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Investigation on the Quality of Commercially Available GABA Tea in Taiwan

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Abstract: This study collected 220 commercially available samples of γ-Aminobutyric acid (GABA) tea produced in Taiwan from 2016 to 2021. The 220 tea samples were categorized into five types of GABA tea, including 108 GABA Oolong tea, 71 GABA Black tea, 21 GABA Paochong tea, 12 GABA Green tea, and 8 GABA Puerh tea samples. The most common type of GABA tea in Taiwan is GABA Oolong tea, followed by GABA Black tea. The physico-chemical constituents and consumer acceptance of the GABA tea samples were analyzed. The GABA content varied among the different types of GABA tea: GABA Oolong tea ranged from 128–286 mg/100 g, GABA Black tea ranged from 182–360 mg/100 g, GABA Paochong tea ranged from 98–203 mg/100 g, GABA Green tea ranged from 56–174 mg/100 g, and GABA Puerh tea ranged from 142–191 mg/100 g. In terms of the commercial standard of GABA tea, 22 out of the 220 GABA tea samples failed to meet the commercial standard, with a failure rate of 10%. During the fermentation process of GABA tea, the contents of GABA increased significantly, but the total polyphenol and total catechin contents remained stable. In terms of consumer acceptance, GABA Black tea is the most accepted by consumers, followed by GABA Puerh tea, GABA Paochong, and GABA Oolong tea. The sour flavor in GABA tea is similar to the original sour sensory properties found in black tea. It is assumed that this is the main reason GABA Black tea has the highest acceptance.

Keywords: Taiwan GABA tea; commercial standard; consumer acceptance; physico-chemical constituents

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1. Introduction

GABA (γ-Aminobutyric acid) is a hydrophilic non-proteinogenic amino acid. GABA is naturally present in the brain and spinal cord of mammals and acts as an important inhibitory neurotransmitter of the central nervous system [1,2]. In the human body, higher GABA concentrations are found in the cerebrospinal fluid, blood, and central nervous system than those found in other parts [3]. GABA tea has many important physiological benefits. Jolivalt et al. indicated that increased GABA release contributes to spinally mediated hyperalgesia in diabetes [4]. Gottesmann et al. and Zhao et al. indicated that GABA Black tea had significant effects on prolonging sleeping time with sodium pentobarbital ($p < 0.05$) and GABA Black tea also improved the sleeping quality of mice to extend with 35 optimal effects in the high dose-treated mice [5,6]. Koob indicated that the effects of alcohol with GABA antagonists can be antagonized, particularly its sedative, anxiolytic-like, and acute reinforcing actions [7]. Powers indicated GABA in the control

of GH release by actions at either hypothalamic or pituitary sites. Therefore, GABA could control GH secretion [8]. Pea and Tapia indicated that GABA receptor antagonists clearly diminished the intensity of seizures and prevented neuronal damage [9]. Since 1963, the antihypertensive properties of GABA have been observed in animals, including rabbits, dogs, mice, pigs, and cats [10]. In the 1980s, many reports verified that GABA inhibits the activation of the sympathetic nervous system and thereby reduces blood pressure in animals and humans. Wamg et al. indicated that once the GABA content in GABA tea is above 150 mg of GABA per 100 g of made tea, there was a good anti-hypertensive effect [10,11].

The risk of mania, bipolar disorder, anxiety, and depression is increased when the level of GABA content in the blood decreases by 10% to 15% [12]. The GABA content in serum of the human body decreases with age, and GABA supplementation through food intake effectively prevents anxiety, uneasiness, fatigue, and nervousness [13,14]. Natural GABA-rich foods include fermented soybeans, soft-shelled turtles, germinated brown rice, mulberry leaves, fermented milk, and pickled cabbage [15].

GABA tea, a GABA-enriched type of Oolong tea, was devised by Tojiro Tsushida in a 1984 study on prolonging the storage period and freshness of tea leaves [16]. In 1987, the results showed that consuming GABA tea significantly reduced the blood pressure of the participants and animal subjects [17]. This tea soon became commercially available in Japan as a natural health beverage. The Japanese standard for commercialized GABA tea is that it must contain a minimum of 150 mg of GABA per 100 g of dried tea [16]. Studies have demonstrated that drinking 4.0 mg of GABA tea per rat per day can help maintain kidney function as it promotes salt excretion and prevents renal cell injury [18,19]. Studies by Taiwanese and Japanese researchers have shown that GABA tea considerably extends the life expectancy of experimental mice [17,20,21].

The method of GABA tea production was introduced from Japan to Taiwan in 1994. Originally, the production of GABA tea was made by a single anaerobic fermentation process (the tea leaves were under anaerobic conditions for a long period at one time). The long period of anaerobic fermentation caused the tea leaves to have a boring, sour taste and odor [22]. Therefore, this made the GABA tea disliked and unacceptable for Taiwanese consumers. TRES and many tea farmers in Taiwan have established the most suitable method of producing GABA tea, which includes anaerobic treatment three times and aerobic stirring twice. Such a production method will increase the GABA content of GABA tea significantly but will not affect the polyphenol content. The flavor of GABA tea is free from the existing boring, sour taste and odor [10]. GABA tea has found its niche in the Taiwanese tea market because of continuous improvements over the last two decades. Locally produced GABA tea, known as Taiwan GABA tea, is now commercially available and parallels the flavor of Taiwan Oolong tea. In Taiwan, various GABA teas such as GABA Green, GABA Paochong tea, GABA Oolong tea, GABA Puerh tea, and GABA Black tea can be made depending on the level of fermentation (oxidation). In Japan, commercialized GABA tea is treated as a health food, and the quality of the tea product is evaluated based on the GABA content as the main criterion. In order to ensure that the beverage products will sell well, it is important to understand the wants and needs of the consumers [23]. But the results of the tea competition in Taiwan usually affect the quality and price of the tea. The award-winning tea selected by the judges does not reflect that it will be liked and purchased by consumers [24]. The consumer acceptance test is the most appropriate way to understand how consumers feel about food and the willingness of consumers to buy it [25].

Wang et al. found that the tea infusion brewer from GABA tea leaves that met Japanese commercial standards (150 mg of GABA per 100 g of tea leaves) was effective against essential hypertension in mice after 12 weeks of feeding [20], and it was also effective in humans [26]. There are various types of GABA tea produced in Taiwan, each with its unique flavor. However, there has been no survey on whether the commercially available GABA teas meet the Japanese commercialization standards. If the GABA content

of GABA tea does not meet the commercial standards, its health benefits may not be achieved after drinking.

Our laboratory began analyzing the GABA content of Taiwan GABA tea in 2010. This study collected 220 commercially available GABA tea samples across Taiwan from 2016 to 2021. The first aim of this study was to check if the GABA tea sold in Taiwan met the commercial standard and to see if consumers accepted the consumption of functional GABA tea. The second aim was to compare the effects of different production methods, production regions, and harvest seasons on the quality of Taiwan GABA tea. The third aim was to compare the effort of different tea manufacturing processes on the GABA content of GABA tea. It is expected that the result could provide a reference for tea manufacturers.

2. Materials and Methods

2.1. Tea Sample

GABA tea has been sold in Taiwan for nearly 30 years. Scholars and farmers making GABA tea usually follow the Japanese commercialized standard of 150 mg of GABA per 100 g of dried tea, even though Taiwan does not have a national standard for GABA tea. GABA tea that meets commercial standards not only has good physiological effects but also helps in sales [10,22]. Most farmers in Taiwan will voluntarily send their GABA tea for testing to ensure it meets commercial standards. The Laboratory of Functional Food at Hungkuang University has been responsible for the detection of GABA content in GABA tea samples in Taiwan since 2010. The composition analysis project of GABA tea was started in 2016. The project aimed to gain a better understanding of Taiwan GABA tea. After the GABA tea samples were delivered to the laboratory, they were immediately divided into two parts. One part of the tea samples was analyzed for physico-chemical constituents. The other part was vacuum-sealed in aluminum bags and stored in a −80 °C freezer to ensure that the quality of the tea leaves could be maintained at a constant level. Temperature records for the freezer over a 5-year storage period show a range of −80.6 to −82.1 °C. Awaiting the end of the whole project in 2021, it was planned for a total of 16 vacuum-sealed and frozen samples to be randomly selected for consumer testing in 2022.

This project collected 220 GABA tea samples sent by Taiwanese GABA tea manufacturers and sellers for testing GABA content between 2016 and 2021. Thus, the number of different types of GABA tea samples can be seen as the profile of GABA tea sold in Taiwan. The 220 tea samples were categorized into five types of GABA tea depending on the degree of fermentation, including GABA Oolong tea (O), GABA Black tea (B), GABA Paochong tea (P), GABA Green tea (G), and GABA Puerh tea (U). The production area of GABA tea samples is shown in Table 1. The GABA tea samples can be categorized according to the area and season of production. They can be divided into Alishan (A), Nantou (N), Central Taiwan (C), and other places in Taiwan (O) according to the production area. They can be divided into spring tea (S), summer tea (H), fall tea (F), and winter tea (W) according to the production season.

Table 1. The 220 Taiwan GABA tea samples used in this study.

Category	Alishan	Nantou	Central Taiwan	Others
GABA Oolong tea	27 [1]	25	31	25
GABA Black tea	13	18	22	18
GABA Paochong tea	4	9	8	–
GABA Green tea	– [2]	6	3	3
GABA Puerh tea	–	4	–	4

[1] The number of the GABA tea samples; [2] no GABA tea samples were produced in this area.

The manufacturing process of various GABA teas with different degrees of fermentation was organized as shown in Figure 1. Anaerobic treatment of GABA should be completed before frying or drying for green and partially fermented tea or before the drying step for black tea. However, for partially fermented tea, the process of promoting GABA

production is more variable. For example, anaerobic fermentation coupled with aerobic stirring can produce less fermented GABA Paochong tea, while anaerobic fermentation coupled with longer aerobic fermentation can produce more fermented GABA Oolong tea.

