	3.27 A	1.18 D	2.55 AB	1.31 CD	6.29	<0.0001	Phenyl acetalddehyde
Boiled Potato	2.62 AB	1.95 BC	2.16 E	0.98 E	1.40 CDE	2.06 BC	1.17 DE	1.18 DE	3.2 A	1.57 CDE	1.12 DE	1.85 CD	7.33	<0.0001	Methional
Bread	2.03 B	1.94 BC	1.80 BCD	0.83 E	1.35 BCDE	1.77 E	0.91 DE	1.25 A	2.91 A	1.58 CDE	1.31 CDE	1.58 BCD	6.78	<0.0001	Fresh bread
Boiled Cabbage	1.57 BC	1.77 BC	2.28 D	0.80 D	0.83 D	1.74 BC	0.75 D	1.14 CD	1.49 CD	1.86 ABC	1.17 CD	2.55 A	5.94	<0.0001	Dimethyl sulfide
Butter	1.14 C	1.12 AB	1.34 D	0.69 D	0.92 C	0.91 C	0.86 BC	1.11 CD	1.18 C	0.98 ABC	1.37 A	1.11 A	1.07	0.3833	Diacetyl
Lactic acid	0.82 C	1.66 AB	1.64 AB	0.92 C	0.75 C	0.88 C	0.85 BC	1.08 C	0.83 ABC	1.38 BC	1.11 A	1.77 A	3.10	0.0004	D, L-Lactic acid
Animal	2.00 BCD	3.12 A	2.50 AB	1.22 DE	0.78 E	3.14 A	1.06 E	1.20 DE	1.42 CDE	2.13 BC	2.58 AB	3.15 A	8.86	<0.0001	Isovaleric acid, Caprylic acid
Bitter	2.55 F	4.74 BCD	5.43 AB	4.54 CD	2.65 F	3.77 E	4.09 DE	4.63 CD	2.68 F	5.55 A	2.95 F	5.23 ABC	19.09	<0.0001	Iso- α -acid
Sweet	5.63 A	1.85 D	1.91 D	3.75 C	5.54 A	4.71 B	4.91 D	1.75 AB	4.91 D	1.58 B	4.60 D	1.45 D	40.78	<0.0001	Sucrose
Sour	1.94 C	4.09 A	4.09 B	3.00 C	1.92 BC	2.32 BC	2.52 A	4.43 BC	2.37 A	4.06 A	2.28 BC	4.71 A	12.79	<0.0001	Citric acid
Tingly	4.17 AB	4.02 ABC	4.78 A	4.94 ABC	4.02 C	3.26 AB	4.45 AB	4.34 AB	4.32 AB	4.40 BC	3.82 AB	4.40 AB	2.44	0.0054	
Thick	4.54 CD	3.89 A	4.05 A	4.02 ABC	4.65 D	4.52 BCD	4.54 ABC	3.60 BCD	4.35 CD	4.12 A	4.00 D	3.85 A	1.60	0.0948	
Mouthcoating	4.17 CD	4.17 CD	5.23 A	4.78 ABC	3.88 D	4.32 BCD	4.68 ABC	5.05 CD	4.05 CD	5.31 A	3.72 D	5.25 A	5.03	<0.0001	
Persistence	3.86 BC	4.45 ABC	5.22 A	4.60 AB	3.64 C	4.48 ABC	4.52 ABC	4.97 A	3.85 BC	5.11 A	3.78 BC	5.20 A	3.96	<0.0001	

obtained by subsequent removal of the alcohol from normally fermented original beer, have significantly lower sugar content than products produced by the biological process. Compared to

beer, the fermentation bouquet is lost or significantly reduced by alcohol removal or suppression of the formation of alcohol [9]. In particular, the lack of fruity odour and a strong wort-like odour are

criticised [12]. Honey-like, malty and boiled potato-like aromatic substances are characteristic of the wort. The aromatic substances phenylacetic acid (honey-like), vanillin (vanilla-like), 3-methylbutanal (malty), methional (boiled potato-like), phenyl acetaldehyde (honey-like), (E)-2-nonenal (cucumber-like) and 2-amino acetophenone (flowery) are reduced during fermentation of the wort and filtration. The compounds hexanal (grassy), (z)-4-heptenal (biscuit-like), 2-acetyl-2-thiazoline (popcorn-like) and 3-hydroxy-5-ethyl-methyl-2(5H)-furanone (spicy and flowery) only exist in the wort [13]. For *Perpète* and *Collin* [12] in particular, methional is responsible for a malty off-flavour in non-alcoholic beers. Methional as well as 3-methylbutanal can be reduced by 75 %, however, by five hours of cold fermentation.

