Foaming and Beer Flavor[1]

M. Ono, S. Hashimoto, Y. Kakudo, K. Nagami, and J. Kumada, *Central Research Institute of SUNTORY Ltd., Osaka, 618 Japan*

ABSTRACT

The influence of foaming and the various effects that it has on the flavor of beer were investigated by sensory analysis and by physical and chemical analyses. The characteristics of the foam itself were strongly affected by the method of pouring, which played an important role in determining taste characteristics, such as mouthfeel and drinkability of a freshly poured beer. Physical and chemical analyses indicated that flavor was affected by the differences in the degree of CO_2 released, by the evolution of some volatile compounds, and by the combination of bitter substances with the CO_2 that remained.

Key words: *Beer, Bitterness, CO_2, Dispenser, Flavor, Foaming*

The remarkable trend during the 1980s in the Japanese beer market was the great increase of canned or bottled unpasteurized draft beers and the multiplicities of their containers in both capacity and materials of construction. Most consumer attention was focused on 2- and 3-L mini-kegs made of aluminum, polyethylene terephthalate, etc. They were marketed with the concept of allowing the users to enjoy the taste of draft beer conveniently at home.

We thought that foam might play an important role in determining the organoleptic characteristics of the poured beer; generally speaking, the finer the foam, the better the beer tastes. Hence, the process of pouring beer from a container is considered to be important in producing a fine foam in a mug. We developed a simple new dispenser to be attached to a new container, the mini-keg, to provide the mellow taste of draft beer with a fine foam.

We describe the effect of the foaming process and the resulting foam on the beer flavor when the dispenser we developed is used.

EXPERIMENTAL

Preparation of Samples

To investigate the effects of the foaming process and the resulting foam, two samples were prepared, one that had a coarse foam and one that had a fine foam. The sample with the coarse foam was prepared by pouring beer from the mini-keg into a 400-ml mug without using the dispenser. The sample with the fine foam was prepared by pouring beer into the mug using the dispenser we developed, the Awamicron. "Awa" is a Japanese word meaning "foam."

The principle of the Awamicron is to allow the beer to be poured into a mug in two separate streams (Fig. 1). The dispenser allows the main stream to be poured at a sufficiently high flow rate to swirl in the mug, thus entraining tiny bubbles. The tiny bubbles are produced by the subsidiary stream in order to produce a fine foam.

For physical and chemical analyses of the poured beer, the foam fraction and liquid fraction were separated after 30 sec of pouring, using a Sigma foam funnel (1), which has the same diameter and height as a 400-ml mug. The fractions of beer thus obtained were called foam beer and liquid beer, respectively. All the unpasteurized draft beers used in this study were attemperated beforehand to 10°C.

Determination of CO_2 Content of Beer

The CO_2 content of beer was measured with a Corning 965 D

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total carbon dioxide analyzer, as described by Whitear et al (8), after the CO_2 was fixed by monoethanol amine.

The fixation of CO_2 in the original beer was performed as follows. A keg was opened, and monoethanol amine was added. The keg was recapped immediately and mixed completely. For fixation of CO_2 in the foam beer or liquid beer, a Sigma foam funnel having a rubber septum attached to the cover was used to prevent the evolution of the CO_2 during the fixing reaction. Thirty seconds after pouring (Fig. 2), the liquid fraction was drained carefully into the beaker containing a definite volume of monoethanol amine, and subsequently the monoethanol amine was injected through the rubber septum into the remaining foam fraction, using a syringe.

This analyzer has greater speed, simplicity of operation, and accuracy, compared to other methods.

