Evaluation of drinking ease relative to the opening diameter and beverage type of aluminum beverage bottles

Evaluation of Drinking Ease Relative to the Opening Diameter and Beverage Type of Aluminum Beverage Bottles

Running title: Drinking Ease of Aluminum Beverage Bottles

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Abstract

This paper investigates the effects of different bottle opening sizes (28, 33, and 38 mm in diameter) and beverage types (e.g., green tea, carbonated beverage) on the drinking satisfaction of consumers, in order to enhance their comfort levels when drinking from aluminum beverage bottles. A survey of 120 Japanese subjects was conducted, and the 33 mm opening size emerged as the most preferred, irrespective of beverage type. The factor analysis results of the questionnaire show that drinking satisfaction is primarily affected by two common factors: the volume of flow from the bottle to the mouth and the adjustability of the flow. The results of the three-dimensional fluid-dynamics analysis indicate that differences in beverage type could influence what consumers regard as an appropriate flow.

Key words: Ergonomics, Drinking ease, Aluminum beverage bottle, Computational fluid dynamics

1. Introduction

In addition to rudimentary factors like functionality, performance and price, there are other vital areas like usability, novelty in design, and conformity with fashion, which affect customers' decisions while purchasing products. Manufactures are, therefore, expected to adopt consumers' sensibilities and preferences in their designs, rather than bank on performance alone for acceptance of their products in the marketplace. From the viewpoint of universal design, it is important to design products that can be used comfortably across all age and gender groups. In order to obtain data for determining consumers' preferences, surveys of trained panelists or consumers are usually carried out, using trial products. The Semantic Differential (SD) method (Iwashita, 1983) and the Factor Analysis (FA) method (Richard, 1983;

Shiba, 1979) are typical techniques used in such questionnaires. In addition, this study employs the Kansei Engineering method, initially proposed by Japanese researchers as a system of rendering thoughts and sensations into product parameters, and now used internationally by designers as a design methodology (Nagamachi et al., 1974; Nagamachi, 1995, 2000). In the product designing stage, numerical simulation serves as an important cost and time saving tool by averting the need to make a lot of trial products; numerical simulation is used in this study to estimate whether a particular design will be loved by consumers or not. Structure optimization techniques based on the Finite Element Analysis (FEA) have been applied to develop 2-piece aluminum beverage cans and bottles in order to get better performance under various loading conditions; for instance, making the lid light-weight can counter subject to the constraints of the buckling strength and maximize the strength of the bottle bottom against the axial load and internal pressure (Yamazaki et al., 2007; Han et al., 2005). Improved shelf life (the length of time that packaged food can be stored), visual appeal, and price are among the anticipated benefits of these beverage containers. In addition, universal designs based on ergonomics have been applied while developing beverage containers and are expected to enhance consumers' convenience (Han et al., 2004; Han et al., 2006; Nishiyama, 2001; Ueno, 2003).

Aluminum beverage bottles with screw tops have been launched in the Japanese market in recent years to meet the modern-day drinking habits of consumers. These can be repeatedly resealed, and are designed to recycle many times better than the resalable PET bottles. In addition, these are used by all consumers, irrespective of age and gender. Thus, the universally used aluminum beverage bottles form the focus of this research, which is based on ergonomics and the Kansei engineering evaluation method that considers physiological and psychological effects on human respondents. Consumers in general have several ways of drinking: directly from the bottle opening, or with a straw, or drinking using a glass. Because aluminum beverage bottles can be resealed, consumers often take these with them outdoors, and drink directly from the opening. It is, therefore, important for makers of aluminum beverage bottles to consider minutely the satisfaction levels of consumers drinking directly from the bottle opening. Although aluminum beverage bottles with 28 mm and 38 mm opening diameters are familiar to Japanese consumers, a section of them feels that the 28 mm opening is too small and consider the 38 mm opening too large. Researchers have, in the past, conducted studies concerning the "openability" of the closures of food and beverage containers. These studies were based on mechanical evaluation, which considered force, torque and friction (Lewis et al, 2007; Yoxall and Janson; 2007; Carus et al, 2006). The subject of drinking ease (in relation to the attributes of beverage containers) has, however, not been studied so far; this is because a study of drinking ease is dominated by the sensuous evaluation of consumers, which makes it difficult to adopt traditional mechanical evaluation techniques. Therefore, we need to develop a method to evaluate human feelings when drinking directly from the bottle opening and then identify the opening size that is most suitable for consumers' drinking satisfaction.

