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로스팅 조건에 따른 백삼의 일반 성분, 항산화 활성 및 진세노사이드 함량 변화

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Change of Proximate Composition, Antioxidant Activity, and Ginsenoside Content of White Ginseng with Different Roasting Conditions

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ABSTRACT

Background: The purpose of this study was to evaluate roasting conditions to optimize the physicochemical properties of ginseng to improve its utilization as a food material.
Methods and Results: Roasting was performed at different temperatures (140, 160, 180, and 200°C) and times (10, 20, and 30 min). The total phenolic content of ginseng powder was greatly between 160°C for 20 and 200°C for 10 min achieving a 7-fold increase (22.92 ㎎·gallic acid equivalents/g) compared to that of the control. As the roasting temperature and time were increased, the 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activities of ginseng powder were significantly increased. The total ginsenoside content was decreased with increasing treatment time at a roasting temperature of 180°C - 200°C. The maximum total ginsenoside content (9.25 ㎎/g) was obtained at 180°C for 10 min, however, there was no significant difference compared to that of the control. The panaxatriol Rh1 content was increased as the roasting level was increased. Overall, this study demonstrated physicochemical changes in 4-year-old ginseng roots according to the roasting conditions.
Conclusions: We suggest the optimal roasting conditions of 160°C for 30 min or 180°C for 10 min to minimize the reduction in total ginsenosides, yield, and proximate composition and maximize the polyphenol content and antioxidant activity.

Key Words: *Panax ginseng* C. A. Meyer, Antioxidant Activity, Functional Foods, Ginsenoside, Roasting

INTRODUCTION

Ginseng (*Panax ginseng* C. A. Meyer) is a medicinal plant of the Araliaceae family that has been used in traditional medicine in East Asia for thousands of years (Zhuravlev *et al.*, 2008).

Various pharmacological effects have been attributed to the saponin (ginsenoside) and non-saponin components of ginseng, including anticancer, anti-oxidant, and blood circulation, enhanced immunity, and decreased cholesterol absorption (Yun, 2001; Hong *et al.*, 2016; So *et al.*, 2018). While these effects have favored the use of ginseng as a material for medicine and

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functional foods, recent efforts have focused on its direct use as a food material.

The moisture content of ginseng roots is greater than 75%, making long-term storage difficult due to a tendency to rot. A variety of processing techniques, such as steaming, heating, and fermentation, have been explored to extend the shelf life of fresh ginseng, as well as to facilitate the absorption of its active ingredients, including ginsenosides.

Therefore, the majority of ginseng, including red and white, are consumed as processed materials (76.1%), with the remainder (23.9%) consumed as fresh ginseng, both domestically and abroad (MAFRA, 2019). However, since ginseng has generally been used as a raw material for functional foods rather than as a food material, the techniques used for its processing are limited when compared to other food materials.

The components of food vary widely depending on the method of processing. Heating can alter food components to increase their bioactivity, as well as enhance the palatability of the food itself.

Roasting is a processing method that involves heating foods for a short time with dry heat (≥ 150℃) and has primarily been used for meat, coffee, cocoa, and barley tea (Park *et al*., 1993). Roasting leads to both physical (e.g., starch gelatinization, protein denaturation, cell wall destruction) and chemical (e.g., browning reaction, release of internal substances) changes, which can have a positive effect on sensory quality factors, such as color and aroma. In particular, roasting temperatures above 180℃ - 200℃ affect physiological activity by changing food components via the Maillard reaction and through the decomposition of organic compounds by pyrolysis (Czerny *et al*., 1999; Daglia *et al*., 2000).

However, excessive heat can also lead to the reduction of biologically active substances, the incomplete combustion of nutrients, or the production of dangerous compounds (Nicoli *et al*., 1997; del Castillo *et al*., 2002; Jin *et al*., 2012). For this reason, both the roasting temperature and time play key roles in the taste and chemical components of food materials.

As for roasting studies, many have been reported on physicochemical properties, antioxidant activity and sensory characteristics of coffee and tea (Kim *et al*., 2019). Recently, It has been reported that antioxidant activity and antidiabetic properties of mixed tea with roasted mulberry leaves and peppermint leaves (Lee and Kim, 2020). The extraction yield of physiologically active substances such as β-glucan, catechin, and tocopherol of barley varies according to the method of roasting. It has been reported that antioxidant characteristics of roasted maize according to cultivation period and variety (Lee *et al*., 2018). Studies were also reported to analyze the physicochemical properties of medicinal crops such as schisandra, chicory, and cassia seed by roasting (Kim *et al*., 1995; Kim *et al*., 1998; Mok *et al*., 2001).

