Sensory Evaluation of Taste of Alkali-ion Water and Bottled Mineral Waters

M. KOSEKI, A. NAKAGAWA, Y. TANAKA, H. NOGUCHI, AND T. OMOCHI

Introduction

BOTTLED WATER CONSUMPTION IN JAPAN HAS INCREASED FROM 10 L/y in 1990 to 20 L/y in 1999. Furthermore, the use of water purifiers has also seen a considerable rise in popularity. Moreover, the number of those who drink alkali-ion water for health reasons are increasing and 4 million sets of alkali-ion water devices were sold between 1989 and 1997 in Japan.

This popularity is partly due to the Ministry of Health and Welfare of Japan recognizing in October 1965 that alkali-ion water improves the health of the digestive tract. Alkali-ion water is made by electrolyzing tap water, which can be performed by the "Alkali-Ion Water electrolyzer" (Kikuchi and others 2001). The Alkali-Ion Water electrolyzer is manufactured by many electric companies as a home electronic device. The electrolyzer has cathode and anode chambers, which have negative and positive electrodes, respectively, which are completely divided by a membrane diaphragm that allows ions to pass but does not permit water to pass. When water is electrolyzed in this apparatus, alkali-ion water will rise in the cathode chamber. At the same time, acidic water arises in the anode chamber and can be used for pasteurizing of various food stuffs and apparatuses (Hotta and others 1994; Izumi 1999; Kim and others 2000; Koseki and others 2001). Since it was specified that alkali-ion water is made by the addition of a calcium agent (nr 763 notification of the Ministry of Health and Welfare of Japan on October 8, 1965), the calcium concentration of alkali-ion water may be generally set to 40 mg/L. Therefore, alkali-ion water may be considered an effective calcium supplement, similar to bottled mineral water with a high calcium concentration (Halperm and others 1991; Couzy and others 1995; Aptel and others 1999). Since tap water contains magnesium before calcium is added, the hardness of the alkali-ion water with a calcium concentration of 40 mg/L is slightly higher than that with a concentration of 100 mg/L. However, the hardness of the good-tasting water, which the water tasting study group of the Ministry of Health and Welfare announced in April 24, 1985, is 10 to 100 mg/L. Thus, to consider whether the taste of alkali-ion water with an added calcium agent is acceptable to the Japanese people, a sensory evaluation of the taste of alkali-ion water in comparison with bottled mineral water and activated carbon filtration water was performed. Moreover, dissolution ingredients of these waters were determined, and the factors influencing sensory evaluation were analyzed statistically.

Materials and Methods

Reagents

Calcium sulfate and calcium lactate were obtained from Wako Pure Chemical Industries, Ltd., Osaka, Japan.

Apparatus

Alkali-Ion-Water electrolyzer.

The device (Type TK-781, Matsushita Electric Works Ltd., Osaka, Japan) was equipped with a water purifier and an electrolyzing chamber having titanium electrodes coated with platinum and separated by the membrane diaphragm between cathode and anode chamber. The tap water is electrolyzed while passing through the electrolyzing chamber after being purified with a water purifier, and alkali-ion water flows from the cathode chamber exit. Alkali-ion water of pH 9.5 was used in this experiment. The water purifier was a tub composed of granular charcoal and several tens of thousands of hollow-fiber membranes. The purification capability of this charcoal filter conforms to the S-102 of the Japan Water Works Association (JWWS) standard.

Samples

Bottled mineral water: The calcium concentration of commercially bottled mineral waters of Europe were indicated as 467, 200, 80, and 68 mg/L, while those of Japan were 24 and 11; these brands of bottled water were designated types A, B, C, D, E, and F, respectively. Examples were placed in polyethylene bottles and stored at room temperature.

Alkali-ion water: Calcium sulfate or calcium lactate were added to tap water with a calcium concentration of 17.5 mg/L, creating a calcium concentration of 40 mg/L. It has been specified that it uses calcium lactate for alkali-ion water by the Ministry of Health and Welfare. However, since the molecular weight of calcium lactate is higher than that of calcium sulfate, a considerably greater amount of calcium lactate must be used relative to the amount of calcium sulfate. Therefore, lactic acid may more strongly influence the taste of the water than sulfate. Moreover, since calcium sulfate is used for tofu, Japanese people are more familiar with its taste than to the taste of lactic acid calcium. The water containing the calcium agent was supplied to the alkali-ion water electrolyzer with a gear pump and passed and then set aside for 30 s after showing a pH of 9.5.