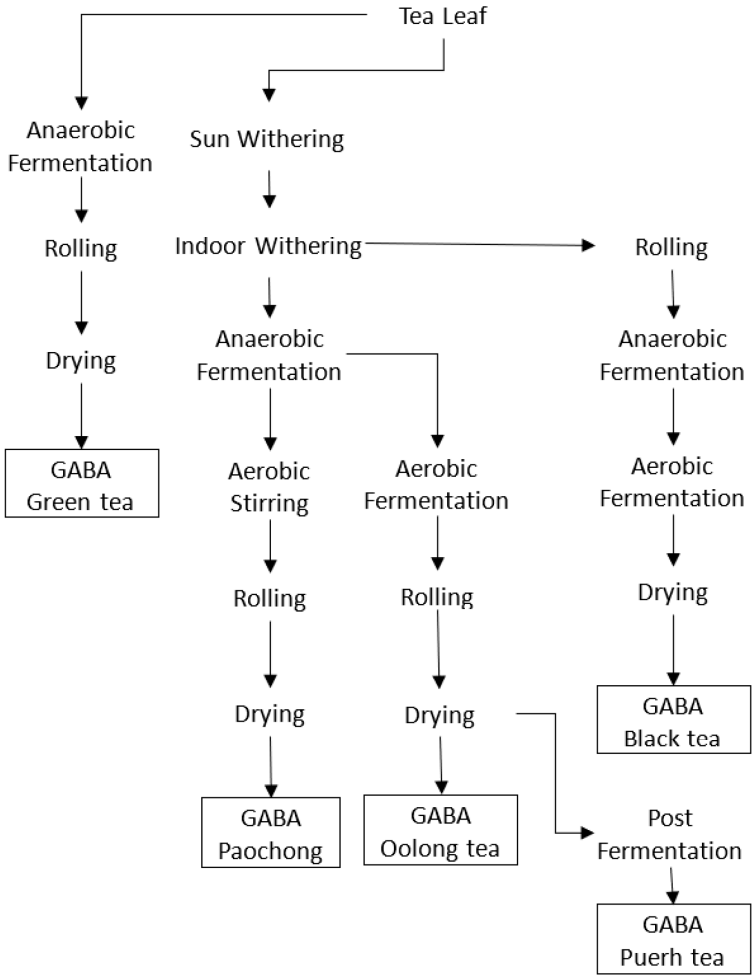

Figure 1. The processing method of different GABA teas.

2.2. The Physico-Chemical Constituents of GABA Tea

2.2.1. GABA Contents

The GABA contents were analyzed by HPLC according to a previous study and modified [27]. The GABA tea samples were extracted with 75 °C boiled water for 1.5 h. The infusion of GABA tea samples was derivatized from phenyl isothiocyanate (PITC). Approximately 120 µL of ethanol-water-triethylamine (2:2:1 $v/v/v$) was added to the residue, dissolved in 180 µL ethanol-water triethylamine-PITC (7:1:1:1 $v/v/v/v$) and kept for 20 min to avoid light. The mobile phase comprised 0.08 M sodium acetate, 0.0029 M triethylamine, and 12.4% acetonitrile. The resultant solution was filtered using a 0.45 µm membrane and analyzed with HPLC. The column was eluted at a flow rate of 0.6 mL/min for 40 min. A sample (20 µL) was injected and detected at a wavelength of 254 nm.

2.2.2. Theaflavin, Thearubigin, and Theabrownin Contents

The theaflavin (TF), thearubigin (TR), and theabrownin (TB) contents were analyzed according to a previous study [28]. A total of 3 g of the GABA tea sample was extracted with 125 mL boiling water for 10 min and filtered. The absorbances of a series of solutions with different reactions were measured using a spectrophotometer of 380 nm. 95% ethanol solution was used as a blank. All analyses were performed in triplicate.

2.2.3. Total Polyphenol Contents

The total polyphenol content (TP) of the GABA tea samples was analyzed by the ferrous tartrate method [10,29]. A calibration curve was prepared, and the results were presented as a percentage of gallic acid equivalents (GAE percent). All analyses were performed in triplicate.

2.2.4. Total Catechin Contents

The total catechin content (TC) of the GABA tea samples was analyzed by Folin–Ciocalteu reagent [29]. A calibration curve was prepared, and the results were presented as a percentage of gallic acid equivalents (GAE percent). All analyses were performed in triplicate.

2.3. Consumer Acceptance of GABA Tea

To understand the consumer acceptability of different types of GABA teas, two samples were randomly selected from each of the six types of GABA teas, including high-GABA and low-GABA content of GABA Oolong tea, GABA Black tea, and GABA Paochong tea, and from each of the two types of GABA teas including GABA Green tea and GABA Puerh tea. The consumer acceptance test was performed with a 9-point hedonic scale with 16 selected GABA tea samples. The questionnaire investigated the acceptability by consumers including the overall liking, the liking of appearance, the liking of flavor, and the liking of aftertaste. In total, 101 volunteer respondents (48 male and 53 female students between the ages of 18–26 years old invited from Hungkuang University) participated in this study. The respondents took part in two rounds of testing, each with eight Taiwan GABA tea samples. All respondents had to sign a consent form, including the purpose and time of evaluation and relevant risks to be borne by the respondents before the test began.

The tea infusions were brewed with 3 g of tea leaf and 150 mL of boiling distilled water for 5 min (strip-type GABA tea) or 6 min (ball-type GABA tea) at a time. As the tasting progressed, the required amount of tea infusion was poured into vacuum bottles and served to the respondents. A total of 30 mL of tea infusion was provided to each respondent; if there was not enough for the respondent, the reserve staff would replenish the tea infusion. In terms of simple consumer acceptance tests, the number of samples that can be evaluated by a tester at one time can be as high as 6–8 [25]. A 30-min break was given to the tasters before the second round of the test. Only tea infusions freshly prepared within 30 min were used for this study.

Before the respondents entered the evaluation environment, the GABA tea samples had been poured into white disposable plastic cups marked by random three-digit numbers. The cups of GABA tea were presented to the respondents by a sequential monadic technique with William Latin square design. Each Latin square consisted of 8 respondents and 8 samples. And the respondents were required to drink the tea according to the order. The respondents were guided to assess the tea samples arrayed in front of them. Before tasting a new sample, the participants had to clean their palates with crackers and pure water. The previous sample could not be retried after evaluation once the next sample was started.

2.4. Statistical Analysis

Consumers' overall liking of the tea infusions averaged from the 9-point hedonic scores was analyzed by one-way ANOVA in conjunction with Tukey's honestly significant difference (HSD) test. Principal component analysis (PCA) was used to simplify the relationship between complex variables and find the relationship between the GABA tea samples and physico-chemical constituents.

3. Results and Discussion

3.1. Commercial Standard for GABA Tea

In this project, 220 Taiwan GABA tea samples were collected from 2016 to 2021. Five types of Taiwan GABA tea were included, which were classified as GABA Oolong tea (ball

type; 108 samples), GABA Black tea (strip and ball type; 71 samples), GABA Paochong tea (strip type; 21 samples), GABA Green tea (strip type; 12 samples), and GABA Puerh tea (strip type; 8 samples). All tea samples were categorized into four different production areas in Taiwan including Alishan (Chiayi County), Nantou County, Central Taiwan (high mountain area in Nantou County and Taichung City), and others (other places in Taiwan outside the above three areas). This revealed that GABA Oolong tea was the most common type of Taiwan GABA tea, followed by GABA Black tea. We found that 87.73% of Taiwan GABA teas met the current commercial standard of 150 mg GABA per 100 g of tea leaves. Approximately 90.87% of GABA Oolong tea samples, 100% of GABA Black tea samples, 57.14% of GABA Paochong tea samples, 33.34% of GABA Green tea samples, and 100% of GABA Puerh tea samples met the standard. Based on the most common forms of Taiwan GABA tea (GABA Oolong and GABA Black tea only), the pass rate of commercially available GABA tea was higher than 90%.

3.2. Physico-Chemical Constituents of GABA Tea

The 220 Taiwan GABA tea samples were analyzed for six physico-chemical constituents: GABA, TF, TR, TB, TP, and TC contents. The results are presented in Appendix A and Table 2. The study of Wu and Ou showed that the GABA contents of GABA tea with aerobic–anaerobic fermentation could increase by 14–104 times [30]. GABA Black tea was the most enriched (247.67 mg/100 g), followed by GABA Oolong tea (182.69 mg/100 g) and GABA Puerh tea (167.23 mg/100 g), while GABA Green tea was the least enriched (120.34 mg/100 g), followed by GABA Paochong tea (158.14 mg/100 g). To increase the GABA level of GABA tea, aerobic fermentation (oxidation) must be combined with anaerobic fermentation during the tea production process. Anaerobic conditions increase the conversion of glutamic acid into GABA and inhibit the effects of GABA aminotransferase [16]. This approach ensures that the GABA formed in the tea does not decompose into succinic semialdehyde. GABA tea is traditionally produced through single anaerobic fermentation which creates a sour taste. Therefore, a repeated aerobic–anaerobic tea fermentation process was created to not only increase the GABA content but also reduce the pungent smell [10]. The original flavors of green and Paochong teas are described as sweet and fresh with a floral aroma [31]. In tea production, green tea undergoes no fermentation, while Paochong tea requires minor fermentation. The aerobic–anaerobic fermentation process is necessary for increasing the GABA content of GABA Green and Paochong tea as well as for preventing a boring flavor [10,22]. If the aerobic–anaerobic fermentation process is overdone, although it will increase the content of GABA, it will affect the original unique taste of green tea and Paochong tea [31]. This explains the low GABA content in commercially available GABA Green and Paochong teas.

Regarding the TF, TR, and TB contents of the various GABA teas, TF content ranged from 0.31–2.73% and TR content ranged from 2.14–8.50%, with the TF and TR contents showing the lowest amount in GABA Green tea and the highest amount in GABA Black tea. The TB content ranged from 1.26–12.94%, with the lowest amount in GABA Green tea and the highest amount in GABA Puerh tea. GABA Black teas are fully fermented and the catechin components polymerize to synthesize TF, TR, and TB, whereas for Puerh tea, which is post-fermented, the long post-fermentation process obviously increases the level of TB. The repeated aerobic–anaerobic fermentation process of the GABA tea samples analyzed in this study caused increases in the TF, TR, and TB contents. In comparison with the results of the study by Zhu et al. (2018), the aggregate tea pigment content of Taiwan GABA Black tea surpassed that of typical black tea [32], while GABA Puerh tea contained more TF and TR than typical Puerh tea [28]. Since the post-fermentation process of GABA Puerh tea differs from that of conventional Puerh tea, the TB produced during the process is less than that of the conventional variety.

Table 2. The physico-chemical constituents of different categories of Taiwan GABA tea.

	GABA (mg/100 g)		TF [2] (%)		TR (%)		TB (%)		TC (%)		TP (%)	
	AVG [1]	Range	AVG	Range	AVG	Range	AVG	Range	AVG	Range	AVG	Range
GABA Oolong tea	182.69 ± 32.56	127.95–285.35	0.62 ± 0.17	0.31–1.15	4.54 ± 0.91	3.05–8.19	8.07 ± 0.92	6.16–9.69	13.83 ± 2.87	12.87–15.88	15.29 ± 0.56	12.33–27.42
GABA black tea	247.67 ± 41.55	181.30–359.75	1.48 ± 0.68	0.46–2.73	5.46 ± 1.43	3.26–8.50	9.79 ± 1.40	7.43–12.94	16.27 ± 1.24	13.75–18.19	12.61 ± 0.80	10.23–15.05
GABA Paochong tea	158.14 ± 26.67	97.05–202.40	0.72 ± 0.22	0.34–1.08	4.39 ± 0.72	3.10–5.54	8.42 ± 0.45	7.59–9.25	14.01 ± 1.14	13.25–14.90	14.03 ± 0.40	12.12–16.30
GABA green tea	120.34 ± 39.89	55.70–173.20	1.53 ± 0.28	1.10–2.10	2.72 ± 0.37	2.14–3.41	2.36 ± 0.48	1.26–3.03	12.06 ± 0.82	11.48–12.60	16.92 ± 0.37	15.69–18.33
GABA Puerh tea	167.23 ± 15.91	140.95–190.25	0.59 ± 0.18	0.40–0.91	4.80 ± 0.64	3.88–5.73	9.50 ± 0.60	8.65–10.42	15.41 ± 1.13	14.49–16.38	16.31 ± 0.63	14.45–18.09

[1] AVG means average. [2] GABA: γ-Aminobutyric acid content; TF: theaflavin content; TR: thearubigin content; TB: theabrownin content; TC: total catechin content; TP: total polyphenol content.

