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Elements and Physical Properties of Green Tea Decoction using *Hakusan-Meisui* Mineral Water

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It has been said that when green tea is made using mineral water, the color is thicker than when made with tap water, and the smell and taste are of a higher quality. This study aimed i) to confirm whether there was a difference in the decoction elements by comparing green tea made with *Hakusan-Meisui* mineral water and purified water, and ii) to examine the preservation of the decoctions in terms of their quality retention effect. The study found that when green tea was made using *Hakusan-Meisui*, a larger amount of nutritional content and inorganic qualities were extracted from the exudate when compared with pure water. However, the quantity of vitamin C with *Hakusan-Meisui* was lower than that of purified water. In addition, the amounts of vitamin C in decoctions using both cold and hot water were also lower. The color and turbidity of green tea exudate made using *Hakusan-Meisui* by heating were higher than those of pure water, and the color was stronger. Though no changes were seen over time in pH, the number of bacteria or precipitation of either *Hakusan-Meisui* or pure water, the color, turbidity and oxidation-reduction potential showed an uptrend in the heated green tea decoction. In contrast to pure water, *Hakusan-Meisui* did not give off any rotten odor or astringency after being preserved for 5 days, and the effect of its quality maintenance was confirmed through a sensory evaluation of the decoction. The results of this study indicated that when green tea is made using *Hakusan-Meisui*, the color is stronger than when made with pure water, and the smell and taste are of a higher quality, as is generally said to be the case with mineral water.

Key words: decoction; dissolved oxygen; green tea; *Hakusan-Meisui*; oxidation-reduction potential

Since ancient times, green tea has been an indispensable part of Japanese traditional food culture. Nowadays, scientists recognize the utility for living beings of green tea elements such as catechins and polyphenol, and the effect of green tea on health enhancement and disease prevention is increasingly attracting attention (Cabrera et al., 2006; Khan and Mukhtar, 2007). Critical factors for tea include the drinking situation, elements of the decoction and a thorough tone study of the taste and smell. These influence the flavor directly and therefore the quality.

Abbreviations: EC, electrical conductivity; ORP, oxidation-reduction potential

Table 1. Method of analysis

Ingredients	Method of analysis
Water	Ordinary pressure ustulation method
Protein	Kel Dahl nitrogen assay
Lipid	Acidolysis method
Carbohydrates	100 − (water + protein + lipid + ash)*
Ash	Direct ashing method
Mineral matter	Ashing/ICP analysis method
Vitamin C	2,4-dinitrohydrazine method

* ( ), percentages of water, protein, lipid and ash.
ICP, inductively coupled plasma.

However, the decoction of green tea changes to brown over time, and this creates a problem for preservation. It has been reported that autoxidation of catechin is promoted in a basic stronger amino-acid although the pigmentation material is generated in the catechin, the green tea element, by oxidizing and polymerizing (Nakagawa, 1969). In addition, it has been reported that discoloration occurs in the decoction of tea according to the temperature and moisture content when percolating, and that the enzyme contained in the tea decoction exerts a great influence (Fukatsu et al., 1969).

Hakusan-Meisui is a famous type of mineral water in the Daisen area of Japan, and is marketed as bottled drinking water. *Hakusan-Meisui* is known as a mineral water with a low oxidation-reduction potential (ORP) value. When used to make green tea, the colors are stronger than those of regular water, and it is known to be excellent in quality as well as in smell and taste (Fujita, 2004). We previously measured the mineral balance of mineral water in 5 places in the Daisen region (Houri and Yoshioka, 2004), including *Hakusan-Meisui*, utlilizing the delicious water index and healthy water index advocated by Hashimoto et al. (1985). In terms of results (delicious water index ≥ 2.1 and healthy water index ≥ 5.2), it can be reported for water classification that only *Hakusan-Meisui* was found to be delicious and healthy. Green tea was also examined as to whether it differed in terms of nutritional content and physical properties when made from a decoction using purified water or *Hakusan-Meisui*. This paper also reports on a preservation examination of green tea exudate from purified water and *Hakusan-Meisui* for a short term, and presents a comparative study of the effects of quality maintenance.

Materials and Methods

Analysis sample

A sample of *Hakusan-Meisui* was collected on January 7, 2005 (7:15 AM) from the water intake source (Kurauchi, Kurayoshi, Japan). It was placed in 1.5-L plastic bottles (5 bottles) and 5-L polyethylene containers (2 pieces), then taken back to Tottori Health Service Association (Tottori, Japan) and analyzed.