They were then used as alkali-ion water for the sensory test. The alkali-ion water made from the water to which had been added calcium sulfate and calcium lactate was indicated as samples G and H, respectively, and they were placed in polyethylene bottles and stored at room temperature.

Activated carbon filtration water: Tap water was supplied to the water purifier in the alkali-ion water electrolyzer with a gear pump and filtrated through the water purifier composed of charcoal and hollow-fiber membranes, but not electrolyzed. The activated carbon filtration water was indicated as I, placed in a polyethylene bottle, and stored at room temperature.

Sensory test

Sensory tests were carried out under fluorescent lighting typical of offices and classrooms.

Sampling. Each water sample that was assigned A to I at random was moved from the polyethylene bottle to a clear vinyl drinking glass by each panelist. Then each panelist put all glasses on a tray and took them to each desk.

Sensory test 1. Each water from A to I was sampled in free order, and its taste was evaluated in terms of 5 grades—very good tasting, good tasting, neither, bad tasting, and very bad tasting—by panelists. Each grade was scored +2, +1, 0, -1, and -2, respectively. The room and sample temperatures were both 26 ºC. Panelists were 166 female junior college students, ranging in age from 19 to 20 years, who had been prepared for the experiment without directions about breakfast, lunch, and tooth brushing.

Sensory test 2. Smell, taste, feeling in the throat (the feel of the liquid passing through the throat), aftertaste (the taste remaining a few seconds after swallowing), and general impression (a synthetic judgment) of the mineral water C (calcium concentration was indicated as 80 mg/L), alkali-ion water G (to which was added calcium sulfate), alkali-ion water H (to which was added calcium lactate) and activated carbon filtration water I were evaluated using the 1-pair comparison method. The 150 panelists for this test were divided into 3 groups of 50 panelists each. The first group evaluated C (labeled as K), H (labeled as L), and I (labeled as M). These waters were presented in 3 separate pairs, C-H, C-I, and H-I, with 1 sample on the left and the other on the right in front of each panelist. The second group evaluated C (labeled as K), G (labeled as L), and I (labeled as M). These were presented in 2 separate pairs, C-G and G-I, with 1 bottle on the left and the other on the right. The third group evaluated G (labeled as L) and H (labeled as M), and again 1 bottle was placed on the left and the other on the right. Each water was evaluated on a 5-grade evaluation: very strong, a little strong, or no difference regarding smell and on a 5-grade evaluation: very good, a little good, or no difference regarding each evaluation item except smell. Scores of very strong or good on the left water, a little strong or good on the left water, or no difference, very strong or good on the right water, a little strong or good on the right were +2, +1, 0, –1, and –2, respectively. The room and sample temperatures were both 26 °C. The 150 panelists were female junior college students, ranging in age from 19 to 20 y, who had been prepared for the experiment without directions about eating and tooth brushing.

Chemical analysis of sample waters

The pH, the rate of electric conduction, concentrations of total organic carbon (TOC), CO_2, residual chlorine, and SiO_2 were measured using a pH meter (F-22, Horiba Co., Ltd., Kyoto, Japan), electric conduction meter (ES-12, Horiba Co., Ltd.), total organic carbon meter (TOC-5000, Shimadzu Co., Ltd., Japan), remaining chlorine meter (46700-00, Hach Co., Loveland, Colo., U.S.A.), and a multi-item quick water quality meter (DR/2000, Hach Co.), respectively. Concentration of ions of Cl, SO_4, Na, K, Mg, and Ca were measured using the ion-chromatography (anion: DX-500, Dionex Japan; separation column: IonPac AS12A; guard column: IonPac AG12A; detector: electrical conductivity detector; cation: DX-120, Dionex Japan; separation column: IonPac CS12A; guard column: IonPac CG12A; detector: electrical conductivity detector).