Our results were like those of Liu et al. (2010) in terms of the total tea polyphenols and total catechin contents of different GABA tea [33]. All tea types contained greater levels of total tea polyphenols than total catechins. The TP contents of GABA tea ranged from 10.23–27.42% and were the lowest in GABA Black tea and the highest in GABA Oolong tea. In contrast, the TC contents ranged from 11.448–18.19% but were the lowest in GABA Green tea and the highest in GABA Black tea. Ou et al. (1988) reported that the analytical methods for TP and TC contents had different specificities for different polyphenols [34], which is presumed to be the main reason for the different contents of TC and TP in GABA Black tea and GABA Green tea in this study. GABA Black tea contained higher levels of TP and TC than conventional black tea, which shows that the aerobic–anaerobic fermentation process of GABA tea not only increased the polymerization ability of TF but also kept the TP that is readily eliminated during conventional black tea production. In addition, Wang et al. (2006) found that green tea and GABA tea produced from the same tea seedlings had similar levels of polyphenols [10]. This shows that the polyphenols are maintained during the long fermentation process that is required for GABA tea.

In total, 71 GABA Black and 108 GABA Oolong tea samples were selected from different production seasons and production areas to compare their physico-chemical constituents. In Taiwan, the fresh leaves of tea harvested from the middle of March to the middle of May were called spring tea, those harvested from late May to the middle of August were called summer tea, those harvested from late August to late October were called fall tea, and those harvested from late October to late November were called winter tea. The results are shown in Tables 3 and 4. The GABA Black and Oolong teas produced in the summer and fall were found to contain greater amounts of GABA than those produced in the spring and winter. In general, GABA content was proportional to the amino acid content in the tea leaves, and leaves grown in the spring and winter contain more free amino acids than those of the summer and fall. The tea produced in the summer is usually used in traditional GABA tea production because of its poor flavor. To improve this defect, appropriate fertilization of the summer and fall tea plants can increase the amino acid contents in the leaves. Therefore, of the 179 GABA Oolong and black tea samples collected in this study, those teas produced in the summer and fall contained higher GABA levels. Regarding the tea pigments, the summer and fall teas contained lower amounts of TF and TR and greater quantities of TB than the spring and winter teas. Thus, we found that the repeated aerobic–anaerobic fermentation process of GABA tea production promotes GABA generation and TF and TR conversion into TB. Therefore, the summer and fall teas contained higher levels of GABA and TB than the spring and winter teas. The opposite trend was observed for the TF and TR contents of the GABA tea.

GABA Black, Oolong, and Paochong teas from Alishan and Central Taiwan had higher GABA contents. The Zhushan township, Ren'ai township, Shuili township, and Xinyi township (Yushan) in Nantou County and Lishan in Taichung City are the famous production areas of high-mountain Oolong tea. We define the GABA teas produced in these high-mountain tea-producing areas as Central Taiwan. Alishan and Central Taiwan are high-mountain tea-producing area with a height of over 1500 m. It can be found that the GABA teas produced in Alishan and Central Taiwan have high GABA content because of the high amino acid content of the tea leaves [35]. The other constituents of GABA tea produced from these four areas had varying differences, and there were no distinct trends in these differences. Wu et al. (2022) reported that the sensory quality of GABA tea primarily differs based on the manufacturer rather than being influenced by factors such as production areas and seasons [24]. In this study, it was observed that GABA tea produced in high-mountainous areas had higher GABA content on average. GABA tea from the same production area can have a difference of over 200% in GABA content. This is similar to the results of Wu et al. It can be found that the main factor affecting the GABA content in GABA tea is also the difference in the manufacturer.

Wang et al. (2005) assessed GABA tea that met the commercial standard of 150 mg GABA per 100 g of tea leaves as well as GABA-enriched tea and found that an antihypertensive effect was present when the standard was met, and the efficacy did not increase with the dosage of GABA, even at GABA contents of up to 300 mg/100 g tea leaves [20]. We classified our samples based on the GABA content: greater than 300 mg/100 g (5 samples), 250–300 mg/100 g (39 samples), 200–250 mg/100 g (31 samples), and 150–200 mg/100 g (118 samples); 27 samples failed to meet the standard. We further divided the samples that met the standards into two groups: 75 samples that contained over 200 mg/100 g of GABA and 118 samples that contained 150–200 mg/100 g of GABA.

Because the number of GABA Black tea and GABA Oolong tea samples is relatively large, it was further examined whether the GABA Black tea and GABA Oolong tea differed in terms of physical and chemical components. The results are shown in Table 5.

Among the 71 GABA Black tea samples, the contents of GABA of 55 samples were over 200 mg/100 g tea leaves and those of 16 samples were between 150–200 mg/100 g leaves. Among the 108 GABA Oolong tea samples, the contents of GABA of 19 samples were over 200 mg/100 g tea leaves, those of 79 samples were between 150–200 mg/100 g tea leaves, and those of 10 samples did not meet the 150 mg/100 g standard. GABA Black and Oolong teas contained similar constituents. Summer and fall GABA teas contained greater amounts of TB than those produced during the spring and winter. This result was not observed in the black and Oolong tea samples with low GABA contents. The repeated fermentation process of GABA tea increases the levels of GABA, TF, TR, and TB, improving its taste. Because of the production processes, the increase in the tea pigment levels in GABA tea samples with lower GABA levels was undetectable. No significant differences in physico-chemical composition were found across GABA tea samples from different areas (data not shown) or seasons.

We then performed principal component analysis (PCA) with the six physico-chemical components of the 220 GABA tea samples to determine the relationships between the different GABA teas and their components. The results are shown in Figure 2. From Figure 2, the first principal component explained 51% of the variance, while the second principal component explained 23% of the variance; therefore, in combination, they sufficiently explained the variance and the correlations between the GABA tea samples. In the results of the PCA plot, a positive value of the distribution position of each physico-chemical component on the X-axis or Y-axis means that the component is positively correlated with that principal component, and vice versa. Figure 2 also showed that the first principal component was positively correlated with the GABA, TF, TR, TB, and TC contents and negatively correlated with the TP content. The second principal component was positively correlated with the GABA and TB contents, and negatively correlated with the TF, TR, and TP contents. This corroborates the previous observation in which spring and winter GABA teas contained lower levels of GABA and TB and higher levels of TF and TR.

Table 3. The physico-chemical constituents of Taiwan GABA teas from different seasons.

	Season	No.	GABA (mg/100 g)		TF [2] (%)		TR (%)		TB (%)		TC (%)		TP (%)	
			AVG [1]	Range	AVG	Range	AVG	Range	AVG	Range	AVG	Range	AVG	Range
GABA Oolong tea	S [3]	27	159.14 ± 15.91	127.95–183.80	0.55 ± 0.13	0.33–0.79	5.30 ± 0.99	4.10–8.19	6.98 ± 0.49	6.16–7.88	13.70 ± 3.75	12.88–14.81	16.99 ± 0.52	14.40–26.01
	H	27	203.49 ± 32.30	155.20–279.15	0.74 ± 0.19	0.42–1.15	3.84 ± 0.46	3.13–4.75	8.87 ± 0.55	8.06–9.69	14.04 ± 0.49	12.93–15.88	13.74 ± 0.65	13.08–15.06
	F	27	198.52 ± 36.55	133.00–285.35	0.57 ± 0.12	0.34–0.83	4.59 ± 0.62	3.05–5.54	8.75 ± 0.53	7.49–9.53	13.98 ± 0.98	13.01–15.06	13.90 ± 0.51	12.33–15.83
	W	27	169.59 ± 16.36	129.20–192.75	0.60 ± 0.16	0.31–0.92	4.45 ± 0.83	3.12–6.03	7.68 ± 0.36	7.12–8.27	13.59 ± 3.10	12.87–14.42	16.54 ± 0.46	14.22–27.42
GABA blacktea	S	17	228.78 ± 39.92	181.30–290.25	2.08 ± 0.40	1.52–2.57	6.81 ± 1.05	5.20–8.50	8.76 ± 0.74	7.74–10.18	15.84 ± 0.88	13.75–17.37	13.45 ± 0.80	12.13–15.05
	H	18	266.19 ± 35.99	181.90–315.20	0.90 ± 0.21	0.58–1.24	4.44 ± 0.79	3.38–5.68	10.75 ± 0.75	9.10–12.07	16.65 ± 0.93	14.44–18.16	11.94 ± 0.88	10.23–13.33
	F	17	270.87 ± 38.27	204.40–359.75	0.95 ± 0.24	0.46–1.29	4.34 ± 0.67	3.26–5.70	11.16 ± 0.92	9.25–12.94	16.64 ± 0.90	15.64–18.19	11.47 ± 0.74	10.37–13.72
	W	19	226.24 ± 33.16	181.35–278.15	1.97 ± 0.59	1.08–2.73	6.22 ± 1.18	4.87–8.34	8.56 ± 0.75	7.43–10.19	15.94 ± 0.71	15.00–16.86	13.52 ± 0.39	11.96–14.47
GABA Paochong tea	H	10	165.06 ± 26.96	119.05–202.40	0.60 ± 0.16	0.35–0.84	4.50 ± 0.67	3.42–5.54	8.23 ± 0.49	7.59–9.25	13.91 ± 0.94	13.25–14.59	14.38 ± 0.39	13.08–16.30
	F	11	151.85 ± 26.02	97.05–177.45	0.82 ± 0.22	0.34–1.08	4.29 ± 0.78	3.10–5.23	8.58 ± 0.35	8.10–9.13	14.10 ± 1.26	13.41–14.90	13.72 ± 0.40	12.12–15.68
GABA green tea	H	12	120.34 ± 39.89	55.70–173.20	1.53 ± 0.28	1.10–2.10	2.72 ± 0.37	2.14–3.41	2.36 ± 0.48	1.26–3.03	12.06 ± 0.82	11.48–12.60	16.92 ± 0.37	15.69–18.33
GABA Puerh tea	H	8	167.23 ± 15.91	140.95–190.25	0.59 ± 0.18	0.40–0.91	4.80 ± 0.64	3.88–5.73	9.50 ± 0.60	8.65–10.42	15.41 ± 1.13	14.49–16.38	16.31 ± 0.63	14.45–18.09

[1] AVG means average. [2] GABA: γ-Aminobutyric acid content; TF: theaflavin content; TR: thearubigin content; TB: theabrownin content; TC: total catechin content; TP: total polyphenol content. [3] The different production seasons of GABA teas were spring (S), summer (H), fall (F), and winter (W).