Esters, higher alcohols and dimethyl sulphide can be reduced in the production of non-alcoholic beer. Less volatile substances such as diacetyl, fatty acids, 2-phenyl ethanol and furfuryl alcohol hardly change in content. A high fatty acid content may cause a billy-goat-like odour [14].

Zufall and *Wackerbauer* [7] rate non-alcoholic beers, which were produced by the physical method, despite their lack of "palate fullness" and their partially sour taste, better than products that were produced by interrupted fermentation and have a wort-like odour.

2 Materials and methods

2.1 Sensory descriptive analysis

The sensory perception of non-alcoholic beer was described by 21 sensorily-trained consumers. The eligibility criteria were sensory sensitivity according to DIN 10961 [15] 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 non-alcoholic beer, meaningful sensory attributes with corresponding reference substances were compiled, using individual descriptions of 12 samples. 21 attributes (Table 1, column no. 1) were selected for the profile test according to frequency distribution and after consultation with the panel. The odour of fatty acids is described as "like a billy-goat" [14], and panellists also recognised this in non-alcoholic beer and described it as "animal-like".

The profile test was carried out in a sensory analysis laboratory. The test room is designed in accordance with DIN 10962 [16]. For the sessions, tulip-shaped tasting glasses were used according to ISO 3591 [17]. The glasses were filled with 50 ml of beer. The beer samples had a drinking temperature of 10 °C and 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 21 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. The descriptive data of the profile test is summarized in a table and shows the averages of all taste tests, the significance and the results of the pair comparisons of averages. The results are represented as a bi-plot of the principal component analysis because of the large number of attributes and tests. The bi-plot of the principal component analysis illustrates sensory similarities and differences between the individual non-alcoholic beer varieties and provides an overview of the sensory perceptions of the beer samples tested. 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 each other. If the attributes are presented in opposite directions in the bi-plot, then a negative correlation exists [18, 19, 20, 21].

2.2 Investigation of consumer acceptance

For the study of acceptance, 9 products were selected to represent the different sensory groups from the 12 non-alcoholic beer samples. 116 beer consumers were invited to the test. Of those who took part in the test, 43 % (n = 50) were female and 57 % (n = 66) were male. The age distribution of the beer consumers who took part in the study is presented in Table 2.

Table 2 Age distribution of test participants

Age group * Gender Contingency table				
Age group		Gender		Total
		Female	Masculine	
16-25 years	Number	13	30	43
	% of total number	11.2%	25.9%	37.1%
26-39 years	Number	16	13	29
	% of total number	13.8%	11.2%	25.0%
40+ years	Number	21	23	44
	% of total number	18.1%	19.9%	37.9%
Total	Number	50	66	116
	% of total number	43.1%	56.9%	100.0%

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 and thereafter about the acceptance of odour and taste. To quantify the acceptance, a nine-point scale was used to make distinctions. For compiling the intensity of the sweet, bitter and sour taste, a five-point „just about right“-scale is employed. To perform split analyses, data concerning age, gender and consumption volume was gathered [18, 19, 20].

To investigate acceptance, average values for each individual product were initially generated and examined for significant differences. Furthermore, split analyses for particular sub-groups (gender, age, consumption volume, consumers' motives and sensory expectations) were performed with the single-factor analysis of variance [22].

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 [22].

The evaluation of the bitterness using the five-point "just about right" scale is made with the corresponding frequency of the five possible designations [19]. The correlation analysis records the connection between the sensory consumer acceptance and sensory attributes of the profile test.

The consumers are asked about the motives of their beer consumption. Here, they must provide information concerning whether they like drinking non-alcoholic beer as a thirst quencher. Additionally, the test subjects are asked to indicate whether non-alcoholic beer has everything a beer needs for them and whether they should not deviate from regular beer.

