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Descriptive sensory analysis of Chinese and Assam drinking green teas from Thailand influenced by varying durations of rolling and pan-firing processes

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Abstract

The sensory profiles were investigated of drinking Chinese green tea (Ch) and Assam green tea (As) processed for different durations of pan-firing (4 levels; 0 min, 5 min, 10 min and 15 min) and rolling (3 levels; 0 min, 2 min and 4 min) based on 24 samples. In total, 33 attributes from all tea samples were evaluated using generic descriptive analysis according to a tea cupping standard, followed by classification using principal component analysis. Based on the results, all the tea samples could be divided into three groups. The first group was influenced by the duration of the pan-firing and rolling processes used with Ch that contributed to the 'Green' and 'Seaweed' attributes. The second group, also Ch, had a positive correlation only to rolling duration that contributed to 'Bitter aromatic', 'Tobacco', 'Brown', 'Dark Brown', 'Sweet aromatic', 'Floral' and 'Spice' attributes. The third group associated with all the As samples was influenced by the duration of both pan-firing and rolling that contributed to 'Dark green', 'Tea ID' and 'Ashtray' attributes. The results revealed that aroma and flavor are important attributes that could be used to categorize the green tea samples into three groups depending on processing duration and the green tea variety. Therefore, the findings regarding green tea attributes could be utilized in tea processing development, especially regarding the pan-firing and rolling process conditions.

Introduction

In general, teas can be divided into many types according to the production processes; the three most common types are green tea (non-fermented), oolong tea (semi-fermented) and black tea (fully fermented) (Trevisanato and Kim, 2000). Furthermore, the various tea types can be classified by the processing regime and the associated oxidation/fermentation level which strongly influence the tea's physical and chemical properties (Ahmed and Stepp, 2013; Kosińska and Andlauer, 2014). In addition, different processes of tea production influenced the organoleptic properties (taste, aroma and flavor profiles) of drinking tea products because of the effects on the phytochemicals and bioactive compounds such as polyphenol, amino acid and other compounds, especially catechin and its derivatives (Theppakorn, 2016). Compared with black tea and oolong tea, green tea has a more bitter taste and is astringent but less fragrant due to higher catechins content (Kosińska and Andlauer, 2014). Drinking green tea has grown in popularity as a symbol of Asian culture as

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it not only has an enhanced aroma and flavor when paired with foods and desserts, but it also provides health benefits such as preventing coronary heart diseases, tumor growth and LDL cholesterol (Kosińska and Andlauer, 2014; Hayat et al., 2015).

Green tea is popular in Asia, which it is produced from two varieties of tea leaves, namely *Camellia sinensis* (Chinese tea) and *Camellia assamica* (Assam tea). The Chinese green teas are grown and harvested primarily in mainland China, Taiwan and Japan, whereas Assam green teas are more popular in India, Sri Lanka and especially Southeast Asia especially in Malaysia and Thailand (Cabrera et al., 2006; Senanayake, 2013). The unique characteristics of the aroma and flavor of green teas are the most important factors that impact on consumer perception. In addition, the aroma and flavor of a tea involve the sensation and emotion of consumer acceptance. In terms of chemical substances in green tea, various studies have found that catechins, caffeine, tannin, amino acids and free sugar mainly contributed to the flavor. For example, it was estimated that 70–75% of the bitterness and astringency was caused by catechins (Zhen et al., 2002). Caffeine has a bitter taste and tannin has a strong astringent or pungent taste whereas amino acids are responsible for the brothy taste and free sugars contribute to sweetness (Lee and Chambers, 2007; Lee and Chambers, 2009; Narukawa et al., 2010; Feng et al., 2014). Tea processing affects the appeal of green tea as reported by Mao et al. (2018). They found that the use of a higher roasting temperature could reduce *cis*-catechins, bitterness and the umami amino acid contents. In contrast, the amount of *trans*-catechins and soluble sugar increased but the caffeine content and sweet amino acids did not change after roasting treatment. Several researchers have conducted sensory evaluation to describe the attributes that can develop during green tea production. For example, there have been studies providing descriptive sensory analysis of Uksoo tea, Hanra tea and Soon tea from Korean green tea (Lee et al., 2008), Hunan tea from Chinese green tea (Li et al., 2019), Fujian oolong tea, Yunnan oolong tea, green tea, black tea, and Pu-erh tea of Chinese green tea (Wang et al., 2016) and green tea from China, Japan and Korea (Lee and Chambers, 2010). Most of these studies conducted descriptive sensory evaluation for Chinese green tea attributes using different processes or tea varieties, or both. Green tea is commonly produced from a Chinese tea variety. However, due to the limited number and output of Chinese tea plantations, green tea is being replaced by the Assam tea variety (Wang et al., 2016). Thus, the current study investigated the sensory profiles of Chinese green tea and compared them with Assam green tea.

