KOREAN J. FOOD SCI. TECHNOL. Vol. 54, No. 2, pp. 228~234 (2022)
https://doi.org/10.9721/KJFST.2022.54.2.228

KOREAN JOURNAL OF
한국식품과학회지
FOOD SCIENCE AND TECHNOLOGY

Comparison of quality and bioactive components of Korean green, white, and black teas and their associated GABA teas

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Abstract Various types of tea have been cultivated to obtain different flavors and enhance their functional properties. The objective of this study was to investigate the physicochemical properties of γ-aminobutyric acid (GABA) teas produced from commercial Korean green, white, and black teas. The concentration of total minerals was reduced in GABA green tea and GABA white tea but was improved in GABA black tea. The essential, non-essential, and total free amino acid contents were remarkably increased in the GABA teas. The amino acid GABA content was increased by 561.00 and 294.20 times in GABA white tea and GABA black tea, respectively. The antioxidant potential was not reduced, although the total polyphenol and total flavonoid contents decreased in GABA green tea and GABA black tea. The results indicated that the overall nutritional value of commercial green, white, and black teas could be improved by processing them into GABA teas.

Keywords: amino acid, flavonoid, γ-aminobutyric acid tea, mineral, polyphenol

Introduction

An attractive aroma, good taste, and health-promoting effects make tea one of the most popular drinks non-alcoholic drinks worldwide. There are different types of tea products available in the market. They can be grouped into six categories; green tea, yellow tea, white tea, Oolong tea, black tea, and dark tea; based on the processing methods (Hilal, 2017). Green tea, yellow tea, and white tea are subjected to minimal processing; oolong tea and black tea undergo oxidization; and dark tea is fermented. The season, age of the leaf, climate, species, and cultivation practices are the major factors affecting the composition of tea (Lin et al., 1996).

Green tea is prepared by rolling and steaming the leaves to minimize oxidation and inactivate polyphenol oxidase before drying (McKay and Blumberg, 2002). Green teas are rich in polyphenols, including flavanols, flavadiols, flavonoids, and phenolic acids, which account for up to 30% of the dry weight (Hertog et al., 1993). The major flavonoids of green tea are various catechins, such as epicatechin, epigallocatechin, epicatechin-3-gallate, and epigallocatechin-3-gallate (Sano et al., 2001), which are more abundant in green tea than in Oolong or black tea (Vinson, 2000). Studies show that green tea catechins provide some protection against degenerative diseases (Crespy and Williamson, 2004), act as antitumorigenic agents (Roomi et al., 2005), and be effective in preventing oxidative stress and neurological problems (Babu et al., 2006; Unno et al., 2007).

White tea is prepared by plucking the buds or very young leaves, followed by drying with minimal processing in such a way that the delicate white leaf hairs remain intact giving the appearance of 'white tea'. Moreover, the shielded buds have minimal exposure to sunlight and thereby reduced chlorophyll content, giving the tea a white appearance (Alcázar et al., 2007).

The preparation of black tea involves several operations, such as harvesting, withering, rolling, fermentation, and drying (Robertson, 1992). During the fermentation process, the enzymatic oxidation of polyphenols results in the formation of theaflavins and thearubigins, which provide unique color and flavor to black tea (Robertson, 1992; Lin and Liang, 2000). Theaflavins show various health benefits, such as anti-obesity, anticancer, anti-atherosclerotic, anti-inflammatory, antiviral, antibacterial, anti-osteoporotic, and anti-dental caries properties (Takemoto and Takemoto, 2018). Similarly, thearubigins possess several health roles, including antioxidant, antimutagenic and anticancer properties, along with the ability to reduce inflammation and improve gastrointestinal motility (Jt and Je, 2020).

Amino acid γ-aminobutyric acid (GABA) is known to be one of the major inhibitory neurotransmitters and be associated with learning and memory enhancement; stroke and neurodegenerative disease control; anxiety, sedation, and anticonvulsant relief; and muscle relaxation functions (Takahashi et al., 1955; Mody et al., 1994; Oh and Oh, 2004). A large amount of GABA was found accumulated in green tea (Tsushida et al., 1987). Later, they found GABA in all teas, including Oolong and black tea. Due to a

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Received January 15, 2021; revised March 5, 2022;
accepted March 11, 2022

number of health benefits of GABA in experimental animals and humans, GABA teas were produced on a commercial scale (Wang et al., 2006).