We predict that the optimum opening diameter for drinking satisfaction exists between 28 mm and 38 mm, because Japanese consumers feel that the 28 mm opening is too small and consider the 38 mm opening too large. In addition, physical factor of drinking satisfaction should be extracted so as to evaluate drinking feeling quantitatively, and the flow in the bottles or the flow rate at the bottle outlet may be related to drinking feeling. Consequently, subjective evaluation (i.e. drinking test, the FA method) and numerical analysis (i.e. fluid-dynamics analysis) will support each other, and they will evaluate the effects of the bottle opening size on drinking satisfaction. At first, this paper appropriates data from a survey of 120 young Japanese subjects, based on a drinking test that was conducted using three kinds of experimental bottles with opening diameters, 28 mm, 33 mm and 38 mm. In addition, green tea and carbonated beverage were selected as test beverages so as to investigate the influence of the beverage type. Questionnaires based on the Kansei Engineering method were circulated, and the drinking test was performed. The results of the test were statistically analyzed to yield data that will determine, in the course of this paper, the consumers' preference among the three opening sizes. The FA technique is used to identify the factors that influence consumers' drinking feelings and investigate the extents of such influence. Further, a fluid-dynamics analysis model is developed to simulate the flow of bottled liquid during a drinking action. The factors influencing the drinking feeling are evaluated numerically, based on the results of the survey and the experimental observations of consumers' drinking actions.

2. Survey on the Drinking Test

2.1 The Drinking Test Method

The survey had 120 young Japanese volunteers as respondents: 60 males and 60 females. All of them are college or university students, and are between 20–26 years of age. Although this study had intended to cover all age groups, the respondents were exclusively young students because their cooperation was obtained without any difficulty. As shown in Fig.1, all subjects sat while drinking and then filled out questionnaires that aimed to define the extent of drinking satisfaction.

Fig.2 shows samples of three kinds of experimental bottles with opening diameters, 28 mm, 33 mm and 38 mm. As noted above (1.Introduction), the 28 mm and 38 mm opening diameters are familiar to Japanese consumers, but a section of them feels that the 28 mm opening is too small and the 38 mm opening is too large. Therefore, we predict that the 33 mm opening diameter, which is intermediate in size between 28 mm and 38 mm, will improve drinking satisfaction, and is used for experimental bottle. These bottles had a capacity of 300 ml and were filled with 200 ml of liquid, which allowed for an intermediate level of remain. All subjects were asked to have one mouthful of drinks from each kind of bottle. The respondents were formed into six groups numbering twenty each; six different drinking orders were set for the three bottle opening sizes, in order to avoid any possible influence of the drinking order. To investigate the influence of the beverage type, green tea and carbonated beverage were chosen as test beverages.

The questionnaires, which are based on the Kansei engineering method, are designed to investigate the factors that influence consumers' feelings while drinking. In general, consumers' feelings may be related to the container (the opening size, shape and material), to the beverage type (the temperature and taste), to personal factors (the age, gender and way of drinking) and the environment (the place and time). In the engineering context, drinking satisfaction may be affected by the volume of flow into the mouth, and by issues like adjustability and stability while drinking. Eleven evaluation items were selected based on the Kansei model to identify and study drinking feelings. Fig. 3 shows the questionnaire for the 28 mm bottle opening. The evaluation items were the same for all kinds of beverages and bottles. The SD method was used, and five levels were set to calculate responses.

2.2 Statistical Results of the Questionnaire

Figs.4 and 5 show questionnaire results based on the drinking test using bottles filled with green tea and carbonated beverage, respectively. The mean values and standard deviations are calculated for the eleven evaluation items. It is found that the mean values for the 33mm opening are high in general, no matter what the beverage type. The 38 mm bottle opening shows the highest mean values for Item 1 (Liquid can easily flow out from the bottle), Item 3 (The flow volume through the opening is large) and Item 5 (The flow into the mouth is fast), while the 28 mm opening shows the highest mean value for Item 8 (Liquid hardly spills from corners of the mouth). It is also apparent that the standard deviations of the 33 mm bottle opening are generally lower than that of the other two opening sizes, irrespective of the beverage type.

Since the 33 mm opening shows the highest mean values and the lowest standard deviations for virtually all evaluation items, the 33 mm opening was clearly highly evaluated by all respondents, irrespective of the beverage type. In contrast, the 28 mm and 38 mm bottle openings show relatively high standard deviations, which shows that subjects had mixed feelings while drinking from these. The 33 mm opening shows a smaller value for Item 3 (The flow volume through the opening is large) but a higher value for Item 2 (The flow volume through the opening is appropriate) when compared with the 38 mm opening. We may, therefore, estimate that there is an appropriate flow of beverages for subjects feeling comfortable when drinking from the bottles.

All subjects were asked to rank the three kinds of bottles in the order of drinking ease so as to determine their preference of opening size. The ranking results for green tea and carbonated beverage, as submitted by all subjects, are shown in Table 1 (a) and (b), respectively. With 3 scores given to the first rank, 2 scores to the second and 1 to the third, the total ranking scores of the three kinds of bottles are calculated as shown in the last column of Table 1. It is found that the 33 mm opening scores the highest among the three kinds of opening diameters, irrespective of beverage type. The ranking scores are plotted in Fig.6, which facilitates the investigation on the influence of the beverage type and the gender of the drinker on the drinking satisfaction obtained. It is established that the first rank is held by the 33 mm opening in both drinking tests, of green tea and carbonated beverage, across both gender groups. Comparing the ranking results for the 28 mm and 38 mm openings, it is observed that consumers prefer to drink green tea from a relatively large opening, and carbonated beverage from a relatively small one. However, the differences in scores are small in comparison with the universal preference for the 33 mm opening.

