Gustatory Evaluation of Still and Carbonated Waters: A Preference Rating Study

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ABSTRACT

We studied the sensory preference of six still waters and four carbonated waters, non-flavored, by eleven tasting experts (4 females and 7 males). Five tasters rated the still waters; four tasters rated the carbonated water; and seven tasters rated twice on each of the still waters when evaluated with a dry red wine. All ratings were performed through answering a set of questions regarding the specific taste and/or smell of the waters. All tasters and statistician were blinded to the water brands during rating and analysis respectively. Multi-dimensional preference analysis and correspondence analysis were used to portray the underlying sensory preference. Still waters with higher mineral content tended to be less favorable for drinking purpose. On the contrary, carbonated waters with more minerals (but not over a certain limit) were favorable, and still waters with higher mineral content were preferable as mouth cleaners for red wine. The methodology can indeed be carried to the food and beverage industries, to the functional foods industry, and medical research where the preference of patients towards certain medications is of interest.

INTRODUCTION

Drinking water is incontrovertibly considered as essential to all groups of people especially the elderly in order to prevent dehydration.[1-3] Epidemiological and clinical studies have shown the important role of minerals for health maintenance. In order to ensure enough nutrients needed for an average individual, drinking water should be rich in magnesium and calcium but low in sodium content.[4] Drinking highly mineralized water is however a high intensity factor producing an untoward effect on the children's physical development, contributing to the rise of the incidence of acute (mainly respiratory) and chronic diseases.[5] Despite of this, different brands of still and carbonated water with different mineral contents have been marketed. For instance, calcium content may range from 0 to over 500 mg/liter, magnesium may range from 0 to over 100 mg/liter, and sodium may range from 0 to over 1,000 mg/liter.[4,6] Relation of sensory preference of still and carbonated drinking waters with their mineral contents is therefore desirable to determine if sensory preference is consistent to healthy practices.

Minerals may generally be classified as cations and anions. Cations include calcium, magnesium, potassium and sodium, while anions include chlorides, nitrates, sulfates, bicarbonates and silica residues. It was demonstrated that an increase in mineral anions would decrease the sensory preference of water in a study which collected the preferences of a group of randomly selected subjects on waters chemically made with different amount of anions.[7] A more recent study however found a general preference of waters with higher mineral content.[8] The seemingly diverse observation may deserve further attention. On the other hand, we were unable to discover studies on the sensory preference of carbonated waters although they have gained much popularity in the recent decade.

On the other hand, the taste quality of red wine is known to be better after sips of still water for cleaning purposes. A desirable “mouth cleaner” is then the one that does not change the taste quality of red wine substantially. To our knowledge, the type of still waters most desirable for mouth cleaning when one alternate sips of wine and water was however not known in the literature.

Our objectives were then to have the first preliminary examination for the influence of mineral content on the sensory preference of still and carbonated waters, and the type of still waters most suitable as a month cleaner for red wine. Moreover, the grading standards of the selected tasters were also studied by using some commonly used statistical techniques.

MATERIALS AND METHODS

Waters, their Mineral Contents, and the Red Wine

Five brands of still water, labeled as S1 to S5, and four brands of carbonated water, labeled as C1 to C4, were examined. All these waters were non-flavored and were selected based on their popularity on the market. Particularly, S1 was distilled water with no minerals. Besides, the local tap water, labeled as S6, was also studied. For safety reasons, tap water was first boiled and chilled down before serving. Except tap water, all selected still waters and carbonated water C3 were packaged in plastic bottles. Carbonated waters C1 and C4 were originally kept in glass bottles, while C2 came from metal cans. Mineral contents of the marketed waters were obtained from their packaging labels or by contacting the distributor. Mineral contents of tap water when it was leaving the treatment plant was obtained from the Hong Kong SAR Government and is deemed to have a large fluctuation.[9] Appendix A summarizes the mineral contents classified by cations and anions of the waters. On the other hand, the red wine selected was dry in nature and had a very high standard as judged by an expert with over 30 years of wine tasting experience.