Table 3 Physical and chemical analysis of alcohol-free and dealcoholized beer samples

Product	Original gravity	Alcohol % by wt	Alcohol % by v	Extract, real % by wt	Extract, apparent % by wt	Final attenuation %, % by v	Density sL20/20	Colour EBC	Bitterness Units BU	pH
Mean ^a	5.22	0.31	0.40	4.61	4.48	14.70			23.7	
Mean ₁₋₁₂	5.79	0.21	0.27	5.37	5.26	9.12	1.02062	7.3	24.3	4.49
Min.	4.20	0.00	0.00	3.79	3.67	0.00	1.01446	5.9	17.0	4.18
Max.	7.35	0.36	0.46	7.01	6.98	14.69	1.02764	9.4	29.5	4.97
No. 1^b	7.15	0.07	0.09	7.01	6.98	2.48	1.02764	7.3	24.0	4.97
No. 2^c	5.88	0.00	0.00	5.88	5.88	0.00	1.02322	9.4	25.0	4.48
No. 3^c	5.12	0.26	0.34	4.58	4.45	13.17	1.01750	6.2	28.3	4.30
No. 4^b	5.55	0.26	0.34	5.02	4.89	12.11	1.01924	6.9	29.5	4.51
No. 5^b	7.35	0.28	0.36	6.80	6.66	9.60	1.02637	8.5	19.0	4.51
No. 6^b	6.70	0.26	0.34	6.17	6.04	9.98	1.02387	7.3	24.8	4.56
No. 7^b	7.00	0.32	0.42	6.36	6.20	10.50	1.02262	8.3	25.3	4.50
No. 8^c	4.73	0.27	0.35	4.18	4.04	14.69	1.01587	7.2	23.8	4.57
No. 9	5.95	0.00	0.00	5.95	5.95	0.00	1.02347	5.9	17.0	4.70
No. 10^c	4.20	0.20	0.26	3.79	3.69	12.33	1.01446	6.3	29.0	4.18
No. 11^b	5.58	0.36	0.46	4.86	4.69	13.29	1.01842	6.7	19.0	4.25
No. 12^c	4.23	0.19	0.24	3.85	3.67	11.30	1.01473	7.4	26.6	4.31

a Kunze [2011, S. 885]

b Non-alcoholic beers produced by biological process and hybrid methods.

c Non-alcoholic beers produced by physical process

Table 4 Sugar spectrum of the beer samples

	tetrasaccharide	trisaccharide	maltose	glucose	fructose	total carbohydrates
No. 1	2.05	6.95	25.80	5.85	2.32	42.97
No. 2	5.44	1.48	1.24	0.18	0.23	8.57
No. 3	3.18	3.79	1.51	0.28	0.24	9.00
No. 4	3.68	4.62	14.19	2.37	1.82	26.68
No. 5	2.77	5.94	21.50	4.44	2.03	36.68
No. 6	2.19	6.44	26.50	1.87	1.91	38.91
No. 7	5.10	6.73	19.28	3.03	2.35	36.49
No. 8	3.84	2.12	0.90	0.12	0.24	7.22
No. 9	2.58	4.00	14.80	2.56	0.69	24.63
No. 10	3.44	1.69	1.35	0.20	0.31	6.99
No. 11	0.68	4.57	20.97	1.51	1.58	29.31
No. 12	3.15	1.55	0.97	0.18	0.21	6.06

2.3 Non-alcoholic beers used in this study

Table 3 shows the physico-chemical analysis of the data for the 12 German products used in this study. It also shows the normal average values of the physico-chemical analysis for non-alcoholic beers [2, 9]. 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 spectrophotometric determination. The beer colour (EBC) was analysed by spectrophotometric determination. The samples have bitter units (BU) ranging from 17.0 to 29.5 BU. Bitter units below 20 BU are characteristic of samples 5, 9 and 11. Samples 3, 4 and 10 have between 28.0 and 29.5 BU.

Table 4 shows the sugar spectrum of non-alcoholic beers. The samples 2, 3, 8, 10 and 12 have a sum of all sugar types of less than or equal to 9 g/L. The other samples show a sum of all sugar types above 24 g/L. A low sugar content indicates subsequent removal of alcohol from fermented beers. For sample number 2, the alcohol content is reduced to non-measurable by this process. Product number 8 follows the same process and is then mixed with pilsner below the usual alcohol concentration. Sample

number 9 shows a large sum of all sugar types (24.6 g/L) and a non-measurable alcohol content.

3 Results

3.1 Sensory descriptive analysis

The results of the sensory descriptive analysis are summarized in table 1 and show the average values, the product's F-value, the significance level ($p < 0.05$) and the results of the post-hoc test. The non-alcoholic beers demonstrate a significant difference in 13 attributes for odour and aroma, in three attributes for taste and three attributes for mouthfeel.