Statistical analysis

The data of sensory test 1 were analyzed using the Wilcoxon rank sum test, and the difference of score between the sample waters was calculated with a significance level of $P < 0.05$. The data of sensory test 2 were analyzed by Student's t-test modified by Haga (1962) in terms of Sceffe's 1-pair comparison method using EXCEL 2000 and Taikou add-in software (Esumi Ltd., Tokyo, Japan), and the difference of score between the sample waters was calculated with a significance level of $P < 0.05$. The multivariate analysis of components influencing the sensory test in each water was performed by multiple regression analysis, which made the criterion variables the average score of sensory test 1 and made the predictor variables the various component levels of each sample water, using EXCEL 2000 and add-in software (Statcel, developed by Dr. Hisae Yanai, Saitama Univ.).

Results and Discussion

Sensory test

Table 1 shows the results of sensory test 1 for the sample waters from A to I as indicated by a panelist's number and average score. The average score is the value acquired using the following formula:

$$\Sigma(\text{score} \times \text{panelist's number}) \;/\; \text{total panelist number} \qquad (1)$$

The results indicated in Table 1 show that the ranking of the taste of water was the order of I, G and H, D, C and E, B and F, and A.

Since the order of taste preference for waters from A to I became clear in sensory test 1, to compare the taste preference for calcium sulfate-added alkali-ion water (G) and calcium lactate-added alkali-ion water (H) in detail, a sensory test using the 1-pair comparison method was conducted. Activated carbon filtration water (I) and bottled mineral water (C) were tested simultaneously because activated carbon filtration water had not been made alkali-ion water, and the bottled mineral water (C) was the most highly consumed bottled mineral water with hardness exceeding 100 in Japan. The result of sensory test 2 is shown as the number of panelists in Table 2, and the average score [Σ (score × panelist number) / total panelist number] of each item of each water of sensory test 2 is shown in the Figure 1. Table 2 shows that the smell of bottled mineral water C was significantly stronger than that of alkali-ion water G; the tastes of G, H, and I were significantly better than that of C, and that of I was significantly better than taste of G and H; the feeling in the throat and the aftertastes of G, H, and I were significantly better than those of C; and the general impressions of G, H, and I were significantly better than those of C, and that of I was significantly better than that of G. There was no difference in acceptability between the alkali-ion water with added calcium sulfate and that with added calcium lactate. An experiment using higher concentrations of calcium agents should be conducted to investigate the difference in acceptability between the 2 types of alkali-ion water.

Chemical analysis of sample waters

The pH, the rate of electric conduction, concentrations of total organic carbon (TOC), CO_2, residual chlorine, and SiO_2 of water from

Table 1—The number of panelist who evaluated waters A to I and the average score of each water in sensory test

	Very good tasting	Good tasting	Neither	Bad tasting	Very bad tasting	Total number of panelist	Average score
A	0	2	12	37	115	166	–1.5963855
B	2	26	73	47	16	164	–0.298780488[a]
C	4	40	65	49	8	166	–0.102409639[b]
D	8	38	73	43	3	165	0.03030303[c]
E	5	36	53	55	16	165	–0.248484848[b]
F	3	28	51	61	22	165	–0.43030303[a]
G	8	39	80	29	9	165	0.048484848[d]
H	6	42	73	38	5	164	0.036585366[d]
I	10	53	68	28	3	162	0.240740741[e]

Scores of very good, good, neither, bad and very bad are +2, +1, 0, –1 and –2, respectively.
The average score is acquired by the fomula of Σ(score × panelist's number) / total panelist number.
[abcde]Within columns, the average scores not having the same alphabetical letters were significantly different by 5% ($p \leq 0.05$).

Table 2—The number of panelist who evaluated the left or right water using the one-pair comparison method

		Number of panelists				
Evaluation item	Pair of waters	Very strong or good on the left water	A little strong or good on the left water	No difference	A little strong or good on the right water	Very strong or good on the right water
Smell	C-G	2	14	29	5	0**
	C-H	2	9	31	8	0
	C-I	2	9	33	5	1
	G-H	0	5	39	6	0
	G-I	0	6	30	12	2
	H-I	2	9	34	4	1
Taste	C-G	0	14	13	20	3*
	C-H	0	13	7	27	3**
	C-I	3	5	9	24	9**
	G-H	2	14	14	19	1
	G-I	0	12	13	24	1**
	H-I	3	9	10	27	1*
Feeling in the throat	C-G	0	7	21	22	0*
	C-H	0	17	14	12	7*
	C-I	2	6	16	19	7**
	G-H	1	13	21	15	0
	G-I	0	7	23	18	2
	H-I	3	7	21	18	1
Aftertaste	C-G	0	9	19	21	1**
	C-H	1	9	17	17	6**
	C-I	2	7	14	22	5**
	G-H	1	13	23	12	1
	G-I	0	9	22	18	1
	H-I	3	9	19	17	2
General impression or Synthetic judgement	C-G	0	12	11	26	1**
	C-H	0	12	7	27	4**
	C-I	2	8	5	30	5**
	G-H	1	14	20	13	2
	G-I	0	13	14	19	4*
	H-I	3	10	14	21	2

