Effects of Growing Altitude, Tea amount and Brewing Time on Multisensory Rating of Oolong Tea

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ABSTRACT— ***The present study proposed a systematic approach to investigate the factors that might affect the multisensory rating (MSR) of oolong tea based on participants' point of view. There were three independent factors investigated: growing altitude, tea amount and brewing time. The results showed the three main factors all significantly affect the MSR. A high growing altitude of 1000m results in better MSR than a low growing altitude of 300m. In terms of tea amount, 2.0g and 2.25g results in better MSR than 1.75g and 2.5g. Brewing times of 60s and 75s resulted in better MSR than 45s. In summary, a growing altitude of 1000m, tea amounts of 2.0g and 2.25g, and brewing time of 60s were the best brewing combinations for experienced consumers when using a 120ml porcelain teapot and a water temperature of 95℃. Further, the results also imply there might be an optimal range of tea amount and brewing time for oolong tea.***

Keywords— Growing altitude, Tea amount, Brewing time, Multisensory rating.

1. INTRODUCTION

Oolong tea is commercially available worldwide and has been studied for its effect on antioxidant properties (Benzie and Szeto, 1999), the cardiovascular system (Yang and Koo, 1997; Bøhn *et al*., 2012), obesity (Han *et al*., 1999), metabolic rate (Rumpler *et al*., 2001), fat oxidation (Rumpler *et al*., 2001), and bioefficacy (da Silva Pinto, 2013). Oolong tea contains several beneficial trace elements such as magnesium, calcium, potassium, and phosphorus (Schwalfenberg *et al*., 2013) which are beneficial to human health. Taheri and Sariri (2011) discussed with reference to laboratory studies various types of tea and certain health disorders, including some types of cancer, coronary heart disease, atherosclerosis, metabolic syndrome, diabetes, resistance to insulin hypertension, and obesity. Hayat *et al*. (2015) also indicated tea possesses significant functions: anti-oxidative, anti-inflammatory, cholesterol-lowering, anti-microbial, anti-carcinogenic, anti-hypertensive, neuroprotective, and thermogenic properties. Therefore, many people in Taiwan drink tea for health.

For the growing altitude of oolong tea leaves, most consumers believe a higher growing altitude results in higher quality. Therefore, the higher growing altitude of tea leaves results in a higher price in Taiwan. However, Chakraborty *et al*. (2015) indicated the contents of total polyphenolics as well as bioactive components like tannins and flavonoids with growing altitude were non-significant. Therefore, the effect of growing altitude on oolong tea leaves in terms of multisensory rating (MSR) requires further investigation.

Tea amount is usually positively related to the concentration of tea infusion when the other factors are the same, and the concentration of tea infusion usually depends on customers' preferences. Hypothetically, there might be an optimal range of concentration of tea infusion for customers.

Brewing time is also one of the important factors that might affect the MSR of tea infusion. In practice, different tea leaves have different brewing times, which might be related to the extent of fermentation of the teas. Further, a shorter brewing time usually results in lighter concentration and color of the tea infusion under the same tea amount. Conversely, a longer brewing time usually results in stronger concentration of the tea infusion. However, these results might not necessarily hold for the 4th or 5th infusion in practical experience. So far, there are no studies on the teas' brewing time on MSR of oolong tea. Therefore, there is a need to investigate brewing time on the MSR of oolong tea.

For tea leaves quality assessment, many studies reported the quantification analyses could be used for the assessment

of tea (Wang *et al*., 2011; Yashin *et al*., 2015). Despite the quantification analysis results of tea leaves, customers usually rely on their MSR (visual, nose and taste) in selecting tea leaves for purchase. Moreover, tea quality competitions are usually assessed by the MSR of juries to determine the winner. Palit *et al*. (2010) also indicated the quality assessment of tea is a difficult task because of the presence of innumerable compounds and their diverse contribution to tea quality. As a result, instrumental evaluation of tea quality is not practiced in the industry, and tea samples are assessed by experienced tea tasters.

Until now, research on the effect of growing altitude, tea amount and brewing time on the MSR of oolong tea has been lacking. Therefore, there is a need to examine the growing altitude, tea amount, and brewing time based on participants' point of view.