To investigate the influence of the subjects' mouth sizes on the drinking ease, the width (*w*) and height (*h*) of the mouth were measured for all subjects while keeping the mouth naturally closed, as illustrated in Fig.7 (a) (National institute of bioscience and human-technology, 1996). The number of subjects, classified by mouth width into five ranges—(1) 35 mm–40 mm, (2) 41mm–45mm, (3) 46 mm–50 mm, (4) 51 mm–55 mm, (5) 56 mm–60 mm—and into four ranges of mouth height—(1) 9 mm–15 mm, (2) 16 mm–20 mm, (3) 21 mm–25 mm, (4) 26 mm–30 mm—are shown in Figs.7 (b) and (c). The drinking ease is assigned as shown in Figs.8 (a), (b). Comparing the drinking ease figures attributed to the 28 mm and 38 mm openings in Fig.8 (a), we observe that subjects with large mouth sizes tend to prefer the 38 mm opening to the 28 mm opening. The superceding result, however, is that the 33 mm opening stays at top preference in every category of mouth size. We may, therefore, conclude that the 33 mm opening is best suited for the Japanese adult consumers' ease of drinking—dominant everywhere in our statistical analysis, prevailing in all segments by gender, beverage type and mouth sizes.

2.3 Results of the Factor Analysis (FA)

The FA is performed in order to gain insight into the data obtained from the responses to the questionnaires. The FA results are shown in Table 2, Table 3 and in Fig.9. We can grasp the characteristics of identified factors and of three opening diameters from Figs.9 (a) and (b), respectively. Two common factors have been identified. The contribution rate of the 1st factor (54.7%) is greater than that of the 2nd factor (45.3%), which indicates that the 1st factor affects drinking ease more than the 2nd. The communality of fluctuation rate of the two factors is 95.9%, which implies that the fluctuation in the drinking test results can almost entirely be explained by these two factors.

The horizontal axes in Figs.9 (a) and (b) indicate the 1st factor, and the vertical axes represent the 2nd factor. Item 1 (Liquid can easily flow out from the bottle), Item 3 (The flow volume through the opening is large) and Item 5 (The flow into the mouth is fast) ascribe large weights to the 1st factor; Item 8 (Liquid hardly spills from corners of the mouth), on the other hand, assigns a small (negative) weight to the 1st factor. Further, Item 2 (The flow volume through the opening is appropriate) and Item 10 (The bottle opening fits with the mouth) ascribe large loads to the 2nd factor. Therefore, the flow amount may be considered to be the 1st factor, and flow adjustability, as the 2nd factor. Good adjustability of flow would imply that the surge of beverage from the bottle opening can be easily and appropriately adjusted, in line with consumer expectations.

In Fig.9 (b), the 38 mm opening shows the highest scores for the 1st factor, followed by the 33 mm opening, and the 28 mm opening, independent of the beverage type. In other words, subjects recognize that the flow volume from the 38 mm opening is large, followed by the 33 mm and 28 mm openings. The factor score, in the case of the 2nd factor, is highest for the 33 mm bottle opening for any beverage type, which indicates that subjects appreciate that the flow adjustability of the 33 mm opening is the best, irrespective of the beverage being consumed. In addition, the difference in the 2nd factor scores between green tea and carbonated beverages for the 33 mm opening is smaller than that for the 28 mm and 38 mm openings. Therefore, the adjustability between beverage types of the 33 mm opening may be considered more robust than that of the 28 mm and 38 mm openings. Between the 28 mm and 38 mm openings, the 2nd factor score in the case of carbonated beverage is higher for the former, while in the case of green tea the 2nd factor score is higher for the latter. Thus, the subjects felt that it is easier to adjust when one drinks carbonated beverage from a bottle with a relatively small opening. This may be explained by the fact that carbonated beverage has a tendency of foaming; thus, the 28 mm opening, which permits a smaller flow amount, makes it easier to adjust than the 38 mm opening. Therefore, preferences of the opening diameter's dimensions may change according to the taste and features of beverage types. However, the range of possible preferences is narrow, and centered around 33 mm.

3. Numerical Simulations

3.1 The Flow-Dynamics Analysis Model

The survey results based on the drinking test show that the beverage flow exerts a great influence on drinking ease, which makes it necessary to develop a three-dimensional flow-dynamics analysis model to estimate the flow-out of beverage from the bottle and to evaluate the drinking ease numerically, instead of relying on experimental observation.

The analysis model is developed as shown in Fig.10, and the properties adopted for consideration are tabulated in Table 4. To simulate the drinking action, the bottle model is rotated from its initial upright position to the inclined drinking position at a constant velocity, and then stopped: the entire action is completed in 2.0 seconds. The inclination angle (θ) of the bottle, shown in Fig.10 (b), is defined as the acute angle between the bottle's central axis and the horizontal line.