In case of ginseng, it has been reported that when ginseng is roasted, changes and dissolution of ginsenoside components occur easily. The content of water-soluble solids also increases, resulting in changes in various components and increasing physiological activity (Seong *et al*., 2018).

Roasting methods include direct fire, hot air and semi-hot air. Among these, the hot air method is that delivers high-temperature air directly to the inside of the drum. The advantage is that it can be roasted uniformly and in a short time, so it is a method widely used in coffee roasting.

As mentioned above, roasting can enhance the active ingredients and improve taste and aroma of ginseng. Therefore, it was attempted to apply the most popular roasting method to ginseng to use a more diverse material. In addition, this study sought to determine the optimal roasting temperature and time for 4-year-old ginseng to further the use of ginseng as a food material. This was achieved by analyzing the physicochemical changes, antioxidant activities, and active ingredients of ginseng powder and extract roasted using the general methods applied to other foods.

MATERIALS AND METHODS

1. Plant materials

Four-year-old ginseng (*Panax ginseng* C. A. Meyer) roots were obtained at Goesan (36.65°39′09″N/127°46′18″E), Republic of Korea. The average root weight and diameter of the fresh ginseng was 30.02 g and 19.38 ㎜, respectively.

2. Sample preparation

Ginseng roots were washed and separated into main and fine roots. The main roots were dried for 16 h at 60℃ using a hot air dryer (DY-220HR, Lassele, Ansan, Korea).

After drying, the roots were roasted at different temperatures (140, 160, 180, 200℃) and times (10, 20, 30 min) using a hot-air rotary roaster (CBR-101, Gene Café, Ansan, Korea). This roaster was capable of uniformly roasting up to 250 g of coffee beans. In this experiment, 80 - 100 g of hot-air dried

and sliced ginseng root was added and performed three times.

Dried and roasted ginseng roots were pulverized using a blender (SFM-555SP, Shinil Industrial Co., Ltd., Seoul, Korea). Ginseng powder with a particle size of less than 500 ㎛ was used.

3. Sample extraction

Ginseng powder (1 g) was suspended in 80% MeOH (15 ㎖) and extracted by sonication for 1 h at room temperature (24℃) in an ultrasonic bath (WUC-D22H, DAIHAN Scientific Co., Ltd., Wonju, Korea).

The resultant extract was then collected by centrifugal separation (2,000 g, 24℃, 7 min). This process was repeated twice to obtain a final extract volume of approximately 30 ㎖.

4. Measurement of hunter's color value and browning color

Hunter's color value of the dried and roasted ginseng powders was measured using the L^*, a^*, and b^* (L^* : lightness, a^* : red/green, b^* : yellow/blue) by a colorimeter (CM-5, Konica minolta Inc., Osaka, Japan).

Browning color of the extracted samples was measured at 420 ㎚ using a UV spectrophotometer (MULTISKAN GO, Thermo Fisher Scientific Inc., Waltham, MA, USA).

5. Proximate analysis

Proximate analysis was performed in accordance with the National Institute of Agricultural Sciences and Technology (NIAST) research analysis criteria for food quality characteristics (NIAST, 2012).

Moisture content was determined by drying the samples in an oven at 105℃ to a constant weight. Crude protein content was determined using the Kjeldahl method. Crude fat content was determined with diethyl ether for 8 hours using a Soxhlet apparatus. Ash content was determined by incinerating the samples at 550℃. Carbohydrate content was calculated by subtracting the crude protein, crude fat, ash, and moisture contents from 100. The results were expressed as g/100 g fresh weight (FW).

6. Analysis of total phenolic content

The total phenolic content (TPC) was determined by modifying the Folin-Ciocalteu method (Folin and Denis, 1912). Briefly, ginseng extract (50 ㎕) was reacted with 2% Na_2CO_3 solution (1 ㎖) for 3 min and then treated with 50% Folin-Ciocalteu's phenol solution (50 ㎕) for 30 min at room temperature.

