G. Derdelinckx, M. Maudoux, S. Collin and J.-P. Dufour

Statistical and sensory differences among special bottle refermented beers of a same type

Some countries such as Belgium, Germany, and the United Kingdom are notable for the large quantities of special beer they produce and sell worldwide. When these special beers are classified by type, some classes may include as many as eighty labels. Our aim was to propose a method for detecting the organoleptic specificity of beers by physicochemical analysis. We thus selected eigtheen parameters, independent of beer aging, which characterize a product's visual aspect, aroma, taste, and mouthfeel. The results were analyzed statistically to allow an evaluation of process reproducibility and a comparison of mean values. We conclude that despite relatively poor process reproducibility, the four beers studied here present sufficient distinctive features to make them different. This finding was corroborated by sensory analysis.

BC 033 Chemical and physical analysis methods/251 Organoleptic specificity/27 Special beers

(Descriptors EBC: beer, organoleptic

Deskriptoren EBC: Bier, Organoleptik).

1. Introduction

Special beers are typical products brewed essentially in Belgium, Germany, and Great Britain, where in 1992 they accounted respectively for 27.9%, 15.1%, and 49.0% of the total volume of beer produced. They can be defined as all kinds of beer except the Pils type, the nonalcoholic or lite (light) alcoholic beers, and the low density bottom fermented beers. Nowadays, local and middle-sized breweries in the US are also developing special beers. Such beers usually present a distinctive external aspect and/or flavor. Table 1 shows a proposed classification based on their original gravity, color, and turbidity. The observed differences mainly reflect the quantity, quality, and type of raw materials used, the kind of yeast, the type of fermentation, sometimes the use of technical adjuncts and additives, and a number of environmental conditions (4, 10). In a same country, it is usual to find more than thirty brands in a same class, yet often only 3 or 4 account for at least 85% of the volume sold. The general public and connoisseurs alike wonder how different all these beers really are and whether their so-called specificity is more than a matter of presentation and advertising claims. We therefore conducted a scientific study based on the statistical analysis and sensory evaluation (5, 6, 8, 9, 12) of eighteen characteristics which beer aging does not significantly affect, to see whether four major brands brewed in Belgium and sold throughout Western Europe and the US are truly different (1, 2, 13, 14).

Table 1 Classification of Belgian special beers

1. Beers of spontaneous fermentation
Lambic
Gueuze
Kriek and sour fruited beers
2. Beers of top fermentation
2.1. Beers with an original gravity higher than 15°Plato
2.1.1. Pale or slightly amber and filtered beers (colour lower than 12 EBC or 5 ASBC)
Abbey beers
Some well known special beers
2.1.2. Pale or slightly amber beers refermented in bottles
Trappists of the type "Triple"
Abbey beers of the type "Triple"
Some special and well known beers
2.1.3 Amber and dark filtered beers (colour higher than 25 EBC or 9.7 ASBC)
Some abbey beers of the type "Double" and others
Some well known special beers
Beers like high gravity "Pale ales"
Beers like "Scottish dark ales"
2.1.4. Amber or dark beers refermented in bottles (colour higher than 25 EBC or 9.7 ASBC)
Trappists of the type "Double" and others
Abbey beers like "Doubles"
Some special and well known beers
2.2 Beers with an original gravity between 11.0 and 13.9 Plato
2.2.1. Pale or slightly amber beers (colour lower than 12 EBC or 5 ASBC)
2.2.1.1. Limipd beers (Turbidity lower than 8 NTU)
Some special and regional beers
2.2.1.2. Turbid (haze) beers refermented in bottles
Wheat beers (Haze higher than 20 NTU)
2.2.2. Amber beers (colour between 20& 30 EBC or 8.0 & 11.5 ASBC)
Amber and well known regional beers
Beers of the "Pale ale" type
Some special sour beers
2.2.3. Dark beers (colour higher than 40 EBC or 15 ASBC)
Beers like "Stout"
Some special sour beers
2.3. Beers of an original gravity between 7° and 9°Plato
2.3.1. Dark beers (colour higher than 40 EBC or 15 ASBC)
Dark ales
2.3.2. Pale beers (colour lower than 12 EBC or 5 ASBC)
Light ales

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2. Experimental

Beers of a same type (pale or slightly colored and refermented in bottles, see Table 1), brewed by three different companies and sold under four different labels (A, B, C, and D) were purchased four times over a six-month period at sixteen different locations in Belgium (four different locations each time). To ensure that the samples were statistically independent, the code number of each beer was checked. The following properties were investigated:

- outer appearance: foam, color
- aroma: esters, higher alcohols, and a sulfur-containing compound : DMS;
- taste: bitterness, acidity, saltiness, sweetness;
- mouthfeel: real extract, CO_2 content, alcohol content, polyphenols, and total nitrogen.