The velocity boundary condition is applied to the wall and bottom of the bottle (Γ_1, Γ_2), and no relative velocity between the fluid and the bottle is considered. The distributed load boundary condition is applied to the opening of the bottle, defined as the flow outlet (Γ_3), and the pressure on the boundary equal to zero. The bottle model is filled with 200ml water, which is assumed to flow out of the bottle without any external resistance. The water and the air in the bottle are assumed to be uncompressible fluids, and the density and viscosity of the water and air shown in Table 4 are adopted. Green tea and carbonated beverage are assumed to have approximately the same properties as pure water. In addition, the flow in the bottle is assumed as turbulent flow, and the zero-equation type turbulence model with mixing length is applied to eddy viscosity model. The VOF method is used in order to represent the interface between water and air. In addition, water is assumed to have no surface tension. When water flows out from the bottle outlet, air that has same volume as outflow water flows into the bottle. The computational fluid dynamics analysis code, FIDAP 8.7 (Fluent Incorporated), is used to estimate the flow of fluid during the drinking action. The finite element method is used for the code, and the Galerkin form of the method of weighted residuals and implicit backward Euler are used for spatial and temporal schemes, respectively. Moreover, hexahedral solid element is applied for all models, and the number of nodes and elements are about 55000 and 60000, respectively.

The drinking actions of five subjects were recorded using a video recorder in order to measure the final inclination angle (θ_e) of the bottle while subjects performed the drinking action. The average values of the final inclination angles are shown in Table 5. The inclination angles for green tea and carbonated beverage obtained experimentally have been set on Models named G1, G2, G3 for green tea and C1, C2, C3 for carbonated beverage (Table 6). In addition, θ_e = –2.0°, the same final inclination angle as that of Model G2 (33 mm opening bottle), is set for Model G4 (28 mm opening) and G5 (38 mm opening). All models are started from θ = –90° and rotated to their final inclination angles.

3.2 Flow-Dynamics Analysis Results

The numerical simulation results of the 33 mm opening bottle (Model G2) are shown in Fig.11. It is observed that the water flows out from this bottle without crashing with the tapered part of the bottle and undulating deeply. Similar behavior of flow is noted in the simulations of the other models.

Fig.12 illustrates the history plots of the flow rates for five models; Table 6 shows the average flow rates of all models. Start time is defined as the beginning of the outflow, and end time is defined as the time at the local minimum point after the 1st peak. In addition, the average flow rate is defined as the average between start time and end time. From Fig.12, it can be observed that two peaks appear in the plot for all models, because the second peak is arisen by a wave that is reflected by the bottom of the bottle. Moreover, it is observed that the starting time and the duration of the two peaks are almost identical for the five models in spite of the differences in opening size and the final inclination angle. The amplitude of the first peak is different for each of the five models.

If the final inclination angle is given as θ_e = –2.0°, the numerical analysis results of Model G2, G4, and G5 show that the average flow rate of the 33 mm bottle is smaller than that of the 38 mm bottle, but greater than that of the 28 mm bottle. The range of differences is about 50%. However, if the final inclination angles measured experimentally are assigned to the models (G1, G2, G3), the range of differences in the average flow rate becomes as narrow as about 10%. Moreover, comparing the average flow rate of green tea models (G1, G2, G3) and that of carbonated beverage models (C1, C2, C3), it is clear that the average flow rate of the carbonated beverage models is lower for all opening diameters, even though the same material properties of fluid are assumed.

3.3 Discussions

Result from the fluid dynamics analysis, it is observed that the flow-out behavior is almost same in the simulations of all models. Therefore, it is probable that the flow-out behavior of bottled liquid does not affect drinking ease in case of usual drinking actions. On the other hand, the amplitude of the first peak is different for each model. Thus, the average flow rate defined the above may be examined to yield a relationship between drinking ease and one of engineering variables. This agrees with the factor analysis results in that the flow has an effect on drinking ease.

The range of differences in the average flow rate of experimentally angle condition is narrower than that of constant angle condition. If the flow of liquid from the 33 mm bottle is regarded as the appropriate flow, consumers probably adjust the inclination angle of other bottles to achieve the requisite flow for drinking ease. This agrees with the results that there is an appropriate flow of beverages for subjects feeling comfortable from the drinking test and the questionnaires. Moreover, the average flow rate of carbonated beverage models is lower than that of green tea models for all opening diameter. The explanation for this is the propensity for foaming that is inherent in carbonated beverage, which causes its appropriate flow for drinking ease to be lower than that of green tea. Therefore, differences in beverage type could bring about changes in what consumers may regard as appropriate flow.

From the statistical analysis of the questionnaires and fluid-dynamics analysis, this paper could establish that there is indeed an appropriate level of flow of beverage that allows subjects to feel comfortable when drinking from the aluminum bottle. Especially, the average flow rate is an important indicator that evaluates drinking satisfaction quantitatively. In addition, we have seen that the flow-dynamic analysis model can explain the observations noted in the drinking test and questionnaires, the flow-dynamic analysis model may be utilized to further develop containers that would ensure consumers' ease of drinking. Moreover, it may be concluded that the 33 mm opening is best suited for Japan's young adult consumers across all beverage types, gender groups and mouth size segments.