Table 4. The physico-chemical constituents of Taiwan GABA teas from different areas.

	Area	No.	GABA (mg/100 g)		TF [2] (%)		TR (%)		TB (%)		TC (%)		TP (%)	
			AVG [1]	Range	AVG	Range	AVG	Range	AVG	Range	AVG	Range	AVG	Range
GABA Oolong tea	A [3]	27	188.25 ± 36.93	130.00–281.40	0.58 ± 0.15	0.34–0.91	4.34 ± 0.81	3.12–6.17	8.15 ± 0.99	6.45–9.69	13.60 ± 1.06	12.87–15.07	14.85 ± 0.59	13.08–16.43
	N	25	175.67 ± 18.35	129.20–226.45	0.69 ± 0.21	0.33–1.15	4.89 ± 1.16	3.59–8.19	8.13 ± 0.95	6.22–9.45	14.24 ± 3.46	13.62–15.88	15.95 ± 0.48	13.27–27.42
	C	31	185.12 ± 37.52	127.95–285.35	0.60 ± 0.15	0.31–0.93	4.66 ± 0.77	3.05–6.03	7.88 ± 0.82	6.16–9.20	13.65 ± 4.13	12.88–14.68	15.78 ± 0.48	12.33–26.01
	O	25	180.68 ± 32.49	135.90–255.30	0.60 ± 0.15	0.36–0.92	4.28 ± 0.79	3.13–5.68	8.16 ± 0.95	6.77–9.57	13.88 ± 0.86	12.96–15.06	14.50 ± 0.50	13.08–16.10
GABA black tea	A	13	275.53 ± 36.09	210.65–359.75	1.05 ± 0.52	0.46–1.87	5.26 ± 0.93	4.04–7.08	10.88 ± 1.27	8.97–12.94	16.45 ± 1.06	13.75–18.19	13.42 ± 1.34	11.82–15.05
	N	18	241.13 ± 43.59	181.35–315.20	1.66 ± 0.74	0.74–2.54	6.69 ± 1.46	4.51–8.50	9.85 ± 1.32	7.47–12.18	16.30 ± 1.04	15.10–17.91	12.60 ± 0.70	10.83–14.53
	C	22	268.99 ± 19.56	226.70–309.25	1.22 ± 0.37	0.68–1.86	4.80 ± 1.20	3.40–7.08	9.15 ± 1.39	7.43–11.55	16.09 ± 1.09	15.03–17.45	11.82 ± 0.57	10.23–13.39
	O	18	208.01 ± 30.41	181.30–288.90	1.93 ± 0.71	1.10–2.73	5.17 ± 1.24	3.26–7.34	9.71 ± 1.16	8.32–11.45	16.32 ± 1.24	15.00–17.42	13.01 ± 0.63	10.63–14.47
GABA Paochong tea	A	4	169.86 ± 20.53	140.30–187.80	0.64 ± 0.17	0.44–0.84	5.09 ± 0.54	4.34–5.54	7.99 ± 0.44	7.59–8.58	14.10 ± 0.78	13.56–14.59	15.25 ± 0.43	14.51–16.30
	N	9	149.02 ± 35.76	97.05–202.40	0.60 ± 0.19	0.34–0.90	4.45 ± 0.62	3.42–5.23	8.38 ± 0.39	7.88–9.25	13.81 ± 0.92	13.25–14.35	14.35 ± 0.36	13.08–15.68
	C	8	162.54 ± 13.50	142.55–177.45	0.89 ± 0.16	0.65–1.08	3.96 ± 0.64	3.10–4.87	8.67 ± 0.37	8.10–9.13	14.18 ± 0.69	13.74–14.90	13.07 ± 0.37	12.12–14.01
GABA green tea	N	6	121.32 ± 37.59	71.15–164.80	1.45 ± 0.20	1.21–1.72	2.79 ± 0.28	2.28–3.08	2.61 ± 0.34	2.17–3.03	12.26 ± 0.67	11.63–12.60	16.49 ± 0.36	15.69–17.49
	C	3	119.70 ± 59.45	55.70–173.20	1.48 ± 0.34	1.10–1.75	2.44 ± 0.28	2.14–2.69	1.80 ± 0.53	1.26–2.32	11.89 ± 0.66	11.67–12.26	17.60 ± 0.32	17.03–18.33
	O	3	119.03 ± 40.96	76.30–157.95	1.73 ± 0.39	1.32–2.10	2.88 ± 0.56	2.30–3.41	2.43 ± 0.17	2.29–2.63	11.84 ± 0.94	11.48–12.15	17.11 ± 0.33	16.14–18.00
GABA Puerh tea	N	4	167.79 ± 13.04	157.25–186.45	0.49 ± 0.09	0.40–0.60	4.44 ± 0.51	3.88–5.07	9.88 ± 0.58	9.18–10.42	15.21 ± 0.85	14.49–16.38	16.95 ± 0.82	16.14–18.09
	O	4	166.68 ± 20.50	140.95–190.25	0.69 ± 0.19	0.44–0.91	5.15 ± 0.61	4.30–5.73	9.11 ± 0.34	8.65–9.45	15.61 ± 1.09	15.27–16.12	15.67 ± 0.37	14.45–16.97

[1] AVG means average. [2] GABA: γ-Aminobutyric acid content; TF: theaflavin content; TR: thearubigin content; TB: theabrownin content; TC: total catechin content; TP: total polyphenol content. [3] The production areas of GABA tea: Alishan (A), Nantou (N), Central Taiwan (C), and others (O).

Table 5. The physico-chemical constituents of different GABA contents of Taiwan GABA Black and Oolong tea.

	GABA Content	Season	No.	GABA (mg/100 g)		TF [2] (%)		TR (%)		TB (%)		TC (%)		TP (%)	
				AVG [1]	Range	AVG	Range	AVG	Range	AVG	Range	AVG	Range	AVG	Range
GABA Oolong tea	H [3]	H [4]	9	241.92 ± 25.37	205.40–279.15	0.84 ± 0.08	0.75–0.93	4.18 ± 0.43	3.47–4.75	9.06 ± 0.62	8.22–9.69	14.29 ± 0.68	13.55–15.07	13.95 ± 0.51	13.20–15.06
		F	10	237.01 ± 28.27	203.00–285.35	0.64 ± 0.11	0.48–0.83	5.04 ± 0.40	4.15–5.54	8.94 ± 0.41	8.45–9.53	14.15 ± 0.89	13.22–15.06	14.23 ± 0.68	13.08–15.83
	L	S	20	167.09 ± 8.61	154.95–183.80	0.59 ± 0.13	0.33–0.79	5.64 ± 0.91	4.45–8.19	7.14 ± 0.45	6.22–7.88	13.86 ± 3.14	12.99–14.81	16.68 ± 0.48	14.42–25.97
		H	18	184.28 ± 10.97	155.20–196.45	0.69 ± 0.21	0.42–1.15	3.68 ± 0.39	3.13–4.25	8.78 ± 0.50	8.06–9.57	13.92 ± 0.35	12.93–15.88	13.63 ± 0.69	13.08–14.12
		F	16	178.55 ± 11.72	160.25–199.95	0.53 ± 0.11	0.34–0.66	4.30 ± 0.58	3.05–5.15	8.61 ± 0.58	7.49–9.45	13.85 ± 1.03	13.01–14.37	13.74 ± 0.37	12.33–15.46
		W	25	172.55 ± 12.87	155.25–192.75	0.61 ± 0.17	0.31–0.92	4.52 ± 0.82	3.12–6.03	7.71 ± 0.35	7.18–8.27	13.58 ± 3.20	12.87–14.42	16.64 ± 0.48	14.22–27.42
GABA black tea	H	S	10	257.01 ± 25.76	213.60–290.25	1.84 ± 0.35	1.52–2.48	6.69 ± 1.10	5.20–8.50	8.76 ± 0.94	7.74–10.18	15.82 ± 1.11	13.75–17.37	13.55 ± 0.98	12.13–15.05
		H	16	276.43 ± 21.50	236.45–315.20	0.87 ± 0.20	0.58–1.24	4.54 ± 0.78	3.40–5.68	10.78 ± 0.79	9.10–12.07	16.62 ± 0.96	14.44–18.16	11.96 ± 0.92	10.23–13.33
		F	17	270.87 ± 38.27	204.40–359.75	0.95 ± 0.24	0.46–1.29	4.34 ± 0.67	3.26–5.70	11.16 ± 0.92	9.25–12.94	16.64 ± 0.90	15.64–18.19	11.47 ± 0.74	10.37–13.72
		W	12	247.19 ± 21.80	209.80–278.15	1.71 ± 0.58	1.08–2.73	6.10 ± 1.14	5.08–8.34	8.63 ± 0.86	7.43–10.19	16.01 ± 0.62	15.39–16.86	13.44 ± 0.39	12.39–14.45
	L	S	7	188.46 ± 5.59	181.30–199.55	2.41 ± 0.14	2.25–2.57	6.98 ± 1.03	5.25–8.29	8.75 ± 0.37	8.32–9.26	15.88 ± 0.40	15.10–16.51	13.32 ± 0.50	12.98–14.04
		H	2	184.33 ± 3.43	181.90–186.75	1.14 ± 0.04	1.11–1.17	3.67 ± 0.42	3.38–3.97	10.50 ± 0.01	10.49–10.51	16.95 ± 0.97	16.61–17.29	11.80 ± 0.48	11.11–12.48
		W	7	190.34 ± 6.77	181.35–199.35	2.43 ± 0.23	2.09–2.71	6.41 ± 1.31	4.87–8.10	8.46 ± 0.55	7.47–9.20	15.83 ± 0.88	15.00–16.18	13.67 ± 0.39	11.96–14.47

[1] AVG means average. [2] GABA: γ-Aminobutyric acid content; TF: theaflavin content; TR: thearubigin content; TB: theabrownin content; TC: total catechin content; TP: total polyphenol content. [3] The high GABA contents are more than 200 mg/100 g (H), and the low GABA contents are between 150–200 mg/100 g (L). [4] The different production seasons of the GABA teas were spring (S), summer (H), fall (F), and winter (W).