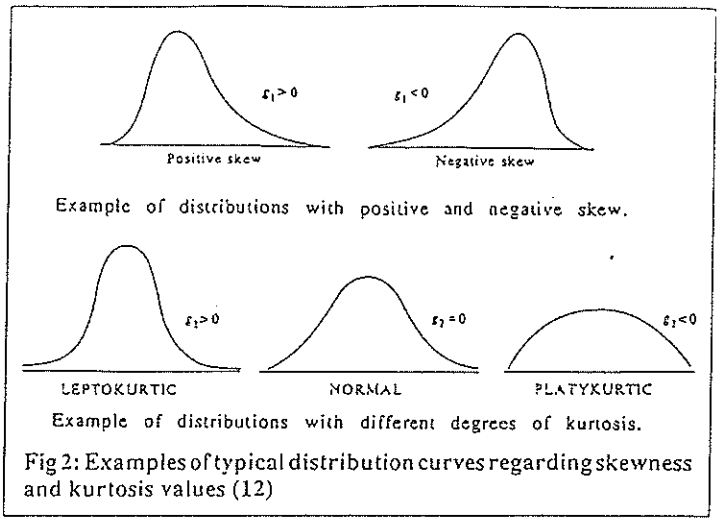

Fig 2: Examples of typical distribution curves regarding skewness and kurtosis values (12)

3. Methods

- Foam: in some countries, each beer has its own glass which can influence head retention (Figure 1). In a same class, moreover, the CO_2 content can vary from 4.5 to 9.0 g/l. We therefore chose Rudin's method which measures foam stability independently of CO_2 content.
- Color, total nitrogen, bitterness, acidity, CO_2, alcohol content, and polyphenols were determined by EBC methods.
- The cation content was determined by flame spectrometry. Chloride and sulfate anions were assayed by recommended EBC methods.
- Higher alcohols and esters were assayed as described by Malcorps (7).
- Statistical analysis based on Student's test was performed by means of the StatWorks program (MacIntosh).
- For sensory evaluation, the beers were tested in triangular tests by two procedures: (1) in opaque vessels as recommended by EBC; (2) in standard transparent glasses (50 cl) of the "Bourgogne" type.

4. Results

4.1 Statistical analysis

For an explanation of skewness and kurtosis, see Figure 2 (11). In Student's-test, the hypothesis is always $H_0 : \mu_1 = \mu_2$; $H_1 : \mu_1 \neq \mu_2$

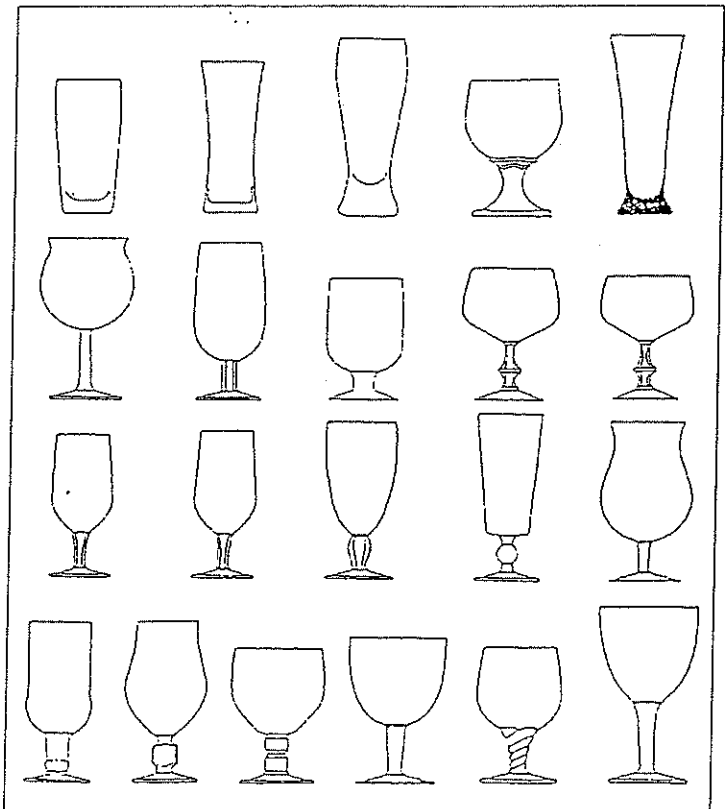

Fig. 1: Typical form of special beer containers (Durobor, Belgium)