4. Conclusions

The results of the factor analysis performed with the SD method show the existence of two factors that are primarily responsible for the quality of the drinking feeling: the first factor corresponds to the flow amount and the second factor relates to the flow adjustability. In addition, the results of the fluid-dynamics analysis show that the average flow rate of the bottled liquid may be used to represent the state of drinking ease and that consumers usually try to realize the ideal flow rate condition by adjusting the inclination angle of the bottle. The results obtained from the fluid-dynamics analysis agree with the factor analysis in that the flow amount and the flow adjustability affect drinking ease. Therefore, it is important that designers of beverage bottles consider, accommodate and get the most out of these two factors, in order to secure the progress toward greater drinking satisfaction.

In order to further enhance the comfort levels of consumers when drinking directly from the bottle opening, the flow-dynamics analysis model developed in this paper may be used to investigate the effects of the bottle shape, opening shape, material and so on. To achieve a developed analysis model for more elaborate evaluation of drinking satisfaction, the number of subjects should be increased while that is only five in this paper. As the next step of this study, drinking actions will be measured in large-scale subjects that cover broad ranges of age, body size, and body shape. In addition, we will also quantify the individual differences of drinking actions and the uncertainty of human's behavior. Then the analysis model may be developed to incorporate further details, for instance, including human mouth sizes, mouth shape, and the role of the hand into the analysis, in order to investigate the influence of consumers' mouth size, mouth shape, and drinking action on drinking ease. Moreover, the average flow rate used as the indicator of drinking satisfaction, that is, drinking satisfaction may be represented quantitatively. Therefore, in future study, we may specify the rigorous dimension of opening diameter for drinking ease due to evaluate the flow rate quantitatively.

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Fig.1 Drinking test

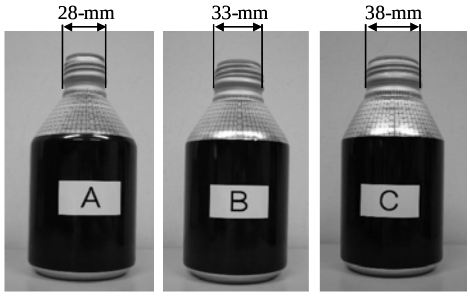


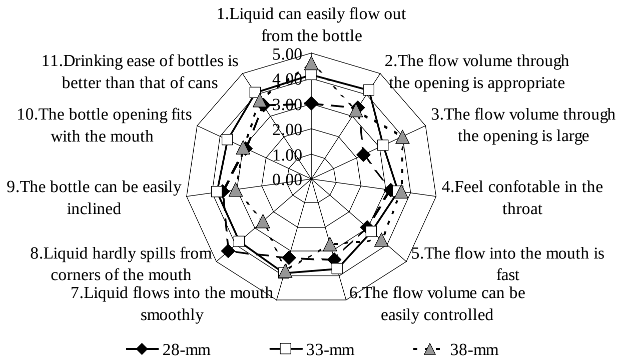
Fig.2 Experimental bottles

(1) Bottle of 28-mm opening

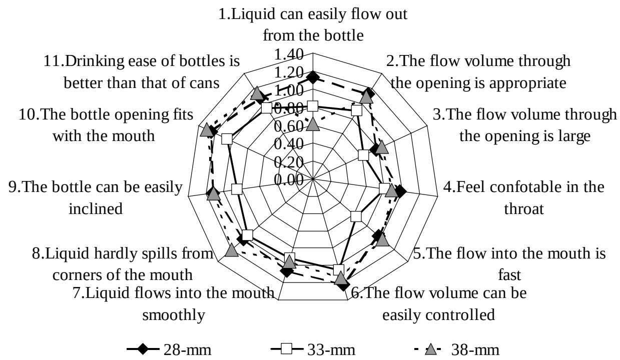
Mark the number with a circle

Evaluation items:	**Level:**	
1. Liquid can easily flow out from the bottle	5 4 3 2 1	Liquid can hardly flow out from the bottle
2. The flow volume through the opening is appropriate	5 4 3 2 1	The flow volume through the opening is inappropriate
3. The flow volume through the opening is large	5 4 3 2 1	The flow volume through the opening is small
4. Feel comfortable in the throat	5 4 3 2 1	Feel uncomfortable in the throat
5. The flow into the mouth is fast	5 4 3 2 1	The flow into the mouth is slow
6. The flow volume can be easily controlled	5 4 3 2 1	The flow volume can be hardly controlled
7. Liquid flows into the mouth smoothly	5 4 3 2 1	Liquid flows into the mouth not smoothly
8. Liquid hardly spills from corners of the mouth	5 4 3 2 1	Liquid easily spills from corners of the mouth
9. The bottle can be easily inclined	5 4 3 2 1	The bottle can be hardly inclined
10. The bottle opening fits with the mouth	5 4 3 2 1	The bottle opening unfits with the mouth
11. Drinking ease of bottles is better than that of cans	5 4 3 2 1	Drinking ease of bottles is worse than that of cans