Green tea decoction

Green tea was prepared based on the method given in the supplementary note of the "Four Correction Food Composition Table (2000)" (Kagawa Nutrition University Publishing Division, 2000). In other words, 2 packs of green tea (5.7 g of tea and 0.4-g pack of Japanese paper) were transferred to a beaker containing 430 mL of *Hakusan-Meisui* boiled to 90˚C which was then stirred slowly, and left sitting for 1 min. The filtrate was made into a decoction. As a contrast, a similar operation was carried out to obtain a decoction of purified water (city water refined by the membrane filtration method, specific resistant value = 1–10 MΩ•cm). In the same way, green tea decoctions using cold water were obtained and adjusted using *Hakusan-Meisui* and purified water at 15˚C, left sitting for 30 min. Finally, to reconfirm the results of the experiment, a similar operation was carried out using *Hakusan-Meisui* and purified water twice each, and the resulting decoctions were adjusted.

Table 2. Comparison of nourishment ingredient of green tea of medium quality exudate by *Hakusan-Meisui* and pure water

Classification of green tea*	Water (g)	Protein (g)	Protein (g)	Carbohydrates (g)	Ash (g)	Mineral matter (mg)					Vitamin C (mg)
						Na	K	Fe	Ca	P	
Hakusan-Meisui†	99.69	0.05	0	0.23	0.03	0.3	9.4	0.08	3.3	0.8	0.7
Pure water†	99.74	0.04	0	0.2	0.02	0.2	5.8	0.06	1.2	0.7	1.1
Quantity of ingredient ratio‡	0.999	1.25	0	1.15	1.50	1.50	1.62	1.33	2.75	1.14	0.64

* Green tea of medium quality exudate (90˚C, 1 min)
† Each component is expressed as weight included per 100 g decoction.
‡ Ratio of *Hakusan-Meisui* when the assumed quantity of pure water exudate is 1.

Items, method and instruments used in the analysis

Nutritional content analysis of the decoction

Moisture, proteins, lipids, carbohydrates, inorganic qualities (sodium, potassium, calcium, iron and phosphorus) and vitamin C (ascorbic acid) of each exudate were analyzed by the method determined in the Food Hygiene Inspection Indicators (Japan Food Hygiene Association, 2005) (Table 1). The amounts of vitamin C in the green tea decoctions using cold water and hot water of both *Hakusan-Meisui* and purified water were obtained and compared.

Physical properties of Hakusan-Meisui and purified water

Both *Hakusan-Meisui* and pure water (200 mL each) were put in 200 mL measuring cylinders equipped with stoppers. For both of these, pH, dissolved oxygen, electrical conductivity (EC) and ORP were measured i) before heating, ii) during heating at 90˚C, iii) 1 min after being heated, iv) 2 h after being heated and v) 5 h after.

Physical properties of the decoction and changes in sensory evaluation over time

The exudates were left to sit until room temperature, and then 200 mL of each was put in a measuring cylinder equipped with a stopper. This was then heated for 1 min at 90˚C. Evaluations of pH, taste, ORP, number of bacteria, color, turbidity and the presence of precipitation were carried out immediately after cooling, 1 day later, 2 days later and 5 days later. For the initial setting, the mouth of the stopper-equipped measuring cylinder containing the decoction was assumed to have been open for 1 h, and preserved in a thermostatic bath set to 20˚C. In addition, the decoction was shaken to a froth for a few seconds, then left sitting and observed. The taste evaluation of the green tea percolation liquid was carried out by 5 laboratory technicians (3 men and 2 women).

Results

Nutritional content analysis of the decoctions

When green tea was made using *Hakusan-Meisui*, its degree of nutrition and inorganic exudate element were found to be greater than those for pure water for all items except vitamin C (Table 2).

Table 3. Quantity of vitamin C of medium quality green tea exudates with cold water and heated water (mg/100 g)

	Cold water (15˚C, 30 min)	Heated water (90˚C, 1 min)	Exudation ratio†
Hakusan-Meisui	2.0	0.7	0.35
Pure water	2.4	1.1	0.46
Quantity of ingredient ratio*	0.83	0.64	

* Ratio of *Hakusan-Meisui* when the assumed quantity of pure water exudate is 1.
† Vitamin C of exudates with heated water/with cold water.

Table 4. Properties of matter change of *Hakusan-Meisui* and pure water by heating

Item	Sample	Before heating	After heating for 1 min at 90˚C		
			Immediately after	After 2 h	After 5 h
pH	*Hakusan-Meisui*	8.3 (10˚C)	8.3 (23˚C)	8.3 (22˚C)	8.3 (20˚C)
	Pure water	6.1 (18˚C)	6.1 (22˚C)	6.1 (22˚C)	6.2 (20˚C)
Dissolved oxygen (mg/L)	*Hakusan-Meisui*	1.6	4.4	5.4	5.7
	Pure water	10	5.8	6.6	6.6
EC (μs/cm)	*Hakusan-Meisui*	193	194	199	194
	Pure water	4.0	5.7	2.6	2.6
ORP (mV)	*Hakusan-Meisui*	–164	62	105	108
	Pure water	62	150	144	160

EC, electrical conductivity; ORP, oxidation-reduction potential.