Table 2 Foam

Descriptive statistic (16 observations)	Mean (sec)	Stand. deviation	Skewness	Kurtosis
Beer A	448	48.3	0.728	- 0.377
Beer B	431	46.1	- 0.100	- 1.113
Beer C	479	54.8	- 0.105	- 0.996
Beer D	496	75.7	- 0.449	- 0.972

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	0.92	1.81	2.20	2.70	2.93	0.70
signification	0.36	0.08	0.04	0.01	0.01	0.49

Table 3 Color

Descriptive statistic (16 observations) EBC units (ASBC=0.375xEBC + 0.46)	Mean	Stand. deviation	Skewness	Kurtosis
Beer A	12.0	0.81	- 0.177	- 1.057
Beer B	7.9	0.78	0.321	- 1.071
Beer C	12.4	0.86	- 0.115	- 1.541
Beer D	6.9	0.31	0.334	- 0.808

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	14.7	1.45	23.61	15.67	4.67	24.16
signification	0.00	0.15	0.00	0.00	0.00	0.00

4.1.1 Visual characteristics

(Table 2 and table 3)

The data for the foam of the beer samples display a wide and platykurtic distribution. The high standard deviations of this parameter point to a lack of process reproducibility and the resulting high H_0 significance levels make it impossible to distinguish A from B by this criterion. Color, on the other hand, is a distinctive feature of all four beers. In sensorial analysis, these beers will also appear different, as it is well known that the human eye distinguishes a color difference of 0.5.

4.1.2 Aroma characteristics

(Table 4 trought 10)

In terms of their overall flavor potential as measured in Flavor Units (FU=concentration/threshold), the four beers appear quite

Table 4 Ethyl acetate (Flavor in beer: Solvent, fruity, sweetish; threshold: 33 mg/L)

Descriptive statistic (16 observations)	Mean (mg/L)	Stand. deviation	Skewness	Kurtosis
Beer A	69.9	7.7	- 0.101	- 1.599
Beer B	44.7	9.6	- 0.264	- 0.984
Beer C	85.6	28.8	- 0.557	- 1.108
Beer D	68.1	16.0	- 0.847	- 0.714

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	8.17	2.10	0.42	5.37	4.95	2.07
signification	0.00	0.05	0.68	0.00	0.00	0.05

Table 5 Isoamyl acetate (Flavor in beer: banana, peary, apple, solvent; threshold: 1.6 mg/L)

Descriptive statistic (16 observations)	Mean (mg/L)	Stand. deviation	Skewness	Kurtosis
Beer A	3.4	0.6	0.050	- 0.481
Beer B	2.5	0.7	1.001	0.156
Beer C	7.0	1.2	0.489	- 0.360
Beer D	8.5	2.6	- 0.404	- 0.922

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	4.26	11.35	7.74	13.70	9.04	2.12
significaction	0.00	0.00	0.00	0.00	0.00	0.04

Table 6 Ethyl caproate (Flavor in beer: apple, fruity, estery, aniseed; threshold: 0,23 mg/L)

Descriptive statistic (16 observations)	Mean (mg/L)	Stand. deviation	Skewness	Kurtosis
Beer A	0.41	0.21	1.014	- 0.886
Beer B	0.47	0.29	1.331	0.849
Beer C	0.35	0.14	0.981	- 0.769
Beer D	0.45	0.23	0.632	- 1.467

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	0.76	0.88	0.53	1.53	0.23	1.42
signification	0.45	0.39	0.60	0.14	0.78	0.17

Table 7 Ethyl caprylate (Flavor in beer: Apple, sweetish, fruity; threshold: 0, 9 mg/L)

Descriptive statistic (16 observations)	Mean (mg/L)	Stand. deviation	Skewness	Kurtosis
Beer A	1.20	0.45	0.837	- 0.541
Beer B	1.20	0.71	1.539	2.613
Beer C	1.08	0.37	1.225	0.378
Beer D	1.21	0.57	0.558	- 1.229