Fig.3 An example of the questionnaire sheets

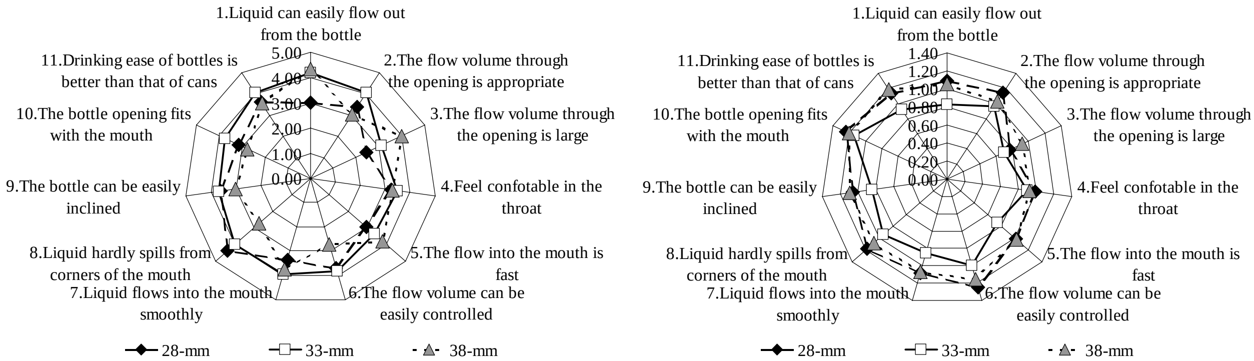


(a) Mean values of 11 items (Green tea)



(b) Standard deviations of 11 items (Green tea)

Fig.4 Evaluation results of questionnaire (Green tea)



(a) Mean values of 11 items (Carbonated beverage) (b) Standard deviations of 11 items (Carbonated beverage)

Fig.5 Evaluation results of questionnaire (Carbonated beverage)

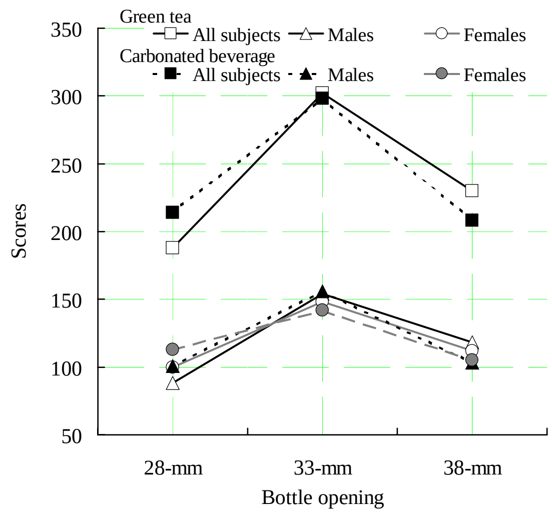
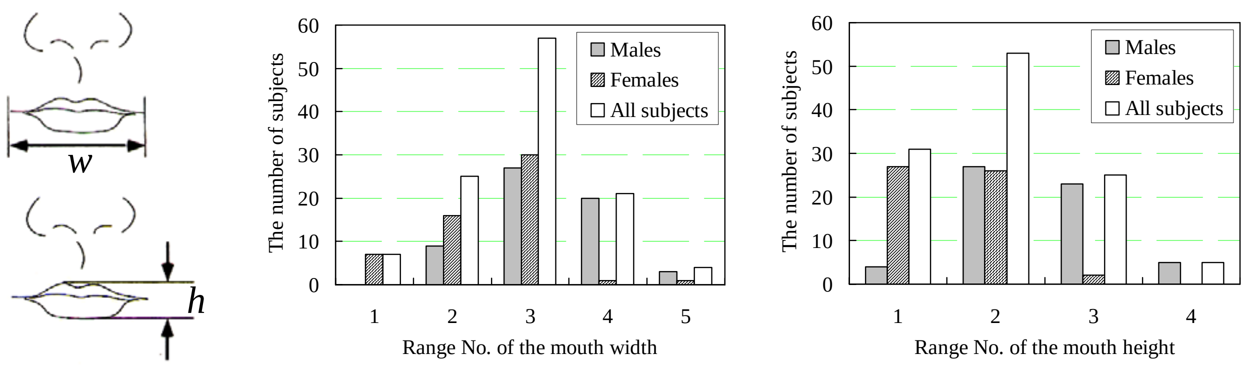
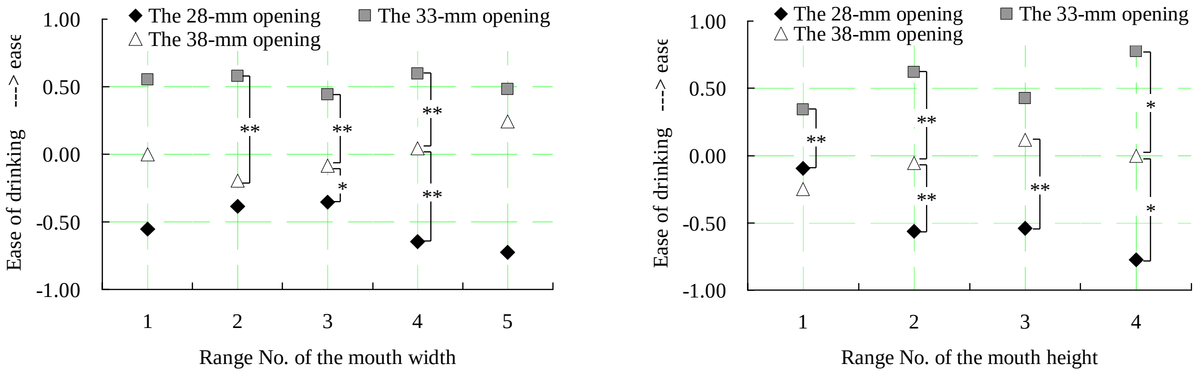