Comparative studies of regular teas and their GABA types are lacking. Wang et al. (2006) studied bioactive components in GABA tea and green tea prepared from fresh tea leaves. The objective of this study was to prepare GABA tea from the commercially available green, white, and black teas and to compare the physicochemical properties and bioactive components among them. The finding of this study could be a useful resource to prepare different GABA teas.

Materials and Methods

Chemicals and reagents

Folin-Ciocalteu phenol reagent and 1,1-diphenyl-2-picrylhydrazyl (DPPH), gallic acid, and quercetin were purchased from Sigma-Aldrich (St. Louis, MO, USA). All chemicals and reagents used were of analytical grade. Three commercial dry teas green tea, white tea, and black tea, grown at Hadong-gun, Gyeongsangnam-do, Korea, were purchased from a local store.

Preparation of GABA teas and tea extracts

The GABA teas of commercially available green tea, white tea, and black tea were prepared following the technique described earlier (Wang et al., 2006) with some modifications. The commercial tea samples were separately put into a nitrogen-filled chamber for 8 h and then continuously shaken under environmentally controlled aerobic conditions for 3 h. These two steps were carried out twice, followed by a 5 h anaerobic fermentation.

All six tea samples were extracted with boiling water as described by Choi et al. (2018). The tea extracts were named as follows: GT: commercial green tea (1.5 g) extracted with boiling water (150 mL); GGT: GABA green tea (1.5 g) extracted with boiling water (150 mL); WT: commercial white tea (1.5 g) extracted with boiling water (150 mL); GWT: GABA white tea (1.5 g) extracted with boiling water (150 mL); BT: commercial black tea (1.5 g) extracted with boiling water (150 mL); and GBT: GABA black tea (1.5 g) extracted with boiling water (150 mL).

Color measurement

Hunter's color values of six tea extracts were determined following the methods described by Kim et al. (2014). The L* (lightness), a* (redness, + or greenness, −), and b* (yellowness, + or blueness, −) values of the extracts were determined using a Chroma Meter (CR-300, Minolta Corp., Osaka, Japan). A Minolta calibration plate (YCIE=94.5, XCIE=0.3160, YCIE=0.330) and a Hunter Lab standard plate (L*=97.51, a*= −0.18, b*= +1.67) were used to standardize the instrument using a D65 illuminant.

Determination of mineral composition

A half gram dry tea sample was digested with 15 mL nitric acid (65%) and then an equal volume of distilled water was added to the mixture. The concentration of mineral elements was determined using an inductively coupled plasma atomic emission spectrometer (ICP AES, Varian Vista Inc., Victoria, Australia) following the method described by Skujins (Skujins, 1998).

Determination of free amino acid composition

The free amino acid profile of tea extracts was determined following the procedure described by Je et al. (2005) with some modifications. One milliliter of tea extract was hydrolyzed with 6 N hydrochloric acid (10 mL) in a sealed-vacuum ampoule at 110°C for 24 h. The hydrochloric acid was removed from the hydrolyzed sample mixture using a rotary evaporator. The volume of the condensed mixture was made to 5 mL with 0.2 M sodium citrate buffer (pH 2.2). The reaction mixture was passed through a Sep-Pak C18 cartridge (Waters Co., Milford, MA, USA) and filtered through a 0.22-μm membrane filter (Millipore, Billerica, MA, USA). The amino acid content was measured using an automatic amino acid analyzer (Biochrom-20, Pharmacia Biotech Co., Stockholm, Sweden).

DPPH free radical scavenging activity measurement

The DPPH radical scavenging activity of tea extracts was determined following a technique described earlier (Blois, 1958; Dhungana et al., 2019). One hundred microliters of freshly prepared 0.2 mM ethanolic solution of DPPH and 100 μL tea extracts were mixed in 96-well plates, followed by incubation for 30 min at room temperature under dark conditions. After 30 min of incubation, the absorbance value of reaction mixtures was measured at 517 nm using a microplate spectrophotometer (Multiskan GO, Thermo Fisher Scientific, Vantaa, Finland).

Measurement of total polyphenol content

The total polyphenol content was measured according to the Folin-Ciocalteau method (Singleton et al., 1999) following the procedures described by Dhungana et al. (2016). Tea extracts (50 μL) and 2% (w/v) aqueous sodium carbonate (1 mL) were mixed in 2 mL tubes and left at room temperature for 3 min. Then, 50 μL of 1 N Folin-Ciocalteau reagent was added to the mixture and incubated at room temperature for 30 min under dark conditions. The absorbance value of the reaction mixtures was measured at 750 nm using a microplate spectrophotometer (Multiskan GO, Thermo Fisher Scientific, Vantaa, Finland). The total polyphenol content was determined using the calibration curve drawn with gallic acid (GA) as standard.