The absorbance of the mixture at 750 ㎚ was measured using a UV spectrophotometer (MULTISKANGO, Thermo Fisher Scientific Inc., Waltham, MA, USA). Gallic acid (GA, Sigma-Aldrich Co., St. Louis, MO, USA) was used as the reference standard, and the results were expressed as mg GA equivalents in 1 g of dried sample (㎎·GAE/g dry weight).

7. Antioxidant activity assays

ABTS (2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulfonic-acid) radical scavenging activity was measured by modifying the method of Re et al. (1999). A solution of 7.4 mM ABTS (Sigma-Aldrich Co., St. Louis, MO, USA) and 2.6 mM potassium persulfate was stored in the dark for 1 day.

Following cation formation, the solution was diluted with distilled water using the ABTS extinction coefficient [$\varepsilon(H_2O) = 3.6 \times 10^4\ M^{-1}\cdot cm^{-1}$] to obtain an absorbance value of 0.73 ± 0.02 at 735 ㎚. The ginseng extract (50 ㎕) was then added to the diluted ABTS solution (1 ㎖), reacted in the dark for 30 min, and the absorbance at 735 ㎚ was measured using a UV spectrophotometer. L-Ascorbic acid (AA, Sigma-Aldrich Co., St. Louis, MO, USA) was used as the reference standard, and the results were expressed as ㎎ AA equivalents in 1 g of dried sample (㎎·AA/g dry weight).

DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activity was measured by modifying the method of Tepe *et al.* (2006). A 0.2 mM DPPH (Sigma-Aldrich Co., St. Louis, MO, USA) solution (0.8 ㎖) was added to the ginseng extract (200 ㎕), and the absorbance at 520 ㎚ was measured after reacting in the dark at room temperature for 30 min. AA was used as the reference standard, and the results were expressed as ㎎·AA/g dry weight.

8. Analysis of ginsenoside content

Eleven ginsenosides from the dried and roasted 4-year-old ginseng roots were analyzed.

The 11 ginsenoside standards used in this analysis were Rb1, Rb2, Rb3, Rc, Rd, Re, Rf, Rg1, Rg2, Rg3, and Rh1 (ChromaDex, Irvine, CA, USA). The mobile phase used for the analysis consisted of solvent A (water) and solvent B (acetonitrile). Powdered ginseng (0.2 g) was suspended in 70% MeOH (1 ㎖), thoroughly mixed, and extracted by sonication for 30 min at 50℃ in an ultrasonic bath. The crude extract was collected by centrifugal separation (31,000 g, 4℃, 15 min) and

1 ㎖ of the sample was passed through a Sep-Pak C18 cartridge (Waters Co., Milford, MASSACHUESTTS, USA) to remove impurities. The purified extract was then filtered through a 0.45 ㎛ membrane filter (Kim *et al.*, 2010), and the ginsenoside content was measured using a Nexera X2 UPLC system (Shimadzu Co., Tokyo, Japan). The extract (10 μL) was analyzed using a Halo RP amide column (4.6 ㎜ × 150.0 ㎜, 2.7 ㎛, Advanced Materials Technology Inc., Wilmington, DE, USA) at a 0.5 ㎖/min flow rate, 50℃ column temperature, and 203 ㎚ UV detection.

9. Statistical analysis

Statistical analyses were performed using SAS v.9.2 (SAS Institute, Cary, NC, USA). Statistical significance was determined using Duncan's Multiple Range Test (DMRT) and One-way analysis of variance (ANOVA). All data were at the 5% significance level and were reported as means ± standard deviation (SD) ($p < 0.05$).

RESULTS AND DISCUSSION

1. Reduction ratio, color, and browning of ginseng powder under different roasting conditions

Under the different roasting conditions, the ginseng powder reduction ratio tended to increase proportionally with the roasting level (Table 1). Reduction ration accounted for less than 5% at 140℃ treatment group, 160℃ treatment group and 180℃ for 10 min. However, it increased to approximately 7% when roasted at 180℃ for 20 min, and reached ≥ 15% after roasting at 200℃ for 20 and 30 min. The moisture remaining in the ginseng following the hot air drying likely decreased after the roasting process, with the evaporation of water accelerating as the roasting temperature and time increased.