Fig.6 Ranking results of drinking ease



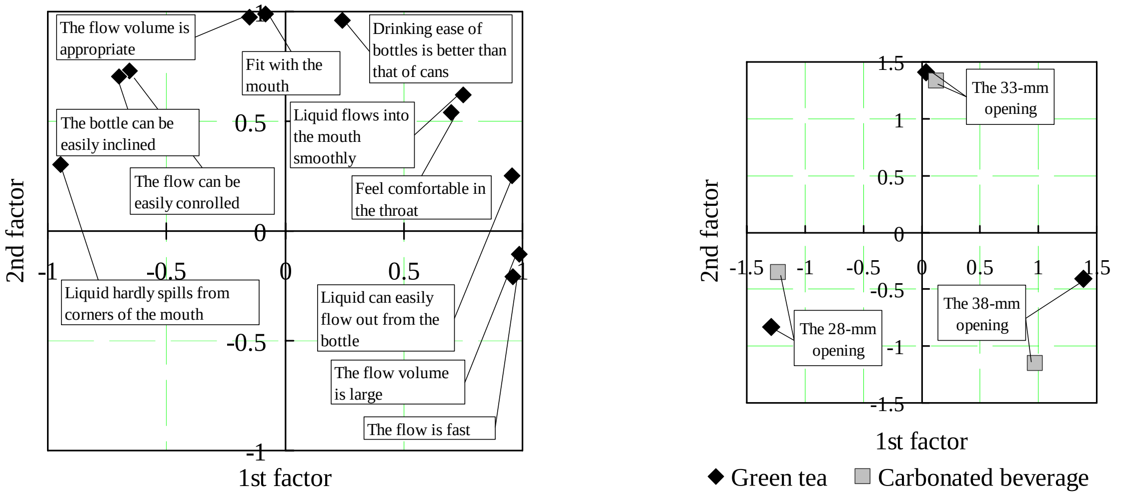
(a) Measurement method (b) Distribution by mouth width (c) Distribution by mouth height

Fig.7 Distributions by mouth dimensions



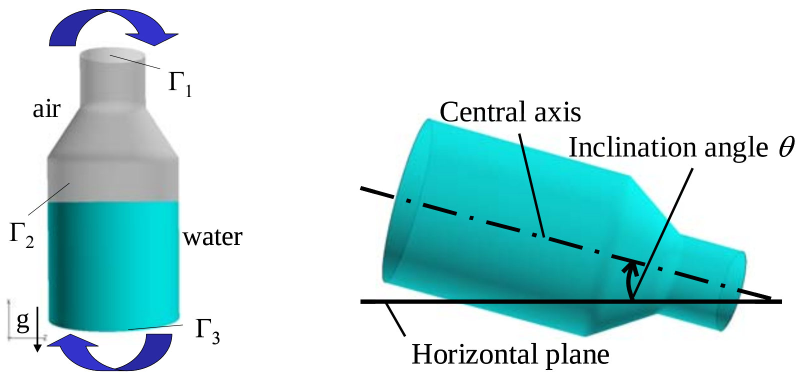
(a) Influence of mouth width (b) Influence of mouth height

Fig.8 Influence of mouth dimensions on drinking ease: ** : p <0.01, * : p < 0.05



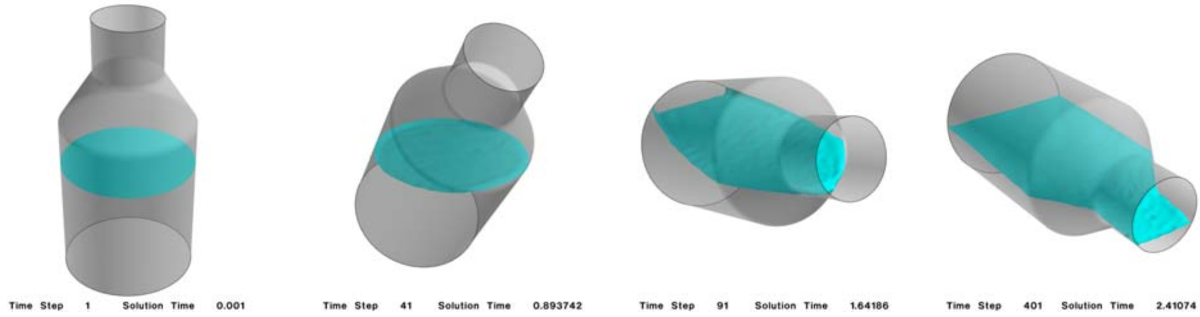
(a) Factor loadings of 11 evaluation items (b) Factor scores of three kinds of bottles