Measurement of total flavonoid content

The total flavonoid content of tea extracts was measured following earlier described methods (Zhishen et al., 1999; Dhungana et al., 2016). Tea extracts (100 μL), methanol (500 μL), 10% aluminium chloride (50 μL), 1 M hydrochloric acid (50 μL), and distilled water (300 μL) were mixed in microtubes and left standstill at room temperature for 30 min under dark conditions. Following the 30-min incubation, the absorbance value of the reaction mixtures was measured at 510 nm using a microplate spectrophotometer (Multiskan GO, Thermo Fisher Scientific, Vantaa, Finland). The total flavonoid content was calculated using the standard calibration curve plotted with quercetin (QE).

Statistical analysis

Data were analyzed using analysis of variance in SAS 9.4 (SAS Institute, Cary, NC, USA) and the significant differences between the sample means were determined using the Tukey test at $p<0.05$. The average values of three replicates were reported.

Results and Discussion

Hunter's color value of tea extracts

The Hunter's color values of tea extracts were significantly different in regular teas and their GABA counterparts except for the yellowness value of black tea (Table 1). The lightness value of green tea (88.35) and white tea (87.45) was higher than that of their GABA teas (86.66 and 86.98, respectively). Conversely, the redness and yellowness values of green tea (–3.68 and 20.93) and white tea (–0.34 and 15.82) were lower than that of their GABA teas (5.81 and 55.03; 0.43 and 17.15, respectively). In the case of black tea, GABA black tea had a higher lightness value but a lower redness value.

Similar results of higher redness and yellowness of GABA tea were also found previously (Wang et al., 2006). The difference in fermentation conditions may affect the color of tea infusions (Liang et al., 2003). The higher redness and yellowness of GABA tea might be due to aerobic and anaerobic fermentations (Millin and Rustidge, 1967; Wang et al., 2006). The color change pattern in the black tea and its GABA version was different from that of the other two teas. The reason behind this might be owing to its previous fermentation (Robertson, 1992). Since the color of tea is a key attribute of all kinds of tea, the conversion of teas into GABA tea could enhance their market value.

Table 1. Hunter color values of six tea extracts

Sample[1)]	Color value[2)]		
	L (lightness)	a (redness)	b (yellowness)
GT	88.35±0.12[a3)]	-3.68±0.03[f]	20.93±0.24[c]
GGT	86.66±0.13[d]	5.81±0.06[c]	55.03±0.14[b]
WT	87.45±0.07[b]	-0.34±0.01[e]	15.82±0.32[e]
GWT	86.98±0.08[c]	0.43±0.01[d]	17.15±0.04[d]
BT	58.60±0.19[f]	32.04±0.09[a]	98.38±0.31[a]
GBT	59.05±0.25[e]	30.48±0.09[b]	98.88±0.39[a]

[1)]GT: commercial green tea (1.5 g) extracted with boiling water (150 mL); GGT: GABA green tea (1.5 g) extracted with boiling water (150 mL); WT: commercial white tea (1.5 g) extracted with boiling water (150 mL); GWT: GABA white tea (1.5 g) extracted with boiling water (150 mL); BT: commercial black tea (1.5 g) extracted with boiling water (150 mL); and GBT: GABA black tea (1.5 g) extracted with boiling water (150 mL). All tea samples were extracted for 3 min with shaking for 30 s.
[2)]L: lightness (100, white; 0, black); a: redness (−, green; +, red); b: yellowness (−, blue; +, yellow).
[3)]Values are presented as mean±standard deviation of three replicates. Values followed by different letters in the same column indicate significant difference ($p<0.05$, Tukey test).

Mineral content

As the color change pattern, the total mineral content variation was different in black tea and its GABA version (Table 2). The total mineral content of GT (564.20 mg/kg) and WT (166.83 mg/kg) was reduced to 434.91 and 139.02 mg/kg in GGT and GWT, respectively. However, 325.33 mg/kg found in BT was increased to 442.44 mg/kg in GBT. Individual mineral elements also varied in different GABA teas. In GGT, the concentration of Ca and Na was higher while that of K, Mg, and Zn was lower than that in GT. In GWT, none of the minerals was significantly increased as compared to WT. Other than Cu, the concentration of all the mineral elements was significantly higher in GBT than in BT. Heavy metals like As, Cd, Hg, and Pb were not detected in the tea extracts.