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	0.01	0.85	0.07	0.63	0.04	0.79
signification	0.99	0.41	0.95	0.54	0.97	0.44

Table 8 β-phenylethanol (Flavor in beer: Roses, sweetish, perfumed, threshold: 125 mg/L)

Descriptive statistic (16 observations)	Mean (mg/L)	Stand. deviation	Skewness	Kurtosis
Beer A	25.6	5.06	- 0.411	0.765
Beer B	42.3	8.67	- 0.900	- 0.467
Beer C	38.1	5.75	- 0.113	- 1.912
Beer D	56.8	7.30	0.584	- 1.329

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	4.81	4.77	10.08	1.13	3.64	5.70
signification	0.00	0.00	0.00	0.28	0.00	0.00

Table 9 Amyl- and isoamyl alcohols (Flavor in beer: Alcohol, banana, sweetish, medicinal, aromatic, solvent; threshold: 70 mg/L)

Descriptive statistic (16 observations)	Mean (mg/L)	Stand. deviation	Skewness	Kurtosis
Beer A	95.2	11.1	- 0.301	- 1.296
Beer B	95.5	13.6	1.100	1.470
Beer C	106.7	6.9	0.583	- 0.087
Beer D	184.9	28.4	1.485	1.930

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	0.07	3.53	11.75	2.96	11.33	10.71
signification	0.94	0.00	0.00	0.01	0.00	0.00

Table 10 Dimethylsulfide (Flavor in beer: Cooked vegetable, onion, garlic; threshold: 50 µg/L)

Descriptive statistic (16 observations)	Mean (µg/L)	Stand. deviation	Skewness	Kurtosis
Beer A	84.2	13.8	- 0.067	- 0.332
Beer B	130.5	66.1	0.265	- 1.458
Beer C	92.1	19.2	- 0.129	- 0.442
Beer D	125.1	28.5	0.023	- 1.321

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	2.75	1.34	5.14	2.23	0.29	3.80
signification	0.01	0.19	0.00	0.03	0.77	0.00

comparable: beer A: 10.6 FU with a standard deviation (s.d.) of 2.43; beer B: 10.6 FU, s.d.: 2.98; beer C: 13.4 FU, s.d.: 3.15; beer D: 16.25 FU, s.d.: 4.76. When specific parameters are considered, similarities appear between some beers (see significance levels for ethyl acetate in A and D; ethyl caproate in A and B; ethyl caprylate and amyl- and isoamyl alcohols in A and B; dimethylsulfide in B and D). All four beers, however, can easily be distinguished on the basis of a single parameter: their isoamyl acetate content. This was confirmed by sensory analysis.

4.1.3 Taste characteristics

(Tables 11 through 15)

While beers B and C are quite similar as regards their bitterness, their other taste characteristics are very different. The mean real extract value is identical for beers A and B but the other parameters differ in these beers. In all cases, we must mention a lack of reproducibility, especially as regards the salt content of beer C and even bitterness, since it is well known that connoisseurs can distinguish a difference of 2 Bitterness Units. Despite this poor reproducibility of some parameters, the specific differences are so marked that we can assert that as far as taste is concerned, the four beers are different.

Table 11 Bitterness

Descriptive statistic (16 observations)	Mean (BU)	Stand. deviation	Skewness	Kurtosis
Beer A	22.4	1.4	0.165	- 0.687
Beer B	27.6	2.2	- 0.066	- 1.461
Beer C	27.7	3.2	1.270	0.637
Beer D	35.7	2.7	- 0.161	- 1.238

Student t-test (30 degrees of freedom)

Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	7.91	6.19	17.39	0.18	9.28	7.63
signification	0.00	0.00	0.00	0.86	0.00	0.00

Table 12 Total acidity

Descriptive statistic (16 observations)	Mean mL NaOH 0.1N/100 mL beer	Stand. deviation	Skewness	Kurtosis
Beer A	36.8	2.9	- 0.030	- 1.106
Beer B	37.9	2.9	- 0.620	- 0.587
Beer C	32.8	1.0	0.016	- 1.474
Beer D	33.6	2.1	0.654	- 0.273

Student t-test (30 degrees of freedom)

Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	1.08	5.28	3.65	6.63	4.83	1.33
signification	0.29	0.00	0.00	0.00	0.00	0.19