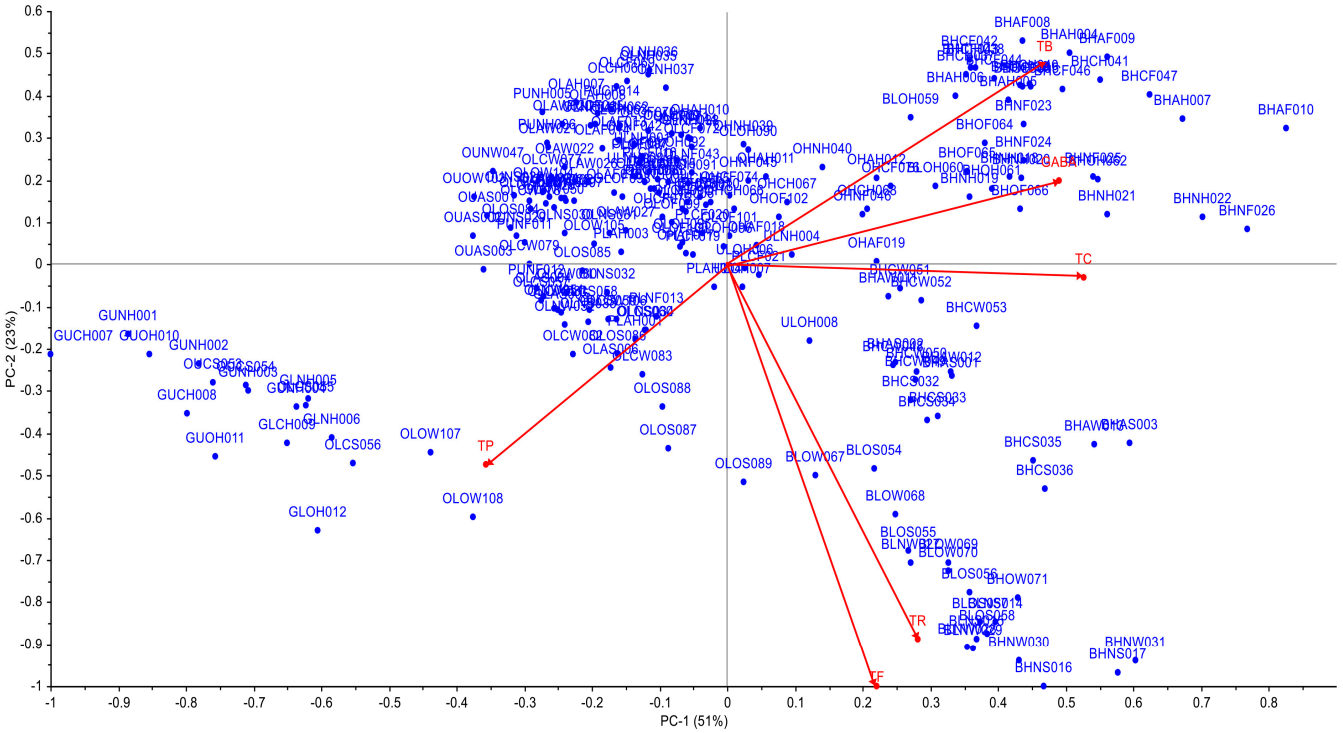

Figure 2. PCA plot of the 220 Taiwan GABA tea samples. Sample codes: the first code means the category of GABA tea: B (GABA Black tea), O (GABA Oolong tea), P (GABA Paochong tea), G (GABA Green tea), and U (GABA Puerh tea); the second code means the GABA contents of GABA tea: H (the GABA content is above 200 mg per 100 g tea), L (the GABA content is between 150 to 200 mg per 100 g tea), and U (the GABA content is below 150 mg per 100 g tea); the third code means the production area of GABA tea: A (Alishan), N (Nantou), C (Central Taiwan), and O (others); the fourth code means the production season of GABA tea: S (spring), H (summer), F (fall), and W (winter); and the final three-digit code means the number of the tea sample from different categories of GABA tea. GABA: γ-Aminobutyric acid content; TF: theaflavin content; TR: thearubigin content; TB: theabrownin content; TC: total catechin content; TP: total polyphenol content.

Figure 2 shows GABA Black tea in the first and fourth quadrants and GABA Green tea in the third quadrant, which shows that they are distinctive from the other tea samples. GABA Oolong and GABA Paochong are mainly in the center of the figure. A few samples of Oolong and green tea that were low in GABA content had similar properties. Based on the PCA comparing different GABA Oolong tea samples (Figure 3a), the first principal component explained 42% of the variance, while the second principal component explained 23% of the variance; in combination, they could explain 65% of the variance, which sufficed to explain the relationships among these samples. Figure 3a shows that the correlations between the GABA, TC, TF, and TB contents were high, but they were negatively correlated with the TP and TR contents. This result meant that GABA Oolong teas with low GABA levels also had lower TC, TF, and TB contents but contained higher TP and TR contents than regular GABA Oolong teas. In GABA Black tea, the first principal component explained 56% of the variance, while the second principal component explained 18% of the variance, with a total explanation for 74% of the variance, which sufficed to explain the relationships among the samples (Figure 3b). Figure 3b shows that the correlations between the GABA, TC, and TB contents were high, but they were negatively correlated with the TP, TF, and TR contents. This result meant that GABA Black tea with high GABA contents had higher TC and TB levels but lower TP, TF, and TR levels than regular GABA Black teas, which is similar to the results of GABA Oolong tea.

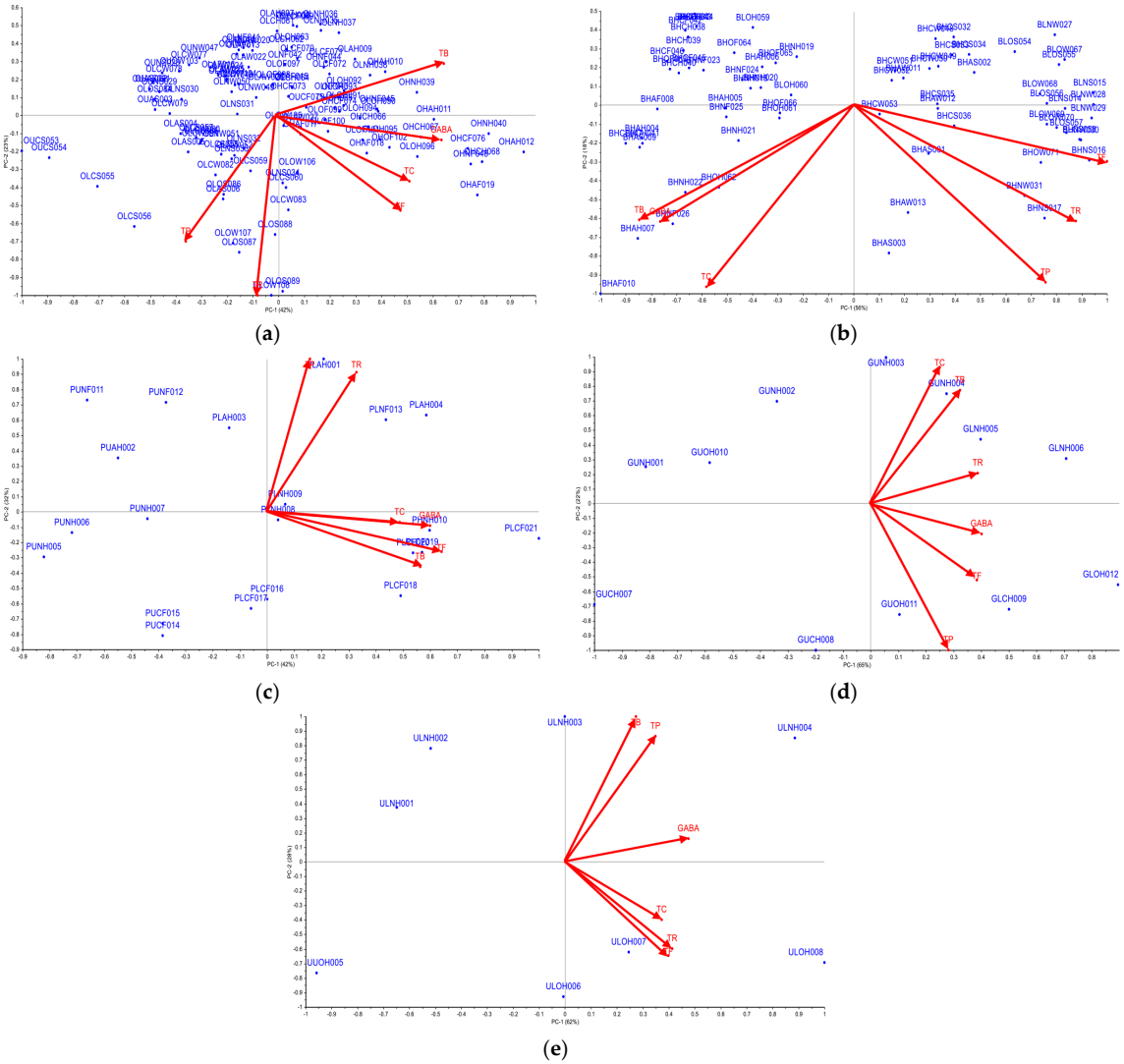

Figure 3. PCA plot of five different Taiwan GABA tea samples. (**a**) GABA Oolong tea, (**b**) GABA Black tea, (**c**) GABA Paochong tea, (**d**) GABA Green tea, (**e**) GABA Puerh tea. Sample codes: the first code means the category of GABA tea: B (GABA Black tea), O (GABA Oolong tea), P (GABA Paochong tea), G (GABA Green tea), and U (GABA Puerh tea); the second code means the GABA contents of GABA tea: H (the GABA content is above 200 mg per 100 g tea), L (the GABA content is between 150 to 200 mg per 100 g tea), and U (the GABA content is below 150 mg per 100 g tea); the third code means the production area of GABA tea: A (Alishan), N (Nantou), C (Central Taiwan), and O (others); the fourth code means the production season of GABA tea: S (spring), H (summer), F (fall), and W (winter); and the final three-digit code means the number of the tea sample from different categories of GABA tea. GABA: γ-Aminobutyric acid content; TF: theaflavin content; TR: thearubigin content; TB: theabrownin content; TC: total catechin content; TP: total polyphenol content.

In terms of the GABA Paochong tea, GABA Green tea, and GABA Puerh tea, the first two components could explain 72%, 87%, and 90% of the variance, respectively. Because of the small number of samples of these three types of GABA tea, it can only be roughly seen that the six main physico-chemical constituents are positively correlated with the first principal constituent, indicating that tea samples with high GABA content have a tendency to have high levels of the other five constituents. The results of the principal component analysis further solidify the previous finding that the repeated aerobic–anaerobic fermentation process of GABA tea increases the GABA and tea pigment contents. The greatest increases occurred with GABA and TB levels, followed by the TF and TR contents.

