

# Optimization of the Brewing Combination of Oolong Tea by Subjective Rating

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**Abstract** – The present study based on consumers' point of view to investigate the optimal brewing combination of oolong tea by subjective rating. There are three independent factors: tea amount, water temperature, and brewing time were investigated. Central composite design (CCD) was conducted to optimize the brewing combination of oolong tea. Results showed that tea amount 2.25g, water temperature 98°C, and brewing time 63s were the optimal brewing combination of oolong tea when used 120ml porcelain teapot.

**Keywords** – Tea Amount, Water Temperature, Brewing Time, Oolong Tea, Subjective Rating.

## I. INTRODUCTION

Oolong tea, which is commercially available in the world, has also been studied for the effect on antioxidant properties [1], cardiovascular [2], obesity [3], metabolic rate [4], fat oxidation [4], and bioefficacy [5]. Rumlper et al. [4] also reported that oolong tea can increase about 2.9% energy expenditure than water. Oolong tea is a semi-fermented tea that is allowed to oxidize only partially to lock-in the rich flavor that is associated with high quality [6].

Although, Yashin et al. [7] indicted that the quantification analyses should be used for the quality assessment of tea. However, the tea quality competition usually conducted subjective rating of juries to determine the championship. Palit et al. [8] also indicated that 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 market, and tea samples are assessed by experienced tea tasters. Therefore, Lin & Chen [9] employed factorial design and subjective rating to evaluate the oolong tea brewing factors, and reported that the tea amount 2.0g, water temperature 95°C, and brewing time 60s might be the optimal brewing combination of oolong tea.

The researches about the quality assessment on subjective rating of oolong tea are lack. Therefore, the present study based on consumers' point of view to optimize the brewing combination of oolong tea by subjective rating.

## II. RESEARCH METHOD

### A. Material

Tea leaves of the Alishan tea bush were harvested from the Alishan mountain (longitude 120°695' E and latitudes 23°505' N) at the altitudes of 1000 meters above the mean

sea level. The price of the tea used was about \$80 per 600 grams (middle quality level in Taiwan). The water is reverse osmosis water which purchased from supermarket and boiled by electromagnetic stove in a stainless kettle.

### B. Experimental Design

Central composite design (CCD) was used, which is generally the best design for response surface optimization [10]. A five-level-three-factor design was selected. The three variables selected were tea amount, water temperature, and brewing time, and their respective levels were as follows: tea amount (1.2-2.8g), water temperature (86.6-100°C), and brewing time (34.8-85.2s). Table 1 shows the coded and uncoded levels of independent variables. The 20 experimental treatment combinations which produce by CCD and the subjective rating are shown in Table 2.

### C. Participants

Four male from Yung Kang 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 tea.

### D. Apparatus

The amount of tea was measured using DH 300 micro scales purchased from Xinike Co. (Taiwan). The measuring range and accuracy are 0~300g and  $\pm 0.005$ g, respectively. The water temperature was measured using a Testo 103 thermometer purchased from Testo Co. (Taiwan). The measuring range and accuracy are -30~220°C and  $\pm 0.5$ °C, respectively. The material of teapot and cup is porcelain. The teapot capacity was about 120 milliliter (ml) and the cup capacity was about 20ml.

### E. Experiment Procedure

The sequence of experimental treatment combination was determined by software (Table 2). The subjects did not know the tea infusions which they drink from what brewing combination. The tea was infused five times for each brewing combination. The brewing time of the first infuse was about 30s to clean (removal pesticide residues) and warm up the tea leaves. The participants drink the second to fifth infusion and subjective rating the second and the fifth infusion.

### F. Dependent Measure and Analysis

The dependent measure was the average subjective rating (Table 2) of the second and the fifth infusion. Participants were asked to overall subjective evaluate the color, concentration, taste, and scent of tea infusions on a 10-point scale, with 0 representing "very poor" and 10 representing "excellent". Analysis was conducted using Deign-Expert 8.0 purchased from SoftHome International Inc. (Taiwan).