Table 5 shows the interdependency between the attributes. With the help of a factor analysis, the variety of attributes can be combined and may contribute to the discovery of descriptive variables, which are mutually independent. In this way the panellists used the attributes "lemon", "grapefruit", "resin", "apple" and "rose" to describe a hop aroma. The odour attributes of component number 2 ("boiled potato", "boiled cabbage", "butter", "lactic acid" and "animal") and component number 3 ("malt", "honey", "boiled potato" and "bread") do not correlate with the hop aroma. The attribute "boiled potato" correlates with attributes of components 2 and 3. The sweet taste is present in both components 1 and 3. In addition to its aromas, component number 2 has a bitter and sour taste. The bitter taste also correlates with intensity and a long lasting aftertaste as well as a thick and tingling mouthfeel. The components can be named as follows:

Table 5 Factor loading and communality of attributes / rotated component matrix

Attribute	Rotated component matrix			
	1	2	3	4
	Hop aroma and sweet	Boiled cabbage-like, sour and bitter	Malty, honey-like and sweet	Bitter and mouthcoating
Lemon	0.764			
Grapefruit	0.807			
Resin	0.517			
Apple	0.665			
Rose	0.724			
Geranium	0.453			
Malt			0.734	
Honey			0.710	
Boiled potato		0.418	0.540	
Bread			0.591	
Boiled cabbage		0.738		
Butter		0.541		
Lactic acid		0.725		
Animal		0.697		
Bitter		0.425		0.404
Sweet	0.457		0.533	
Sour		0.523		
Tingly				0.492
Thick				0.629
Mouthcoating				0.852
Persistence				0.822

KMO value: 0,807

- Hop aroma and sweet
- Boiled cabbage-like, sour and bitter
- Malty, honey-like and sweet
- Bitter and mouth coating

The values of the individual non-alcoholic beers are presented in a bi-plot of the PCA (Fig. 1) according to the descriptive variables formed. Detailed statements about the intensity of individual attributes require a comparison of the mean values (Table 1). The samples were described as follows:

Samples 4 and 7 are characterized by an intense hop aroma. The panellists strongly assessed them for the attributes "lemon",

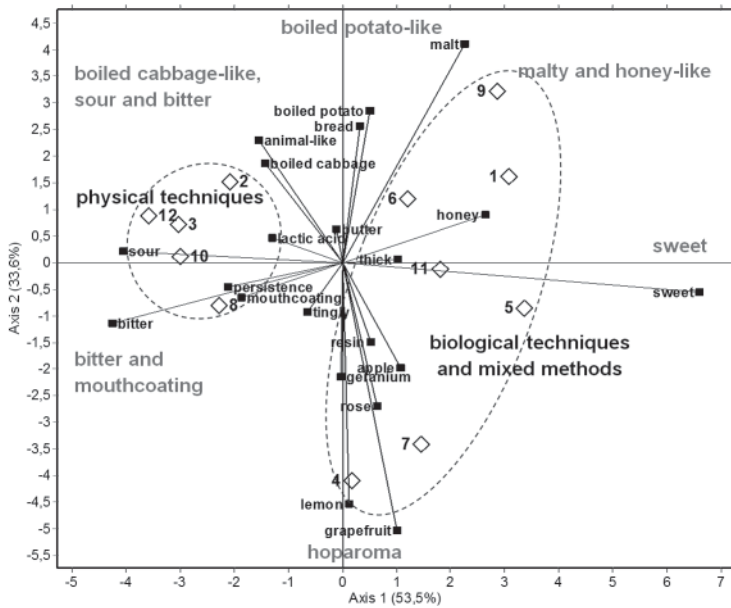


Fig. 1 Bi-plot of the principal component analysis of means products/attribute

“grapefruit”, “resin”, “rose” and “geranium”. Sample 7 is, however, sweeter than number 4. Beer number 9 has an intense malty odour and is very sweet. Sample 1 is just as sweet, but has not such a strong malty odour. Beer number 6 has a more bitter taste compared to number 1. The tingly perception of product number 6 was rated the weakest. Sample 5 has a light fruity odour and a sweet taste. Beer number 11 was rated more intense compared to number 5 in the attributes “butter” and “animal”, weaker in the attributes “sweet” and “thick”. The dealcoholized beers 3, 10 and 12 in comparison to all other samples are more intense in the attributes “boiled cabbage”, “bitter”, “aftertaste” and “persistence”. Beers 2, 3, 8, 10 and 12 have a sour taste. Sample number 8 has a weaker boiled cabbage-like odour compared to beers 3, 10 and 12. Samples 2, 3, 6, 11 and 12 have an animal-like odour.