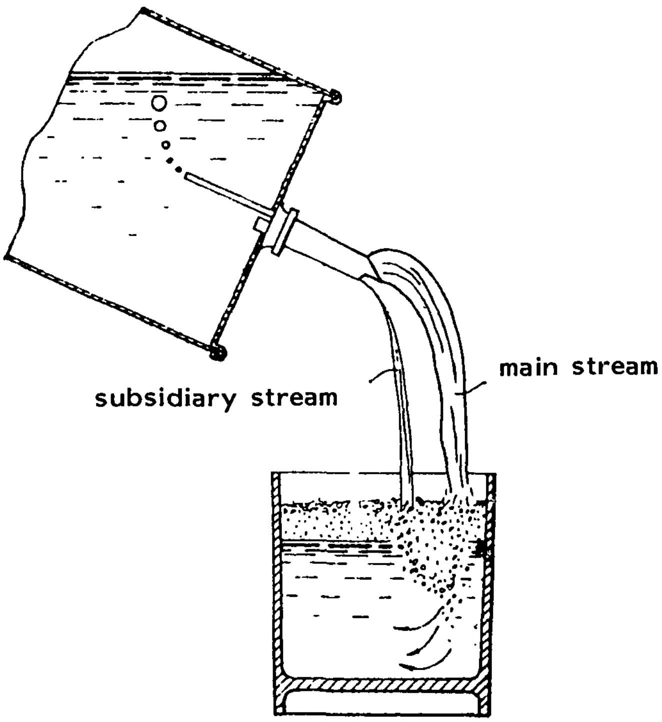

Fig. 1. A cross-sectional view illustrating the performance of the Awamicron dispenser.

HPLC Analysis for Iso-α-Acids in Beer

Isohumulone, isocohumulone, and isoadhumulone were determined by a modification of the ion-pairing high performance liquid chromatography (HPLC) method of Verzele and Dewaele (7), using a commercially available HPLC column rather than a column packed with specially purified materials.

Preparation of Sample. Sample size was half of that used in the Verzele and Dewaele procedure. A degassed sample (10.0 ml) was transferred into a 100-ml separation funnel, acidified with 1 ml of 3*N* HCl, and extracted with 25.0 ml of isooctane by mechanical shaking for 30 min. Fifteen milliliters of the isooctane layer was completely evaporated in vacuo. The residue was dissolved in 0.5

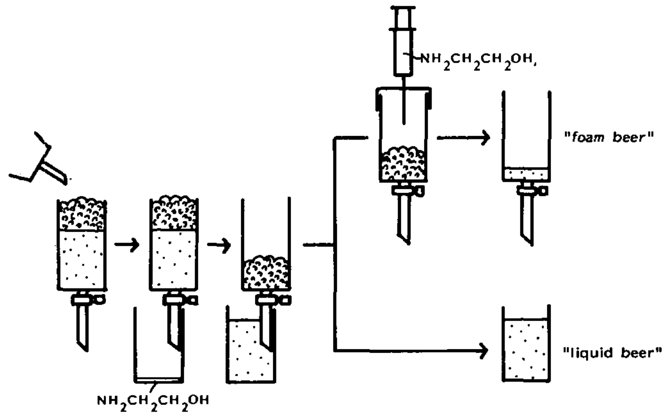

Fig. 2. The fixation of CO_2 in beer.