Total panelist number was 150, but each 1-pair comparison test was done by 50 panelists.
*The left water is significantly strong or good by 5% ($p<0.05$).
**The left water is significantly strong or good by 1% ($p<0.01$).
The term strong was used only for describing smell, and good was used for the other items.

samples A to I are shown in Table 3; Concentration of ions of Cl, SO_4, Na, K, Mg, and Ca of water from A to I are shown in Table 4.

Relation of the sensory test and chemical analysis of waters

To determine whether the results of sensory test 1 were influenced by a particular component, a multivariate analysis using the following 2 formulas was performed in regard to each component.

$$A1 \times N_{pH} + B1 \times N_{\text{rate of electric conduction}} + C1 \times N_{TOC} + D1 \times N_{CO2} + E1 \times N_{SiO2} + \text{Constant} \quad (2a)$$

$$A2 \times N_{Cl} + B2 \times N_{SO4} + C2 \times N_{Na} + D2 \times N_{K} + E2 \times N_{Mg} + F \times N_{Ca} + \text{Constant} \quad (2b)$$

However, factor with significant correlation could not be determined. Multiple regression analysis like the following formulas was

Table 3—The pH, Rate of electric conduction, total carbon, inorganic carbon, total organic carbon, CO2, Residual chlorine, and SiO2 of sample waters

Water	pH	Rate of electric conduction (μS/cm)	TC[a] (mg/L)	IC[b] (mg/L)	TOC[c] (mg/L)	CO_2 (mg/L)	Residual chlorine (mg/L)	SiO_2 (mg/L)
A	7	2230	87.4	59.2	28.2	217.1	0.1	1.2
B	7.4	582	60.4	40.5	19.8	148.5	0.1	4.6
C	7.7	484	83.1	54.4	28.8	199.4	0	7.9
D	7.8	380	55.9	36.4	19.5	133.3	0	3.1
E	8	243	23.4	15.3	8.1	56.1	0	14.6
F	7.8	90	12.1	8.5	3.6	31	0.1	15
G	9.5	303	13	8.7	4.3	31.9	0	1.8
H	9.5	302	35.4	19.4	16	71.2	0	10.6
I	7.7	203	13.3	7.7	5.6	28.1	0	7.5

[a]Total carbon
[b]Inorganic carbon
[c]Total organic carbon

Table 4—Concentration (mg/L) of ions in sample waters

Water	Cl	SO_4	Na	K	Mg	Ca
A	6.7	1138.7	60	3.3	84.1	427.8
B	2.8	139.6	7.5	4.4	20.2	82.5
C	5	11.6	6.9	0.9	25.4	61.1
D	2.7	16.9	3.8	0.3	2.9	72.6
E	13.3	15.4	15.3	0.3	4.9	24.2
F	1.1	3.1	5.9	2.3	1.3	7.9
G	14.9	64.9	11.6	2	4	40.2
H	15.1	25.1	12.4	2	3.9	40
I	16.4	21.6	13.3	2.1	4.1	19.9

performed, according to the law of Weber-Fechner (Fechner 1859; Yamano and Yamaguchi 1994; Kawai 2000).

$$A1 \times \log N_{\text{rate of electric conduction}} + B1 \times \log N_{TOC} + C1 \times \log N_{CO2} + D1 \times \log N_{SiO2} + \text{Constant} \quad (3a)$$

$$A2\_\log N_{Cl} + B2\_\log N_{SO4} + C2\_\log N_{Na} + D2\_\log N_K + E2\_\log N_{Mg} + F\_\log N_{Ca} + \text{Constant} \quad (3b)$$