Gustatory Evaluation Procedures

Eleven wine tasting experts from different ethnic groups (1 British, 8 Chinese, 1 French, and 1 Japanese), labeled as A-K, were invited to participate into the study. They were selected for their high sensory sensitivity in lieu of using a large group of lay consumers. Moreover, their diversity in ethnicity would hopefully represent a wider range of sensory behavior. Indeed, it was demonstrated that small expert panel and large consumer panels could have similar ability to distinguish any differences in drinking waters.[10] Each taster was explained with the study details and had signed an informed consent form before the study commenced. The study comprised of three sessions where selected tasters answered a set of questions pertaining to the taste and smell of the waters (Table 1).

The first session consisted of five randomly selected tasters out of the seven who rated the taste quality of the six brands of still water in a randomized order. The second session consisted of four randomly selected tasters rating four brands of carbonated water in another randomized order. The third session concerned with the rating of still waters when they were used as a mouth cleaner with few sips of the red wine by seven randomly selected tasters in a randomized order. The taste quality ratings of the waters were then repeated with the same group of tasters but in a different randomized order. The red wine was served at room temperature (18 – 20°C).

All still and carbonated waters were served in thin and odorless Riedel glasses at 7°C chosen for better appreciation of the waters. Original containers of all marketed waters were not exposed to the tasters, and the waters identities remained blinded during the study. Moreover, the serving table was covered with a white cloth and the room was kept silent during the whole study period.

Statistical Analysis

All data collected from the structured questions (Table 1) were analyzed without knowing the waters identities and their mineral contents. Apart from using some descriptive statistics, multi-dimensional preference analysis and correspondence analysis were also employed to visually examine the tasters' sensory preference of waters.[11] Moreover, for the two rating rounds of waters with red wine, the Mantel-Haenszel χ^2 test was used to determine if the tasting order and round affected the tasters' ratings. Based on the overall rating, and tasters' preferences, still and carbonated waters were given a general grade as fair, fairly good, good, very good, or excellent. A 0.05 level of significance was adopted for all significance tests, and the Statistical Analysis System (SAS) version 8.0 was used for all statistical analyses.[12]

RESULTS

Grading of Still and Carbonated Waters

Table 2(a) and (b) provide a summary of taste quality of still and carbonated waters. Tap water (S6) had the lowest total score and more foul ratings. Figure 1 shows the results from the correspondence analysis for the ratings of tap water where each asterisk represents a rating. The further is an asterisk away from the origin, the less often the rating has been given. Furthermore, the closer the asterisks are, the more often the corresponding ratings have been given simultaneously by the same taster. From Figure 1(a), tap water tended to be rated as sweet and not bitter but foul with a fair overall rating.

(Insert Table 2 and Figure 1)

Table 3 summarizes the rated taste quality of still waters. For drinking purpose, all still waters had no strong taste except for distilled water (i.e. S1) which was tended to be rated as sweet and metallic. On the other hand, carbonated waters were all similarly rated as no taste (Table 2(b)). Carbonated water C4 was however rated as salty (Table 2(b) and Figure 2). Indeed, C4 had higher contents in sodium and chlorides (Appendix A) which contribute to the salty taste.

(Insert Table 3 and Figure 2)

The general grades of all waters based on all tasters' ratings are summarized in Table 4. For drinking purpose, still waters with low mineral contents such as S1 and S2 were more favorable to those with higher mineral content such as S4 and S5. On the contrary, higher (but not over a certain extent) mineralized carbonated waters were favorable than low mineralized carbonated waters. Besides, whether the carbonated waters were packaged in glass (C1 and C4) or plastic (C3) bottles did not appear to influence the taste quality grading. On the other hand, the amount of cations did not appear to have a large influence on taste. For instance, still water S5 had slightly more cations then S4 while both of them had similar amount of anions. However, S4 had the same grade as S5.

(Insert Table 4)

Grading of Still Waters as a Mouth Cleaners for Red Wine

Table 2(c) summarizes the ratings of still waters when used as a mouth cleaner for red wine. Interestingly, tap water did not have the lowest overall rating among the other still waters. Indeed, tap water had a good overall taste quality though it was often rated as metallic (Figure 1(b)). The general grades of still waters as mouth cleaners for red wine decreased from S1 to S5 (Table 4). In other words, still waters with high mineral contents were preferable for mouth cleaning. Moreover, there was no evidence for an effect of tasting order or round of still waters on tasters' water quality ratings ($\chi^2(1) < 2.0$, exact $p > 0.235$).

