Optimization of Chemical properties, Sensory Descriptive and Consumer Acceptance of Jiaogulan tea Using Response Surface Methodology (RSM)

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ABSTRACT

Jiaogulan (Gynostemma pentaphyllum, GP) is a Chinese medicinal herb which can grow in Thailand. The objective of this study was to optimize the chemical component, the sensory quality and consumer acceptance of Jiaogulan tea. The sensory descriptive analysis was conducted to describe the sensory properties of Jiaogulan tea. The hedonic scaling method was used to measure the consumer acceptability of this product (n=50). The chemical properties- total saponin and antioxidant activity- were analyzed. The two- -factors rotatable design (pentagon design) with saponin content (0-500 mg) and water (50-250 ml) was employed to optimize the results by using the Response Surface Methodology (RSM). The result showed that Jiaogulan tea could be described in terms of 13 attributes by the sensory descriptive analysis. Consumers' acceptability test indicated that they liked this tea if the saponin content was not too high. The optimization result of the maximum chemical components overlaid with the acceptability score (> 6). Based on response surface plots, the optimum dried Jiaogulan contained 292mg of saponin in 100 ml of hot water. In conclusion, this study suggests that the formulation of Jiaogulan tea should be in the optimum concentration so that consumers will accept this tea.

Key words: Jiaogulan, *Gynostemma pentaphyllum*, sensory descriptive analysis, Response Surface Methodology (RSM), optimization

INTRODUCTION

Jiaogulan (*Gynostemma pentaphyllum*, GP) is a Chinese medicinal herb called "Amachazuru" in Japanese (Blumert and Liu, 2003) and "Panjakan" in Thai. *G. pentaphyllum* (family *Cucurbitaceae*) is a perennial liana. The stems of the plant grow like vines and the leaves have five oval-shaped, saw-toothed edges with white hairs. GP can be cultivated from seeds and plant cuttings and is harvested in 4-5 months after planting (Takemoto, 1984). *G. pentaphyllum* grows abundantly in Southern China, Japan and Korea. In Thailand, it can grow easily with good quality. Now, there are a lot of GP in the Northern region of Thailand, such as Chiang Mai, Chiang Rai and Mae Hong Son. The leaf and stem of the plant contain saponin glycosides and possess antioxidant activity. It has been reported that GP have identified the saponin glycosides as a series of dammarane-type saponin called gypenoside (Piacente and Pizza, 1995; Hu et al., 1997; Liu et al., 2004), closely related to the ginseng saponins (Cui et al., 1999). Pharmacological studies of GP and its isolated saponins indicate a variety of biological activities which include: anticancer, antioxidant, antitumor, cholesterol-lowering and immonopotientiating activities (Blumert and Liu, 2003). Compared to ginseng, GP is less expensive and readily available in Thailand. Therefore, GP has the potential as a raw material for nutraceutical and functional food applications.

Jiaogulan tea is available only at local markets in China, Japan and Korea. No research work has yet been published on the sensory properties of GP tea. Generally, the sensory properties of GP tea are bitter, astringent and unfamiliar in flavor, such that some consumers would not find this product acceptable.

Modern food industries have long been using sensory consumer tests, both in projects for the development of new product and in the optimization of formulation and processes (Galvez et al., 1990; Bastos et al., 1991; Chang et al., 1998; Frank, 2001; Luciane et al., 2001; Belgin et al., 2003; Rai et al., 2004; Lee et al., 2005; Sin et al., 2005). Response surface methodology (RSM) is used to model the responses of sensory attribute and chemical analysis to generate predictive equations which correlate the consumer response with the variables studied in food product design and the process (Schutz, 1983; Gacula, 1993; Hu, 1999). These predictive equations (models) can be used to optimize the formulation or the process and to estimate the expected consumer response to combination of factors not directly tested (Moskowitz, 1994). As a rule, the use of RSM in the process optimization stage leads to the need for an experimental design which can generate a lot of samples for consumer evaluation in a short period of time, and thus laboratory level tests are more efficient (Rudolph, 2000). Therefore, our research objective was to optimize the chemical component, the sensory quality and consumer acceptance of Jiaogulan tea using RSM.

MATERIALS AND METHODS

Raw Materials

The raw material of this research was the Jiaogulan plant from the Tongreng Station, Royal Project, Amphur Samerng, Chiang Mai. Jiaogulan was dried by vacuum microwave drier (March Cool Ltd., Thailand) using 2400 watt for 25 minutes. Dried Jiaogulan consisted of 6.94±0.13% moisture, 16.75±0.24% total ash, 11.63±0.52% insoluble ash, 5.11±0.30% soluble ash and 49.87±0.57% solid extraction yield by hot water. The dried Jiaogulan consisted of 95.93 mg/g of total saponin. The dried raw material was ground to a powder form by milling process and sieved into 0.30–0.85 mm. particle size. The tea powder was then packed into tea bags.

Experimental Design

This experiment was conducted to model the saponin dilution of Jiaogulan tea which could be accepted by the target consumer. The two-factor second-order rotatable design consisted of 6 design points called a pentagon design (Gacula and Singh, 1984). The independent variables were the saponin content in dried Jiaogulan, X1 (0-500 mg), as calculation from dried Jiaogulan containing 95.93 mg/g of total saponin, and the water, X2 (50-250 ml). The experimental design of the coded and actual levels of variable is shown in Table 1. The responses were measuring the tea infusion; chemical properties, sensory descriptive and consumer acceptance.