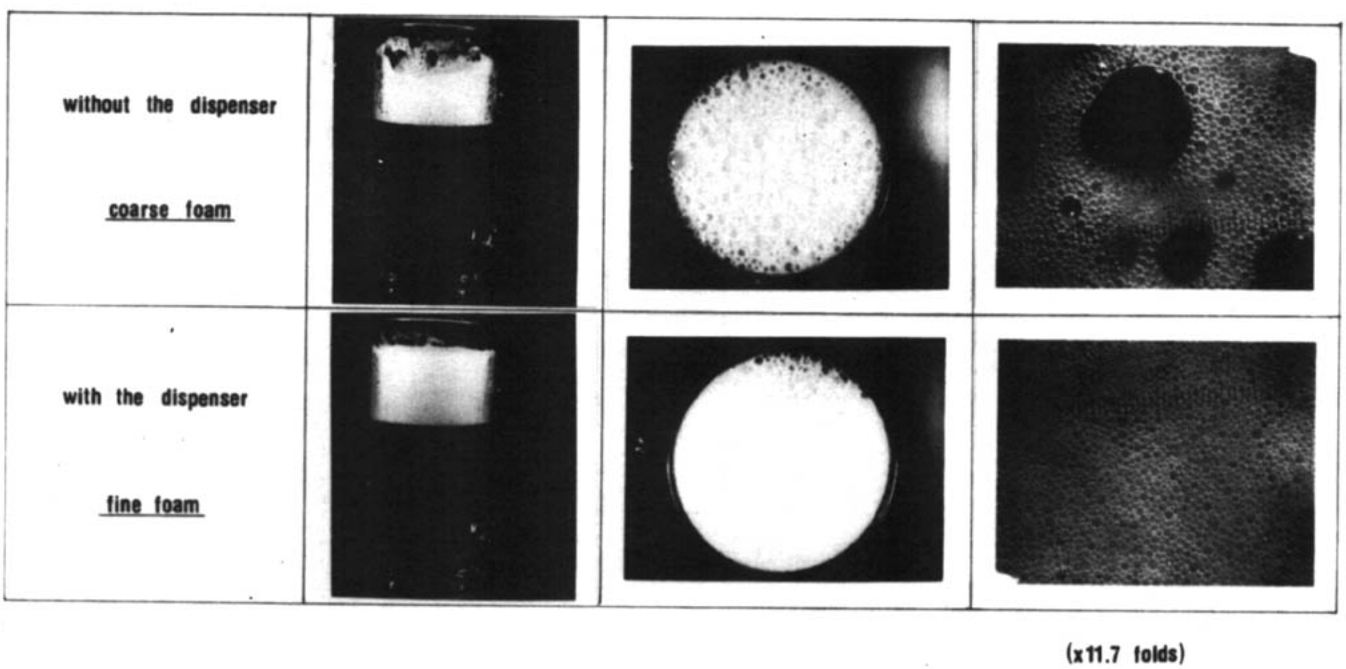

Fig. 3. Appearance of foam of beers poured without use of the dispenser and with the dispenser.

ml of methanol containing the internal standard, β-phenylchalkone (12.5 mg/100 ml), which was synthesized according to Clemo et al (3), and was protected from light with aluminum foil.

Chromatography. A liquid chromatograph (Shimadzu model LC-4A with SIL-IA injector), detector (Shimadzu SPD-2AS), integrator (Shimadzu C-RIAS), and Zorbax ODS column, 5 μm, 4.6 mm × 25 cm (DuPont Co.) were used.

The following chromatographic conditions were used: detector, UV at 270 nm; injection volume, 10 μl; flow rate, 1.5 ml/min; attenuation, 0.08 AUFS; column temperature, 50°C; and eluting solvent, CH_3OH (72.5 ml), H_2O (27.5 ml), 85% H_3PO_4 (1 ml), and tetraethylammonium hydroxide (2 m*M*).

RESULTS AND DISCUSSION

Characterization of Foam

Figure 3 shows the appearance of the foam in the two kinds of beer. In this experiment, approximately the same volume of beer was poured into the mug with and without using the dispenser. Almost the same volumes of foam were evolved in each beer.

Table I shows the characterization of the foams shown in Fig. 3. Beer poured without using the dispenser had a foam that was characterized as rough. Beer poured using the dispenser had a foam characterized as silky and creamy. The mean diameter of the fine bubbles in the coarse foam was 0.132 mm, and that in the fine foam was 0.115 mm. Additionally, a greater proportion of coarse bubbles was found in the coarse foam than in the fine foam. However, foam retention and adhesion were not markedly different between both beers.

Sensory Evaluation of Beers Having Different Foams

Table II shows the results of sensory evaluation of two beers, one with a coarse foam and one with a fine foam. Each of 10 well-trained and of 10 untrained panelists was asked to indicate which sample was preferred. All the panelists preferred the beer having a fine foam, which was obtained by pouring beer using the Awamicron dispenser. The beer having a coarse foam was described as having weak carbonation and weak bitterness, and was too soft and dull. The beer having a fine foam was found to have suitable carbonation, fine foam, and a well-balanced flavor. These same results in preference and discrimination were obtained at all stages of beer, from opening to emptying the mini-keg.