Table 13 Sulfate

Descriptive statistic (16 observations)	Mean mg/L	Stand. deviation	Skewness	Kurtosis
Beer A	209	25	0.005	- 1.512
Beer B	334	15	- 1.951	2.742
Beer C	176	59	0.279	- 1.862
Beer D	128	12	0.017	- 0.779

Student t-test (30 degrees of freedom)

Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	9.00	2.04	11.51	8.21	16.17	3.20
signification	0.00	0.05	0.00	0.00	0.00	0.19

Table 14 Chloride

Descriptive statistic (16 observations)	Mean mg/L	Stand. deviation	Skewness	Kurtosis
Beer A	349	12	0.553	- 0.647
Beer B	249	44	- 0.390	0.221
Beer C	412	76	- 1.490	1.144
Beer D	159	10	0.341	- 0.171

Student t-test (30 degrees of freedom)

Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	8.75	3.27	47.80	7.43	8.02	13.2
signification	0.00	0.00	0.00	0.00	0.00	0.00

Table 15 Real extract

Descriptive statistic (16 observations)	Mean Plato	Stand. deviation	Skewness	Kurtosis
Beer A	5.31	0.23	- 0.760	0.876
Beer B	5.31	0.57	0.903	0.164
Beer C	5.52	0.29	0.024	- 1.752
Beer D	4.39	0.15	- 0.650	- 0.297

Student t-test (30 degrees of freedom)

Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	0.00	2.40	13.24	1.39	6.18	13.76
signification	1.00	0.02	0.00	0.17	0.00	0.19

Table 16 Carbon dioxide

Descriptive statistic (16 observations)	Mean g/L	Stand. deviation	Skewness	Kurtosis
Beer A	5.87	0.41	0.564	- 0.674
Beer B	6.15	0.68	- 0.813	- 0.666
Beer C	5.83	0.41	0.690	- 0.654
Beer D	6.52	0.39	- 0.804	- 0.851

Student t-test (30 degrees of freedom)

Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	1.43	0.30	4.65	1.64	1.89	4.89
signification	0.16	0.76	0.00	0.11	0.07	0.00

Table 17 Ethanol

Descriptive statistic (16 observations)	Mean g/100 mL	Stand. deviation	Skewness	Kurtosis
Beer A	8.46	0.09	0.154	- 1.327
Beer B	8.91	0.37	- 1.211	1.379
Beer C	8.54	0.19	0.255	- 0.107
Beer D	8.36	0.13	- 0.609	- 0.972

Student t-test (30 degrees of freedom)

Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	4.74	1.43	2.40	3.66	5.58	2.94
signification	0.00	0.16	0.02	0.00	0.00	0.01

Table 18 Polyphenols

Descriptive statistic (16 observations)	Mean mg/L	Stand. deviation	Skewness	Kurtosis
Beer A	251	37	0.023	- 1.461
Beer B	179	24	- 0.138	- 1.581
Beer C	253	32	0.092	- 1.637
Beer D	239	21	- 0.477	- 1.182

Student t-test (30 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	6.65	0.12	1.21	7.37	7.60	1.48
signification	0.00	0.90	0.24	0.00	0.00	0.15

Table 19 Total nitrogen

Descriptive statistic (12 observations)	Mean mg/L	Stand. deviation	Skewness	Kurtosis
Beer A	1115	50	0.143	- 1.488
Beer B	1009	63	0.327	- 0.197
Beer C	995	69	0.160	- 1.877
Beer D	672	35	- 0.277	- 1.530

Student t-test (22 degrees of freedom)						
Means compared	Beer A/Beer B	A/C	A/D	B/C	B/D	C/D
t-value	4.58	4.92	25.2	0.53	16.15	14.44
signification	0.00	0.00	0.00	0.60	0.00	0.00

4.1.4 Mouthfeel characteristics

(Tables 16 through 19)

We believe that the measured mouthfeel differences are insignificant from a sensory standpoint, except for the much lower polyphenol content of beer B and the lower total nitrogen level of beer D (one-half to two-thirds of the value found in other beers).

4.2 Sensory analysis

To confirm the above results, triangular tests were performed on the four beers.

First, we tested the similarity of beers of a same label bought at the same time at four different locations. The beers were tasted by 16 consumers. The results of these tasting sessions clearly demonstrated, as expected, the absence of a constant organoleptic profile in most special bottle-refermented beers. This is due to the variability of some production parameters as shown in our statistical analysis and to bottling with or without air in the neck, combined with variable storage conditions (3).