3.3. Consumer Acceptance of GABA Tea

Finally, we examined consumer acceptance of the GABA teas through the nine-point hedonic scale. We randomly selected two samples of both high and low GABA content from GABA Oolong, black, and Paochong tea to represent the group of high and low GABA content of GABA tea. For GABA Green tea and GABA Puerh tea, because of their low GABA content, two randomly selected tea samples from these two kinds of GABA tea were regarded as the low-GABA-content group. We wanted to compare the consumer acceptability of GABA teas with different GABA content and different types of GABA teas with randomly selected tea samples. The results were showed in Table 6. No clear trend in the acceptance of appearance and aftertaste was seen between the high and low-GABA-content groups in GABA Black tea, GABA Oolong tea, and GABA Paochong tea. However, in terms of flavor, the high-content group is more acceptable than the low-content group. In the overall acceptability, it was also observed that the GABA tea in the high-content group was higher than that in the low-content group. Therefore, it can be hypothesized that the flavor of GABA is an important factor affecting overall acceptability. The study of Huang et al. showed that as long as the GABA content of the GABA tea was over 150 mg per 100 g of tea leaves, it will be effective against the essential hypertension of humans [26]. The results of the animal test by Wang et al. showed that as the GABA content in GABA tea increased, the ability to reduce hypertension did not increase with the contents of GABA [20]. Therefore, these results showed that the GABA Black, Oolong, and Paochong teas with GABA content between 150–200 mg per 100 g of tea leaves had good blood pressure-lowering effects [10] and were preferred by consumers. Consumers do not have to buy GABA tea with higher GABA content. Regarding the five different GABA teas, GABA Green tea was the least accepted, while GABA Black tea was the most preferred. Nonetheless, overall liking ranged from "dislike slightly" to "like moderately", suggesting that different types of GABA teas are accepted by consumers and have potential for marketability [31]. The full fermentation process of black tea and the post-fermentation process of Puerh tea will give the finished tea a sour flavor [35,36]. The light fermentation of Paochong tea gives the finished tea a special floral flavor [35]. These special flavors of these three teas are the same as the floral and acidic flavor produced by the anaerobic process of the original GABA tea [31]. We hypothesize that this is the reason for the higher acceptability of GABA Black tea, GABA Puerh tea, and GABA Paochong tea.

This finding suggests that the anaerobic fermentation process of GABA tea produces a sour taste [10,18], which can be closely combined with the flavor characteristics of black tea [33] to enhance the acceptability of GABA teas by consumers.

Table 6. Consumer acceptance of different Taiwan GABA teas.

Sample	GABA Content	Overall Liking	Liking of Appearance	Liking of Flavor	Liking of Aftertaste
GABA Black tea	H [1]	5.84 ^{a} ± 0.31 [2]	5.97 ^{b} ± 0.30	5.54 ^{b} ± 0.33	5.65 ^{a} ± 0.10
	L	6.31 ^{a} ± 0.33 [3]	6.23 ^{b} ± 0.40	6.43 ^{a} ± 0.42	5.34 ^{ab} ± 0.21
GABA Oolong tea	H	5.13 ^{bc} ± 0.40	6.42 ^{ab} ± 0.37	5.65 ^{b} ± 0.41	5.39 ^{ab} ± 0.14
	L	5.33 ^{b} ± 0.45	6.74 ^{a} ± 0.27	6.13 ^{ab} ± 0.44	5.86 ^{a} ± 0.24
GABA Paochong tea	H	5.36 ^{b} ± 0.42	5.93 ^{b} ± 0.49	5.15 ^{bc} ± 0.25	5.83 ^{a} ± 0.14
	L	5.82 ^{a} ± 0.31	5.71 ^{bc} ± 0.28	6.34 ^{a} ± 0.33	5.75 ^{a} ± 0.11
GABA Green tea	–	4.56 ^{c} ± 0.47	5.32 ^{c} ± 0.34	3.84 ^{d} ± 0.45	4.75 ^{b} ± 0.11
GABA Puerh tea	–	5.84 ^{a} ± 0.34	4.93 ^{c} ± 0.55	4.37 ^{c} ± 0.34	5.33 ^{ab} ± 0.17

[1] The high GABA contents are more than 200 mg/100 g (H), and the low GABA contents are between 150–200 mg/100 g (L). [2] Average of two randomly selected tea samples for five different GABA teas. [3] The average with the same letter for each column were not significantly different at $p > 0.05$.

4. Conclusions

Our laboratory specializes in the GABA contents inspection of Taiwan GABA. Based on our survey and comparison of 220 Taiwan GABA tea samples collected from 2016 to 2021, we found that the most common type of GABA tea on the Taiwanese market was GABA Oolong tea, followed by GABA Black tea. Approximately 87.73% of the tea samples met the current GABA content standard, and this percentage exceeded 90% when only GABA Oolong and black teas were included. The results of physico-chemical constituents analysis revealed that during the anaerobic fermentation process in the production of GABA tea, the GABA content increased and TB increased considerably, while TF and TR increased marginally. Regarding the variation in the GABA contents in teas produced in different seasons, GABA tea samples produced in the summer and fall contained more GABA contents than winter and spring teas in all 220 samples. In terms of consumer acceptance, GABA Black tea was the most popular, followed by GABA Paochong and GABA Oolong tea, while all five types (GABA Oolong, black, Paochong, green, and Puerh tea) of commercially available GABA teas reached the commercialization standard. This shows that the different GABA teas on the market have high commercialization potential. For the production of different GABA teas, the flavor of GABA Black tea and GABA Puerh tea is similar to the original black tea and Puerh tea in terms of acidity, while the flavor of GABA Paochong tea has the floral flavor and aroma of the original Paochong tea. GABA Black tea, GABA Paochong tea, and GABA Puerh tea have higher consumer acceptance. However, on the former Taiwanese market, the most common is still the traditional GABA Oolong tea, only the flavor is becoming more and more varied. And there are more and more kinds of GABA Black tea can be found in the market due to the high consumer acceptance. In conclusion, GABA tea is a promising type of Taiwanese tea that should be promoted for its unique benefits and flavors. The results of this study can also be used as a reference for GABA tea manufacturers.

Author Contributions: Methodology and conceptualization: M.-C.W., B.-K.L. and S.-L.L.; software, analysis, and data curation: M.-C.W., B.-K.L., S.-L.L. and C.-Y.C.; writing and editing—original draft: M.-C.W. and S.-L.L.; investigation: M.-C.W., C.-Y.C. and S.-L.L.; supervision and review: Y.-S.C. and S.-L.L. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The datasets generated for this study are available on request from the corresponding author upon request.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. The Physico-Chemical Constituents of 220 Taiwan GABA Tea Samples.

Sample	GABA (mg/100 g)	TF (%)	TR (%)	TB (%)	TC (%)	TP (%)	Sample	GABA (mg/100 g)	TF (%)	TR (%)	TB (%)	TC (%)	TP (%)
BHAS001 [1]	238.90	1.67	5.20	9.25	16.51	14.70	BLOS056	187.00	2.57	6.58	8.43	16.38	13.05
BHAS002	269.45	1.73	5.49	10.13	13.75	14.50	BLOS057	185.90	2.52	7.07	8.62	16.51	13.72
BHAS003	290.25	1.87	6.38	10.18	17.37	15.05	BLOS058	187.65	2.56	7.34	9.26	16.10	14.04
BHAH004	274.85	0.58	4.05	11.30	17.45	12.02	BLOH059	186.75	1.11	3.38	10.49	16.61	11.11
BHAH005	282.35	0.62	4.70	11.53	15.75	12.81	BLOH060	181.90	1.17	3.97	10.51	17.29	12.48
BHAH006	284.55	0.65	4.69	11.87	14.44	12.97	BHOH061	255.25	1.24	4.17	10.65	16.47	13.05
BHAH007	308.05	0.73	4.87	12.07	18.16	13.28	BHOH062	288.90	1.22	4.31	11.17	17.42	13.33
BHAF008	255.75	0.46	4.04	11.16	17.15	11.82	BHOF063	237.95	1.11	3.26	10.59	17.35	10.63
BHAF009	292.55	0.53	4.70	12.40	16.74	12.18	BHOF064	204.40	1.10	4.14	10.95	16.77	10.84