2. METHODS

2.1 Fixed Factors

There are many factors that might affect the taste of tea infusion. These include the material of the teapot and cup (stone, pottery, porcelain, and metal), water temperature (which might be related to the extent of fermentation), types of water (reverse osmosis, mineral, spring, running, and well water), and so on. Therefore, the material of the teapot and cup, water temperature, and types of water used in the present study were fixed. The material of the teapot and cup was porcelain. The teapot capacity was about 120 milliliters (ml) and the cup capacity was about 20ml (Figure 1). The water temperature was 95°C (Lin and Chen, 2015). Reverse osmosis water was used, which was purchased from the supermarket and boiled on an electromagnetic stove in a stainless kettle.

Figure 1: The Teapot and Cup used in the Present Study

2.2 Experimental Design

This study evaluated three independent factors: growing altitude, tea amount, and brewing time. The experiment used two levels for the growing altitude of tea: 1000m (Alishan tea) and 300m (Tungting tea). Tea leaves of the Alishan tea bush (Figure 2a) were harvested from Alishan mountain at altitudes of 1000 meters above the mean sea level. Tea leaves of the Tungting tea bush (Figure 2b) were harvested from Nantou mountain at altitudes of 300 meters above the mean sea level. The price of the two tea leaves used was about $55 per 600 grams (middle quality level in Taiwan).

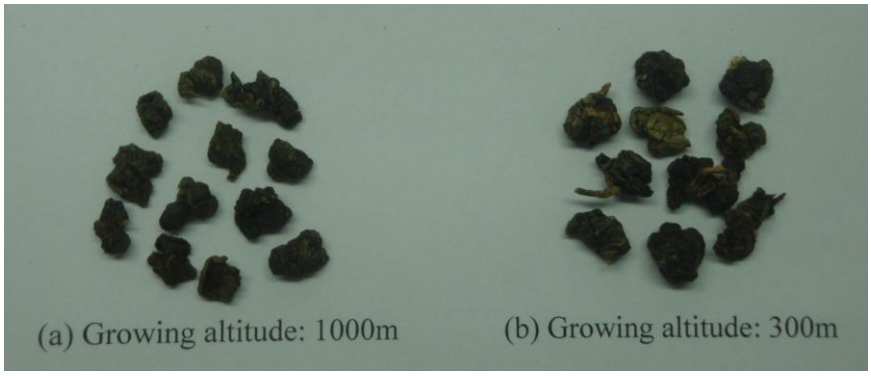

Figure 2: The Tea Leaves used in the Present Study

Four levels of tea amount were used: 1.75 gram (g), 2.0g, 2.25g (Lin and Chen, 2015) and 2.5g. Three levels of brewing time were used: 45 seconds (s) (the shortest time according to participants' experience), 60s (Lin and Chen, 2015; Lee *et al*., 2008), and 75s (the longest time according to participants' experience).

All of the participants completed 24 within-subject experimental treatment combinations (2 growing altitude × 4 tea amount × 3 brewing time).

2.3 Participants

Four male from Yungkang community development association were enrolled as participants (age range = 60~73 years old). The four participants all had at least 20 years of experience in drinking oolong tea.

2.4 Apparatus

The amount of tea was measured using DH 300 micro scales purchased from Xinike Co. (Taiwan). The measuring range and accuracy were 0~300g and ±0.005g, respectively. The water temperature was measured using a Testo 103 thermometer purchased from Testo Co. (Taiwan). The measuring range and accuracy were -30~220°C and ±0.5°C, respectively.

2.5 Experiment Procedure

Before the experiment, the sequence of experimental treatment combination was determined by ballot. The subjects did not know which experimental treatment combinations they were drinking. The tea was infused five times for each experimental treatment combination. The brewing time of the first infusion was about 30s to clean (remove pesticide residues) and warm up the tea leaves. The participants drank the 2nd to 5th infusion and multisensory rating the 2nd and the 5th infusion (Table 1).