However, since the influence of water A was too high due to its high concentration of calcium, multiple regression analysis was performed excluding water A. Then, the following formula was obtained, and the multiple correlation and *P* value of analysis of variance were 0.89 and < 0.02, respectively.

$$0.779 \times \log N_{Cl} - 1.15 \times \log N_{Na} + 0.366 \quad (4)$$

Therefore, regression was highly accurate and it became clear that it was the factor in which chlorine and sodium ions influence the sensory test of the taste of the waters B to I, excluding A. Moreover, since Toko (1995) had reported that the taste of mineral water was influenced by the concentration of calcium ions, to examine whether calcium influenced taste, multiple regression analysis of the following formula was performed except for A.

$$A \times Nca + B \times \log N_{Ca} + \text{Constant} \quad (5)$$

However, since multiple correlation and *P* value of analysis of variance were 0.69 and < 0.20, respectively, the influence of calcium was not accepted.

The average score value of C, G, H, and I in sensory test 1, the average prediction value which was acquired from substitution of the chemical analysis value of Cl and Na ions using the formula

$$0.779 \times \log N_{Cl} - 1.15 \times \log N_{Na} + 0.366$$

obtained from multiple regression analysis (except water A), and the general impression (a synthetic judgment) score of sensory test 2 are shown in Table 5. Since the average score of sensory test 1 is similar to the general impression score of sensory test 2, it is thought that the result of sensory evaluation of waters C, G, H, and I is in agreement in both sensory tests. However, the average prediction value of activated carbon filtration water I obtained from formula (4) differs from the average score. This is considered because the calcium concentration of activated carbon filtration water I was low compared with the other 3 waters. Therefore, it might be impossible that the taste of water was due only to the sodium and chlorine ions contents in the water. Then, although the calcium content could not be verified as a factor, the analysis of the taste of water, which also took calcium content into consideration, is required as mentioned by Iiyama and others. Therefore, to examine the taste of drinking water in light of calcium concentration, an experiment using mineral water or calcium-added water that distinguishes the calcium concentration stage more precisely is needed. And, since few reports have described the sensory evaluation of bottled mineral water compared with tap water or river water (Anselme and others 1987; Suffet and others 1988; Meng and others 1992), research that analyzes the relationship between the results of the

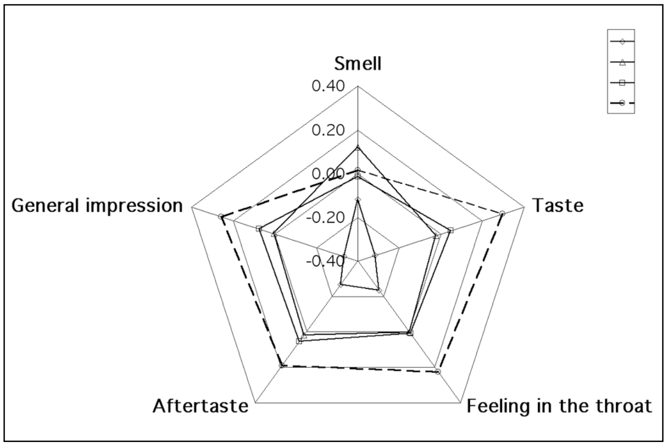

Figure 1—The average score [Σ(score × panelist number) / total panelist number] of smell, taste, feeling in the throat (the feel of the liquid passing through the throat), aftertaste (the taste remaining a few seconds after swallowing), and general impression (a synthetic judgment) of sensory test 2

Table 5—Levels of Cl, Na, and Ca ions determined using ion-chromatography, the average score in sensory test 1, the average prediction value which was acquired from substitution of the analysis value of Cl and Na ions of waters C, G, H, and I at the formula (4), and general impression (a synthetic judgement) score of sensory test 2.

Water	Cl	Na	Ca	Average score in test 1	Prediction average value	General impression score of test 2
C	5	6.9	61.1	–0.1024	–0.0542	–0.335
G	14.9	11.6	40.2	0.0485	0.0558	0.005
H	15.1	12.4	40	0.0366	0.027	0.075
I	16.4	13.3	19.9	0.2407	0.0199	0.255

taste test and the components of mineral water is still required using a greater variety mineral waters.