Table 1. The pentagon design with 6 design points of Jiaogulan tea treatments.

Treatment	Saponin content (X_1)			Water (X_2)	
	Coded X_1	Saponin	Dried Jiaogulan[1] (g)	Coded X_2	Water (ml)
1	1.0	500.0	5.21	0	150.0
2	0.309	327.3	3.41	0.951	245
3	-0.809	47.75	0.50	0.588	208.8
4	-0.809	47.75	0.50	-0.588	91.2
5	0.309	327.3	3.41	-0.951	54.9
6	0	250.0	2.61	0	150.0

[1]Saponin content was calculated from dried Jiaogulan containing 95.93 mg/g of total saponin.

Chemical Analysis

Total saponin analysis

The total saponin content was determined based on the methods of Ando et al., (1971); Hong et al., (1979); The Korean Ginseng & Tobacco Research Institute (1991) and Kwon et al., (2003). The tea solution was washed twice with 50 ml of diethyl ether to remove the fat content using a separatory funnel. The aqueous layer was extracted four times with 50 ml of water-saturated n-butanol. The butanolic extract was washed twice with 30 ml of distilled water to remove the impurities. The 100 ml of remaining butanolic solution was transferred to tarred round-bottom flask which was dried at 105°C to a constant weight (W1) For the evaporation, a rotary evaporator (BuchiRotavapor R-205, Switzerland) under vacuum at 55°C was used. The flask with the evaporated residue was dried at 105°C to a constant weight (W_2). Therefore, the difference in weight (W2–W1) corresponded to the total saponin content of the sample.

Total Antioxidant Activity

The total antioxidant activity (TAA) was tracked using the ABTS metmyoglobin method as a Trolox Equivalent Antioxidant Capacity (TEAC), modified from

George and Irvine (1952) by an extraction with ethanol with 200 rpm shaking at 25°C for 6 hours. The dispersions were filtered with Whatman No. 1 and evaporated by a vacuum rotary evaporator at 50°C, then lyophilized as a dried ethanolic extract. TAA was measured using the metmyoglobin/ABTS spectrophotometric assay, generating the chromogenic $ABTS^{\circ +}$ radical cation from the interaction between ABTS (2,2'azino-bis-(3-ethyl benzothiazoline-6-sulfonic acid) diammonium salt) and hydrogen peroxide. The mixed solution was metmyoglobin (76 μM, 70 μl), ABTS (5 μM, 500 μl), PBS (phosphate buffer saline, 5 mM, 980 μl), hydrogen peroxide (500 μM, 450 μl) and sample solution 20 μl, forming a bluish-green complex. The reaction rate was recorded on a time course program of UV-VIS spectrophotometer (UV-1601 Shimadzu, Japan) for 180 seconds at 414 nm. Trolox (Aldrich Chem., Co.) was used as an antioxidant standard, using the calibration curve plotted with different amounts of Trolox. The TEAC of pure compounds as antioxidant in comparison to Trolox was calculated as a percentage of inhibition as seen in Equation 1.

$$\% \text{ Inhibition} = \frac{\text{O.D. (Negative control)} - \text{O.D. (sample or standard)}}{\text{O.D. (Negative control)}} \times 100 \quad \text{(Equation 1)}$$

Sensory descriptive analysis

A hybrid descriptive analysis method (Einstein, 1991; Resureccion, 1998) that was modified from both Quantitative Descriptive Analysis (Tragon Corp., Redwood City, CA., U.S.A.) and the Spectrum™ Analysis methods (Sensory Spectrum, Inc., Chatham, NJ, U.S.A.) was used for the evaluation of Jiaogulan tea.

Selection of the panelist. (ASTM, 1981; Meilgaard et al., 1999) The panels of 12 people were selected from 30 candidates. They were screened by a pre-screen questionnaire and scaling exercises which required 80% correct answers as the criteria pass.

Matching and description test. A taste and aroma matching and description test were used for selecting the panelists. A description test was conducted on the candidate's sensory impression of the products in terms of their fragrance, flavor and odorant. Candidates should be able to describe 80% of the stimuli (Meilgaard et al., 1999) and should at least attempt to describe the remaining stimuli with less specific terms.

Detection: 12 Triangle discrimination tests, where each was replicated twice, were used for selecting subjects who achieved 66% correct replies, out of the total of 24 candidates (ASTM, 1981).

Training for descriptive testing

- *Terminology development.* Panelists individually examined the sample, generated descriptive terms and had a discussion (Cairncross and Sjostrom, 1997; Lawless and Heymann, 1998; Grosso and Resurreccion, 2002). The panels discussed the attributes and agreed upon common description of the samples. Redundant terms were subsequently grouped and named an appropriate term for reduction. The definitions of terms were proposed. The reference standards were decided through the consensus of the panelists. The Jiaogulan tea attributes and definitions are shown in Table 2, as well as, the reference standards used for descriptive analysis are shown in Table 3.