Table A1. *Cont.*

Sample	GABA (mg/100 g)	TF (%)	TR (%)	TB (%)	TC (%)	TP (%)	Sample	GABA (mg/100 g)	TF (%)	TR (%)	TB (%)	TC (%)	TP (%)
BHAF010	359.75	0.85	5.19	12.94	18.19	13.72	BHOF065	209.65	1.15	4.45	11.45	16.07	11.78
BHAW011	210.65	1.08	5.50	8.97	16.06	13.25	BHOF066	241.35	1.29	4.71	11.44	16.32	12.57
BHAW012	247.20	1.29	6.55	9.50	15.39	13.79	BLOW067	187.25	2.36	4.87	8.58	15.00	14.47
BHAW013	267.65	1.60	7.08	10.19	16.86	14.42	BLOW068	194.00	2.56	5.13	8.49	15.94	14.02
BLNS014	190.30	2.29	7.99	9.07	15.83	13.07	BLOW069	197.55	2.67	5.80	8.90	16.18	14.14
BLNS015	199.55	2.30	8.29	9.07	15.10	13.23	BLOW070	199.35	2.71	5.89	9.20	15.94	14.38
BHNS016	213.60	2.48	8.50	9.08	16.04	13.97	BHOW071	230.45	2.73	6.43	9.23	16.18	14.45
BHNS017	254.50	2.46	8.41	9.23	16.65	14.53	OUAS001	130.00	0.45	4.12	6.45	13.73	14.53
BHNH018	236.45	0.74	5.26	10.12	16.90	11.50	OUAS002	130.90	0.52	4.24	6.65	13.34	15.05
BHNH019	239.45	0.82	5.51	10.47	15.66	11.73	OUAS003	142.40	0.60	4.58	6.54	13.12	15.29
BHNH020	276.85	0.80	5.40	10.51	15.88	11.97	OLAS004	154.95	0.54	5.35	7.08	13.30	15.45
BHNH021	288.30	1.05	5.60	11.03	16.65	12.11	OLAS005	165.45	0.51	5.58	6.88	13.56	15.87
BHNH022	315.20	1.11	5.68	11.13	17.64	11.98	OLAS006	169.85	0.62	6.17	6.86	14.04	16.07
BHNF023	248.95	0.82	4.51	10.33	16.86	10.83	OLAH007	155.20	0.68	3.15	9.13	12.93	13.08
BHNF024	253.25	0.90	5.05	11.12	16.10	11.54	OLAH008	159.55	0.71	3.34	9.37	12.94	13.10
BHNF025	288.25	1.11	5.16	11.91	15.94	11.98	OLAH009	190.25	0.79	3.62	9.53	13.40	13.38
BHNF026	308.95	1.29	5.70	12.18	17.91	12.22	OHAH010	205.40	0.75	3.47	9.50	14.02	14.18
BLNW027	181.35	2.09	7.20	7.47	15.69	11.96	OHAH011	232.95	0.81	4.11	9.68	14.39	15.06
BLNW028	184.55	2.27	8.10	8.24	15.96	13.23	OHAH012	279.15	0.91	4.22	9.69	15.07	14.59
BLNW029	188.30	2.35	7.90	8.33	16.09	13.53	OLAF013	169.70	0.34	4.22	8.08	13.83	13.24
BHNW030	209.80	2.54	7.89	8.82	16.02	13.72	OLAF014	177.50	0.42	4.23	8.33	13.17	13.53
BHNW031	262.70	2.52	8.34	9.25	16.47	13.75	OLAF015	190.20	0.54	4.68	8.59	13.58	13.47
BHCS032	226.70	1.52	6.17	7.88	15.52	12.13	OLAF016	184.90	0.34	5.06	8.24	13.01	13.98
BHCS033	246.35	1.62	6.22	7.74	15.60	12.33	OHAF017	214.30	0.61	5.40	8.47	13.42	14.92
BHCS034	263.50	1.58	6.40	7.78	15.03	12.77	OHAF018	236.30	0.70	5.25	8.45	14.09	14.48
BHCS035	279.90	1.68	7.08	8.10	15.88	12.49	OHAF019	281.40	0.83	5.54	9.24	14.75	15.06
BHCS036	286.90	1.86	7.06	8.28	15.86	13.06	OLAW020	181.10	0.45	3.12	7.62	13.96	15.10
BHCH037	262.35	0.87	3.40	9.10	16.56	10.23	OLAW021	189.35	0.51	3.38	7.58	13.32	15.18
BHCH038	265.80	0.82	3.45	9.50	16.59	10.68	OLAW022	191.45	0.54	3.69	7.87	13.28	15.40
BHCH039	272.00	0.92	3.87	10.52	16.29	10.68	OLAW023	189.05	0.56	4.11	7.88	12.87	15.98
BHCH040	279.55	0.90	3.79	10.47	16.55	11.13	OLAW024	190.50	0.51	4.16	8.06	12.87	16.09
BHCH041	292.95	0.87	3.88	11.13	17.45	11.88	OLAW025	192.75	0.45	4.32	8.13	13.00	16.21
BHCF042	269.25	0.68	3.61	9.25	16.54	10.55	OLAW026	189.05	0.46	3.93	8.15	13.95	16.43
BHCF043	269.80	0.83	3.64	9.79	15.96	10.37	OLAW027	189.10	0.63	4.33	8.08	14.27	16.30
BHCF044	278.30	0.88	3.92	10.50	15.64	10.63	OUNS028	143.75	0.36	4.22	6.77	13.67	14.40
BHCF045	289.85	0.98	3.88	11.06	15.89	11.33	OUNS029	144.85	0.45	4.72	6.88	13.27	14.48
BHCF046	287.60	1.04	3.98	11.14	16.14	10.59	OLNS030	157.45	0.36	5.06	7.22	13.55	14.44
BHCF047	309.25	1.11	3.91	11.55	17.32	11.39	OLNS031	160.65	0.48	4.92	7.63	14.05	14.42
BHCW048	240.45	1.68	5.08	7.43	15.71	12.39	OLNS032	160.05	0.64	5.32	7.55	13.89	15.06
BHCW049	245.60	1.70	5.26	7.76	15.85	12.88	OLNS033	161.05	0.72	5.52	7.47	13.47	15.38
BHCW050	246.70	1.62	5.25	7.43	16.12	12.78	OLNS034	161.05	0.74	5.68	7.88	14.33	15.60
BHCW051	260.40	1.11	5.30	8.12	15.64	13.22	OLNH035	180.65	0.44	3.13	9.05	14.30	13.82
BHCW052	266.50	1.22	5.29	8.25	15.72	13.23	OLNH036	180.90	0.42	3.19	9.38	14.10	13.87
BHCW053	278.15	1.46	5.29	8.58	16.14	13.39	OLNH037	188.75	0.56	3.35	9.57	13.73	13.51
BLOS054	181.30	2.25	5.25	8.32	15.81	12.98	OLNH038	194.25	0.73	3.63	9.35	14.05	13.98
BLOS055	187.55	2.38	6.39	8.53	15.43	13.15	OHNH039	227.55	0.80	3.71	9.47	14.13	14.18
OHNH040 [1]	250.45	0.92	3.87	9.46	14.97	14.33	OLOH095	187.35	1.10	4.13	8.58	13.95	14.12
OLNF041	169.90	0.44	3.57	7.49	13.90	13.08	OLOH096	187.55	1.15	4.14	8.63	14.59	13.91
OLNF042	177.50	0.55	3.87	8.17	13.89	13.24	OLOF097	160.85	0.42	4.33	8.96	14.18	14.37
OLNF043	199.95	0.65	4.20	8.25	14.11	13.28	OLOF098	160.25	0.51	4.65	9.17	13.62	14.88
OHNF044	213.80	0.53	4.15	8.88	13.58	13.63	OLOF099	170.65	0.62	4.76	9.18	14.29	15.23
OHNF045	231.20	0.65	4.63	9.25	13.91	14.24	OLOF100	170.95	0.66	5.10	9.45	14.09	15.46
OHNF046	255.30	0.75	5.09	9.53	15.06	14.40	OLOF101	198.30	0.64	5.15	9.45	14.37	15.40
OUNW047	135.90	0.55	3.38	7.40	13.62	15.05	OHOF102	226.45	0.48	5.17	9.33	15.02	15.83
OLNW048	155.50	0.69	3.58	7.37	13.64	15.18	OUOW103	129.20	0.53	3.59	7.12	13.67	15.53
OLNW049	160.45	0.61	3.76	7.48	14.21	15.41	OLOW104	155.25	0.65	3.59	7.22	13.87	14.65
OLNW050	164.55	0.55	4.07	7.60	13.69	15.47	OLOW105	164.35	0.77	4.23	7.88	14.03	15.56
OLNW051	168.55	0.75	5.16	7.53	13.01	16.05	OLOW106	167.65	0.90	5.08	8.09	13.89	16.28
OLNW052	172.95	0.83	5.24	7.55	12.96	16.10	OLOW107	172.65	0.78	4.97	8.24	14.01	26.70
OUCS053	127.95	0.35	4.10	6.16	12.89	26.01	OLOW108	180.80	0.92	5.55	8.27	14.42	27.42
OUCS054	135.35	0.45	4.17	6.29	12.88	25.37	PLAH001	176.50	0.84	5.40	7.59	14.22	16.30
OLCS055	156.45	0.46	4.51	6.63	13.34	25.97	PUAH002	140.30	0.44	4.34	7.72	14.04	14.51

Table A1. *Cont.*

Sample	GABA (mg/100 g)	TF (%)	TR (%)	TB (%)	TC (%)	TP (%)	Sample	GABA (mg/100 g)	TF (%)	TR (%)	TB (%)	TC (%)	TP (%)
OLCS056	165.75	0.71	5.12	6.72	13.13	25.41	PLAH003	174.85	0.60	5.10	8.09	13.56	14.83
OLCS057	176.75	0.62	5.18	7.12	12.99	16.22	PLAH004	187.80	0.68	5.54	8.58	14.59	15.35
OLCS058	174.90	0.56	5.60	7.53	13.52	16.22	PUNH005	119.05	0.35	3.42	7.88	14.17	13.08
OLCS059	175.45	0.65	5.47	7.42	13.97	16.28	PUNH006	139.85	0.45	3.87	8.26	13.25	13.49
OLCS060	183.80	0.72	5.57	7.66	14.25	16.45	PUNH007	145.30	0.70	4.10	8.03	13.49	13.73
OLCH061	176.90	0.42	3.21	8.08	14.09	13.10	PLNH008	176.95	0.64	4.25	8.42	14.03	13.98
OLCH062	190.45	0.56	3.57	8.34	13.50	13.64	PLNH009	187.55	0.60	4.49	8.54	13.79	14.12
OLCH063	187.45	0.62	3.57	8.59	13.26	13.48	PHNH010	202.40	0.78	4.46	9.25	13.94	14.42
OLCH064	196.45	0.65	4.25	8.06	13.49	13.58	PUNF011	97.05	0.34	5.11	8.21	13.89	15.09
OHCH065	218.20	0.75	4.50	8.22	13.55	13.27	PUNF012	113.00	0.66	5.15	8.41	13.41	15.57
OHCH066	232.30	0.81	4.57	8.25	13.84	13.50	PLNF013	160.00	0.90	5.23	8.41	14.35	15.68
OHCH067	253.55	0.91	4.47	8.46	14.05	13.20	PUCF014	142.55	0.65	3.10	8.10	14.33	12.12
OHCH068	277.70	0.93	4.75	8.83	14.61	13.22	PUCF015	144.00	0.71	3.24	8.39	13.77	12.48
OLCF069	175.65	0.56	3.05	8.27	13.87	12.33	PLCF016	155.70	0.81	3.81	8.50	14.12	12.69
OLCF070	179.30	0.60	3.73	8.11	13.87	12.34	PLCF017	167.75	0.87	3.57	8.42	13.74	12.75
OLCF071	184.25	0.59	4.03	9.09	13.80	12.89	PLCF018	171.25	0.97	4.11	8.89	14.37	13.04
OLCF072	187.00	0.56	4.21	9.02	14.01	13.22	PLCF019	167.50	1.07	4.50	8.99	14.10	13.82
OHCF073	203.00	0.55	5.13	8.53	13.22	13.08	PLCF020	174.15	0.95	4.50	9.00	14.17	13.70
OHCF074	223.00	0.61	4.88	8.54	13.78	13.45	PLCF021	177.45	1.08	4.87	9.13	14.90	14.01
OUCF075	133.00	0.70	4.79	9.04	14.26	13.09	GUNH001	71.15	1.21	2.28	2.17	11.63	15.69
OHCF076	285.35	0.68	5.15	9.20	14.68	13.25	GUNH002	92.65	1.28	2.71	2.36	12.12	15.93
OLCW077	159.90	0.34	4.32	7.41	13.49	14.22	GUNH003	103.85	1.40	2.91	2.64	12.54	16.34
OLCW078	158.20	0.31	4.65	7.18	13.34	14.92	GUNH004	139.45	1.52	2.97	2.50	12.60	16.54
OLCW079	162.50	0.41	5.08	7.19	13.28	16.05	GLNH005	156.00	1.60	2.80	2.95	12.30	16.98
OLCW080	161.40	0.50	5.41	7.43	13.59	15.98	GLNH006	164.80	1.72	3.08	3.03	12.40	17.49
OLCW081	166.80	0.60	5.51	7.48	13.08	16.02	GUCH007	55.70	1.10	2.14	1.26	11.75	17.03
OLCW082	164.65	0.70	5.87	7.48	13.29	16.48	GUCH008	130.20	1.58	2.48	1.83	11.67	17.44
OLCW083	165.35	0.80	6.03	8.10	14.24	16.99	GLCH009	173.20	1.75	2.69	2.32	12.26	18.33
OLOS084	156.05	0.33	4.45	6.22	13.91	15.38	GUOH010	76.30	1.32	2.30	2.29	11.88	16.14
OLOS085	165.60	0.40	5.15	6.51	14.38	15.28	GUOH011	122.85	1.78	2.93	2.39	11.48	17.20
OLOS086	174.20	0.60	6.05	6.57	14.16	15.58	GLOH012	157.95	2.10	3.41	2.63	12.15	18.00
OLOS087	170.30	0.68	7.48	7.13	14.14	16.02	ULNH001	157.25	0.40	3.88	9.18	15.15	16.14
OLOS088	171.85	0.79	6.56	7.33	14.37	16.21	ULNH002	160.75	0.43	4.23	9.65	14.49	16.49
OLOS089	180.10	0.66	8.19	7.49	14.81	16.24	ULNH003	166.70	0.55	4.61	10.27	14.83	17.08
OLOH090	182.05	0.53	4.02	8.33	15.88	13.27	ULNH004	186.45	0.60	5.07	10.42	16.38	18.09
OLOH091	190.20	0.70	4.13	8.45	14.37	13.85	UUOH005	140.95	0.44	4.30	8.65	15.27	14.45
OLOH092	189.75	0.68	3.80	8.55	14.37	14.00	ULOH006	163.25	0.69	5.25	9.11	15.60	15.21
OLOH093	191.75	0.85	3.90	8.63	13.63	14.10	ULOH007	172.25	0.74	5.35	9.24	15.44	16.05
OLOH094	187.55	0.93	4.08	8.48	14.04	13.68	ULOH008	190.25	0.91	5.73	9.45	16.12	16.97

[1] Sample codes: the first code means the category of GABA tea: B (GABA Black tea), O (GABA Oolong tea), P (GABA Paochong tea), G (GABA Green tea), and U (GABA Puerh tea); the second code means the GABA contents of GABA tea: H (the GABA content is above 200 mg per 100 g tea), L (the GABA content is between 150 to 200 mg per 100 g tea), and U (the GABA content is below 150 mg per 100 g tea); the third code means the production area of GABA tea: A (Alishan), N (Nantou), C (Central Taiwan), and O (others); the fourth code means the production season of GABA tea: S (spring), H (summer), F (fall), and W (winter); and the final three-digit code means the number of the tea sample from different categories of GABA tea.