Conclusions

THE TASTE OF ALKALI-ION WATER TO WHICH CALCIUM SULFATE OR calcium lactate was added to attain a calcium concentration of 40 mg/L was found to be preferable to any mineral water but inferior to the activated carbon filtration water examined in this experiment. There was no difference between the taste of alkali-ion water to which was added calcium sulfate and that of alkali-ion water to which was added calcium lactate. The waters B to I examined in this experiment showed a high score in regard to small sodium ion levels and large amounts of chlorine. Based on only the water used here, the correlation of calcium ion concentration and the taste can not be accepted as valid.

References

Anselme C, Mallevialle J, Bordet JP. 1987. Utilisatio du profil de flaveur pour la caracterisation des qualities organoleptiques des eaux potables. Trib Cebedeau 40:3-16.

Aptel I, Cance-rouzaud A, Grandjean H. 1999. Association between calcium ingested from drinking water and femoral bone density in elderly women: evidence from the EPIDOS cohort. J Bone Min Res 14:829-33.

Couzy F, Kastenmayer P, Vigo M, Clough J, Box RM, Barclay DV. 1995. Calcium bioavailability from a calcium and sulfate rich mineral water, compared with milk in young adult women. Am J Clin Nutr 62:1239-44.

Fechner G. 1895. Elemente der psychophysik. Leipzig, Germany: Breitkopf und Härtl.

Haga T. 1962. The modified method of Scheffe. The material of the R-44 study meeting for sensory test by Nikkagiren, Tokyo, Japan: Nikkagiren. p 143-145.

Halperm GM, Keen CL, Water JV, Gershwin ME, Delabroise A. 1991. Comparative uptake of calcium from milk and a calcium-rich mineral water in lactose intolerant adults: implications for treatment of osteoporosis. Am J Clin Nutr 7:379.

Hotta K, Kawaguchi K, Saito F, Saito N, Suzuki K, Ochi K, Nakayama T. 1994. Antimicrobial activity of electrolyzed NaCl solutions: Effect on the growth of Streptomyces spp. Actinomycetology 8:51-6.

Iiyama S, Yahiro M, Toko K. 1995. Quantitative sensing of mineral water with multichannel taste sensor. Sense Mater 7:191-201.

Izumi H. 1999. Electrolyzed water as a disinfectant for fresh-cut vegetables. J Food Sci 64:536-9.

Kawai N. 2000. Sensory evaluation of Food Palatability. Dairy Ind Technol 50:206-26.

Kikuchi K, Takeda H, Rabolt B, Okaya T, Ogumi Z, Saihara Y, Noguchi H. 2001. Hydrogen particles and supersaturation in alkaline water from an alkali-ion-water electrolyzer. J Electroanal Chem 506:22-7.

Kim C, Hung YC, Brackett RE. 2000. Roles of oxidation-reduction potential in electrolyzed oxidizing and chemically modified water for the inactivation of food related pathogens. J Food Prot 63:19-24.

Koseki S, Yoshida K, Isobe S, Itoh K. 2001. Decontamination of lettuce using acidic electrolyzed water. J Food Prot 64:6529-658.

Meng AK, Brenner L, Suffet IH. 1992. Correlation of chemical and sensory data by principal component factor analysis. Wat Sci Tech 25:49-56.

Suffet IH, Brady BM, Bartels JHM, Burlingame G, Mallevialle J, Yohe T. 1988. Development of the flavor profile analysis method into a standard method for sensory analysis of water. Wat Sci Tech 20:1-9.

Yamano Y, Yamaguchi S. 1994. Science of delicacy. Tokyo: Asakurashoten. p 100.

MS 20020247 Submitted 4/18/02, Revised 7/23/02, Accepted 8/22/02, Received 8/26/02

We thank Miss M. Fukuda and Miss N. Tanzawa of Yamawaki Gakuen Junior College for their very useful and kind help.

Authors Koseki and Nakagawa are with Yamawaki Gakuen Junior College, 4-10-36, Akasaka, Minato-ku, Tokyo 107-8371, Japan. Authors Tanaka, Noguchi, and Omochi are with Research & Development Center, Home Appliances Co., Matsushita Electric Works Ltd., 1048, Kadoma-shi, Osaka 571-8686, Japan. Direct inquiries to author Koseki.