- *Introduction to the descriptive scale.* The graphic scale used to evaluate the intensity of each of the sensory attributes was an unstructured horizontal line of 15 cm.(6 inch) in length (Stone et al., 1980), usually anchored 1/2 inch from each end (1.25 cm.) by a pair of words which described or limited the attribute of the product (ASTM, 1992). Reference rating and the controlled Jiaogulan tea were also decided by the consensus of the panelists. Some references were obtained from literatures. Reference standards played an important role in the sensory analysis (Wolfe, 1979) by helping panelists relate to a specific perception (Stone and Sidel, 1993)

- *Training.* Panelists were trained to evaluate the sensory characteristics of Jiaogulan tea by a descriptive scale, using reference standards (Table 3) and warm-up samples to increase the reliability of ratings (Plemmons and Resurreccion, 1998).

Testing the products. Before evaluating samples in the booth, the panel was calibrated using reference standards and warm-up samples to heighten the reliability of the rating. Each serving of Jiaogulan tea infusion as a sample of 30 ml in a 1 oz plastic cup with cover slip. Temperature of the tea served was controlled at 65-75°C (Resurreccion, 1998). The panels tested the samples in three sections. Between the sections, they were allowed to rest. The samples were individually tested with paper ballots to be completed by the panelists.

Consumer acceptance test

Fifty consumers who were members of the elder circle of Thammasart Hospital and the retired circle of the air force, Bangkok, Thailand, were selected by the following criteria: they have to be over 55 years old, health conscious and regularly exercise. The sample tea was placed in a 2 oz plastic cup covered with a cap coded with three-digit random numbers and served monadically with a 10-15 min break after 3 samples. The order of serving to each panelist was randomized to minimize bias. Panelists rated each sample using a 9-point hedonic scale, with 1 being dislike extremely and 9 being like extremely (Peryam and Pilgrim, 1957) for the overall acceptability, color, odor, taste and aftertaste of the tea using a paper ballot.

Statistical Analysis

The response data obtained from the chemical measurements (total saponin and antioxidant activity), sensory descriptive analysis and consumer acceptance test were analyzed. A multiple regression analysis by stepwise regression was used to fit a second-order model as follow:

$$\mathbf{Y = b_0 + b_1 X_1 + b_2 X_2 + b_{12} X_1 X_2 + b_{11} X_1^2 + b_{22} X_2^2}$$

where Y were the response variables (chemical quality, sensory descriptive and consumer acceptance data), X_1 was total saponin content in dried Jiaogulan and X2 was water for tea dilution. The coefficients of the polynomial were presented by b_0 (constant term), b_1 and b_2 (linear effects), b_{11} and b_{22} (quadratic effects) and b_{12} (interaction effects).

The response surface graphs from the quadratic model were generated by a statistic program (Design-Expert version 6.0.10, Stat-Ease Inc., MN). Finally, all graphs were optimized by using the criteria: (1) consumer acceptance score > 6.0. (Resurreccion, 1998; Grosso and Resurreccion, 2002) and (2) maximum saponin content and total antioxidant activity. An optimized formula of saponin content of Jiaogulan tea was figured out for raw material which had different soponin content.

Table 2. Definition of descriptive attributes for Jiaogulan tea.

Attributes	Definition
Appearance	
Yellowish green	Light yellow to dark green
Clearness	The degree of clarity of sample
Aroma	
Dried leaf aroma	Aromatic associated with dried grass or rice leaf or bamboo leaf
Green tea aroma	Aromatic associated with green tea
Jiaogulan aroma	Aromatic associated with Jiaogulan
Taste	
Sweet	The taste on the tongue associated with aqueous solution of sugar
Bitter	The taste on the tongue associated with aqueous solution of caffeine
Flavor	
Green tea flavor	Flavor associated with green tea
Jiaogulan flavor	Flavor associated with Jiaogulan
Feeling factor	
Astringency	The shrinking of the tongue surface caused by tannin or alum
Aftertaste	
Sweet	The sweet taste after the product is swallowed
Bitter	The bitter taste after the product is swallowed
Astringent	The shrinking of feeling after the product is swallowed

Table 3. Reference samples for the 13 descriptive attributes of Jiaogulan tea.

Attributes	Reference	Intensity (mm)
Appearance		
Green yellow	0.05% tartarzine 0.125 % Bromocresol green[1] Jiaogulan tea control[2]	45 120 70
Clearness	Distilled Water 0.4% Corn starch solution[3] Jiaogulan tea control	0 150 47
Aroma		
Dried leaf aroma	Dried Jiaogulan Jiaogulan tea control	30 32.3
Green tea aroma	Green tea bag[4] Jiaogulan tea control	15 40.5
Jiaogulan aroma	Jiaogulan tea control	65
Taste		
Sweet[5]	2.0% sucrose 5.0% sucrose 10.0% sucrose 16.0% sucrose Jiaogulan tea control	20 50 100 150 32.6
Bitter[6]	0.05% caffeine 0.08% caffeine 0.15% caffeine Jiaogulan tea control	20 50 100 51.5
Flavor		
Green tea flavor	Green tea bag Jiaogulan tea control	10 33.2
Jiaogulan flavor	Jiaogulan tea control	62.5
Feeling factor		
Astringency	0.07% Alum[7] 0.3% Alum tea bag / 1 hr soak[8] Jiaogulan tea control	27 50 95 42
Aftertaste		
Sweet	2.0% sucrose 5.0% sucrose 10.0% sucrose 16.0% sucrose Jiaogulan tea control	5 25 45 85 23.5
Bitter	0.05% caffeine 0.08% caffeine Jiaogulan tea control	27 80 60.5
Astringency	0.07% Alum 0.3% Alum tea bag / 1 hr soak[8] Jiaogulan tea control	5 80 110 59