References

1. Wagner, D.A.; Czajkowski, C. Structure and dynamics of the GABA binding pocket: A narrowing cleft that constricts during activation. *J. Neurosci.* **2001**, *21*, 67–74. [CrossRef]
2. Godfrey, K.E.M.; Gardner, A.C.; Kwon, S.; Chea, W.; Muthukumaraswamy, S.D. Differences in excitatory and inhibitory neurotransmitter levels between depressed patients and healthy controls: A systematic review and meta-analysis. *J. Psychiatr. Res.* **2018**, *105*, 33–44. [CrossRef]
3. Watanabe, M.; Maemura, K.; Kanbara, K.; Tamayama, T.; Hayasaki, H. GABA and GABA receptors in the central nervous system and other organs. *Int. Rev. Cytol.* **2002**, *213*, 1–47. [CrossRef]
4. Jolivalt, C.G.; Lee, C.A.; Ramos, K.M.; Calcutt, N.A. Allodynia and hyperalgesia in diabetic rats are mediated by GABA and depletion of spinal potassium-chloride co-transporters. *Pain* **2008**, *140*, 48. [CrossRef]
5. Gottesmann, C. GABA mechanisms and sleep. *Neuroscience* **2002**, *111*, 231–239. [CrossRef]
6. Zhao, W.; Li, Y.; Ma, W.; Ge, Y.; Huang, Y. A study on quality components and sleep-promoting effects of GABA black tea. *Food Funct.* **2015**, *6*, 3393–3398. [CrossRef]

7. Koob, G.F. A Role for GABA in Alcohol Dependence1. In *Advances in Pharmacology*; Academic Press: Cambridge, MA, USA, 2006; Volume 54, pp. 205–229.
8. Powers, M. GABA Supplementation and Growth Hormone Response. *Med. Sport Sci.* **2012**, *59*, 36–46. [CrossRef]
9. Pea, F.; Tapia, R. Seizures and neurodegeneration induced by 4-aminopyridine in rat hippocampus in vivo: Role of glutamate- and GABA-mediated neurotransmission and of ion channels. *Neuroscience* **2000**, *101*, 547–561. [CrossRef]
10. Wang, H.F.; Tsai, Y.S.; Lin, M.L.; Ou, A.S.M. Comparison of bioactive components in GABA tea and green tea produced in Taiwan. *Food Chem.* **2006**, *96*, 648–653. [CrossRef]
11. Shimada, M.; Hasegawa, T.; Nishimura, C.; Kan, H.; Kanno, T.; Nakamura, T.; Matsubayashi, T. Anti-Hypertensive Effect of γ-Aminobutyric Acid (GABA)-Rich Chlorella on High-Normal Blood Pressure and Borderline Hypertension in Placebo-Controlled Double Blind Study. *Clin. Exp. Hypertens.* **2009**, *31*, 342–354. [CrossRef]
12. Bannister, P.; Levy, L.; Bolton, R.; Losowsky, M.S. Acute ethanol ingestion raises plasma gamma amino-butyric acid levels in healthy men. *Alcohol Alcohol.* **1988**, *23*, 45–48. [PubMed]
13. Erdal, J.; Gram, L.; Alving, J.; Löscher, W. Changes in plasma GABA concentration during vigabatrin treatment of epilepsy: A prospective study. *Epilepsy Res.* **1999**, *34*, 145–150. [CrossRef] [PubMed]
14. Hinton, T.; Johnston, G.A.R. GABA-enriched teas as neuro-nutraceuticals. *Neurochem. Int.* **2020**, *141*, 104895. [CrossRef] [PubMed]
15. Garbutt, J.C.; Miller, L.P.; Kramer, G.; Davis, L.L.; Mason, G.A.; Prange, A.J.; Petty, F. Increased serum γ-aminobutyric acid (GABA) levels in young men at high-risk for alcoholism. *Biol. Psychiatry* **1995**, *38*, 704–706. [CrossRef] [PubMed]
16. Tsushida, T.; Mural, T.; Omori, M.; Okamoto, J. Production of a New Type Tea Containing a High Level of γ-Aminobutyric Acid. *Nippon. Nogeikagaku Kaishi* **1987**, *6*, 817–822. [CrossRef]
17. Omori, M.; Yano, T.; Okamoto, J.; Tsushhida, T.; Murai, T.; Higuch, M. Effect of Anaerobically Treated Tea (Gabaron Tea) on Blood Pressure of Spontaneously Hypertensive Rats. *Nippon. Nogeikagaku Kaishi* **1987**, *61*, 1449–1451. [CrossRef]
18. Abe, Y.; Umemura, S.; Sugimoto, K.i.; Hirawa, N.; Kato, Y.; Yokoyama, N.; Yokoyama, T.; Iwai, J.; Ishii, M. Effect of green tea rich in γ-aminobutyric acid on blood pressure of Dahl salt-sensitive rats. *Am. J. Hypertens.* **1995**, *8*, 74–79. [CrossRef]
19. Hakamata, K. Anaerobically treated tea and its hypotensive effects. *Jpn. Agric. Res. Q.* **1990**, *24*, 105–110.
20. Wang, H.F.; Tsai, Y.S.; Lin, M.L.; Ou, A.S.M. Investigation of hypertension moderation and bioactive functions of Taiwan GABA tea by animal test. In Proceedings of the 2005 International Symposium on Innovation in Tea Science and Sustainable Development, Hangzhou, China, 11–15 November 2005.
21. Daglia, M.; Lorenzo, A.D.; Nabavi, S.F.; Sureda, A.; Khanjani, S.; Moghaddam, A.H.; Braidy, N.; Nabavi, S.M. Improvement of Antioxidant Defences and Mood Status by Oral GABA Tea Administration in a Mouse Model of Post-Stroke Depression. *Nutrients* **2017**, *9*, 446. [CrossRef]
22. Tsai, Y.-S.; Juan, I.-M.; Chang, R.-H. Studies on the Manufacturing of GABA tea. *Spec. Issue Agric. Prod. Process. Semin.* **1995**, *56*, 162–178.
23. Mamede, M.E.D.O.; Kalschne, D.L.; Santos, A.P.C.; Benassi, M.D.T. Cajá-flavored drinks: A proposal for mixed flavor beverages and a study of the consumer profile. *Food Sci. Technol.* **2015**, *35*, 143–149. [CrossRef]
24. Wu, M.-C.; Liou, B.-K.; Chen, Y.-S.; Lee, S.-C.; Xie, J.-J.; Jaw, Y.-M.; Liu, S.-L. Understanding Young Taiwanese Consumers' Acceptance, Sensory Profile, and Drivers of Liking for GABA Oolong Tea Beverages with Cold Infusions. *Foods* **2022**, *11*, 2989. [CrossRef] [PubMed]
25. Liou, B.K.; Chuang, G.C.C. *Principles and Practices of Sensory Evaluation of Food*; New Wun Ching Developmental Publishing Co., Ltd.: New Taipei City, Taiwan, 2020.
26. Huang, Y.H.; Zheng, H.F.; Zeng, Z.; Liu, X.L. The manufacturing study and clinical test of GABA tea. *Tea Commun.* **2001**, *4*, 3–5.
27. Rossetti, V.; Lombard, A. Determination of glutamate decarboxylase by high-performance liquid chromatography. *J. Chromatogr. B Biomed. Sci. Appl.* **1996**, *681*, 63–67. [CrossRef]
28. Wang, Q.; Peng, C.; Gong, J. Effects of enzymatic action on the formation of theabrownin during solid state fermentation of Pu-erh tea. *J. Sci. Food Agric.* **2011**, *91*, 2412–2418. [CrossRef]
29. Liu, S.L.; Tsai, Y.S.; Ou, A.S.M. Chemical characteristics and discrimination of different grades of Taiwan high-mountain tea. *Taiwan J. Agric. Chem. Food Sci.* **2008**, *46*, 70–77.
30. Wu, T.Y. *Effects of Different Manufacturing Conditions on the γ-Aminobutyric Acid (GABA) Content of GABA Tea in Taiwan*; National Chung Hsing University: Taichung, Taiwan, 2003.
31. Liou, B.K.; Jaw, Y.M.; Chuang, G.C.C.; Yau, N.N.J.; Zhuang, Z.Y.; Wang, L.F. Important Sensory, Association, and Postprandial Perception Attributes Influencing Young Taiwanese Consumers' Acceptance for Taiwanese Specialty Teas. *Foods* **2020**, *9*, 100. [CrossRef]
32. Zhu, J.Y.; Ni, D.J.; Qu, F.F.; Zeng, W.C.; Chen, Y.Q.; Yu, Z. Research on the Quality Status and technical Improvment of Black Tea in Qinba and Dabie Mountain Area. *Hubei Agric. Sci.* **2018**, *57*, 63–66.
33. Liu, S.L. *Studies on the Rapid Analysis and Classification of Taiwan Oolong Tea by Near Infrared Spectroscopy*; National Chung Hsing University: Taichung, Taiwan, 2010.
34. Ou, A.S.M.; Tsai, Y.-S.; Chang, R.-H. Comparison and evaluation of analytical methods for phenolic compounds of Paochong tea. *Taiwan Tea Res. Bull.* **1988**, *7*, 43–61.

35. Zhang, X.; Du, X.; Li, Y.-z.; Nie, C.-n.; Wang, C.-m.; Bian, J.-l.; Luo, F. Are organic acids really related to the sour taste difference between Chinese black tea and green tea? *Food Sci. Nutr.* **2022**, *10*, 2071–2081. [CrossRef]
36. Ge, Y.; Li, N.; Fu, Y.; Yu, X.; Xiao, Y.; Tang, Z.; Xiao, J.; Wu, J.-L.; Jiang, Z.-H. Deciphering superior quality of Pu-erh tea from thousands of years' old trees based on the chemical profile. *Food Chem.* **2021**, *358*, 129602. [CrossRef] [PubMed]