Descriptive sensory analysis has been applied for identification and description in relation to both qualitative and quantitative sensory characteristics using trained panelists (Riu-Aumatell, 2012). Descriptive sensory analysis is an important tool mostly used to evaluate the sensory quality of food products (Lawless and Heymann, 2010). Generic descriptive analysis (GDA), adapted from the quantitative descriptive analysis (QDA®) method (Lawless and Heymann, 2010), is one of several descriptive sensory analysis methods used to generate and explain the attributes of food products. The GDA method can be applied in identifying the intensity of the attributes and in defining the sensory characteristics of food products in order to improve understanding of consumer perception in new product development. The GDA method has been applied to study sensory profiles in extra virgin olive oil (Delgado and Guinard, 2011), fresh bread (Heenan et al., 2008), drinking yoghurt (Pohjanheimo and Sandell, 2009) and marine oils (Larssen et al., 2018). However, only a few studies have identified the sensory components of green tea in relation to green tea varieties under different durations of processing. Therefore, the objectives of the current study were to develop a sensory lexicon of Assam green tea and Chinese green tea under different duration of processing using pan-firing (0, 5, 10 and 15 min) or rolling (0, 2 and 4 min) by applying the GDA method and to understand the relationships between sensory characteristics and quality properties (color and bioactive compounds) of all the tea samples. The results should be beneficial to the development of industrial tea processing by providing the important sensory profile information and trend directions as a basis for the development of green tea products that are acceptable to consumers.

Materials and Methods

Tea samples

Of the 24 samples, 12 were Chinese green tea (Ch-1 to Ch-12) and 12 were Assam green tea (As-1 to As-12) that were prepared from the Boonrawd farm and the Suwirun Thai Tea farm, Chiang Rai province, Thailand, respectively. The fresh tea leaves were pan-fired at 250–300°C with a rotation rate of 1,500–2,000 rpm using a degreening machine (Yuan Cheng Machinery, Taiwan). The pan-fired tea leaves were rolled at 40 rpm using a rubbing machine (Yuan Cheng Machinery, Taiwan). The pan-firing and rolling times were varied (pan-firing: 0, 5, 10 and 15 min and rolling: 0, 2 and 4 min) as shown in Table 1. After that, the tea leaves were dried using a hot-air tray dryer at 125–140°C for 2 hr to reduce the moisture content to less than 8%. The tea leaves were sorted and graded, and then kept in aluminum foil for use in further experiments.

Determination of color

The preparation of drinking green tea was carried out according to the tea cupping standard method (American Specialty Tea Alliance, 2016). Three grams of fine green tea powder (60 mesh) was infused in 235 mL hot water (71 ± 2°C) for 1 min. Then, the infused tea was separated using filtration through Whatman No.1 filterpaper. The drinking green tea was cooled to ambient temperature (30 ± 2°C) for color measurements. The color of drinking green tea was measured using transmittance and expressed as the CIELAB L* (lightness), a* (redness), b* (yellowness), C* (chroma) and h° (hue angle) values. The spectrophotometer (CM3500d; Minolta Co. Ltd.; Osaka, Japan) was standardized using a black-and-white plate. The illuminant used was D65, with a standard observer angle of 10°. Color measurement was performed in triplicate, each with five measurements.