Table 1: MSR under each level of the independent factors

***Independent* Factors**			**MSR**		
Growing altitude	Tea amount	Brewing time	2nd Infusion	5th Infusion	Ave
300	1.75	45	7.00	3.75	5.375
300	1.75	60	7.25	4.25	5.750
300	1.75	75	7.25	4.25	5.750
300	2.00	45	7.25	4.25	5.750
300	2.00	60	8.00	5.00	6.500
300	2.00	75	7.75	5.00	6.375
300	2.25	45	7.25	4.50	5.875
300	2.25	60	8.00	5.50	6.750
300	2.25	75	7.75	5.00	6.375
300	2.50	45	7.00	4.50	5.750
300	2.50	60	7.75	5.25	6.500
300	2.50	75	7.25	5.00	6.125
1000	1.75	45	7.00	3.75	5.375
1000	1.75	60	7.25	4.25	5.750
1000	1.75	75	8.00	5.50	6.750
1000	2.00	45	7.25	4.25	5.750
1000	2.00	60	8.00	5.25	6.625
1000	2.00	75	8.00	5.75	6.875
1000	2.25	45	7.25	4.50	5.875
1000	2.25	60	8.50	6.00	7.250
1000	2.25	75	7.75	5.25	6.500
1000	2.50	45	7.00	4.75	5.875
1000	2.50	60	7.75	5.50	6.625
1000	2.50	75	7.50	5.00	6.250

2.6 Dependent Measures and Data Analysis

Participants were asked to give an overall multisensory (visual: appearance color of tea infusion; nose: scent, aroma or odor of tea infusion; taste: astringency, bitterness, concentration and sweet aftertaste of tea infusion) rating the tea infusions on a 10-point scale, with 0 representing "very poor" and 10 representing "excellent".

Analysis of variance (ANOVA) was conducted using a Statistical Analysis System (SAS 9.0), and calculation of the effect size (η^2) was conducted using Statistical Products & Service Solutions (SPSS 13.0). Participant was treated as a blocking effect (Montgomery, 1991) in the analysis.

3. RESULTS

Table 1 shows the MSR under each level of the independent factors. The mean, standard deviation (SD), and Duncan

grouping of the MSR for each level of independent factors are shown in Table 2. The results of the ANOVA (Table 3) show growing altitude, tea amount, and brewing time all significantly (p<0.01) affect the 5th and the average (Ave) MSR. However, the MSR difference between growing altitude 1000m and 300m of the 2nd infusion did not reach a statistically significant level ($F_{1,69}$=3.66, p=0.0600). Duncan multiple paired-comparisons (Table 2) shows a growing altitude of 1000m results in better 2nd and Ave MSR than 300m. In terms of tea amount, 2.25g and 2.00g result in better MSR than 2.50g and 1.75g. Brewing times of 60s and 75s result in better MSR than 45s.

Table 2: Mean, SD, and Duncan grouping of the MSR for each level of independent factors

	***Independent* Factors**	**n**	***Mean***	***SD***	***Duncan* Grouping**
2nd infusion	Growing altitude (GA)				
	1000m	48	7.604	0.610	A
	300m	48	7.458	0.544	A
	Tea amount (TA)				
	2.25g	24	7.750	0.608	A
	2.00g	24	7.708	0.464	A
	2.50g	24	7.375	0.495	B
	1.75g	24	7.292	0.624	B
	Brewing time (BT)				
	60s	32	7.813	0.535	A
	75s	32	7.656	0.483	A
	45s	32	7.125	0.492	B
5th infusion	Growing altitude (GA)				
	1000m	48	4.979	0.812	A
	300m	48	4.688	0.776	B
	Tea amount (TA)				
	2.25g	24	5.125	0.741	A
	2.50g	24	5.000	0.590	A
	2.00g	24	4.917	0.776	A
	1.75g	24	4.292	0.859	B
	Brewing time (BT)				
	60s	32	5.125	0.793	A
	75s	32	5.094	0.641	A
	45s	32	4.281	0.683	B
Ave	Growing altitude (GA)				
	1000m	48	6.292	0.659	A
	300m	48	6.073	0.583	B
	Tea amount (TA)				
	2.25g	24	6.438	0.613	A
	2.00g	24	6.313	0.567	AB
	2.50g	24	6.188	0.412	B
	1.75g	24	5.792	0.721	C
	Brewing time (BT)				
	60s	32	6.469	0.581	A
	75s	32	6.375	0.475	A
	45s	32	5.703	0.537	B

Further, the effect size (Table 3) showed brewing time had the most effect on the 2nd, 5th and Ave MSR, followed by tea amount and growing altitude. The model F-value of 2nd, 5th and Ave MSR were 6.13 (p<0.0001), 11.81 (p<0.0001), and 13.42 (p<0.0001), respectively, implies the models are significant (Box and Draper, 1986; Khuri and Cornell, 1987).

Only the interaction effect of tea amount and brewing time reached a statistically significant level (Table 3) at 5th and Ave MSR. For example, experimental treatment combination with 2.25g and 60s resulted in the best Ave MSR (7.000), and 1.75g and 45s resulted in the worst Ave MSR (5.375).