**Table 1. Coded and uncoded levels of independent variables for CCD.**

Independent variable		Codes factor levels				
		$-\alpha$	-1	0	+1	$+\alpha$
Tea amount (g)	TA	1.2 <sup>a</sup>	1.5	2.0	2.5	2.8 <sup>a</sup>
Water temperature (°C)	WT	86.6 <sub>a</sub>	90	95	100	100 <sup>b</sup>
Brewing time (s)	BT	34.8 <sub>a</sub>	45	60	75	85.2 <sup>a</sup>

<sup>a</sup> Rounded to one decimal point; <sup>b</sup> The water temperature can't greater than 100°C in normal environment.

**Table 2. Experimental data for five-level-three-factor response surface analysis**

Std	Run	Tea amount	Water temperature	Brewing time	Average subjective rating
12	1	0 (2.0)	$+\alpha$ (100)	0 (60)	7.5
19	2	0 (2.0)	0 (95)	0 (60)	8
14	3	0 (2.0)	0 (95)	$+\alpha$ (85.2)	6
18	4	0 (2.0)	0 (95)	0 (60)	8
13	5	0 (2.0)	0 (95)	$-\alpha$ (34.8)	4.375
20	6	0 (2.0)	0 (95)	0 (60)	8
15	7	0 (2.0)	0 (95)	0 (60)	8.125
5	8	-1 (1.5)	-1 (90)	+1 (75)	7.25
2	9	+1 (2.5)	-1 (90)	-1 (45)	6.125
6	10	+1 (2.5)	-1 (90)	+1 (75)	6.875
1	11	-1 (1.5)	-1 (90)	-1 (45)	5.375
17	12	0 (2.0)	0 (95)	0 (60)	8.125
16	13	0 (2.0)	0 (95)	0 (60)	8
3	14	-1 (1.5)	+1 (100)	-1 (45)	6.375
4	15	+1 (2.5)	+1 (100)	-1 (45)	6.625
9	16	$-\alpha$ (1.2)	0 (95)	0 (60)	4.5
8	17	+1 (2.5)	+1 (100)	+1 (75)	6.375
10	18	$+\alpha$ (2.8)	0 (95)	0 (60)	7.875
11	19	0 (2.0)	$-\alpha$ (86.6)	0 (60)	4.375
7	20	-1 (1.5)	+1 (100)	+1 (75)	6.375

### III. RESULTS

All 20 of the designed experiment combinations were conducted, which included eight factorial points, six axial points, and six central points to provide information regarding the interior of the experiment region, allowing for the evaluation of the curvature [10,11]. The experimental results are summarized in Table 2. The average subjective rating ranged from 4.375 to 8.125, depending on the experimental conditions. Figure 1 and 2 showed the predicted average subjective rating of contour and isoresponse surface plot, respectively.

#### A. Development of Regression Model Equation

The model F-value of 4.28 implies that the model is significant. The *p*-value is 0.042, i.e., there is less than 4.2% chance that this error is caused by noise, implying a very high significance of the regression model [10]. The goodness-of-fit of the model is verified by the determination coefficient ( $R^2$ ). In this case, the value of adjusted determination coefficient ( $Adj R^2 = 0.69$ ) is also relatively high for subjective evaluation [11].

The application of response surface method [12] yields the following regression equation, which is an empirical

relationship between the average subjective rating of oolong tea and the test variables in the coded unit:

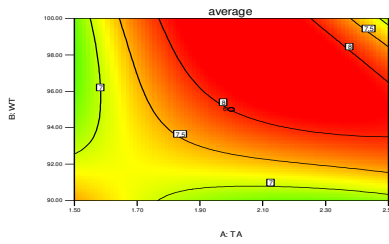
$$\begin{aligned}
 Predict = & 8.01 + 0.71A + 0.93B + 0.48C + 0.009AB + \\
 & 0.17AC - 0.37BC - 0.63A^2 - 0.54B^2 - 0.81C^2 + \\
 & 0.12ABC - 0.92A^2B - 0.19A^2C - 0.62AB^2 \dots\dots\dots(1)
 \end{aligned}$$