Table 1 Process conditions and description of green tea samples used in the study

Process condition		Sample type	
Pan-firing (min)	Rolling (min)	Chinese green tea	Assam green tea
0	0	Ch-1	As-1
	2	Ch-2	As-2
	4	Ch-3	As-3
5	0	Ch-4	As-4
	2	Ch-5	As-5
	4	Ch-6	As-6
10	0	Ch-7	As-7
	2	Ch-8	As-8
	4	Ch-9	As-9
15	0	Ch-10	As-10
	2	Ch-11	As-11
	4	Ch-12	As-12

Determination of total phenolic contents

Extraction of total phenolic contents (TPC) was carried out according to the method of Theppakorn (2016) with some modifications. Two grams of fine green tea powder (60 mesh) was extracted with 200 mL boiling reverse osmosis (RO) water (100°C) and allowed to infuse for 15 min with continuous stirring. The extracts were cooled to ambient temperature (30 ± 2°C) and filtered through Whatman No. 1 filter paper. Then, the tea solution was adjusted to 250 mL with RO water for determination of TPC. One milliliter of green tea extracts was mixed with 5 mL of Folin-Ciocalteu's reagent, which was diluted with distilled water (1:10). After 3 min, 4 mL of 7.5% sodium carbonate was added. The mixture was agitated and allowed to stand for a further 60 min. The absorbance was measured at 765 nm using a spectrophotometer (UV-160A; Shimadzu Co.; Tokyo, Japan). The TPC was standardized against gallic acid. The data were expressed in micrograms of gallic acid equivalents (GAE) per 100 g on a dry basis (μg GAE/100g db). All determinations were performed in triplicate.

Determination of total catechins

The preparation of green tea extracts for the determination of total catechins used the same procedure as for the determination of TPC. After extraction, the tea solution was filtered through 0.45 μm polytetrafluoroethylene filter (Millipore Ltd.; Bedford, MA, USA) and transferred to brown glass vials. Total catechins were performed using high performance liquid chromatography (HPLC), according to the ISO 14502-2 (2005) method with slight modifications. The column used was a Platinum EPS C18 reversed phase, 3 μm (53 x 7 mm) with the column temperature at 30°C. The mobile phase was water:acetonitrile (87:13) containing 0.05% (v/v) trifluoroacetic acid (TFA). An autoinjector was used to inject 10 μL of the tea solution onto the HPLC column, and the flow rate was 1 mL/min. The substances were detected using a diode array detector (Waters; Shanghai Corporation; Shanghai, China) at 210 nm. The total catechins were characterized according to their spectra and the retention times were compared with commercial standards. All calculations and individual standard preparation were done using the method of ISO 14502-2 (2005). A calibration curve was obtained by injection of known concentrations of different standard compounds: catechins, catechin gallate, epigallocatechin gallate, epigallocatechin, epicatechin gallate, epicatechin, gallocatechin and gallocatechin gallate (Sigma Chemical; St. Louis, MO, USA.). The results were expressed in grams per 100 g on a dry basis (g/100 g db).

Generic descriptive analysis

The descriptive sensory attributes of 24 green tea samples were determined following the GDA method (Lawless and Heymann, 2010), which involved recruiting and screening the panel and then undertaking panel training and product evaluation.

Panel training

Eight highly trained descriptive panelists selected from the Kasetsart University Sensory and Consumer Research Center (KUSCR), Department of Product Development, Faculty of Agro-Industry, Kasetsart University, Bangkok, Thailand participated in the evaluation. These panelists were experienced in various food products and had previously participated in the descriptive analysis of green tea. The training sessions lasted 12 hr (6 hr/d). During the sessions, the panel generated sensory characteristics for the drinking green tea. They defined and selected an appropriate reference sample for each sensory characteristic of drinking green tea. After generating the sensory characteristics with the references, the intensity of the sensory characteristics of a selection of eight different green tea samples were evaluated using a numerical line scale from 0 to 15 with 0.5 increments where zero was defined as no intensity and 15 was extremely high intensity. The pre-test was performed in an identical fashion to the actual descriptive test. The panelists were trained until they obtained consensus agreement. When evaluating samples, standard reference materials were presented to ensure a more accurate evaluation.