Generally, the Ave MSR in the present study was lower than Lin and Chen (2015), which might be due to the lower price of the tea leaves. Does a higher price really imply higher quality and higher-graded tea leaves? This result is worth further investigating.

Table 3: ANOVA and effect size measures of the MSR for each level of independent factors

	Source	***DF***	***SS***	*MS*	*F-value*	*Pr>F*	*Effect* size[a]
2nd	Participant	3	6.115	2.038	14.60	<.0001	
	GA	1	0.510	0.510	3.66	0.0600	0.016
	TA	3	3.865	1.288	9.22	<.0001	0.121
	GA×TA	3	0.115	0.038	0.27	0.8443	0.004
	BT	2	8.313	4.156	29.76	<.0001	0.261
	GA×BT	2	0.396	0.197	1.42	0.2493	0.012
	TA×BT	6	2.104	0.351	2.51	0.0295	0.066
	GA×TA×BT	6	0.854	0.142	1.02	0.4201	0.027
	Error	69	9.635	0.140			
	Total	95	31.906				
5th	Participant	3	15.750	5.250	32.20	<.0001	
	GA	1	2.042	2.042	12.52	0.0007	0.033
	TA	3	9.917	3.301	20.27	<.0001	0.162
	GA×TA	3	0.208	0.069	0.43	0.7350	0.003
	BT	2	14.646	7.323	44.91	<.0001	0.239
	GA×BT	2	1.021	0.510	3.13	0.0500	0.017
	TA×BT	6	4.521	0.753	4.62	0.0005	0.074
	GA×TA×BT	6	1.980	0.330	2.02	0.0741	0.032
	Error	69	11.250	0.163			
	Total	95	61.333				
Ave	Participant	3	8.362	2.787	31.02	<.0001	
	GA	1	1.148	1.148	12.78	0.0006	0.031
	TA	3	5.633	1.878	20.89	<.0001	0.150
	GA×TA	3	0.133	0.044	0.49	0.6885	0.004
	BT	2	11.161	5.581	62.10	<.0001	0.297
	GA×BT	2	0.672	0.336	3.74	0.0287	0.018
	TA×BT	6	3.047	0.508	5.65	<.0001	0.081
	GA×TA×BT	6	1.203	0.201	2.23	0.0502	0.032
	Error	69	6.201				
	Total	95	37.560				

[a] Effect size, Eta square (η^2) = SS $_{effect}$ / SS $_{total}$ (Kirk, 1982; Tabachnick and Fidell, 1989)

4. DISCUSSION

4.1 Growing Altitude

Despite the insignificant difference in MSR of growing altitude at the 2nd infusion. The Ave MSR of Alishan tea was significantly greater than the Tungting tea ($F_{1,69}$=12.78, p=0.0006) and the 5th MSR of Alishan tea was also significantly greater than the Tungting tea ($F_{1,69}$=12.52, p=0.0007).

Two reasons may be offered to explain these results. First, the mean atmospheric temperature was lower at high altitude. Low mean atmospheric temperature might slow the growth speed of tea leaves. Figure 3 showed the volume of Alishan tea was slightly less than the Tungting tea. This result may indicate there are more tea leaves at high altitude than low altitude under the same weight. More tea leaves might result in more scent at the 5th infusion and lead to a higher MSR. Second, the duration of sunshine is greater at high altitude than low altitude. Longer duration of sunshine might increase the photosynthesis of tea leaves. This might also increase the scent of Alishan tea at the 5th infusion and result in higher MSR.

4.2 Tea Amount

The ANOVA results show tea amount significantly affects MSR. MSR at 2.25g and 2.00g is better than at other tea amounts. This result is similar to Drobna *et al*. (2004) that the best reference standard for the astringency of black tea is a solution of 0.7 g/L alum as it is low in perceived bitterness and sourness. This result indicated the infusion of oolong tea used in the experiment might be an optimal tea amount (concentration) for people. People may dislike drinking oolong tea with concentrations too light or too strong. In other words, an overdose of tea amount might make the concentration of tea infusion too strong. An insufficient tea amount might make the concentration of tea infusion too light, especially at the 5th infusion.

The variation in participants also significantly affects MSR (Table 3). This result implies different participants might prefer different concentrations of tea infusion. Additionally, the MSR of 2.5g of tea is greater than 1.75g of tea (Table 2).