Table 2. Mineral content (mg/kg) of six tea extracts

Element	Sample[1)]					
	GT	GGT	WT	GWT	BT	GBT
K	511.17±7.27[a2)]	377.35±5.78[b]	136.96±0.33[e]	109.98±1.65[f]	256.88±2.25[d]	352.22±5.77[c]
Ca	13.33±0.01[c]	14.59±0.13[a]	12.27±0.33[d]	12.53±0.27[d]	14.18±0.13[b]	12.49±0.30[d]
Na	10.34±0.13[e]	14.83±0.21[c]	10.82±0.02[d]	10.92±0.13[d]	38.45±0.29[b]	59.90±0.85[a]
Mg	28.08±0.19[a]	27.33±0.50[b]	6.40±0.01[e]	5.25±0.06[f]	14.76±0.09[d]	17.11±0.35[c]
Cu	0.23±0.01[b]	0.24±0.01[ab]	0.15±0.01[c]	0.15±0.01[c]	0.25±0.01[ab]	0.26±0.01[a]
Zn	1.05±0.01[a]	0.57±0.01[c]	0.23±0.01[e]	0.19±0.01[f]	0.51±0.01[d]	0.66±0.01[b]
As	ND	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	ND	ND
Hg	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND	ND
Total	564.20	434.91	166.83	139.02	325.33	442.44

[1)]Samples are defined in Table 1.
[2)]Values are presented as mean±standard deviation of three replicates. Values followed by different letters in the same row indicate significant difference ($p<0.05$, Tukey test).
[3)]Non-detectable.

Table 3. Free amino acid composition (mg/g) of six tea extracts

Amino acid	Sample[1)]					
	GT	GGT	WT	GWT	BT	GBT
Essential amino acid						
L-Threonine	0.18±0.01[b2)]	0.25±0.01[a]	0.05±0.01[d]	0.19±0.01[b]	0.09±0.01[c]	0.28±0.02[a]
L-Valine	0.32±0.02[b]	0.44±0.02[a]	0.31±0.02[b]	0.08±0.02[d]	0.22±0.02[c]	0.35±0.01[b]
L-Methionine	ND[3)]	ND	ND	ND	ND	ND
L-Isoleucine	0.20±0.01[c]	0.28±0.01[b]	0.17±0.03[d]	0.43±0.03[a]	0.15±0.01[d]	0.20±0.01[c]
L-Leucine	0.24±0.04[b]	0.34±0.02[a]	0.05±0.01[d]	0.17±0.01[c]	0.16±0.02[c]	0.21±0.01[b]
L-Phenylalanine	0.51±0.02[b]	0.58±0.02[a]	0.15±0.01[d]	0.36±0.02[c]	0.38±0.03[c]	0.21±0.02[d]
L-Lysine	0.46±0.03[b]	0.56±0.01[a]	0.03±0.02[f]	0.13±0.01[d]	0.08±0.01[e]	0.18±0.01[c]
L-Histidine	0.08±0.02[b]	0.11±0.01[a]	ND	0.04±0.01[c]	ND	0.04±0.01[c]
Sub-Total	1.99	2.56	0.76	1.40	1.08	1.47
Non-essential amino acid						
L-Aspartic acid	2.30±0.02[b]	2.66±0.02[a]	0.16±0.02[d]	0.33±0.02[c]	0.36±0.02[c]	0.36±0.02[c]
L-Serine	0.32±0.01[b]	0.61±0.03[a]	0.09±0.03[f]	0.28±0.03[c]	0.19±0.01[e]	0.23±0.01[d]
L-Glutamic acid	0.41±0.04[e]	2.12±0.05[a]	0.19±0.01[f]	0.74±0.04[b]	0.69±0.02[c]	0.54±0.02[d]
Glycine	0.02±0.01[b]	0.02±0.01[b]	0.01±0.01[b]	0.03±0.01[b]	0.01±0.01[b]	0.09±0.01[a]
L-Alanine	0.27±0.01[c]	0.38±0.02[b]	0.09±0.01[e]	0.27±0.01[c]	0.17±0.02[d]	0.46±0.02[a]
L-Tyrosine	0.40±0.02[a]	0.46±0.03[a]	0.07±0.02[e]	0.16±0.02[d]	0.21±0.01[c]	0.26±0.01[b]
L-Arginine	1.12±0.01[b]	1.45±0.05[a]	0.01±0.01[e]	0.06±0.01[d]	0.05±0.01[d]	0.16±0.01[c]
Proline	0.27±0.01[b]	0.37±0.01[a]	0.07±0.02[d]	0.28±0.01[b]	0.14±0.01[c]	0.26±0.02[b]
Sub-Total	5.11	8.07	0.69	2.15	1.82	2.36
Other free amino acid						
Cystathionine	ND	ND	ND	0.02±0.01[b]	0.09±0.01[a]	ND
?, L-b-Aminoisobutyric acid	0.09±0.01[a]	0.09±0.01[a]	0.01±0.01[b]	ND	0.01±0.01[b]	0.03±0.01[b]
Ethanolamine	0.02±0.01[b]	ND	0.02±0.01[b]	0.04±0.01[b]	0.03±0.01[b]	0.09±0.01[a]
Ammonia	0.14±0.02[c]	0.08±0.02[d]	0.05±0.02[d]	0.09±0.02[d]	0.23±0.02[a]	0.18±0.01[b]
Hydroxy lysine	ND	ND	ND	ND	ND	ND
L-Citrulline	ND	ND	ND	0.01±0.01	ND	ND
L-Cystine	ND	ND	ND	ND	ND	ND
L-Ornithine	0.04±0.01[c]	0.02±0.01[c]	ND	0.05±0.01[b]	ND	0.19±0.02
L-Sarcosine	15.51±2.12[b]	17.31±2.35[b]	5.42±0.19[d]	10.39±2.11[c]	9.09±0.58[c]	23.47±2.23[a]
L-a-Amino adipic acid	ND	ND	ND	0.02±0.01[b]	ND	0.04±0.01[a]
L-α-Amino-n-butylric acid	ND	ND	ND	0.02±0.01[a]	ND	0.04±0.01[a]
O-Phospho-L-serine	0.38±0.01[b]	0.36±0.01[c]	0.08±0.02[d]	ND	0.40±0.02[a]	ND
Taurine	ND	ND	ND	ND	ND	ND
β-Alanine	0.07±0.01[a]	0.07±0.02[a]	0.02±0.01[b]	0.03±0.01[b]	0.03±0.01[b]	0.07±0.02[a]
γ-Amino-n-butyric acid	0.07±0.01[d]	0.10±0.03[c]	0.02±0.01[f]	11.22±1.33[b]	0.05±0.01[e]	14.71±1.33[a]
Sub-Total	16.32	18.03	5.62	21.89	9.93	38.82
Total	23.42	28.66	7.07	25.44	12.83	42.65