Tea preparation and presentation

The preparation of drinking green tea was carried out according to the tea cupping standard method (American Specialty Tea Alliance, 2016). Three grams of fine green tea powder (60 mesh) was infused in 235 mL hot water (71 ± 2°C) for 1 min. Then, the infused tea was separated using filtration. Before serving, the drinking green tea was poured into a warmed bowl through a porcelain strainer and served in white porcelain tea cups, which were coded with three-digit random numbers.

Descriptive analysis of green tea samples

The sensory attributes (appearance, aroma/flavor, taste, chemical feeling and aftertaste) were specified using the terms and definitions of drinking green tea obtained from the training sessions. The panelists were asked to sip each sample (approximately 10 mL per sip) and to evaluate the intensity of each sensory attribute. Unsalted crackers and water were provided for palate cleansing between samples. The panelists sniffed the steam from hot water to clear their nose between samples. The panelists had 40 min for each sample, typically 30 min to evaluate and 10 min to rest before the next sample (depending on the level of fatigue of the panelist). Sample testing was performed in duplicate. All sensory attributes were evaluated on a numerical line scale from 0 to 15 with 0.5 increments where zero was defined as no intensity and 15 was extremely high intensity. The reference sample was also prepared as a scoring standard for each aspect.

Statistical analysis

An independent sample t-test was conducted to investigate the differences in the quality properties (color and bioactive compounds) of the Chinese and Assam green tea varieties using the statistical package SPSS® (version 12.0; SPSS [Thailand] Co. Ltd.; Bangkok, Thailand). Mean values were considered significantly different at the 95% confidence level ($p < 0.05$). Principal component analysis (PCA) was used to correlate between the green tea samples based on the mean values of sensory attributes. Hierarchical cluster analysis (HCA) was performed to classify groups based on the dissimilarities of the abundance of samples varied during the processing conditions with sensory attributes (XLstat 2017 software; Addisoft; Paris, France).

Results and Discussion

Color values and phenolic compounds

Prior to the determination of some sensory attributes, the green tea varieties were examined for their color profiles and phenolic compounds as shown in Table 2. The colors of both the Chinese and Assam green teas were yellowish-green evidenced by high b* values (32.35 ± 0.43 and 17.57 ± 1.35, respectively). The results indicated that the L* (lightness), a* (greenish) and b* (yellowness) values of Chinese green tea were significantly greater than those of Assam green tea. The total phenolic compound content of Assam green tea was significantly higher than that of Chinese green tea (15.51 µg GAE/100 g db and 10.66 µg GAE/100 g db, respectively). These results were similar Anesini et al. (2008) who reported that Assam variety teas had higher polyphenol contents than those from the Chinese variety and the total catechin content of Assam green tea (15.07 g/100 g db) was higher than that of Chinese green tea (9.8 g/100 g db). The chemical constituents of the fresh Chinese (C. *sinensis*) and Assam (C. *assamica*) green tea in the current study were similar to those reported by Theppakorn et al. (2014).

Table 2 Color and total phenolic and total catechin contents of Chinese and Assam green tea varieties

Parameter	Chinese tea	Assam tea
Color		
L*	66.79 ± 0.26^a	56.70 ± 1.64^b
a*	-5.01 ± 0.07^b	-3.34 ± 0.03^a
b*	32.35 ± 0.43^a	17.57 ± 1.35^b
C*	32.74 ± 0.42^a	17.88 ± 1.33^b
h°	98.80 ± 0.21^b	100.82 ± 0.80^a
Total phenolics (µg GAE/100g db)	10.66 ± 0.20^b	15.51 ± 1.22^a
Total catechins (g/100g db)	9.80 ± 0.19^b	15.07 ± 0.05^a

L* = lightness; a* = redness; b* = yellowness; C* = chroma; h°= hue angle; GAE = gallic acid equivalents; db = dry basis; GAE = gallic acid equivalents
Means ± SD of triplicate measurements with different lowercase superscripts in each row are significantly ($p < 0.05$) different.