The sugar spectrum shows a correlation with the sweet taste in figure 2 ($p = 0.000$, $R = 0.963$, $R^2 = 0.928$). The non-alcoholic beers, from which the alcohol was subsequently removed, hardly show any sweet taste. In samples with a carbohydrate content of more than 24 g/L, the sweetness is clearly perceived. However, the bitter taste also has an influence on the perceived intensity of sweetness. Product number 4 with 25.3 BU and 36.4 g/L carbohydrates thus shows the same intensity of sweetness as product number 9 with 17 BU and 24.6 g/L carbohydrates.

3.2 Consumer acceptance

Figure 3 shows the average values of acceptance of the samples by all the consumers who took part in the test ($n = 116$), as well as the results of the pair comparisons of averages (Duncan test 5 %). The Duncan test measures which product groups differ in consumer acceptance (identified by letters).

The sweet sample number 5 with a light fruity odour was preferred. The following non-alcoholic beers were not preferred:

- No. 2 with a sour and bitter taste and an animal-like odour
- No. 6 with a flat mouthfeel and an animal-like odour
- No. 4 with a strong bitter taste (29.5 BU) and a strong hop aroma.

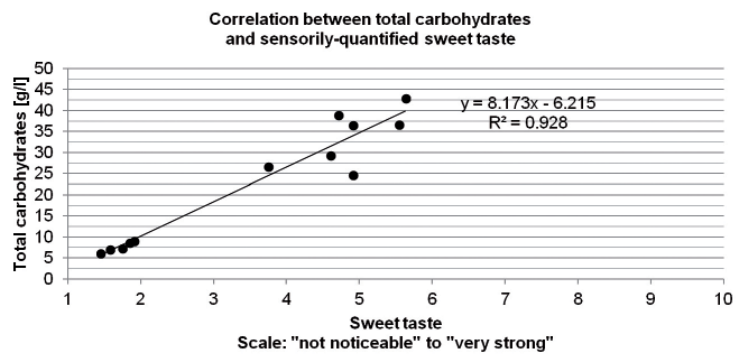


Fig. 2 Correlation between total carbohydrates and sensorily-quantified sweet taste

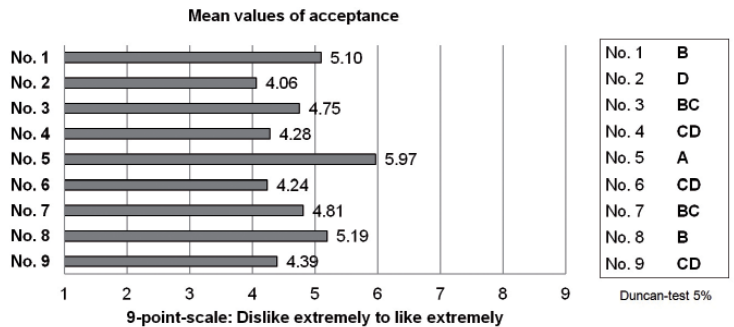


Fig. 3 Mean values of acceptance (overall impression) and Duncan test

- No. 9 with an intense malty, bread-like and boiled potato-like odour

Table 6 shows the average acceptance values of the samples in terms of colour, odour and taste. The products show a significant difference in acceptance in the individual characteristics. The light fruity odour of samples 5 and 8 was preferred. The taste of the sweet products 1 and 5 showed the highest acceptance.

Table 7 shows the connection between consumer acceptance and the sensory features. A connection exists between consumer acceptance and the sensory features of the apple-like and boiled cabbage-like odour. The better the non-alcoholic beer was evaluated by the test participants, the more intense the apple-like odour

Table 6 Mean values of odour and taste acceptance

Product	Odour		Taste	
	Mean Value	Duncan 5%	Mean Value	Duncan 5%
No. 1	4.80	BC	5.15	B
No. 2	4.32	CD	3.92	F
No. 3	4.98	B	4.57	CDE
No. 4	4.30	CD	4.07	EF
No. 5	5.66	A	6.12	A
No. 6	4.08	D	4.26	DEF
No. 7	4.59	BCD	4.67	BCD
No. 8	5.56	A	4.96	BC
No. 9	4.02	D	4.28	DEF
Comp. F	10.20		12.62	
Sig. p	<0.0001		<0.0001	