Table 5. Properties of matter change of medium quality green tea exudate of *Hakusan-Meisui* and pure water by heating

Item	Classification of medium quality green tea exudate	After heating for 1 min at 90˚C			
		Immediately after	After 1 day	After 2 days	After 5 days
pH	*Hakusan-Meisui*	6.7 (20˚C)	6.7 (22˚C)	6.6 (21˚C)	6.3 (20˚C)
	Pure water	5.7 (20˚C)	5.7 (22˚C)	5.7 (21˚C)	6.1 (21˚C)
Color (degree)	*Hakusan-Meisui*	1200	1500	1400	1600
	Pure water	770	820	760	860
Turbidity (degree)	*Hakusan-Meisui*	48	87	86	91
	Pure water	47	40	35	84
ORP (mV)	*Hakusan-Meisui*	38	47	54	85
	Pure water	75	71	96	70
Presence of sediment	*Hakusan-Meisui*	None	None	None	None
	Pure water	None	None	None	None
General bacteria (cfu/mL)	*Hakusan-Meisui*	0	0	0	0
	Pure water	2	1	1	1

ORP, oxidation-reduction potential.

When compared with purified water, the amount of vitamin C of the *Hakusan-Meisui* decoction made with both cold and hot water was low, registering at 0.83 (for cold water) and 0.64 (for hot water) (Table 3). The proportion of vitamin C content in the hot water decoction compared to the cold water decoction was 0.35 for *Hakusan-Meisui*, and 0.46 for purified water.

Physical properties of Hakusan-Meisui and pure water after heat-treatment

The values of pH and EC of *Hakusan-Meisui* after heating showed almost no change. However, the values of dissolved oxygen and ORP rose (Table 4). On the other hand, pure water did not show any change after heating for pH, while the values of dissolved oxygen and EC fell, and the value of ORP rose.

Changes over time of decoctions using Hakusan-Meisui and purified water

There were virtually no changes over time in bacteria, pH or precipitate in the green tea decoctions made with either *Hakusan-Meisui* or purified water. However, for green tea made with *Hakusan-Meisui*, the color, turbidity and ORP showed an uptrend (Table 5). Furthermore, when the decoction was shaken to frothing for a few seconds,

Table 6. Sensory evaluation of taste by state of preservation of exudate

Item	Classification of medium quality green tea exudate	Dis-penser	After heating for 1 min at 90˚C			
			Immediately after	After 1 day	After 2 days	After 5 days
Taste	*Hakusan-Meisui*	1	Taste is thick, but mellow	Taste of normal tea	Taste of normal tea	Smell of tea
		2	Mellow taste	Taste weaker than the day before	Taste weaker than at first	Smell of roasted tea
		3	Mellow taste	Taste weaker than the day before	Taste weaker than at first	Normal smell of tea
		4	Thick taste	Thick taste	Thick taste	Normal smell of tea
		5	Thick taste	Thick taste	Thick taste	Smell of roasted tea
	Pure water	1	Strong bitter taste	Slightly bitter taste	Slightly bitter taste	Bad smell
		2	Strong bitter taste	Bitter taste	Bitter taste	Smell of putrescence
		3	Bitter taste	Bitter taste	Bitter taste	Depressing smell
		4	Bitter taste	Taste weaker than *Hakusan-Meisui*	Taste weaker than *Hakusan-Meisui*	Depressing smell
		5	Bitter taste	Taste weaker than *Hakusan-Meisui*	Taste weaker than *Hakusan-Meisui*	Depressing smell

then left sitting, the bubbles in purified water disappeared after a few seconds. In contrast, for *Hakusan-Meisui*, there was a larger amount of the effervescence and this took a longer time to disappear.

As for the taste of the decoction and sensory evaluation concerning odor, the taste of *Hakusan-Meisui* weakened as time passed from an initial evaluation of "mellow though thick", changing to an ordinary smell after 5 days (Table 6). In contrast, pure water had a more astringent taste than at the beginning. As time passed, the taste and astringency gradually weakened, then changed to a "rotten odor" after 5 days.

Discussion

In this study, a higher degree of nutritional content and inorganic qualities were found in green tea exudate extracted using *Hakusan-Meisui* mineral water when compared with pure water. The only element which was found to be lower than pure water was vitamin C. Moreover, the color and turbidity of the heated *Hakusan-Meisui* exudate were higher than those for pure water, while the color was stronger, as well. In terms of sensory evaluation, as time passed, the pure water began tasting bitter and gave off a putrid odor. In contrast, *Hakusan-Meisui* was evaluated with a "mellow but thick" taste over 5 days.