Note :
[1]0.125% Bromocresol green and 1%citric acid at pH = 4.0
[2]Jiaogulan tea control consisted of Jiaogulan tea 1 g (total saponin 95 mg/g) in tea bag with extraction 80°C, 5 min
[3]Clearness reference was 0.04% corn starch (Yau and Huang, 2000)
[4]Japanese green tea (Chen Cha) with extraction 90°C, 5 min
[5]Standard solutions for sweet were 2.0, 5.0, 10.0 and 16.0% sucrose solution. (Meilgaard et.al., 1999)
[6]Standard solutions for bitter were 0.05, 0.08 and 0.15% caffeine solution. (Meilgaard et.al., 1999)
[7]Standard solution for astringency was 0.07% Alum (Drobna, 2004)
[8]Green tea bag (Lipton , green tea) soaked for 1 hour (Meilgaard et al., 1999).

RESULTS AND DISCUSSION

Chemical properties

Regression analysis (Table 4) shows the models of total saponin and antioxidant activity in Jiaogulan tea infusion when R^2 are 0.8294 and 0.9696, respectively. Joglekar and May (1987) suggested that for a good fit of a model, R^2 should be at least 0.80. It means that the model can be used for predicting the response. Therefore, the models of saponin and antioxidant activity could predict the total saponin content and antioxidant activity in Jiaogulan tea infusion. The total saponin content in Jiaogulan tea increased when the water quantity was reduced (Figure 1a) as the concentration of saponin got higher nearly 0.1 mg/ml of tea infusion. The soluble solid including saponin could diffuse in the water phase by a hot water infusion. Similarly, the antioxidant activity (Figure 1b) of the tea solution increased when the saponin content was high in concentration. This is on the principle of diffusion; the transfer of solutes from a solid to a fluid state is used to extract sugar, pectin, coffee and tea (Schwartzberg, 1980). From the study of Jaganyi and Ndlovu (2001) on the kinetics of tea infusion, the results indicated that the shape of a tea bag had no influence on the rate of infusion but the tea bag membrane offered some hindrance to the infusion of caffeine. Likewise, the saponin and other components in Jiaogulan tea can infuse through the tea bag, although the tea-bag material slowed the infusion of tea (Jaganyi and Mdletshe, 2000). Therefore, the saponin content in dried Jiaogulan had a positive effect to the total saponin and antioxidant activity in tea infusion.

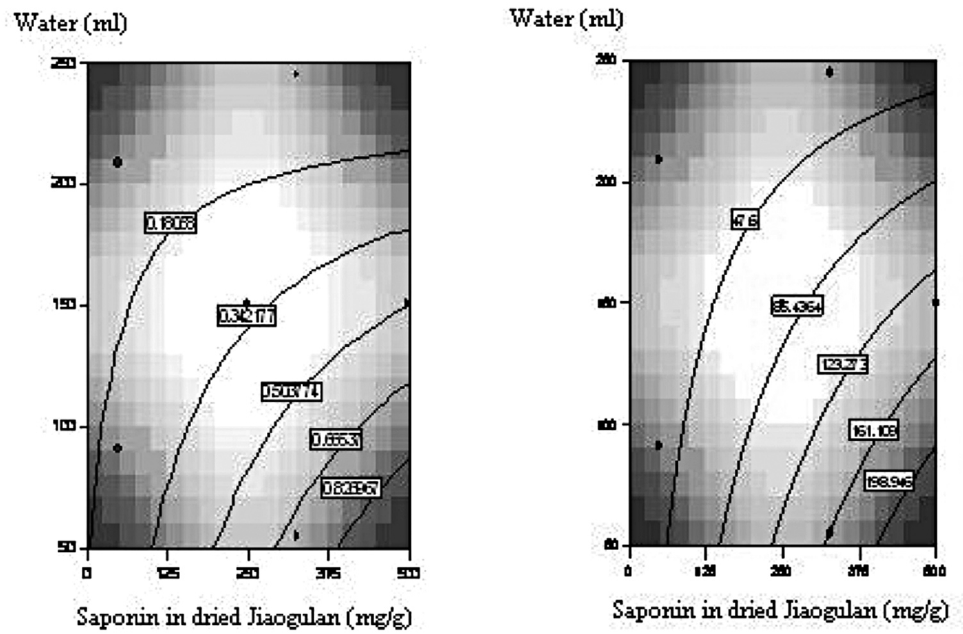
Table 4. The regression models of chemical component, sensory descriptive1, consumer acceptance[2].