The reduction ratio ranges from 75% to 85% when 4-year-old fresh ginseng steamed and dried under the steaming conditions (90℃ - 100℃ for 12 - 24 hours) and it increased up to 90% depending on steaming temperature and time (Yu *et al*., 2019). And the reduction ratio of ginseng during 9 steaming process was about 79% (Hong *et al*., 2007). In this experiment, the average dry yield was about 25%, that is, the reduction ratio was 73%. Even if it is roasted, there is not much difference from red ginseng production. In addition, main and fine roots with high water content were used, but the reduction ratio will be reduced when all ginseng roots are used.

Although the reduction in the moisture content of the ginseng powder is advantageous in terms of storage, the reduction in yield is disadvantageous in terms of production efficiency. Therefore, the roasting level should be determined in reference to these advantages and disadvantages.

The Hunter L value, representing brightness, decreased signi-

Table 1. Reduction ratio, Hunter's color value, and browning color under different roasting conditions.

Roasting		Reduction ratio[2)] (%)	Hunter's color value			Browning color (O.D. at 420 ㎚)
Temperature (℃)	Time (min)		L	a	b	
Control[1)]		–	89.72±0.05^{a}	0.66±0.01^{i}	10.61±0.17^{h}	0.033±0.006^{i}
140	10	1.72±0.15	86.27±0.18^{b}	3.51±0.06^{h}	17.36±0.12^{d}	0.182±0.012^{hi}
	20	2.55±0.20	82.37±0.49^{c}	5.27±0.17^{e}	19.81±0.08^{bc}	0.408±0.040^{g}
	30	2.55±0.23	82.87±1.23^{c}	4.83±0.47^{f}	19.51±0.54^{c}	0.341±0.058^{gh}
160	10	2.64±0.10	82.27±0.07^{c}	5.09±0.19^{ef}	20.29±0.18^{b}	0.410±0.106^{g}
	20	3.57±0.24	76.40±0.49^{d}	6.89±0.26^{d}	21.19±0.54^{a}	0.734±0.049^{f}
	30	4.62±0.25	72.96±2.70^{e}	7.67±0.15^{bc}	21.31±1.31^{a}	1.191±0.237^{e}
180	10	4.52±0.25	71.64±1.90^{e}	8.28±0.40^{a}	21.69±0.37^{a}	1.251±0.161^{e}
	20	7.48±0.36	59.67±0.90^{f}	7.92±0.05^{b}	14.89±0.44^{e}	2.931±0.145^{c}
	30	7.73±0.38	58.27±0.48^{f}	7.76±0.30^{b}	14.14±0.56^{f}	2.752±0.124^{d}
200	10	8.75±0.70	55.56±1.13^{g}	7.42±0.09^{c}	12.47±0.78^{g}	3.359±0.111^{a}
	20	15.34±1.10	48.54±0.29^{h}	4.93±0.06^{f}	5.89±0.36^{i}	3.192±0.212^{b}
	30	17.76±1.54	46.72±0.12i	3.92±0.28^{g}	3.95±0.27^{j}	2.873±0.128^{cd}

[1)]Control; dried (60℃, 16 hours) ginseng powder. The average dry yield was about 25%. [2)]Reduction ratio (%); (1 - dry and roasting yield/dry yield) × 100. Each value represents the means ± SD (n = 6). Different letters within columns indicate significant differences by Duncan's Multiple Range Test (DMRT, $^{*}p < 0.05$)

Fig. 1. Ginseng powder under different roasting conditions. Control; dried (60℃, 16 hours) ginseng powder.

ficantly with increasing roasting time and temperature (Fig. 1). The Hunter a value, representing redness, increased to 8.28 after roasting at 180℃ for 10 min, and then decreased with longer times and higher temperatures.

For example, at 200℃, the Hunter a value rapidly decreased from 5.89 to 3.95 when roasted between 20 and 30 min. The Hunter b value, indicating yellowness, ranged from 20.29 to 21.69 after roasting at 160℃ for 20 min to 180℃ for 10 min and tended to increase significantly compared to that of the non-roasted control.

After roasting at 200℃ for at least 20 min, the color of ginseng powder is black to the naked eye, suggesting that the Hunter a and b values decrease sharply. When rice germ was roasted, the Hunter b value increased at the beginning of roasting and then decreased, with a subsequent increase in the Hunter a value (Ko *et al.*, 2003). Therefore, Hunter b and a values tend to increase and decrease after roasting in both ginseng and rice germ.