From the above results, we presumed that the foam is strongly affected by the manner in which it is developed, ie, the methods of pouring provided by the dispenser. Fineness of the foam plays an important role in determining the organoleptic characteristics of poured beer, especially mouthfeel, which is expressed by carbonation, and bitterness and drinkability.

Physical and Chemical Analyses of Beer Having Different Foams

We studied the chemical and physical factors affecting the organoleptic characteristics of beers with different foams. For this purpose, about 30 analytical items were selected, and more than 300 compounds were analyzed. We found some interesting results from the great mass of data.

Evolution of Low Volatiles. Table III shows the evolution of low volatiles. The original beer was the beer in the mini-keg. CO_2 content among the beers was markedly different, ie, a great decrease of CO_2 in the liquid beer was observed in comparison with the original beer. This decrease rate was more moderate in the beer having a fine foam than in the beer having a coarse foam. Furthermore, a great deal of CO_2 was transferred into the foam beer.

Low-volatile sulfur compounds in the liquid beer decreased remarkably as the result of foaming. The degree was slightly less in the beer having a fine foam than in the beer having a coarse foam.

The other young-beer flavor compounds, vicinal diketones, did not decrease.

Transfer of Some Compounds into the Foam Beer. Table IV shows the transfer of some compounds into the foam beer. Ethyl hexanoate, ethyl octanoate, and ethyl decanoate decreased in the liquid beer and increased in the foam beer.

The same result was obtained with fatty acids, C_{6-10}, of medium length. No significant difference existed, however, in the extent of decrease or increase of all the substances between the two beer samples having different foams.

Iron was considerably concentrated in the foam beer. Many other metals, such as calcium, magnesium, sodium, zinc, and copper, were not affected.

The surface tension of the foam beer slightly decreased as the result of foaming, and the pH value of the beer, especially in the

TABLE I
Characterization of Foam

Characteristic	Type: Coarse	Fine
Appearance	Rough	Silky, Creamy
Bubble diameter (mm)		
Fine	0.132 ± 0.042	0.115 ± 0.034
Coarse[a]	2.2 ± 0.7	2.2 ± 0.5
Occupation rate of coarse bubble on surface (%)	26.5	4.5
Retention[b]	9.4 ± 0.7	8.9 ± 1.0
Adhesion (Schaumhaftvermogen)[c]	60.2	55.4

[a] A bubble having a diameter greater than 2 mm.
[b] The time, in minutes, when the foam-occupied area became half of the surface of beer, as the foam disappears.
[c] By photographic method of Kumada (5).

TABLE II
Sensory Evaluation of Beers Having Different Foams

	Appearance of Foam	Preference of Panel Members: 10 Well-Trained	10 Untrained	Discrimination
Without dispenser	Coarse	1	3	Weak carbonation Too soft Dull
With dispenser	Fine	9	7	Suitable carbonation Fine foam Well balanced

TABLE III
Evolution of Low Volatiles

Analytical Items	Original Beer	Liquid beer: Coarse Foam	Liquid beer: Fine Foam	Foam beer: Coarse Foam	Foam beer: Fine Foam
CO_2[a]	5.15	3.0	3.8	1.54	1.05
H_2S[b]	2.5	0.9	1.1	···	···
DMS[b]	27.0	18.4	20.4	···	···
Diacetyl[c]	0.034	0.034	0.034	···	···
2,3-pentanedione[c]	0.050	0.048	0.049	···	···

[a] Concentration in g/L.
[b] Concentration in μg/L.
[c] Concentration in mg/L.

foam beer, increased. The extent of changes in these properties was less in the beer having a fine foam than in the beer having a coarse foam.

Table V shows the results on the transfer of the bitter substances into the foam beer, indicating that the bitter substances were also concentrated into the foam beer: the increase of bitterness in the foam beer was apparent. The decrease of the bitterness in the liquid beer, as compared with the original beer, was about 1 unit. This finding was confirmed more clearly by HPLC analysis for iso-α-acids. The iso-α-acids were concentrated into the foam beer, as seen with the bitterness units. Among them, isohumulone and isoadhumulone were concentrated more strongly than isocohumulone. This indicates that the foam beer was enriched in isohumulone and isoadhumulone. A difference in the contents between the beer having a fine foam and the beer having a coarse foam was not observed.