Descriptive sensory attributes

The dominant characteristic from the GDA of the 24 drinking green tea (Chinese and Assam) samples with different pan-firing times and rolling times are shown in Table 3. Two green tea variety showed some color differences; Chinese green tea was identified as ‘Green’ while Assam green tea was identified ‘Brown’. The color attributes from the GDA were similar to the results from colorimetry, as shown in Table 2. For odor and flavor attributes, Chinese green tea contained more ‘Greenish-like’ and/or ‘Seaweed-like’ characteristics. On the other hand, ‘Tea ID’, ‘Bitter aromatic’, ‘Floral’,‘Tobacco’, ‘Dark brown’, ‘Brown’ and ‘Sweet aromatic’ attributes were identified in Assam green tea for odor and flavor. Other prominent attributes in the flavor of Assam green tea were ‘Dry’ and ‘Ashtray’, while the chemical feeling (CF) and aftertaste (AT) were ‘Astringent’, ‘Tooth-etch’, ‘Freshening throat’, ‘Bitter aromatic’, ‘Tea ID’, ‘Floral’ and ‘Tobacco’. The ‘Bitter’ taste, ‘Astringent’ and ‘Tooth-etch’ were more intense in Assam green tea than Chinese green tea because the correlation between phenolic compounds and bitterness sensation of green tea is highly positive (Pedan et al., 2019). In addition, compared to Chinese green tea, Assam green tea has a higher content of epicatechin gallate (ECG) and epigallocatechin gallate (EGCG) which are the essential precursors of bitter and astringent tastes in tea (Wang et al., 2000).

Table 3 Generic descriptive analysis of drinking green teas (Chinese and Assam) from different pan-firing and rolling treatments in processing

Sample	Attribute				
	Appearance	Aroma	Flavor	Taste	CF* AT**
Chinese	Green	Green Seaweed	Green Seaweed		
Assam	Brown	Tea ID ^A^ Bitter aromatic Floral Tobacco Dark brown Brown Sweet aromatic	Tea ID ^A^ Bitter aromatic Dry Floral Tobacco Ashtray Brown Dark brown Sweet aromatic	Bitter	Astringent (CF) Tooth-etch (CF) Freshening throat (CF) Bitter aromatic (AT) Tea ID (AT) Floral (AT) Tobacco (AT)
Chinese/Assam	Turbidity Sediment	Dark green Dry Ashtray Smoke Spice	Dark green Smoke Spice	Sweet	Ashtray (AT)

* Mean of chemical feeling (CF); ** Mean of aftertaste (AT)

^A^ Tea ID is the aroma/flavor characteristic of the tea leaves consisting of the smells of dry tobacco, smoke, bitter, brown, sweetness, may be mixed with flowers, green and burnt.

Some similar attributes were found in both tea varieties, namely 'Turbidity' and 'Sediment' (appearance); 'Dark green', 'Smoke', 'Spice' (odor/flavor); 'Sweet' (taste) and 'Ashtray' (aftertaste). In addition, 'Dry' and 'Ashtray' attributes were most relevant to the odors. These attributes have were compatible with previous research where the appearance ('Turbidity'), odor ('Floral', 'Seaweed', 'Sweet aromatic' and 'Green'), taste ('Sweet' and 'Bitter') and chemical feeling ('Astringent' and 'Tooth-etch') have been also used to identify the general attributes of tea samples (Lee and Chambers, 2007; Lee et al., 2008).