Table 7 Correlation between acceptance and sensory terms

Attribute	Explained variance R ²	Sig. p	Coefficient R
Lemon	0.248	0.086	0.498
Grapefruit	0.201	0.113	0.448
Resin	0.178	0.129	0.421
Apple	0.626	0.006	0.791
Rose	0.217	0.103	0.466
Geranium	0.096	0.208	0.310
Malt	0.067	0.251	-0.259
Honey	0.060	0.262	0.245
Boiled Potato	0.311	0.059	-0.558
Bread	0.307	0.061	-0.554
Boiled Cabbage	0.561	0.010	-0.749
Butter	0.269	0.076	-0.519
Lactic acid	0.207	0.109	-0.455
Animal	0.299	0.064	-0.547
Bitter	0.141	0.160	-0.375
Sweet	0.177	0.130	0.420
Sour	0.145	0.156	-0.380
Tingly	0.013	0.383	-0.116
Thick	0.128	0.173	0.357
Mouthcoating	0.134	0.166	-0.366
Persistence	0.212	0.106	-0.460

was. Consumer acceptance is determined by this odour by up to 62.6 %. The more intense the odour of boiled cabbage, the worse the test participants evaluated the non-alcoholic beer. The attribute “boiled potato” shows a negative trend of correlation with acceptance ($p = 0.059$).

Figures 4 to 6 show a significant difference between the products in the evaluation of the sweet, bitter and sour taste ($p < 0.0001$). In the case of products 2, 3 and 8, where alcohol was subsequently removed, the test participants missed the sweet taste more than in other products. Between 39 and 52 % of the test participants evaluated the sweetness of products 2, 3 and 8 as “too weak” or “much too weak”. With the exception of number 4, the products in which the fermentation was suppressed or which were prepared by hybrid processes, showed an increase in the assessment of its sweet taste as being “too strong” and “much too strong”. In particular, product number 9 was perceived as too sweet. Product number 4 has an intense hop aroma as well as an additional bitter taste (29.5 BU) (Fig. 4).

The bitter taste of samples 2, 3 and 8, in which the alcohol was reduced, was considered by 46–66 % of the test participants as “too strong” and “much too strong” (Fig. 5). Also, product number 4 with 26.6 g/L carbohydrates and 29.5 BU was perceived as too bitter by 47 % of the test participants. In the sweet product number 9 the bitter taste was missing according to 41 % of test participants. None of the products in the category of “just right” achieved more than 70 % for the sweet and bitter taste quality – not even the highly – accepted product number 5.

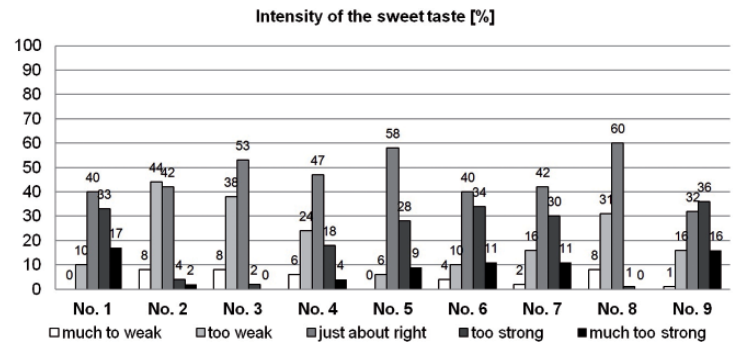


Fig. 4 Intensity of the sweet taste

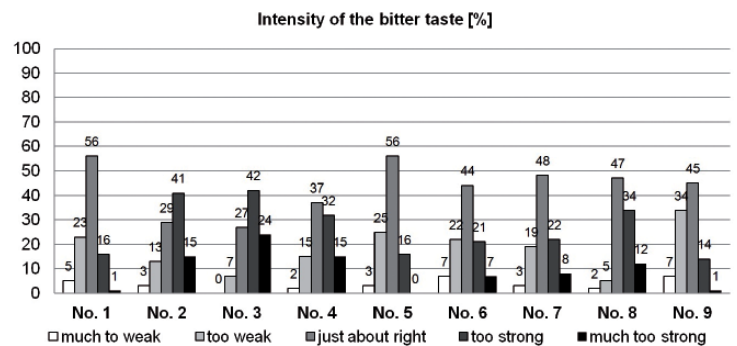


Fig. 5 Intensity of the bitter taste

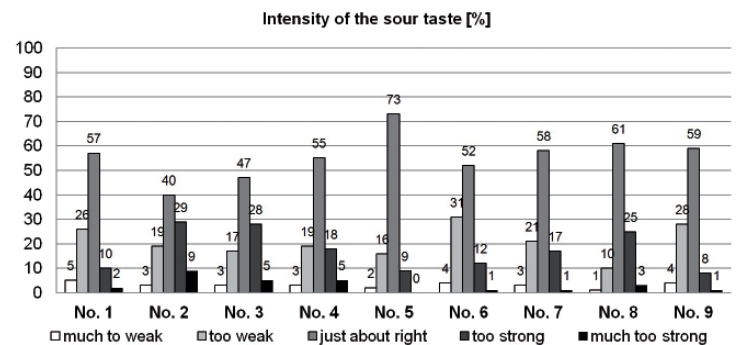


Fig. 6 Intensity of the sour taste

The sour taste of products 2 and 3 was rated by 33–38 % of the test participants as “too strong” and “much too strong” (Fig. 6). A total 70 % of the test participants rated the favoured product number 5 as “just right” with respect to the sour taste.