When the mineral water was used and extracted, it was found that the dissolving ability was strong, and that there were differences in the color and density of the taste (Fujita, 2004). Moreover, it was determined that mineral water has an extraction power which draws out the taste of the ingredient, and that the extracted material contains a large number of glutamic acids that seem to be *umami* elements (Murata, 2004). It was found that the results obtained in the present study concerning sensory evaluation and amount of nutritional content confirmed previous reports. In the article on "tea" in Heibonsha's "Great World Encyclopedia" (Kawashima, 1981), it states that "While it is safe to make tea with soft water, using hard water can slightly improve the taste". In analyzing the taste of tea, it is said that there is a strong relationship between amino acid (as the taste ingredient) and catechins (as the bitterness element). The taste of the green tea decoction extracted from *Hakusan-Meisui* was thick

and mellow. It was found that, as a mineral water, *Hakusan-Meisui* has excellent dissolution and extraction powers which draw out the taste of the ingredients.

In this study, changes over time in EC and ORP were measured for the physical properties of water. As for the water, the greater the number of electrolytes, the less the electrical resistance there was. Conversely, the fewer the electrolytes, the greater the resistance there was. As a result, EC is widely used as an index to determine the electrolytic concentration of water. *Hakusan-Meisui* showed a higher degree of EC than purified water, which implies a greater quantity of electrolytes. Moreover, the hardness of *Hakusan-Meisui* is 25.8 mg/L, which is known to be high compared with the hardness (13.0 mg/L) of city water (Houri and Yoshioka, 2004). It is also said that the bitterness of tea is related to the amount of tannin it contains. In the present study, although the amount of tannin was not measured, it was supposed that *Hakusan-Meisui* suppressed the leaching of tannin related to bitterness because its EC was higher and its hardness greater than purified water, thus giving it a mellow taste, and extracting a large amount of *umami* elements.

In general, the moisture content of fresh tea leaves is 20% to 25% and the solid contents 75% to 80%. About 40% of the solid content is water soluble, and this contains catechin, amino-acid, caffeine, saccharide, saponins, minerals, Vitamin C, etc. When shaken to a froth for a few seconds, then left sitting, a large amount of effervescence was produced by *Hakusan-Meisui* and this did not disappear easily. In contrast, for the decoction using purified water, the bubbles disappeared in just a few seconds. Thus, it seems that the *Hakusan-Meisui* decoction contains a large amount of saponins. In terms of nutritional content, when compared with purified water, a larger number of elements with nutritional content and inorganics were extracted from the *Hakusan-Meisui* decoction, except for vitamin C. Moreover, the amount of vitamin C in the green tea decoctions using both cold and hot water was also low. The green tea exudate for *Hakusan-Meisui* was 6.7 while its pH registered 8.3 with slight alkalinity. In contrast, the exudate for pure water was 5.7 while its pH was acidic at 6.1. Because vitamin C shows an unstable degree of alkalinity, it was judged, based on pH differences, that there was a difference in the amount of vitamin C in *Hakusan-Meisui* and pure water.

At present, tea beverages in plastic bottles can easily be bought and consumed from retail stores. As a result, the preservation of tea exudates is very important. In the present study, the preservative effect of green tea decoctions extracted from *Hakusan-Meisui* and purified water were examined. As for the properties of heated green tea exudate, no changes over time were seen in either *Hakusan-Meisui* or pure water for pH, number of bacteria or precipitation, although color, turbidity and ORP showed an uptrend. It is thought that this originated from the effects of atmospheric oxygen and carbon dioxide in the air at the time of cooling. Moreover, in the green tea exudate of pure water, bacteria were detected and putrescence advanced to the stage where a rotten odor appeared after 5 days. It was thought that the foul smell was caused by organisms in the purified water decoction, in particular proteins which were decomposed by bacteria. In contrast, with *Hakusan-Meisui*, no putrid odors were produced even after 5 days of storage. It was judged, therefore, that *Hakusan-Meisui* has a greater preservative effect than purified water.

The present results indicate that when green tea is made using *Hakusan-Meisui*, the colors are stronger than when made with pure water, and the smell and taste are of a higher quality, as is generally said to be the case with mineral water. However, it cannot be said that the unique qualities of *Hakusan-Meisui* have been fully clarified. One reason is that no analysis has yet been made of the large amounts of catechins and polyphenols contained in green tea made with *Hakusan-Meisui*. It is also necessary to carry out comparisons with other mineral waters.

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