[1)]Samples are defined in Table 1.
[2)]Values are presented as mean±standard deviation of three replicates. Values followed by different letters in the same row indicate significant difference ($p<0.05$, Tukey test).
[3)]Non-detectable.

Table 4. DPPH free radical scavenging activity and total polyphenol and total flavonoid contents of six tea extracts

Antioxidant	Sample[1)]					
	GT	GGT	WT	GWT	BT	GBT
DPPH[2)] (% Inhibition)	92.11±0.72[a5)]	93.22±0.83[a]	86.57±1.32[b]	86.57±0.81[b]	93.93±1.38[a]	91.96±0.73[a]
Total polyphenol (mg GAE[3)]/mL)	19.38±0.43[a]	12.73±0.42[d]	4.45±0.08[e]	4.65±0.06[e]	16.15±0.08[b]	13.52±0.04[c]
Total flavonoid (mg QE[4)]/mL)	37.45±1.59[a]	22.74±0.74[d]	12.45±0.62[e]	13.34±1.00[e]	33.39±1.70[b]	27.41±1.09[c]

[1)]Samples are defined in Table 1. [2)]DPPH: 1.1-Dipheny1-2-picry1hydrazy1. [3)]Gallic acid equivalent. [4)]Quercetin equivalent. [5)]Values are means±SD of duplicate measurements. Values followed by different superscript letters in the same column are significantly different (p<0.05, Tukey test).

Although the reason was not clear, the total mineral content of GBT was interestingly increased while it was reduced in GGT and GWT. A similar pattern of results for Ca content was found in a previous study (Hazra et al., 2017), however, the results varied for other minerals. The discrepancies might be due to the variation in the season, age of the leaf, climate, species, and cultivation practices that substantially affect the composition of tea (Lin et al., 1996). Similar results of higher Zn, and Mg but lower Cu content was found in green tea than in black tea (Shen and Chen, 2008). The concentration of Na was also significantly higher in black tea than in green tea (Ramdani et al., 2013) as found in the present study. Various minerals play different roles in the human body. Na helps maintain body fluid levels and is essential for healthy heart, liver, and kidneys (Munteanu and Iliuţă, 2011). Mg, K, and Ca contribute to minimizing the risk of hypertension (Houston and Harper, 2008). Different GABA teas had increased levels of various minerals, implying a potential scope of GABA tea production.