This might be due to the greater tea amount resulting in more scent than the less tea amount at the 5th infusion.

4.3 Brewing Time

The results show brewing time had the most significant effect on MSR (Table 3). MSR at brewing times of 60s and 75s are better than 45s (Table 2). Further, though the difference in MSR between brewing time of 60s and 75s did not reach a statistically significant level (0.01), the MSR at 60s was slightly greater than at 75s. This result is consistent with Lin and Chen (2015) and similar to that obtained by Lee *et al.* (2008), the optimum infusing time is 1 min for green tea. This result indicated there might be an optimal brewing time for oolong tea. In other words, the long brewing time (75s) might make the concentration too strong; and the short brewing time (45s) might make the concentration too light.

4.4 Interaction Effect of Tea Amount and Brewing Time

Figure 3 shows the interaction effect of tea amount and brewing time on Ave MSR. The experimental treatment combination with 2.25g and 60s resulted in the best Ave MSR and the 1.75g and 45s combination resulted in the worst Ave MSR.

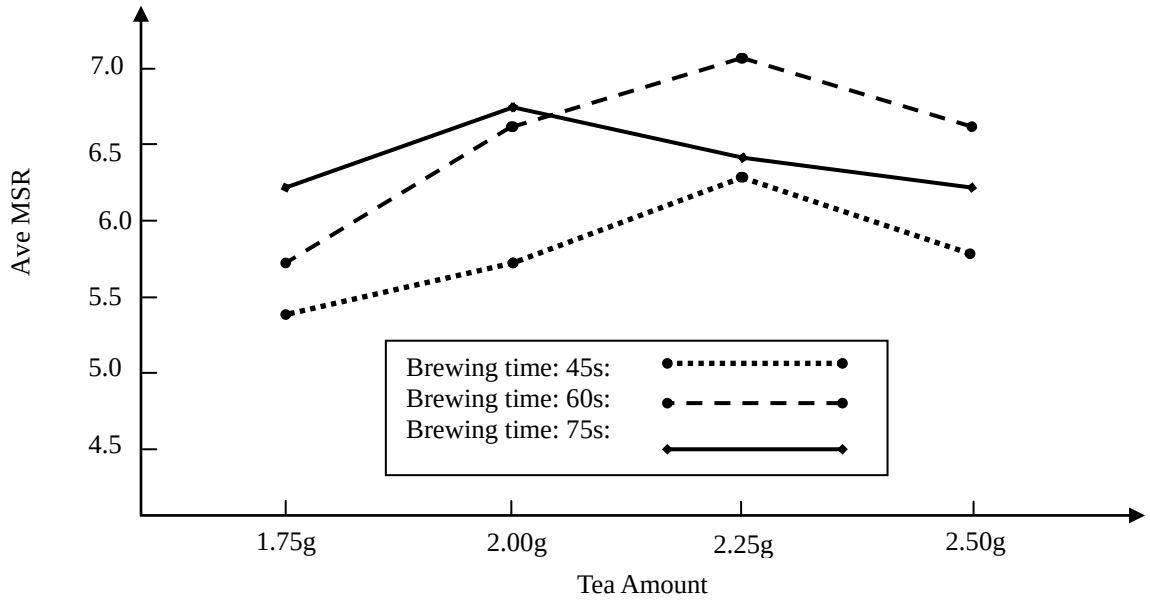

Figure 3: Interaction Effect of Tea Amount and Brewing Time on Ave MSR

Two explanations are offered for this result. First, a short brewing time (45s) and a lower amount of tea leaves might make the concentration too light, especially for the lower tea amount (1.75g) and after the 5th infusion (Table 1). Second, a long brewing time (75s) and greater tea amount of tea leaves might make the concentration too strong, resulting in lower MSR. This may explain why the 1.75g and 2.0g resulted in higher MSR than 2.25g and 2.50g at the 2nd infusion, and the 2.25g and brewing time 60s resulted in the highest Ave MSR.

In summary, tea amounts of 2.00g and 2.25g, and a brewing time of 60s were the better brewing combinations of oolong tea for experienced consumers when using a 120ml porcelain teapot and water temperature of 95°C. Further, the results also imply there might be an optimal range of tea amount and brewing time for oolong tea based on experienced consumers' point of view.

5. REFERENCES

List and number all bibliographical references in 10-point Times New Roman, single-spaced, at the end of your paper. For example, [1] is for a journal paper, [2] is for a book and [3] is for a conference (symposium) paper.

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