Sensory Preference of Tasters

Figure 3 displays the overall sensory preferences of tasters at respective tasting sessions. Each arrow represents a taster, and points to the direction of increasing preference, whereas each asterisk corresponds to a type of water. The closer the arrows, the more alike the preferences of the corresponding tasters are. Moreover, the projected length of an asterisk on an arrow measures the level of preference of the corresponding taster. From the figure, the standards of tasters I and H for still waters, and tasters A and E for carbonated waters coincided, whilst those of the four tasters in mouth cleaners for red wine were rather diverse.

(Insert Figure 3)

Figure 4 shows the correspondence analysis of taster A's sensory preference at different tasting sessions. She rated bitter still waters as very good and sweet still waters as good or fair for drinking purpose. In contrast, she favored sweet still waters and rated metallic and bitter still waters as bad for mouth cleaning. For carbonated waters, she distinctively disliked salty taste. Nevertheless, taster A could be considered as a sensitive taster though she had a peculiar interest in bitter water for drinking. Table 5 summarizes the gustatory evaluation behavior of the other tasters. Around half of the tasters could be considered as sensitive, i.e. those who tended to give different ratings to different waters.

(Insert Figure 4 and Table 5)

DISCUSSION

All still and carbonated waters studied, except tap water, did not appear to have a strong taste and smell despite of their differentials in mineral contents. For drinking purpose, distilled water appeared to be sweet and metallic. Moreover, still waters with higher mineral content tended to be less favorable. This was indeed similarly observed in a study conducted by Bruvold & Gaffrey.[7] The contrary was however observed in a more recent study of several types of drinking waters evaluated by a number of untrained assessors.[8] Nevertheless, carbonated waters with more minerals were favorable but highly mineralized waters, in both cations and anions, were not preferable.

On the other hand, still waters with higher mineral content were preferable as mouth cleaners for red wine. Tap water, in particular, was consistently not highly graded or favored. Influence of pH value on gustatory preference is expected to be similar to that of mineral content as pH was shown to be linearly related with cations calcium, magnesium, and sodium, and the anion bicarbonates.[13] On the other hand, a coherent general sensory preference was observed in still and carbonated waters but a rather diverse preference was observed in rating mouth cleaners for red wine.

The temperature and environment were properly controlled throughout the whole tasting period and thus they would not contribute to any differences of water ratings.[14] Furthermore, there were indications that element concentrations for some unwanted constituents (e.g. Pb) were higher in waters packaged in glass bottles than those in plastic bottles.[15] We did not however observe the influence of this differential in carbonated waters based on their preference.

Bruvold & Gaffey described that significant impact on tasting quality of waters was strongest with anion carbonate, the medium with anion chlorides, and weakly with bicarbonates and sulfates anions.[7] From our results, there did not seem to have a large influence of the amount of cations on the taste quality of waters. For instance, still waters S4 and S5 had the same quality rating although S5 had a slightly larger amount of cations than S4 while both of them had similar amount of anions.

Tap water in Hong Kong in general, when it leaves the treatment plant, meets the World Health Organization guidelines for drinking-water quality.[16] There may however be a big variation when water is delivered to the consumers' taps via inside plumbing. Thus tap water may sometimes be contaminated with a metallic or unpleasant taste due to the presence of dissolved iron from rusty pipes and tanks during water transportation and storage. Moreover, the inferiority of gustatory preference of tap water may also partially due to the presence of chloroform which was found almost exclusively in samples that could have been obtained from public water supplies.[14] Chloroform is a by-product of chlorine, a disinfectant added in tap water, which do not have a pleasant taste and smell. It should not however be a major factor of the taste inferiority of tap water as it was boiled before it was served, and most chloroform should have been vaporized.

Despite the advantage of minerals on health, they seemed to be not preferred for drinking purpose. Epidemiological and clinical studies have shown the benefits of magnesium and calcium. Magnesium is important to prevent sudden death and is a vital element for the central nervous system and the immunity system while calcium is essential to normal growth and maintenance of bone that helps to prevent osteoporosis.[4,18,19] Excess sodium content may however contribute to the occurrence of hypertension.[4,20-22] Hence, C4 that had a high sodium content is not recommended. On the other hand, although S4 and S5 were both rich in magnesium and calcium while low in sodium content, they were less preferred when compared with other still waters (except tap water) that were apparently less healthy. Education on the benefits of magnesium and calcium in mineral water may perhaps be desirable.