Free amino acid content

The essential, non-essential, and total free amino acid contents of GABA teas were higher than those of the commercial regular green tea, white tea, and black tea (Table 3). Interestingly, an essential amino acid histidine was detected in the GABA teas of white and black tea but not in WT and BT. The essential amino acid content was increased by 28.64, 84.21, and 36.11%, in the GABA version than in the regular green tea, white tea, and black tea. Similarly, the total amino acid content of GGT, GWT, and GBT was 22.37, 259.83, and 232.42% higher than that of GT, WT, and BT, respectively. As per the name implied, the GABA content of GWT and GBT was remarkably increased by 561.00 and 294.20 times, respectively.

The higher amino acid GABA content in GABA teas could be result of anaerobic fermentation (Tsushida et al., 1987). Similar results of higher concentrations of many amino acids were found in GABA tea (Wang et al., 2006). The reason for the lower increment in GABA content in GGT compared to the other two tea samples GWT and GBT was unknown. Essential amino acids are not synthesized in the human body. They need to be supplied through diet. Various amino acids have different functions in the human body. Proline, which was increased in all three GABA teas, has role regulatory functions that are vital for maintenance, growth, reproduction, and immunity (Wu, 2009). GABA is supposed to enhance brain functions and also contributes to improving the blood cholesterol level, blood pressure, cerebral blood flow as well as against diabetes, insomnia, depression, and pain (Dhakal et al., 2012; Nikmaram et al., 2017). GABA is useful for enhancing learning and memory, against stroke and neuro-degenerative diseases; relieving anxiety, sedation, anticonvulsant, and muscle relaxation functions (Krogsgaard-Larsen, 1989; Mody et al., 1994; Oh and Oh, 2004). The increased amino acid content in GABA teas offers a good option of producing GABA teas from regular green, white, and black teas.

Antioxidant activity of blended tea

The DPPH free radical scavenging activity of regular green tea, white tea, black tea, and their GABA versions was not significantly different (Table 4). On the other hand, the total polyphenol and total flavonoid contents were significantly equal in GABA white tea but reduced in GABA green and GABA black teas (Table 4).

The higher polyphenol content in the commercial green tea than in black tea and white tea found in the present study was in agreement with previous studies (Rusak et al., 2008; Widowati et al., 2015; Zhao et al., 2019). Similarly, in another study, the total polyphenolic compound content was slightly lower in the GABA tea as compared to green tea (Wang et al., 2006) as found in the present study. The lower polyphenolic content in the GABA teas might be due to the extended fermentation by polyphenol oxidases (Atoui et al., 2005). Although the amount of total polyphenol and total flavonoid was significantly reduced in the GABA green tea and GABA black tea, the antioxidant potential measured through the DPPH free radical scavenging activity was not reduced. The overall antioxidant potential of food is an outcome of the interaction of a number of factors, such as the partitioning properties of particular antioxidants, oxidation conditions, and the physical state of the oxidizable substrate (Frankel and Meyer, 2000). Moreover, food materials contain several antioxidants, including polyphenols and flavonoids. So, a visible decrease in the amount of total polyphenol and/or total flavonoid may not always result in reduced antioxidant potentials as found in the present study.

Conclusion

The quality and bioactive components of Korean green tea, white tea, and black tea and their GABA teas were evaluated. Hunter's color value was affected by processing the green, white, and black teas to GABA teas. The total mineral content was decreased in GABA green tea and GABA white tea, however, was increased in GABA black tea. The concentration of essential, non-

essential, and total free amino acids was substantially improved in GABA teas. Amino acid GABA content of GABA white tea and GABA black tea was remarkably increased by 561.00 and 294.20 times, respectively. Although the total polyphenol and total flavonoid content were reduced in GABA green tea and GABA black tea, the antioxidant potential measured through DPPH free radical scavenging activity was not decreased. Overall results suggest that the nutritional value of commercial green tea, white tea, and black tea could be improved by processing them to GABA tea.

Conflicts of Interest

The authors declare no conflict of interest.

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