Properties	Regression model[3]	R^2
Chemical component		
Total saponin	$0.32+0.19X_1–0.27X_2–0.23X_1X_2$	0.8294
Antioxidant activity	$75.86+62.34X_1–55.46X_2–48.19X_1X_2$	0.9696
Sensory descriptive		
Color	$68.31+12.72X_1–25.34X_2–10.34X_2^2$	0.9993
Clearness	$45.00+12.16X_1–23.69X_2$	0.9856
Dried leaf aroma	$33.26+6.25X_1–10.81X_2$	0.9622
Green tea aroma	$36.57+7.51X_1–14.02X_2$	0.9536
Jiaogulan aroma	$58.83+9.63X_1–20.51X_2$	0.9299
Sweet taste	$29.63+4.47X_1–12.55X_2$	0.8689
Bitter taste	$47.17+14.65X_1–24.81X_2$	0.9435
Green tea flavor	$28.21+5.70X_1–10.03X_2$	0.9174
Jiaogulan flavor	$56.86+10.41X_1–21.96X_2$	0.8874
Astringency	$43.29+12.18X_1–20.83X_2$	0.9453
Sweet aftertaste	$23.23+4.11X_1–11.39X_2$	0.8878
Bitter aftertaste	$58.40+17.51X_1–29.40X_2–14.57X_2^2$	0.9958
Astringent aftertaste	$54.50+12.84X_1–23.08X_2–12.52X_2^2$	0.9976
Consumer acceptance		
Overall liking	$6.15–0.39X_1+0.0027X_2+0.56X_1X_2$	0.9705
Color rating	$6.38–0.31X_1–0.23X_2+0.44X_1X_2$	0.8717
Aroma rating	$6.46–0.17X_1–0.082X_2+0.47X_1X_2–0.34X_2^2$	0.7847
Taste rating	$6.31–0.43X_1+0.14X_2+0.57X_1X_2–0.52X_2^2$	0.9784
Aftertaste rating	$6.38–0.43X_1+0.091X_2+0.48X_1X_2–0.45X_2^2$	0.9696

[1]Sensory descriptive scales are based on 150 mm unstructured line scale (Stone et al., 1980)

[2]Consumer acceptance ratings are based on a 9-point hedonic scale, 1=dislike extremely, 5=neither like nor dislike and 9=like extremely (Peryam and Pilgrim, 1957)

[3]Independent variables are X_1 = saponin content in dried Jiaogulan, X_2 = water.



(a) (b)

Figure 1. The chemical component of Jiaogulan tea infusion (total saponin (a), antioxidant activity(b)).

Sensory descriptive analysis

Twelve trained panelists developed 13 terms of Jiaogulan tea, based on the perception of the following attributes: appearance, aroma, taste, flavor, feeling factor and aftertaste. Table 2 shows the attributes and definition of Jiaogulan tea which consists of 2 attributes of appearance (yellowish green color and clearness), 3 attributes of aroma (dried leaf aroma, green tea aroma and Jiaogulan aroma), 2 attributes of tastes (sweet and bitter), 2 attributes of flavors (green tea flavor and Jiaogulan flavor), 1 attribute of feeling factor (astringency), and 3 attributes of aftertaste (sweet, bitter and astringent aftertaste). The consensus of references by trained panels and the intensity of each of the references are shown in Table 3. The appearance of Jiaogulan tea was yellowish green in color because of the chlorophyll pigment. The intensity scale was from light yellow to dark green. The color references were 0.05% tartarzine for yellow color and 0.125 % bromocresol green for green color. Yau and Huang (2000) reported that the clearness is an important attribute of Oolong tea which is the same as Jiaogulan tea but the sedimentation is not a requirement of tea infusion. Baykan (1981) pointed that the aroma is one of the most important criteria of tea. The aromatic attribute of Jiaogulan tea consists of specific Jiaogulan aroma and green tea aroma. It contains dried leaf aroma, such as dried grass or dried rice leaf or dried bamboo leaf, which may get in during the drying process of Jiaogulan tea. The astringency attribute is one of the tea characteristics of green tea and black tea, the likes of Jiaogulan tea. The alum solution is used as a reference for astringency of Jiaogulan tea (Drobna, 2004). The bitter taste of Jiaogulan is from its saponin glycoside content (Cheeke, 2001) which is the active compound in *G. pentaphyllum* (Hu et al., 1996; Cui et al., 1999) and the bitter taste still endures as an aftertaste. Normally, the glycosides structure is connected to a sugar molecule. For this reason, the panel could detect the sweet taste and sweet aftertaste of Jiaogulan tea that is different from other tea products. The intensity of Jiaogulan tea treatments are significantly difference that show in spider web plot (Figure 2).