The second test included two parts:

- during a first session, the beers were presented in opaque vessels. Different beers sold at a same location were compared (2 by 2) in triangular tests. More than 90% of the tasters were able to discriminate correctly between beers;
- during a second session, the same beers were provided in transparent "Bourgogne" type glasses. All tasters but one correctly distinguished the four different brands of bottle-refermented beer.

5. Conclusion

In order to detect statistical and sensory differences between special bottle-refermented beers of a same type, we deliberately determined parameters which activate the senses: visual features (foam and color), aromatic parameters (ethyl acetate, isoamyl acetate, ethyl caproate, beta-phenylethanol, amyl and isoamyl alcohols, dimethylsulfide), taste indicators (bitterness, total acidity, sulfate and chloride contents, real extract), and mouthfeel parameters (carbon dioxide, ethanol, polyphenols, total nitrogen). The advantage of these attributes is that they are unaffected by storage conditions which alter the true characteristics of the beers studied.

Our results clearly show that the beers differ both organoleptically and analytically, even considering the poor reproducibility of certain parameters due to some inconstancy in the process. Our chosen parameters thus appear as a good choice for the future investigation of other special beers.

6. Zusammenfassung

Derdelinckx, G., Maudoux, M., Collin, S., and Dufour, J.-P.: Statistische und sensorische Unterschiede zwischen auf Flaschen nachvergorenen Bieren des gleichen Typs — Monatsschrift für Brauwissenschaft 47, Nr. 3, 88 - 93, 1994

BC 033 Chemisch-physikalische Untersuchungen/251 Organoleptische Eigenschaften/27 Spezialbiere

Einige Länder wie Belgien, Deutschland und Großbritannien, sind bekannt für die große Zahl von Spezialbieren die sie herstellen und weltweit verkaufen. Wenn man die Spezialbiere nach Typen einteilen würde, so würden einige Sorten nicht weniger als 80 Marken umfassen. Unser Ziel war es, eine Methode anzubieten, mit der organoleptische Merkmale von Bieren mittels physiochemischer Analysen nachzuweisen sind. 18 Kriterien wurden dafür ausgewählt, die, unabhängig vom Alter des Bieres, Aussehen, Aroma, Geschmack und Vollmundigkeit des Produktes charakterisieren. Die Ergebnisse wurden statistisch ausgewertet, um zu einer Beurteilung der Reproduzierbarkeit des Verfahrens und zu einem Vergleich der Hauptwerte zu gelangen. Wir kommen zu dem Schluß, daß für die vier untersuchten Biere, trotz geringer Reproduzierbarkeit des Verfahrens, ausreichende Unterscheidungsmerkmale geliefert werden. Dieses Ergebnis wurde durch Sinnesanalysen bestätigt.

Derdelinckx, G., Maudoux, M., Collin, S., et Dufour, J. P.: Différences statistiques et sensorielles parmi des bières refermentées en bouteille d'un meme type. — Monatsschrift für Brauwissenschaft 47, Nr. 3, 88 - 93, 1994

BC 033 Méthods d'analyses chimiques et physiques/251 Spécificité organoleptique/27 Bières spéciales.

Certains pays comme la Belgique, l'Alemagne et la Grande Bretagne sont connus pour les grandes quantités de bières spéciales qu'ils produisent et vendent dans le monde. Lorsque ces bières sont classées par type, certaines classes peuvent comprendre jusqu'à quatre-vingt labels. Notre but a été de proposer une méthode pour détecter la spécificité organoleptique des bières par des analyses physicochimiques. Nous avons ainsi sélectionné dix-huit paramètres, indépendants de l'âge de la bière, qui caractérisent l'aspect visuel du produit, son arôme, son goût et son moelleux. Les résultats ont été analysés statistiquement pour permettre une évaluation de la reproductibilité de la fabrication et une comparaison des valeurs moyennes. On en conclut que malgré une faible reproductibilité de la fabrication, les quatre bières étudiées ici présentent des caractéristiques suffisamment distinctes pour être différenciées. Ce résultat a été confirmé par l'analyse sensorielle.

7. Acknowledgement

The authors gratefully acknowledge the help and advice given by Anne-Marie Meyer, John Clayson, Freddy Drochmans, Paul Riguelle and Jean-Paul Van Helleputte in the preperation of this communication. S. C. thanks the Belgian National Foundation for Scientific Research (FNRS, Belgium) for financial support.

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