The transfer of bitter substances into the foam beer was also observed in a model experiment using the foam tower according to the method of Gray and Stone (4).

Figure 4 shows the changes of the residual iso-α-acids in the liquid beer during successive foaming with the foam tower. The relative residual concentrations of each iso-α-acid were calculated from the residual concentration of each iso-α-acid at the definite time of foaming on the basis of the concentration of the original beer as 1.00. Isohumulone and isoadhumulone were more rapidly decreased than isocohumulone. Thus, this result indicates that isohumulone and isoadhumulone were transferred more easily into the foam beer than isocohumulone.

These results confirmed that the effects of foaming on the foam and beer depend on the method of pouring, in which the following factors are involved: formation of foam; evolution of CO_2 and low-volatile sulfur compounds; transfer of the surface-active materials, such as iso-α-acids, higher ethyl esters etc into the foam beer; and change of the surface tension and the pH value. The last one is thought to be a result of the evolution of CO_2 and the transfer of the above-mentioned compounds into the foam beer.

Mutual Effect of CO_2 with Bitterness on Sensory Analysis

Table VI indicates the CO_2 content and the bitterness in beers at the time of drinking, 30 sec after pouring. Between the two kinds of beer, the bitterness in the liquid beer was not markedly different, but the CO_2 content in the liquid beer differed greatly. The beer having a coarse foam with the lower CO_2 content was evaluated as having weak carbonation and weak bitterness, and was too soft and dull; conversely, the beer having a fine foam with adequate higher CO_2 content was evaluated as having suitable carbonation and was well balanced. Therefore, the difference in the perceived bitter intensity of beer is thought to be due to the difference in the CO_2 content in each beer.

To verify these findings, the effect of CO_2 content on the perceived bitter intensity was studied by the paired-comparison test.

In the test shown in Table VII, samples without foaming were used because the pouring method was set to avoid a difference in the evolution of CO_2 between the beers. Eight trained panelists were given 70-ml samples in 200-ml glass tumblers, and the test was repeated six times. The values of bitterness and the CO_2 content in the control sample were 23 bitterness units (BUs) and 4.9 g CO_2/L, respectively. After each panel member was given the control sample

TABLE IV
Transfer of Some Compounds into Foam Beer

Analytical Items	Original Beer	Liquid Beer: Coarse Foam	Liquid Beer: Fine Foam	Foam Beer: Coarse Foam	Foam Beer: Fine Foam
Higher ethyl esters[a]					
Ethyl hexanoate	0.52	0.45	0.47	0.53	0.56
Ethyl octanoate	0.47	0.38	0.41	0.55	0.49
Ethyl decanoate	0.11	0.09	0.09	0.15	0.12
Middle fatty acids[a]					
C_6	1.90	1.85	1.88	1.98	2.07
C_8	5.07	4.99	5.03	5.77	5.76
C_{10}	0.51	0.48	0.48	0.81	0.80
Metal[a]					
Fe	0.114	0.080	0.086	0.222	0.165
Surface tension[b]	50.2	49.8	50.1	47.2	48.3
pH	4.220	4.240	4.235	4.280	4.270

[a] In mg/L.
[b] In dyne/cm^2.

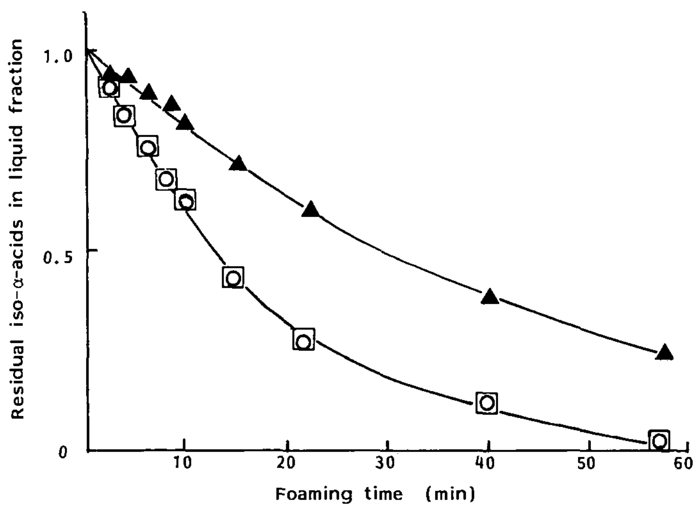

Fig. 4. Changes of iso-α-acids in liquid beer with foam tower. o = isohumulone, ▲ = isocohumulone, and □ = isoadhumulone.