Figure 7 shows the investigation with the k-means cluster analysis of a completely random sample of certain sub-groups who differ markedly in their acceptance behaviour. Samples 4 and 7 with an intense hop aroma and the sweet sample 1 are preferred markedly more by cluster 2 (44.8 %, $n = 52$) than by cluster 1 (55.2 %, $n = 64$). In addition, products 2, 6 and 9 show these polarisation effects. However, these products are not evaluated as well as 1, 4 and 7 by cluster 2.

Regarding the gender, age and consumption volume, motives and expectations, the consumer groups showed different assessments of acceptance (Table 8). The sweet product number 5 with a light fruity aroma was preferred significantly more by women than by men. Men dislike the malty odour of sample 9 more than women.

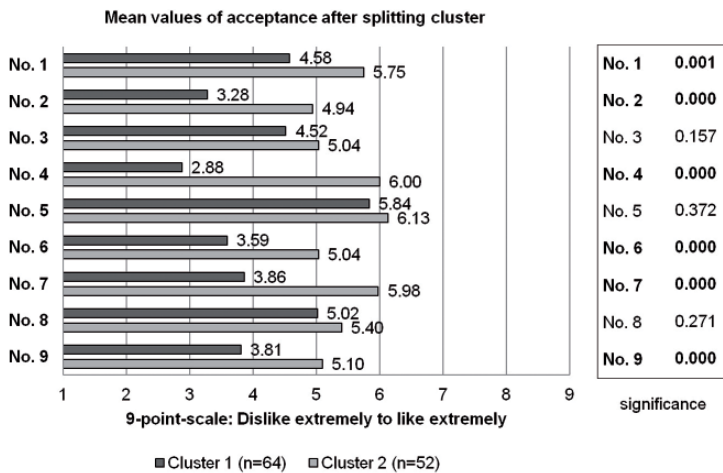


Fig. 7 K-means cluster analysis

Consumers between 16 and 39 dislike non-alcoholic beers with a malty odour less than consumers aged over 40.

In relation to the consumption volume, there is no significant difference in the acceptance of non-alcoholic beer. The evaluation of the samples by consumers, who do not usually drink any non-alcoholic beer, does not differ significantly from the assessment of test participants who drink non-alcoholic beer.

Table 9 shows the split analysis data for the study of consumer acceptance of motive and sensory expectations. Consumers who like to drink non-alcoholic beer as a thirst quencher, evaluated product number 6, which hardly has any tingling mouthfeel, significantly worse than consumers who do not.

The majority of test participants indicate that non-alcoholic beer does not have “everything that a beer needs” and it may not taste different than an alcoholic beer. In terms of acceptance, however, the test participants see no significant difference.

Table 8 Split analyses for gender, age group and consumption volume

Product	Mean value			Sig. p	Mean value			Sig. p	Mean value		Sig. p
	Gender		Age group		Consumption NAB						
	Female	Masculine			16-39 years	40 years and older	≥once a month		never		
No. 1	5.32	4.94	0.303	5.13	5.07	0.880	5.12	5.04	0.842		
No. 2	4.12	4.02	0.770	4.15	3.91	0.509	4.25	3.42	0.055		
No. 3	4.92	4.62	0.422	4.72	4.80	0.847	4.73	4.81	0.846		
No. 4	4.08	4.42	0.424	4.44	4.00	0.311	4.42	3.81	0.232		
No. 5	6.40	5.65	0.021	5.96	6.00	0.901	6.07	5.67	0.296		
No. 6	4.08	4.36	0.465	4.32	4.11	0.603	4.15	4.56	0.368		
No. 7	4.74	4.86	0.753	4.71	4.98	0.502	4.81	4.81	0.990		
No. 8	5.18	5.20	0.962	5.08	5.36	0.439	5.28	4.89	0.346		
No. 9	4.82	4.06	0.037	4.71	3.86	0.023	4.43	4.26	0.697		
number	50	66		72	44		89	27			
% of total number	43.1	56.9		62.1	37.9		76.7	23.3			