The predicted optimum levels of tea amount, water temperature, and brewing time of the average subjective rating were obtained by applying the regression analysis to equation (1). The positive sign in front of the terms indicates synergistic effect, while the negative sign indicates antagonistic effect. Equation (1) shows that the average subjective rating has linear, quadratic and interaction effects on the three variables studied. The predicted theoretical subjective rating of 8.2 was obtained at tea amount of 2.25g, water temperature of 98°C, and brewing time of 63s.

#### B. Effects of Variables in Average Subjective Rating

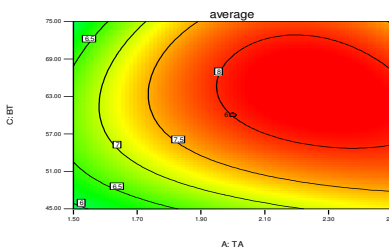
Among the three individual factors studied, water temperature ( $F=5.72$ ) has the largest effect on the average subjective rating (due to the highest F-value) followed by tea amount ( $F=4.26$ ), and brewing time ( $F=2.00$ ). The effects of the main and the interaction effects of these three factors have been discussed fully in Lin & Chen [9].

Design-Expert® Software  
Factor Coding: Actual  
Average  
● Design Points  
▲ Design points above predicted value  
8.125  
8.25  
8.375  
90 = A: TA  
90 = B: WT  
Actual Factor  
C: BT = 60.00



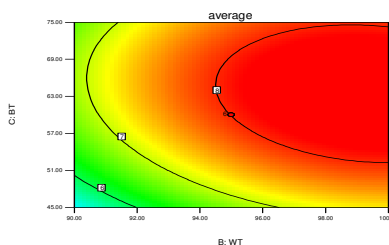
(a) Contour plot of TA\*WT

Design-Expert® Software  
Factor Coding: Actual  
Average  
● Design Points  
▲ Design points above predicted value  
8.125  
8.25  
8.375  
90 = A: TA  
90 = C: BT  
Actual Factor  
B: WT = 90.00



(b) Contour plot of TA\*BT

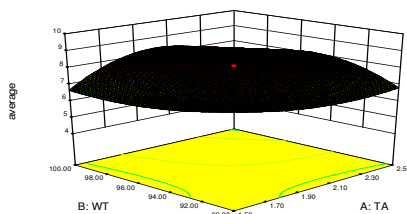
Design-Expert® Software  
Factor Coding: Actual  
Average  
● Design Points  
▲ Design points above predicted value  
8.125  
8.25  
8.375  
90 = B: WT  
90 = C: BT  
Actual Factor  
A: TA = 2.00



(c) Contour plot of WT\*BT

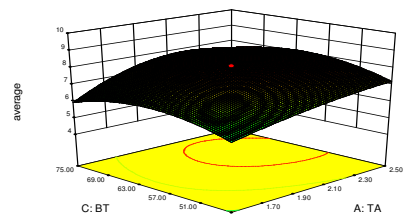
Fig.1. Contour plot of predicted average subjective rating

Design-Expert® Software  
Factor Coding: Actual  
Average  
● Design points above predicted value  
▲ Design points above predicted value  
8.125  
8.25  
8.375  
90 = A: TA  
90 = B: WT  
Actual Factor  
C: BT = 60.00



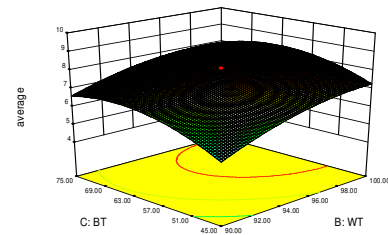
(a) Isoresponse surface plot of TA\*WT

Design-Expert® Software  
Factor Coding: Actual  
Average  
● Design points above predicted value  
▲ Design points above predicted value  
8.125  
8.25  
8.375  
90 = A: TA  
90 = C: BT  
Actual Factor  
B: WT = 90.00