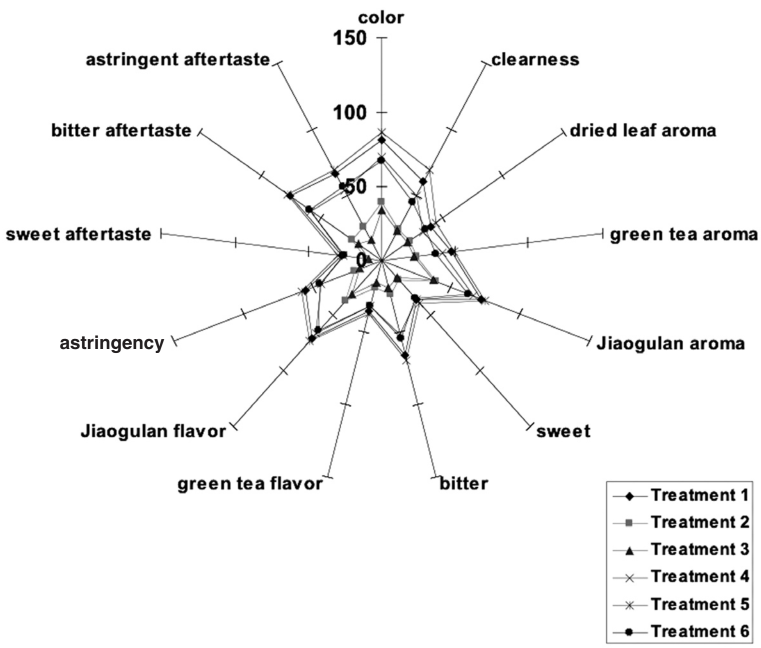
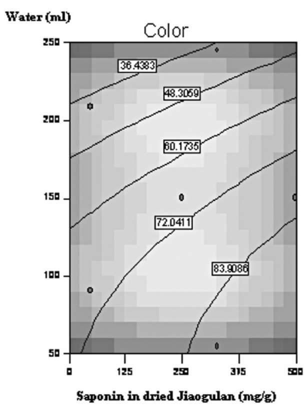


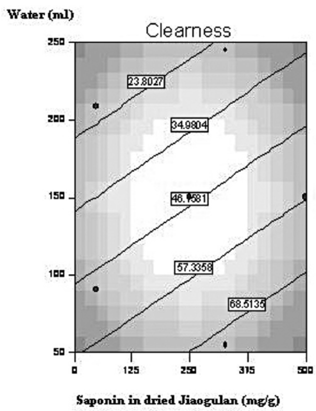
Figure 2. Descriptive analysis of Jiaogulan tea treatments.

Regression analysis of the sensory attributes of Jiaogulan tea and the R^2 values are listed in Table 4. The coefficient of determination, R^2, is defined as the ratio of the explained variation to the total variation and is a measure of the degree of fit (Haber and Runyon, 1977). It is also the proportion of the variability in the response variables, which is accounted for by the regression analysis (Mclaren et al., 1977). Henika (1982) stated that explained variances above 85% are sufficient for sensory data. Therefore, all regression models were used to predict the responses of sensory descriptive attributes of Jiaogulan tea because the R^2 values are greater than 0.85. The results show that the saponin content increases all sensory attributes. On the other hand, the water could decrease the intensity of all sensory attributes because the amount of water could dilute the intensity of saponin.

The study of saponin content on sensory properties of Jiaogulan tea infusion is shown by response surface graphs (Figures 3 and 4). High saponin content leads to an increase in the intensity of all sensory attributes. For the color and flavor, the solutes transfer from a solid to an adjacent fluid in the leaching process of tea (Schwartzberg, 1980; Schwartzberg and Chao, 1982), resulting in a higher intensity of color, aroma and flavor with attributes of yellowish green, dried leaf aroma, green tea aroma, Jiaogulan aroma, green tea flavor and Jiaogulan flavor, as well as sweet and bitter taste. Dos et al. (2005) investigated the effect of different factors on sensory attributes (odor, taste and pungency), overall acceptance and preference of Rooibos (*Aspalathus linearis*) tea. The results indicated that the odor of the infused tea was higher intensity than the traditionally brewed tea. Yin et al. (2004) analyzed the glycosides from *G. pentaphyllum* and isolated sugars from aglycone which consisted of glucose, rhamnose, xylose and arabinose. These sugars could diffuse into the drink to make it sweeter. This study also demonstrates that saponin could cause the bitter taste (Cheeke, 2001) of Jiaogulan tea as well as other food and beverage products. The astringency attribute is influenced by saponin content. Moreover, the aftertaste is also affected by the saponin content, causing it to have a sweet, bitter or astringent aftertaste. Studying the flavonoid compound in tea by a time-intensity procedure, the maximum bitter intensity decreased whereas the astringency increased (Peleg et al., 1999), that means there is an interaction between bitterness and astringency attributes. But in this study, if the saponin content increases, the bitter taste and astringency attributes would also increase.



(a)



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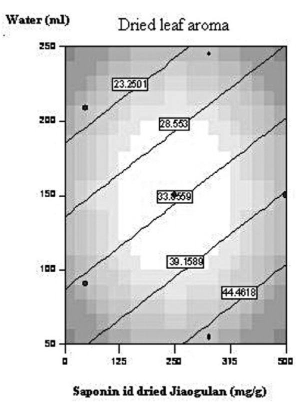

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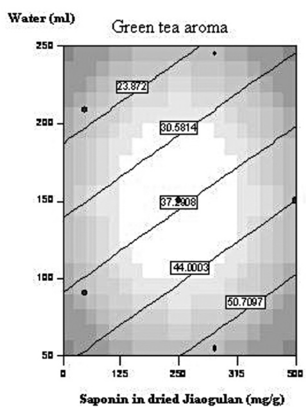