The mineral contents of S3 and C2 were unknown. The bottle label of S3 had only printed the presence of magnesium, sodium, potassium, chlorides, and sulfates but not their concentration levels. Similarly, the metal can for C2 only mentioned the presence of sodium and bicarbonates. Based however on our results, the overall mineral content of S3 should be similar to S2 while that of C2 should be similar slightly lower than C1 but higher than C3.

Despite the diverse preference standard towards still waters when they were used as mouth cleaners for red wine, three out of the seven selected tasters did not however distinguish any differences among all still waters. Interestingly, distilled water was the worst when used as a mouth cleaner for red wine. Still waters with higher mineral content (e.g. S5) were most favorable for mouth cleaning without significantly changed the taste of the red wine.

We conducted a small experimental study on evaluating of the preference of waters with different mineral contents at different circumstances. The results would have been more generalizable if a larger sample of consumers were recruited instead of a limited number of wine tasting experts. Further studies with the mineral content of water experimentally controlled and tasted by a large group of consumers are desirable. The present study however provided a first insight on the influence of general mineral content on water taste quality through a small group of mostly sensitive tasters rather than a large but perhaps less sensitive group from the public. Moreover, a common statistical approach was adopted in study of gustatory evaluation of waters. The methodology can indeed be carried to the food and beverage industries, to the functional foods industry, and medical research where the preference of patients towards certain medications is of interest.

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TABLE 1

Questions used for the three tasting sessions

Session 1 (Still water)	Session 2 (Carbonated water)	Session 3 (Still water with wine)
Rating Questions		
1. Overall rating[a]	1. Overall rating[a]	1. Overall rating[a]
2. Overall impression[b]	2. Overall impression[b]	2. Sweet taste[c]
3. Taste rating[b]	3. Size of bubbles[b]	3. Bitter taste[c]
4. Metallic taste[c]	4. Sweet taste[c]	4. Metallic taste[c]
5. Sweet taste[c]	5. Bitter taste[c]	5. Unusual (i.e. unpleasant) taste[c]
6. Bitter taste[c]	6. Salty taste[c]	6. The favorite two waters
7. Specific (i.e. unpleasant/foul) taste[c]	7. Funny taste[c]	
	8. Foul taste[c]	
	9. Smell[c]	
Taster		
A, F, G, H, I	A, E, G, H	A, B, C, D, F, J, K

[a]Measurement scale: 1=Very Bad, 2=Bad, 3=Fair, 4=Good, 5=Very Good.

[b]Unstructured question.

[c]Measurement scale: Y=Yes, N=No.

TABLE 2

Summary of ratings of (a) still waters, (b) carbonated waters, and (c) mouth cleaners for red wine.

(a) still waters

	Total score[a]	Metallic[b]	Sweet[b]	Bitter[b]	Specific (unpleasant/foul)[b]
S1	22	3	4	0	1
S2	20	0	1	0	0
S3	21	2	2	0	1
S4	21	2	2	0	0
S5	20	2	1	1	1
S6	15	2	3	0	3

(b) carbonated waters

	Total score[a]	Sweet[b]	Bitter[b]	Salty[b]	Funny[b]	Foul[b]	Smell[b]
C1	18	0	0	0	0	0	0
C2	17	0	0	1	0	0	0
C3	14	1	1	1	0	0	1
C4	11	0	0	4	2	0	1

(c) mouth cleaners for red wine

	Total score[a]	Sweet[b]	Bitter[b]	Metallic[b]	Unusual[b]	Favorite[b]
First round						
S1	26	1	0	2	3	1
S2	21	3	0	2	0	1
S3	27	2	1	2	0	0
S4	28	3	0	1	0	3
S5	28	1	0	1	0	2
S6	22	0	1	5	3	1
Second round						
S1	25	3	2	3	1	1
S2	27	3	2	2	0	0
S3	26	2	0	4	2	2
S4	29	3	0	2	0	0
S5	26	3	1	2	0	2
S6	26	2	0	6	2	1

[a]Total score = sum of all overall ratings (i.e. Question 1).

[b]Total number of “Yes”.