The 33 sensory attributes were classified into six categories. For appearance, there were four attributes: 'Green color', 'Brown color', 'Turbidity' and 'Sediment'. The aroma and flavor were composed of 14 attributes such as 'Tea ID', 'Green', 'Floral', 'Bitter aromatic' and 'Tobacco'. The taste and chemical feeling comprised two attributes ('Bitter' and 'Sweet') and three attributes ('Astringent', 'Tooth-etch' and 'Freshening throat'), respectively. The 10 attributes of aftertaste included 'Bitter aromatic', 'Tea ID', 'Floral', 'Tobacco', 'Ashtray' and 'Sweet taste'.

Principal component analysis

Attributes of Chinese green tea under different processing conditions

The PCA biplot of the relationship between Ch and its attributes revealed that the first principal component (PC1; 62.57%) and the second principal component (PC2; 13.02%) explained 75.59% of the cumulative variance, as shown in Fig. 1. The results from the PCA and HCA were classified into two groups according to positive high-low intensity attributes. The first group (Ch-1 and Ch-4 to Ch-12) correlated to the positive high characteristic showing 'Green' (appearance), 'Green' (aroma and flavor) and 'Seaweed' (flavor and aftertaste), whereas many attributes, such as 'Brown' (appearance), 'Bitter aromatic', 'Tobacco', 'Sweet aromatic', 'Brown' and 'Floral' (aroma and flavor), were related to the second group (Ch-2 and Ch-3). The differences between the two groups of Ch may have been influenced by different tea processing durations. Increasing the rolling time without applying heat enhanced many of the aroma and flavor attributes of green tea. In contrast, increasing the rolling time along with the pan-firing time produced similar results to the high-temperature process that reduced some of the aroma and flavor attributes in drinking green tea. These results were similar to the study by Odunmbaku et al. (2015).

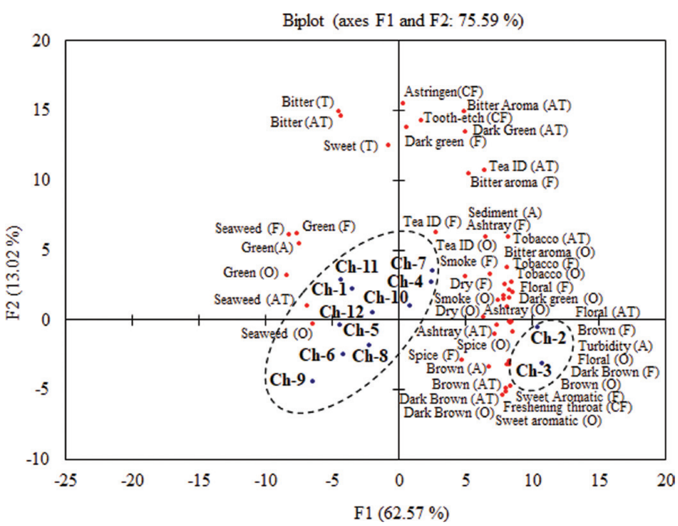

Fig. 1 Principal component analysis of Chinese green tea samples (Ch-1 to Ch-12) from different pan-firing and rolling treatments in the processing and their sensory attributes using appearance (A), aroma (O), flavor (F), taste (T), chemical feeling (CF) and aftertaste (AT)

Attributes of Assam green tea under different processing conditions

The relationship between As and its attributes is illustrated in the PCA biplot in Fig. 2, accounting for 71.66% (PC1; 53.05% and PC2; 18.61%) of the cumulative variance. The PCA and HCA of the As samples indicated three groups according to different pan-firing times, whereas the rolling time had little influence on the classification. Group 1 (As-1, As-2 and As-3) based on As in non pan-firing was related to high intensity attributes, not only 'Brown', 'Turbidity' and 'Sediment' (appearance) but also 'Tea ID', 'Bitter aromatic', 'Floral', 'Tobacco' and 'Brown' (aroma, flavor and aftertaste). Group 2 (As-4, As-5 and As-6) based on Assam green tea with a short pan-firing (5 min) process expressed 'Green', 'Dark green', 'Seaweed', 'Sweet aromatic', 'Dark brown' aroma and flavor attributes, while 'Dark green' and 'Seaweed' were positive in the aftertaste attributes. Group 3 (As-7 to As-12) based on As having medium and long times in pan-firing (10 and 15 min) consisted of a moderate intensity scale for most attributes. Furthermore, this group dominantly expressed 'Bitter' as a taste and aftertaste characteristic. However, increasing the duration of pan-firing produced similar results to the high-temperature tea process. Friedman et al. (2009) reported that high temperature processes, such as steaming and pan-firing, potentially induced the sweet flavor and taste (bitter/sweet) characteristics of fresh tea leaves, which produced a positive impact on these satisfaction attributes of drinking green tea. In addition, the interaction between temperature and duration of production was reported to have a significant effect on developing the flavor in tea products (Teshome et al., 2013).