Hunter's color value of red ginseng powder, which was manufactured according to the red ginseng manufacturing regulations of Korea Tobacco and Ginseng Central Research Institute, was L (68.18 - 72.08), a (4.21 - 5.73), b (26.56 - 28.36) (Seo *et al.*, 2002). This value was slightly similar to the Hunter a value of the 180 roasting treatment group and the Hunter L and 160 roasting treatment groups.

Brownness has been reported to increase significantly depending on the roasting level and decrease above certain temperatures and times (Kim *et al.*, 2018). The increase is due to the formation of browning substances by Maillard reactions (Jing *et al.*, 2004). The substrates of the browning reaction, sugars and amino acids, are presumed to be reduced under long-term heating at high temperatures, and become insoluble polymers via polymerization and condensation (Kwon *et al.*, 1997).

Browning color of white ginseng powder and red ginseng on sale was 0.14, 1.28, respectively (Hong *et al.,* 2007). Browning of white ginseng powder was similar to 140℃ for 10 min treatment. In case of commercial red ginseng, browning color was similar to the value between 180℃ for 10 min and 180℃ for 20 min.

Chromaticity and brownness are visual indicators of the degree of roasting and are important factors influencing consumer preference; therefore, these features should be considered when marketing agricultural products as food materials.

2. Proximate composition of ginseng powder under different roasting conditions

The proximate composition of ginseng powder varied with different roasting conditions (Table 2). Carbohydrate content of roasted ginseng powder ranged from 71.71 g/100g to 76.40 g/100g. When roasted at 140℃ - 160℃, it increased slightly compared to that of the non-roasted ginseng powder (control) but decreased at temperatures above 180℃.

Protein content of ginseng powder increased in proportion to the roasting level, culminating in an increase of approximately 22% at 200℃/30 min (21.45 g/100g) compared to the case of the control. This differs from the work of Park *et al.* (1993) who found that the protein content of red ginseng decreased with an increasing roasting temperature of 170℃ - 250℃ but is consistent with results from air-roasted acorns (Jung and Park, 2019).

The moisture content of the control was 4.11 g/100g. The moisture content of the roasted ginseng powder was lower than that of the control and significantly decreased as the roasting temperature and time increased. In contrast, the fat and ash

Table 2. Proximate composition of ginseng powder under different roasting conditions.

Roasting		Carbohydrate (g/100 g)	Protein (g/100 g)	Fat (g/100 g)	Ash (g/100 g)	Water content (g/100 g)
Temperature (℃)	Time (min)					
Control[1)]		72.12±0.15^{e*}	17.65±0.11^{h}	1.11±0.08^{ab}	5.02±0.03^{de}	4.11±0.07^{a}
140	10	73.40±0.07^{d}	18.22±0.01^{f}	0.99±0.10^{bc}	5.29±0.02^{c}	2.10±0.04^{b}
	20	74.96±0.10^{b}	17.52±0.08^{h}	1.11±0.03^{ab}	4.85±0.02^{e}	1.56±0..05^{c}
	30	74.35±0.30^{c}	18.17±0.18^{fg}	1.21±0.16^{a}	5.16±0.03^{cd}	1.11±0.02^{d}
160	10	73.55±0.12^{d}	18.42±0.06^{e}	1.11±0.14^{ab}	5.38±0.02^{c}	1.54±0.06^{c}
	20	76.40±0.26^{a}	16.78±0.20^{i}	0.99±0.10^{bc}	5.16±0.02^{cd}	0.67±0.02^{g}
	30	74.95±0.14^{b}	18.15±0.03^{fg}	0.83±0.09^{c}	5.35±0.04^{c}	0.72±0.02^{fg}
180	10	74.43±0.24^{c}	17.98±0.16^{g}	1.23±0.14^{a}	5.31±0.02^{c}	1.04±0.03^{d}
	20	73.71±0.18^{d}	18.96±0.11^{d}	1.28±0.08^{a}	5.30±0.06^{c}	0.75±0.01^{f}
	30	71.76±0.13^{e}	20.24±0.02^{c}	1.29±0.13^{a}	5.65±0.03^{b}	1.06±0.07^{d}
200	10	71.79±0.08^{e}	20.12±0.11^{c}	1.17±0.07^{ab}	5.85±0.04^{ab}	1.07±0.01^{d}
	20	71.80±0.21^{e}	20.61±0.07^{b}	1.16±0.13^{ab}	6.05±0.15^{a}	0.37±0.04^{h}
	30	70.71±0.50^{f}	21.45±0.04^{a}	1.14±0.06^{ab}	5.82±0.48^{ab}	0.88±0.05^{e}