TABLE 3

Summary of rated taste of still waters

Still water (amount of mineral contents)	Taste	
	Plain drinking	Evaluated with wine
S1 (distilled)	Sweet and metallic	No strong taste
S2 (low)	No taste	No strong taste but diverse opinion on sweetness
S3 (unknown)	Diverse opinion on sweetness and metallic taste	No strong taste
S4 (medium)	No taste	No strong taste but diverse opinion on sweetness
S5 (medium)	No taste	No strong taste
S6 (tap water)	Sweet but foul	Metallic

TABLE 4

Summary of the general grades of waters

General grade	Still water	Carbonated water	Still water with red wine
Excellent	-	-	S5
Very Good	S1, S2, and S3	C1	S4
Good	S4, and S5	C2	S2, S3, and S6 (tap water)
Fairly Good	-	C3	-
Fair	S6 (tap water)	C4	S1

Table 5

Summary of tasters' gustatory evaluation behavior

Peculiar taster	Consistent taster	Sensitive taster
A	C, E, F, G, and I	A, B, D, J, K, and H

FIGURE 1

Ratings of tap water (S6) when (a) drink alone, and (b) evaluated with wine

(a) (b)

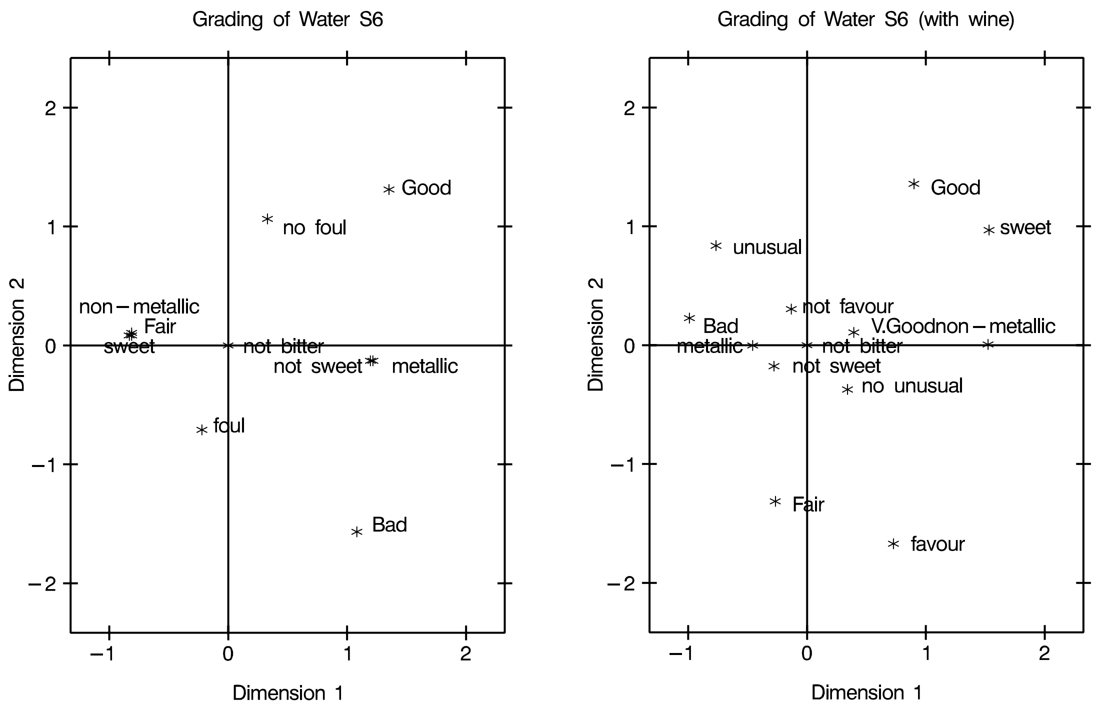


FIGURE 2

Grading of carbonated water C4

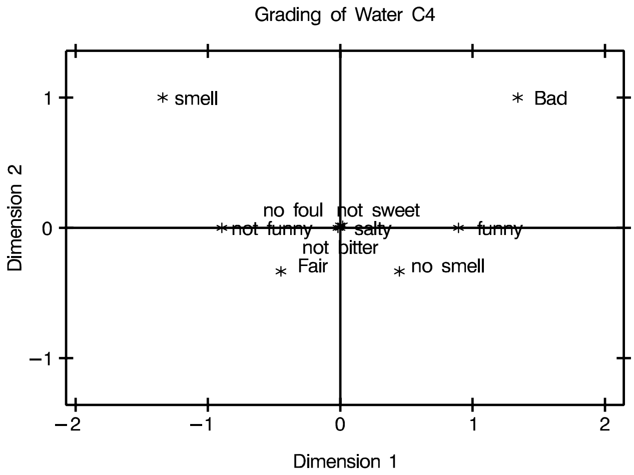
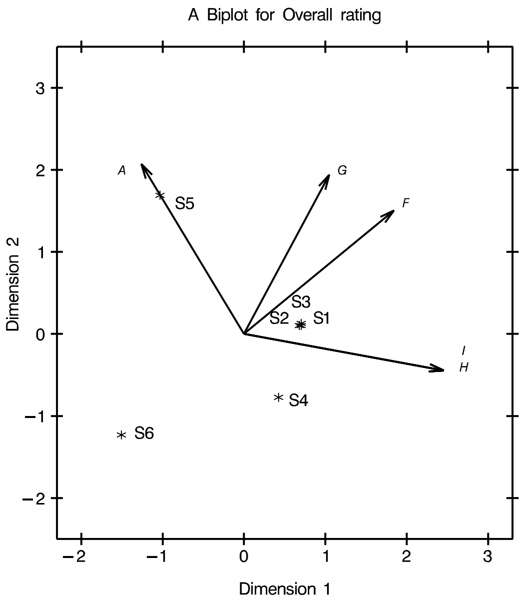


FIGURE 3

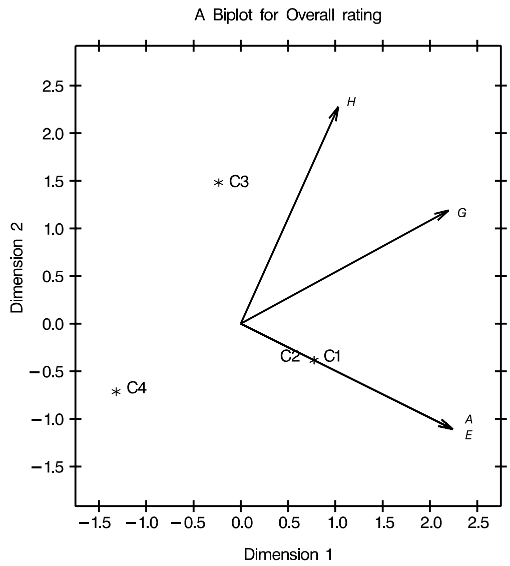
Overall rating of tasters in (a) session 1, (b) session 2, and (c) session 3

(Note: S1_2 indicates S1 that was evaluated at round 2 and similarly for the others.)

(a)



(b)



(c)

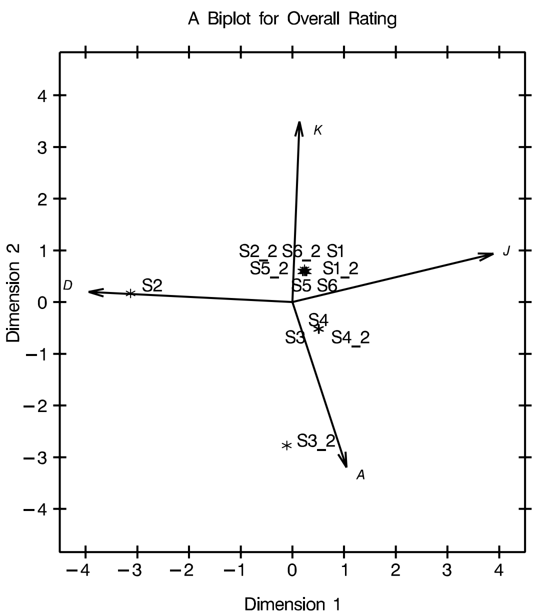
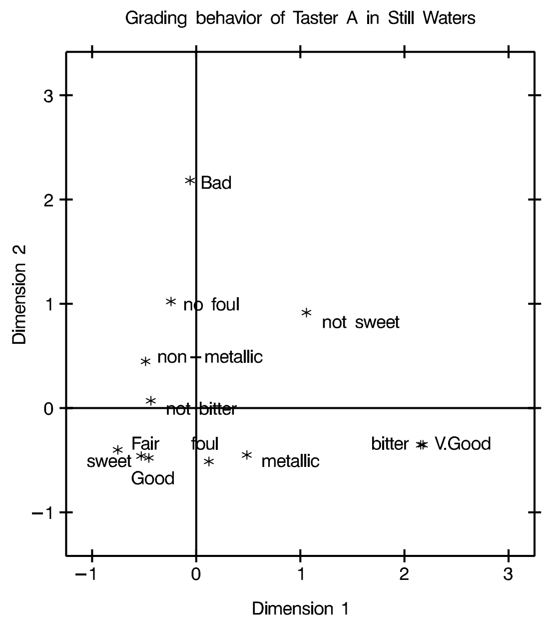