Relationship of Chinese green tea and Assam green tea attributes under different processing conditions

The PCA biplot for the two types of green tea from different production processes and the sensory attributes of various drinking green teas consisted of the first principal component (PC1; 68.51%) and the second principal component (PC2; 8.74%) that explained 77.25% of the cumulative variance. The results showed that drinking green tea made using different processes could be classified into three groups based on HCA, as shown in Fig. 3.

The first group consisted of processed (pan-firing/rolling: Ch-4 to Ch-12) and non-processed (Ch-1) Chinese green tea, which dominated with a high intensity of appearance of 'Green' color and aroma/flavor of 'Green' and 'Seaweed' attributes. Liang et al. (2005) reported that green tea manufacturers prevented the green color of green tea leaves being too evident by using a thermal process such as steaming and roasting (pan-firing) to inactivate various enzymes in the tea leaves. The aroma and flavor attributes were probably due to different original cultivars and the pan-firing process relating to strong volatile compounds and the fresh green plant flavor. Pripdeevech and Machan (2011) revealed that the use of high temperature during the pan-firing process in the production of non-fermented tea could induce increased lipid degradation of tea leaves. This lipid degradation product may provide the highly volatile compound and enhance the grassy and greenish aroma (*trans*-2-hexenol). Lee et al. (2008) found strong aromas of 'cut grass' and 'floral' in green tea obtained from a roasting and steaming process to prevent fermentation. Furthermore, trained panelists in the current study described the aroma and flavor of green, marine plants and a fishy aroma involved in the 'Seaweed' (aroma/flavor) attribute of Ch.

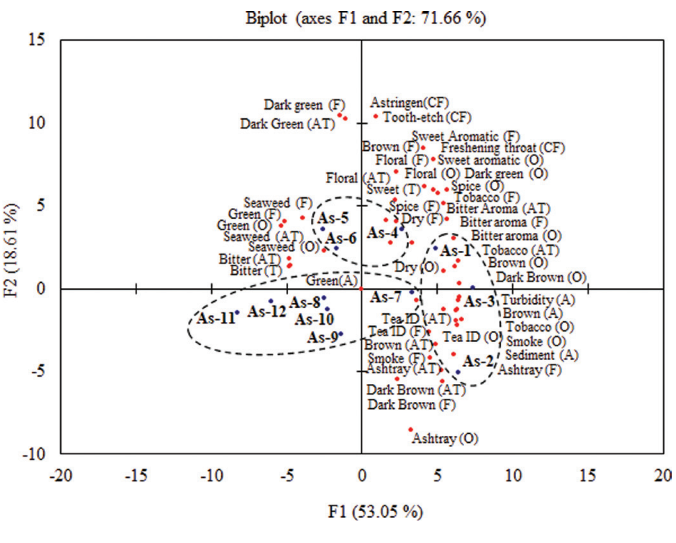

Fig. 2 Principal component analysis of Assam green tea samples (As-1 to As-12) from different pan-firing and rolling treatments in processing and their sensory attributes using appearance (A), aroma (O), flavor (F), taste (T), chemical feeling (CF) and aftertaste (AT)