Table 9 Split analyses for motivation and attitudes of consumers

Product	Mean value			Sig. p	Mean value			Sig. p	Mean value		Sig. p
	“NAB is a real thirst quencher”		“NAB has everything a beer needs.”		“NAB should not differ from regular beer.”						
	No	Yes			No	Yes	No		Yes		
No. 1	5.06	5.15	0.820	5.03	5.35	0.476	5.26	5.01	0.523		
No. 2	3.82	4.33	0.155	4.03	4.15	0.781	4.37	3.88	0.183		
No. 3	4.85	4.63	0.542	4.74	4.77	0.955	5.02	4.59	0.254		
No. 4	4.27	4.28	0.993	4.31	4.15	0.758	4.77	3.99	0.075		
No. 5	6.15	5.78	0.258	5.91	6.19	0.470	6.12	5.89	0.501		
No. 6	4.68	3.74	0.014	4.21	4.35	0.770	4.14	4.30	0.684		
No. 7	4.74	4.89	0.706	4.77	4.96	0.676	5.07	4.66	0.305		
No. 8	5.31	5.06	0.477	5.34	4.65	0.100	5.21	5.18	0.932		
No. 9A	4.53	4.22	0.396	4.51	3.96	0.207	4.72	4.19	0.159		
number	62	54		90	26		43	73			
% of total number	53.4	46.6		77.6	22.4		37.1	62.9			

4 Discussion

4.1 Sensory descriptive analysis

The non-alcoholic beers which were investigated represented a selection of products offered on the German market and can be assigned to two groups according to their production method due to their carbohydrate content and their sweet taste.

The observation by Zufall and Wackerbauer [6, 7] that non-alcoholic beers that are produced by inhibited or interrupted fermentation, have a strong wort-like odour and a sweet taste, can be confirmed with respect to the taste. However, an intense wort-like odour is not perceived in all beers based on this production process. It is impossible to say whether a wort-like odour is masked by a hop aroma [6, 7], or whether wort-scented substances like methional and 3-methyl butanal are reduced by a certain fermentation period [12]. Detailed manufacturing processes of the products are not known and also mixed forms of methods are used.

Panelists also recognised the characteristic attributes for wort in non-alcoholic beer, such as “honey”, “malt” and “boiled potato” [13] and they show significant product differences.

Zufall and Wackerbauer [6, 7] describe the sensory properties of non-alcoholic beer produced by the subsequent reduction of alcohol as a “neutral aroma” and “less palate fullness”. However, the products examined show no significant difference in the thick mouthfeel. The odour of these beers ranges from a slight hop aroma to animal notes, depending on the product.

In addition to the taste classification of non-alcoholic beer, the products can be divided in whole or in part into three sensory directions: non-alcoholic beer with a hop aroma, a wort-like odour or products with an animal-like and boiled cabbage-like odour.

4.2 Consumer acceptance

Consumers prefer sweet and slightly fruity non-alcoholic beers. If the brewery wants to apply these sensory characteristics to their non-alcoholic beer, attention should be paid to low intensity of malty and honey-like odours in beers that are produced by inhibited or interrupted fermentation. It was confirmed that a malty and honey-like odour in non-alcoholic beer is not particularly favoured [12].

Non-alcoholic beers with a very intense hop aroma only received a low average of acceptance. However, the test participants differ in the acceptance rating, with 44.8 % of the test participants assessing products with a strong hop aroma very well while 55.2% of the participants dislike this aroma. Non-alcoholic beer with a strong hop aroma is a very acceptable product among a segment of the test participants.

Beers, which are produced by subsequent removal of the alcohol from finished beers, show a slightly fruity aroma when they are blended with normal beer up to the usual alcohol limit.

It was impossible to confirm that non-alcoholic beers, which were subsequently dealcoholized, are better than products produced

by interrupted fermentation, despite their lack of “palate fullness” and partially sour taste [7]. If the alcohol is subsequently reduced, care must be taken to avoid a sour taste in order to achieve better acceptance.

To what extent the acceptance of bitter non-alcoholic beers can be improved by appropriate communication, was not tested. However, the sensory description provides the basis for product development and the decision to focus on successful products or alternative development.

Although the majority of test participants indicate that non-alcoholic beer does not have “everything that a beer needs”, and that it should not differ from regular beer in taste, their acceptance rating is not significantly different from that of test participants who do not see it this way. Therefore, the question arises as to what extent the non-alcoholic beer should be developed in line with normal beer, or may be considered in product development as a product category of its own. Analysing the sensory descriptions, it is apparent that the preferred sensory directions (sweet and slightly fruity) are barely represented among these products.

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