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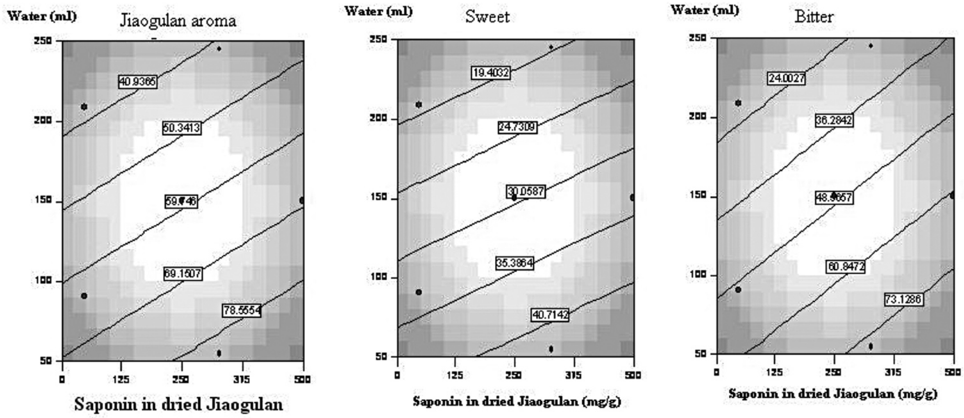
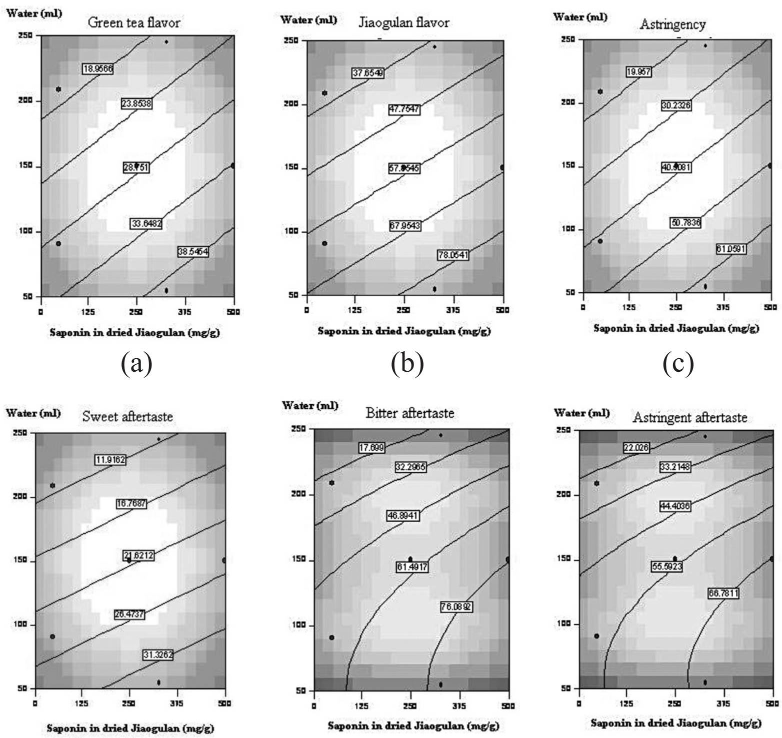


(e) (f) (g)

Figure 3. Response surface of Jiaogulan tea in terms of descriptive attributes: appearance, aroma and taste. (color (a), clearness (b), dried leaf aroma (c), green tea aroma (d), Jiaogulan aroma (e), sweet (f) and bitter (g))



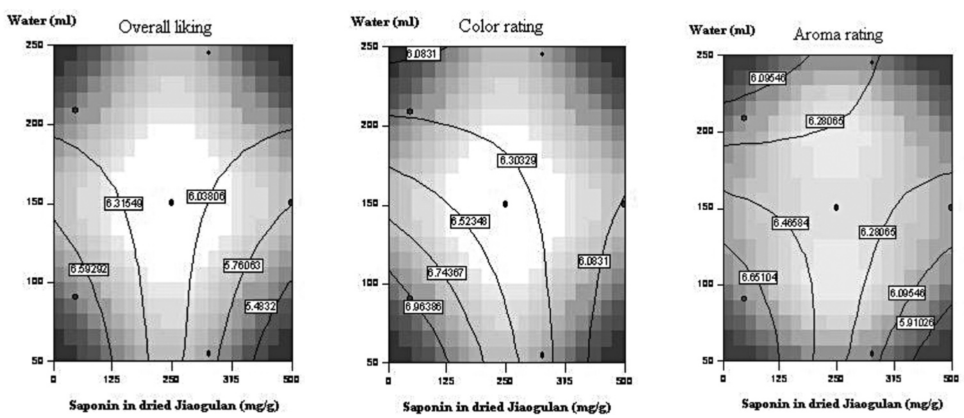
(d) (e) (f)

Figure 4. Response surface of Jiaogulan tea in terms of descriptive attributes: flavor, feeling factor and aftertaste. (green tea flavor (a) and Jiaogulan flavor(b), astringency (c), sweet aftertaste (d), bitter aftertaste (e) and astringent aftertaste (f)).