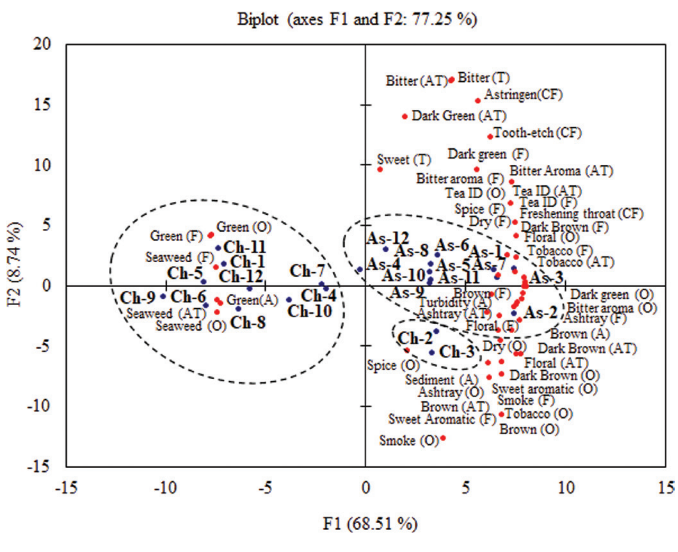

Fig. 3 Principal component analysis for two types of green tea (Chinese = Ch-1 to Ch-12 and Assam = As-1 to As-12) from different pan-firing and rolling treatments in processing and their sensory attributes using appearance (A), aroma (O), flavor (F), taste (T), chemical feeling (CF) and aftertaste (AT)

The second group involved rolling processing for different times of Chinese green tea (Ch-2 and Ch-3), which resulted in a unique character from non pan-firing. This group had a positive correlation between aroma and flavor attributes ‘Bitter aromatic’, ‘Tobacco’, ‘Brown’, ‘Dark Brown’, ‘Sweet aromatic’, ‘Floral’ and ‘Spice’. The chemical-like (‘Freshening throat’) and aftertaste (‘Floral’, ‘Tobacco’, ‘Dark Brown’ and ‘Brown’) attributes were also evident in the sample groups. Furthermore, the ‘Brown’ color attribute was clearly distinguishable from the first groups. This was perhaps due to the process affecting the color attribute between these two sample groups. An increased brown color of tea leaves may have occurred due to the polyphenol oxidase enzyme that was disrupted and released from their cell walls during rolling (Teshome, 2019). This enzyme could react with oxygen (O_2) and provided a high degree of enzymatic browning reaction resulting in the increased brown color in the tea samples. The degradation of the lipid membrane by enzymatic catalyzation can produce oxidized catechin during the rolling tea process. The catechin oxidation products may include chemical compounds such as amino acids, carotenoids and unsaturated fatty acids, resulting in the formation of various aromatic volatile compounds of the teas (Zheng et al., 2016). As a result, Ch-2 and Ch-3 samples were discriminated based on sensory attributes from the other Chinese green tea samples that had passed through the pan-firing process because of the deactivation of enzymes by the high temperatures.

Finally, regarding the aroma and flavor, the ‘Dark green’, ‘Tea ID’ and ‘Ashtray’ attributes dominated with the highest intensity scores in the third group of all As samples. In addition, attributes of samples in this group were similar to some characteristics in the second group such as ‘Bitter aromatic’, ‘Floral’, ‘Tobacco’ (aroma/flavor and aftertaste), ‘Spice’ and ‘Smoke’ (aroma/flavor). As was correlated with a clear intensity of many attributes compared to Ch. The differences in aroma and flavor between the two types of green tea were due to the different volatile compositions of the various tea cultivars, resulting in variation in those characteristics (Wang et al., 2011; Zheng et al., 2016). The current study demonstrated that the sensory characteristics of both tea varieties depended on processing variations during pan-firing and rolling, while the original tea variety affected the characteristic color, aroma, flavor and taste of drinking green tea. The resultant sensory attributes could be used to distinguish differences and similarities due to changes in the processing conditions of Chinese and Assam green teas. The descriptive analysis of drinking green tea could be used as a product development tool to evaluate the sensory attributes most suitable for a certain consumer perception from the tea production.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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