TABLE V
Transfer of Some Compounds into "Foam Beer"

Bitter Substances	Original Beer	Liquid Beer: Coarse Foam	Liquid Beer: Fine Foam	Foam Beer: Coarse Foam	Foam Beer: Fine Foam
Bitterness[a]	25.0	24.2	24.2	30.9	31.7
Isocohumulone	1.00	0.97	0.98	1.21	1.19
Isohumulone	1.00	0.94	0.96	1.54	1.41
Isoadhumulone	1.00	0.95	0.95	1.42	1.43

[a] Measured in bitterness units.

TABLE VI
CO_2 Content and Bitterness in Beer at Time of Drinking

Analytical Items	Original	With Coarse Foam	With Fine Foam
CO_2 (g/L)			
In liquid beer	5.0	3.2	3.8
In foam beer	···	12.3	12.5
Bitterness[a]			
In liquid beer	25.0	24.2	24.2
In foam beer	···	30.9	31.7

[a] Measured in bitterness units.

TABLE VII
Relationship Between CO_2 and Bitterness on Perceived Bitterness Intensity

Beers	Bitterness Units	CO_2 (g/L)	Probability Level (%)
Control	23	4.9	...
Sample	27	4.9	91.6
	23	5.4	89.9
	27	5.4	99.9

TABLE VIII
Mutual Effect of CO_2 with Bitterness on the Perceived Bitter Intensity

	Samples Having	
Bitterness Intensity	Bitterness Units	CO_2 (g/L)
5	23	4.9
4	25	5.15
2	27	4.9
2	23	5.4
1	27	5.4

and one of the three other samples, the question was asked: "Which sample is more bitter?" The probability level was obtained from the panelists who responded that the sample was more bitter than the control (2,6). The probability level in the control was 91.6% compared with the sample, which had 27 BUs and the same CO_2 content as the control sample. When the value of bitterness in the sample was the same as that in the control, and the CO_2 content was increased from 4.9 to 5.4 g/L, the probability level was 89.9%. When both the value of BUs and CO_2 content were increased, the probability level increased significantly, up to 99.9%. These results suggest that the panelists felt that the beer became more bitter as the CO_2 content increased, even when the beer had the same BU values. In other words, CO_2 in beer had a combined effect with BU values on the sensory evaluation of bitterness.

These results were confirmed by the ranking test, which was performed using five samples. Eight trained panelists were given 70-ml samples in 200-ml glass tumblers, and the test was repeated eight times (Table VIII). The sample having the highest BU value and the highest CO_2 content was strongest in intensity of bitterness, and vice versa. The difference in the bitterness intensity between the sample with 23 BUs and 5.4 g CO_2/L, and the sample with 27 BUs and 4.9 g CO_2/L could not be discriminated.

SUMMARY

The methods of pouring provided by the Awamicron dispenser strongly affected the foaming process. The foaming process affects the appearance of the resulting foam, producing a fine foam. It is related to the evolution and the transfer of various compounds into the foam beer and consequently to the physical properties of beer. Among these effects, the balance of BU values with the CO_2 content that remained in the beer just before drinking played a very important role in determining the total organoleptic evaluation of beer as well as the fine foam, which attracts the user's eyes and the first mouthfeel. The mutual effect of the CO_2 content with BU on the bitter intensity was indicated by sensory analyses.

These results indicate that a careful control of the basic quality of beer, the selection of an appropriate container, including dispensers, and the combination of these two factors should be closely examined to produce good products. This is an essential part of the total design of beer.

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