(b) Isoresponse surface plot of TA\*BT

Design-Expert® Software  
Factor Coding: Actual  
Average  
● Design points above predicted value  
▲ Design points above predicted value  
8.125  
8.25  
8.375  
90 = B: WT  
90 = C: BT  
Actual Factor  
A: TA = 2.00



(c) Isoresponse surface plot of WT\*BT

Fig.2. Isoresponse surface plot of predicted average subjective rating

### C. Validation Experiment

The present study also performed validation experiment to confirm the optimum brewing combination: tea amount of 2.25g, water temperature of 98°C, and brewing time of 63s. Result of validation experiment shows that the average subjective rating was 8.25, which was slightly greater than that predicted by the model. Nevertheless, the model was validated by conducting experiments at optimal design conditions.

## IV. CONCLUSION

In the present study, CCD was employed to optimize the brewing combination of oolong tea by subjective rating. A mathematical model predicted that the theoretical average subjective rating of 8.2 can be obtained under the following optimum brewing combinations: tea amount of 2.25g, water temperature of 98°C, and brewing time of 63s. Validation experiment also confirmed the results.

## REFERENCES

- [1] Benzie, I. F. and Szeto, Y. T. (1999). Total antioxidant capacity of teas by the ferric reducing/antioxidant power assay. *Journal of Agricultural and Food Chemistry*, 47, 633-636.
- [2] Bohn, S. K., Ward, N. C., Hodgson, J. M. and Croft, K. D. (2012). Effects of tea and coffee on cardiovascular disease risk. *Food and function*, 3(6), 575-591.
- [3] Han, L. K., Takaku, T., Li, J., Kimura, Y. and Okuda, H. (1999). Anti-obesity action of oolong tea. *International Journal of Obesity and Related Metabolic Disorders*, 23, 98-105.
- [4] Rumpler, W., Seale, J., Clevidence, B., Judd, J., Wiley, E., Yamamoto, S., Komatsu, T., Sawaki, T., Ishikura, Y. and Hosoda, K. (2001). Oolong tea increases metabolic rate and fat oxidation in men. *The Journal of Nutrition*, 131(11), 2848-2852.
- [5] da Silva Pinto, M. (2013). Tea: a new perspective on health benefits. *Food Research International*, 53(2), 558-567
- [6] Chen, Y., Jiang, Y., Duan, J., Shi, J., Xue, S. and Kakuda, Y. (2010). Variation in catechin contents in relation to quality of 'Huang Zhi Xiang' oolong tea (*Camellia sinensis*) at various growing altitudes and seasons. *Food chemistry*, 119(2), 648-652.
- [7] Yashin, A. Y., Nemzer, B. V., Combet, E. and Yashin, Y. I. (2015). Determination of the chemical composition of tea by chromatographic methods: a review. *Journal of Food Research*, 4(3), 56-87
- [8] Palit, M., Tudu, B., Dutta, P. K., Dutta, A., Jana, A., Roy, J. K., Bhattacharyya, N., Bandyopadhyay, R. and Chatterjee, A. (2010). Classification of black tea taste and correlation with tea taster's mark using voltammetric electronic tongue. *Instrumentation and Measurement, IEEE Transactions on*, 59(8), 2230-2239.

- [9] Lin, C.-C. and Chen, Y.-C. (2015). Investigation of factors affecting subjective rating of oolong tea. *Mitteilungen Klosterneuburg*, 65(5), 103-113.
- [10] Box, G. E. P. and Draper, N. R. (1986). *Empirical Model-building and Response Surfaces*. New York: John Wiley & Sons.
- [11] Montgomery, D. C. (1991). *Design and Analysis of Experiments*. New York: John Wiley & Sons.
- [12] Khuri, A. I. and Cornell, J. A. (1996). *Response Surfaces*, 2nd Edition, New York: Dekker.

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