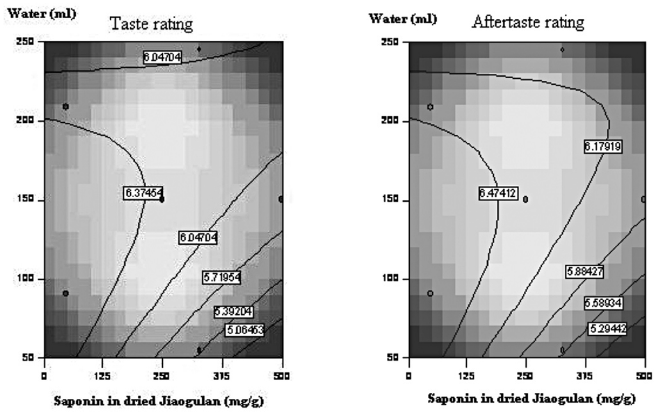
Consumer acceptance

Table 4 shows the list of regression equations and their corresponding R^2 values which are mostly higher than 0.85 (Henika, 1982) except aroma acceptance (0.7847). The regression models show that the saponin content reduced the acceptability of Jiaogulan tea. However, the water content could increase acceptability score of overall liking, taste and aftertaste rating because the amount of water could dilute the intensity of taste and aftertaste, treading to the increase in the acceptance of this product. There are interaction terms between saponin and water content.

The response surface graphs of hedonic rating are shown in Figure 5. The overall liking, color, aroma, taste and aftertaste rating score have increased when the saponin content is lower. The reason may be due to the intensity of the bitter taste, astringency and aftertaste which increases when saponin is high in content. Mattes (1994) reported that bitter-tasting foods and beverage generally are disliked by most human, thus, foods with a prominent bitter taste constitute a very small proportion of human's total consumption. But the factors that would underlie a possible reversal of innate rejection of bitter taste and the rated shift in hedonic response to bitter foods and beverage remain unclear (Stein et al., 2003). Mattes (1994) described that there are variations in the influence of the factors between individuals and products that may explain the differences in an individual's acceptability and use of foods and beverages containing alcohol, caffeine and other bitter compounds. Akella et al., (1997) reported that rated acceptance of green tea decreases as bitterness increases. Stein et al., (2003) suggested that repeated exposure can enhance a hedonic evaluation of a bitter sweet beverage, perhaps through a learned association of flavor with post-ingestive consequences. Maile and Heymann (1998) evaluated the changes of flavored and herbal teas stored at different temperatures over 11 months and concluded that although the descriptive analysis of panel indicated overall changes in the products, the consumers either did not detect or care about the changes. Mostly, the hedonic rating of overall liking, color and aroma of Jiaogulan tea is higher than the 6 point. These mean that consumers accepted the overall, color and aroma of this product (Resurreccion, 1998; Grosso and Resurreccion, 2002).



(a) (b) (c)



(d) (e)

Figure 5. The hedonic rating of consumer acceptance. (overall liking (a), color rating(b), aroma rating (c), taste rating (d), aftertaste rating (e)).

Optimization

The optimization technique provides product formulation for consumer evaluation (Gacula, 1993). The optimum formula is determined by superimposing the contour plots of all the responses (Sin et al., 2005). The optimum contour map of Jiaogulan tea for sensory descriptive attribute and hedonic rating over 6.0 (Resurreccion, 1998; Grosso and Resurreccion, 2002). The concentration of saponin that consumers like is not highly concentrated. This means that the saponin content must be infused in a large quantity of water. However, as we need this product to contain the maximum active components, so the optimum area should be in the highest saponin content and highest antioxidant activity. Therefore, by overlaying all the responses, the optimum combined condition is shown in Figure 6. The optimum Jiaogulan tea formula consisted of the dried Jigogulan containing 235-310 mg of total saponin, infusing in hot water (80-115 ml). Furthermore, the computer generated the optimized point that consisted of 292 mg of saponin and 100 ml of water. This tea infusion could be the optimum of active components that consumer would accept in terms of its sensory properties.

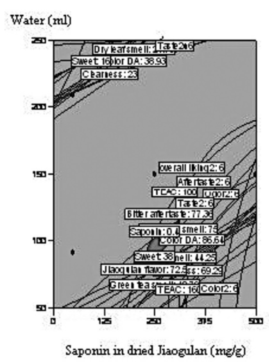


Figure 6. The optimization of sensory descriptive and consumer acceptance test overlap with chemical component.

CONCLUSION

The Jiaogulan tea can be described in terms of its 13 attributes by sensory descriptive analysis, these attributes include: yellowish green color, clearness, dried leaf aroma, green tea aroma, Jiaogulan aroma, sweet taste, bitter taste, green tea flavor, Jiaogulan flavor, astringency, sweet aftertaste, bitter aftertaste and astringent aftertaste. Consumer acceptability test indicated that they liked this tea if the saponin content was not too high. The optimization of the maximum chemical components overlaid with the acceptability score (> 6) which is in the area of 235-310 mg total saponin content and 80-115 ml water. Finally, this study suggests that the formulation of Jiaogulan tea should contain 292 mg of saponin in dried Jiaogulan and 100 ml of hot water, so that consumers accept this tea.

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