[1)]Control; dried (60℃, 16 hours) ginseng powder. Each value represents the means ± SD (n = 6). Different letters within columns indicate significant differences by Duncan's Multiple Range Test (DMRT, $^{*}p < 0.05$).

contents did not differ significantly from those of the control during roasting.

Although the composition of Korean ginseng varies greatly across different types, it is generally composed of 60% - 70% carbohydrate, 12% - 16% protein, 1% - 2% fat, and 4% - 6% ash (RDA, 2018).

The protein content of the sample in this work differs from these established measurements as only the main root of ginseng was used. In addition, the proximate composition of ginseng powder is expected to change during roasting, as heat treatment decreases the water content and destroys cell walls, resulting in the elution or destruction of organic substances (Jang *et al.*, 2018) and the altering of carbohydrate and protein content.

3. Total phenolic content of ginseng powder under different roasting conditions

The TPC of the control was 3.53 ㎎·GAE/g and increased with roasting level, with the exception of the 200℃ treatment (Fig. 1). The TPC increased rapidly from the 160℃ for 20 min treatment, reaching the highest value of 22.92 ㎎·GAE/g with the 200℃ for 10 min treatment, which is an approximately 7-fold increase compared to the case of the control. Roasting above 140℃ for 20 min is presumed to increase TPC via the conversion of bound polyphenol compounds to free polyphenols, which are easily eluted due to the destruction of the internal tissue. This aligns with previous studies in which TPC increased in coffee and *Cassia tora* L. depending on the roasting level, and in grains, such as cowpea and sorghum, depending on the roasting time (Lee *et al.*, 2013).

The TPC of 4-year-old ginseng with high heat and pressure treatment increased to 29.46 ㎎·GAE/g at 150°C for 1 hour and then decreased (Yang *et al.,* 2006). As in this experiment, when the same part of 4-year-old ginseng root was steamed at 110°C for 48 hours, the TPC showed a peak value of 14.63 ㎎·GAE/g (Yu *et al.*, 2019). Steaming treatment of ginseng showed a generally lower the TPC value than heat treatment.

Prolonged heating at 200℃ decreased the TPC, which is consistent with the findings of Jung *et al.* (2019) that TPC was significantly reduced in acorn extract air-roasted at 207℃ for 60 s as compared to that in the raw acorn. The TPC increased at a high roasting temperature and then decreased again as time passed. It has been reported that The TPC increased due to destruction of the internal tissue at a certain level of roasting conditions, but the exposed phenolic components were destroyed by excessive high temperature and lost as the roasting temperature increased (Yun *et al.*, 2012).

The TPC is reported to have various physiological activities,

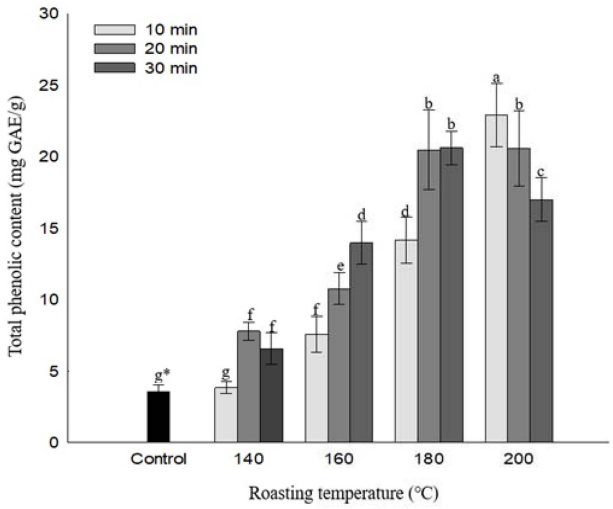

Fig. 2. Total phenolic content (TPC) of ginseng powder under different roasting conditions. The results represent the means ± SD (n = 6). Different letters within columns indicate significant differences by Duncan's Multiple Range Test (DMRT, $^{*}p < 0.05$).

including antioxidant activity, due to the ability of its phenolic ring to stabilize free radicals (Kandaswami and Middleton, 1994). As roasted ginseng powder has a higher TPC than the control, it is expected to have increased antioxidant activity. Therefore, further research regarding the roasting temperature and time of ginseng powder would aid in optimizing its TPC, and consequently, its antioxidant activity.