Fig.9 Factor analysis results



(a) Model (b) Inclination angle

Fig.10 Three dimensional fluid-dynamics analysis model



(a) t = 0.00 (θ = –90.0°) (b) t = 0.80 (θ = –54.8°) (c) t = 1.60 (θ = –19.6°) (d) t = 2.40 (θ = –2.00°)

Fig.11 Fluid-dynamics analysis results

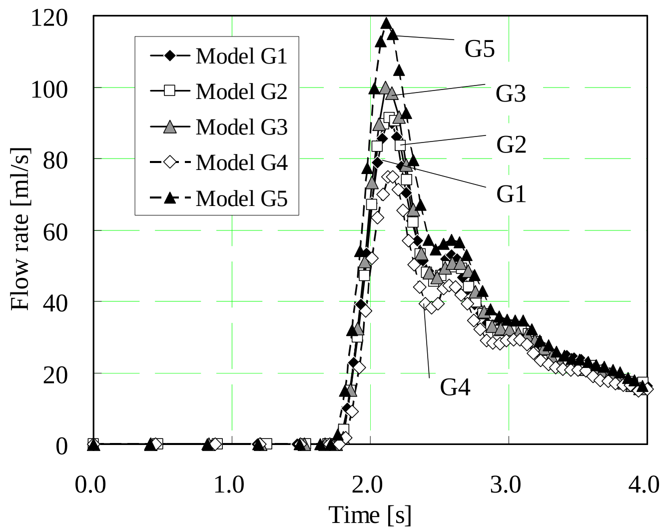


Fig.12 History plots of the flow rate

Table 1 Ranking results of drinking ease

(a) Green tea

Sample	The number of subjects			Scores
	Primary	2nd	3rd	
The 28 mm opening	16	36	68	188
The 33 mm opening	71	40	9	302
The 38 mm opening	33	44	43	230

(b) Carbonated beverage

Sample	The number of subjects			Scores
	Primary	2nd	3rd	
The 28 mm opening	26	42	52	214
The 33 mm opening	70	38	12	298
The 38 mm opening	24	40	56	208

Table 2 Factor loadings obtained in the factor analysis

Items	Factor loadings		Communality
	1st factor	2nd factor	
1.Liquid can easily flow out from the bottle	0.96	0.25	0.98
2.The flow volume through the opening is appropriate	–0.15	0.98	0.97
3.The flow volume through the opening is large	0.99	–0.11	0.99
4.Feel comfortable in the throat	0.70	0.54	0.78
5.The flow into the mouth is fast	0.96	–0.21	0.96
6.The flow volume can be easily controlled	–0.66	0.73	0.96
7.Liquid flows into the mouth smoothly	0.75	0.62	0.95
8.Liquid hardly spills from corners of the mouth	–0.95	0.30	0.99
9.The bottle can be easily inclined	–0.70	0.70	0.99
10.The bottle opening fits with the mouth	–0.08	0.99	0.99
11.Drinking ease of bottles is better than that of cans	0.24	0.96	0.98
Contribution quantity	5.77	4.77	10.5
Contribution rate (%)	54.7	45.3	100
Fluctuation rate (%)	52.5	43.4	95.9

Table 3 Factor scores obtained in the factor analysis

Sample	1st factor	2nd factor
28 mm (Green tea)	–1.29	–0.83
33 mm (Green tea)	0.04	1.41
38 mm (Green tea)	1.39	–0.41
28 mm (Carbonated beverage)	–1.23	–0.35
33 mm (Carbonated beverage)	0.12	1.33
38 mm (Carbonated beverage)	0.97	–1.15

Table 4 Properties of the fluid-dynamics analysis

Materials	Density [kg/m^3]	Viscosity [Pa·s]
Water	998	1.00×10^{-3}
Air	1.20	1.82×10^{-5}

Table5 Final inclination angles of the fluid-dynamics analysis

Beverage type	Final inclination angle θ_e [deg]		
	28 mm	33 mm	38 mm
Green tea	0.00	–2.00	–4.00
Carbonated beverage	–3.50	–4.00	–6.00

Table6 Average rate of flow

Sample	Final inclination angle θ_e [deg]	Start time [s]	End time [s]	Average flow rate [ml/s]
Model G1 (28 mm)	0.00	1.77	2.49	55.1
Model G2 (33 mm)	–2.00	1.79	2.46	57.7
Model G3 (38 mm)	–4.00	1.78	2.48	60.1
Model G4 (28 mm)	–2.00	1.80	2.42	46.7
Model G5 (38 mm)	–2.00	1.74	2.47	70.8
Model C1 (28 mm)	–3.50	1.83	2.42	40.1
Model C2 (33 mm)	–4.00	1.82	2.46	47.2
Model C3 (38 mm)	–6.00	1.82	2.46	49.4