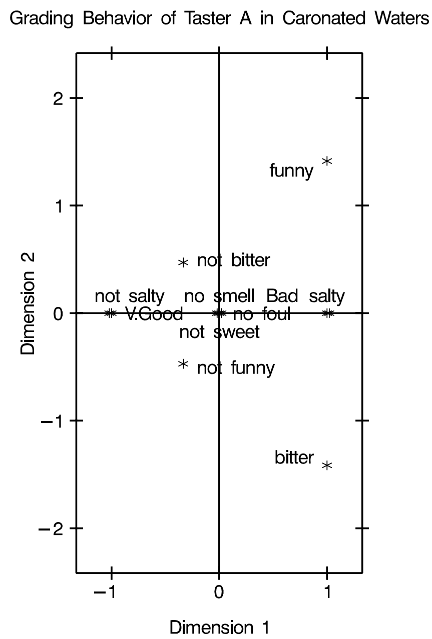
FIGURE 4

Grading behavior of taster A in (a) session 1, (b) session 2, and (c) session 3

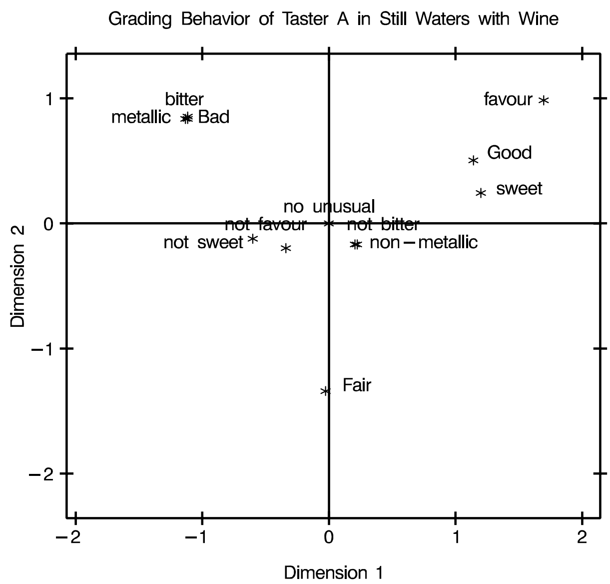
(a)



(b)



(c)



Appendix A

Mineral contents (mg/liter) and pH values of all study waters[a]

	Still water						Carbonated water			
	S1	S2[b]	S3	S4[b]	S5[b]	S6[c]	C1[b]	C2	C3[b]	C4[b]
Cations										
Calcium	NIL	9.9	UK	78.0	91.0	17.0	147.3	UK	46.0	208.0
Magnesium	NIL	6.1	UK	24.0	19.9	1.8	3.4	UK	27.0	55.9
Sodium	NIL	9.4	UK	5.0	7.3	UK	9.0	UK	7.2	43.6
Potassium	NIL	5.7	UK	1.0	4.9	UK	UK	UK	1.0	2.7
Anions										
Chlorides	NIL	8.4	UK	4.5	3.7	19	21.5	UK	2.3	74.3
Nitrates	NIL	6.3	UK	1.0	0.6	UK	18.3	UK	UK	0.45
Sulfates	NIL	6.9	UK	10.0	105.0	16	33.0	UK	6.3	549.2
Bicarbonates	NIL	65.3	UK	357.0	258.0	UK	390.0	UK	274.5	219.6
Silica Residues	NIL	30.0	UK	13.5	UK	8.9	UK	UK	UK	UK
pH	UK	7.0	UK	7.2	UK	8.1	6.0	UK	UK	UK

[a]UK = Unknown.

[b]Values were provided by Wan (Corporate Services) Ltd.

[c]Values (averaged) when the drinking water was leaving the treatment plant (Hong Kong SAR, 2000).

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