4. Antioxidant activity of ginseng powder under different roasting conditions

The antioxidant activity of ginseng powder was measured under different roasting conditions (Fig. 2). The ABTS and DPPH free radical scavenging activities of the control were 2.46 and 0.93 ㎎·AA/g, respectively.

The roasted ginseng powder had higher ABTS radical scavenging activity than DPPH radical scavenging activity, both of which significantly increased with increasing roasting temperature and time.

The ABTS radical scavenging activity increased ≥ 2-fold from the initial roasting treatment of 140℃ for 10 min, reaching a peak value of 13.56 ㎎·AA/g at 200℃ for 20 min. However, the activity decreased using the 200℃ for 30 min treated sample. The DPPH radical scavenging activity increased gradually from the 140℃ for 20 min and decreased after obtaining a peak value of 5.30 ㎎·AA/g at 200℃ for 20 min. This resembles a previous study investigating the anti-

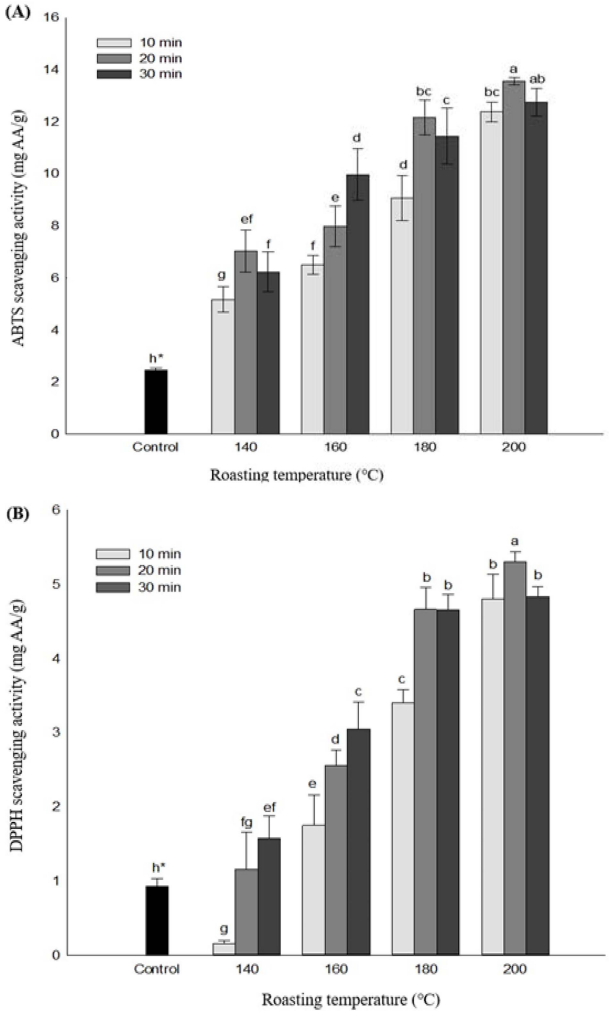

Fig. 3. (A) ABTS radical scavenging activity and (B) DPPH radical scavenging activity of ginseng powder under different roasting conditions. The results represent the mean ± SD (n = 6). Different letters within columns indicate significant differences by Duncan's Multiple Range Test (DMRT, $^{*}p < 0.05$).

oxidant activity of red ginseng roasted from 170℃ to 250℃ (Park *et al*., 1993). In this study, the DPPH scavenging activity increased sharply from 170℃ to 230℃, and moderately thereafter.

Although the DPPH radical scavenging activity of roasted red ginseng was lower than that of brown rice green tea, antioxidant activity was significantly increased by more than 80% at 150°C for 30 min or more treatment (Seong *et al*., 2018). The fermented ginseng extract using various strains also showed similar or slightly lower values to the scavenging activity (57.66 ± 0.98%) of vitamin C (Doh *et al*., 2010). As such, when fresh ginseng was processed in various ways such

as steaming, heat and fermentation etc, antioxidant activity tended to increase.

In general, appropriate heat treatment of raw materials used as functional food ingredients or medicines increases the antioxidant composition (Jung and Park, 2019), but results in diminished antioxidant capacity under excessive roasting conditions (Suh and Chun, 1981). The increase in antioxidant activity after roasting is linked to the production of the antioxidant melanoidin via browning reactions, such as the Maillard reaction (Lee *et al.*, 2018). As natural phenol components exhibit radical scavenging activity (Choi *et al*., 2007), the increase in the radical scavenging activity of ginseng powder is likely due to a roasting-induced increase in phenolic compounds.

The results from this work indicate that roasting conditions affect the quality of ginseng powder by changing its anti-oxidant properties.

5. Total ginsenoside content and composition of ginseng powder under different roasting conditions

There was no consistent trend for total ginsenoside content at roasting temperatures of 140℃ - 160℃ (Table 3). In contrast, the total ginsenoside content decreased as the treatment time increased at roasting temperatures of 180℃ - 200℃. The highest total ginsenoside content was 9.25 ㎎/g at 180℃ for 10 min, but this was not significantly different from the control.

This agrees with the findings of Yoon *et al*. (2005) that the high crude saponin content of ginseng roasted between 150℃ - 170℃ for 16 min - 23 min decreased at higher temperatures and times. This decrease in total ginsenoside content after reaching a maximum is due to the decomposition of polar ginsenosides, leaving only non-polar ginsenosides at high temperatures (Yang *et al*., 2006).

Ginsenoside is a glycoside containing a dammarane terpenoid and is classified into panaxadiol (PD) and panaxatriol (PT) lines according to the binding position of the sugar.

Ginsenoside composition changes with the roasting level. The PD ginsenoside Rg3 content increased significantly at higher roasting temperatures and times in this study. The Rg3 content increased 2-fold compared to that of the control at 180 ℃ for 20 min, attaining its highest value (0.17 ㎎/g) at 200℃ for 30 min.

In several reports, Rg3 is present in minute quantities in fresh ginseng and increases after heat treatments, such as steaming (Kim *et al*., 2007; Yu *et al.*, 2019). As Rd is relatively heat stable (Sung and Yang, 1986), its content was relatively unaffected by roasting as compared to the case of the other components. The PT ginsenoside Rh1 content increased as the roasting level increased, reaching 0.24 ㎎/g at 200℃ for 20 min, which was 10 times higher than that of the control.

At a constant roasting time, Rh1 content tended to increase with increasing temperature, which is consistent with previous results that Rh1 content increased with heat treatments at temperatures above 80℃. It has been suggested that Rh1 content increases during heating due to the release of the sugar bound at the C-20 position of another ginsenoside or isomerization of the C-20 hydroxyl group (-OH) (Yang *et al*., 2006). Rf is reported to be relatively heat stable (Hong *et al.*, 2007), which correlates with the finding that its content was minimally changed until 180℃ for 30 min, but rapidly decreased at higher temperatures.

The PT ginsenosides Re and Rg1 contents showed the largest decreases with increasing roasting levels. Re and Rg1 contents were decreased by 37% and 40%, respectively, as compared to those of the control at 180℃ for 30 min, resulting in 0.74 and 0.91 ㎎/g, respectively.

Polar ginsenosides, such as Re, Rb1, and Rc, have a low heat-tolerance (Hong *et al*., 2007), and Re and Rg1 are particularly vulnerable to heat. In the control, the PD/PT ratio was 0.56. As the roasting temperature and time increased, the ratio increased up to 1.21.

Contrary to previous work (Choi *et al.*, 2008), this study found that PT-based ginsenosides were more unstable than PD-based ginsenosides at higher temperatures, resulting in an increased PD/PT ratio at increased roasting levels. As the heat-tolerance of the ginsenosides varies with their structure, the pattern of roasting-associated ginsenoside content also varied, and consequently affected the PD/PT ratio and total ginseno-side content.

During food processing, dangerous substances can be pro-duced as carbohydrates, proteins, and fats undergo incomplete combustion processes. For example, benzopyrene can be pro-duced via carbonization during the high-temperature treatment of fresh ginseng. 0.01 ppb of benzopyrene was produced when red ginseng was roasted at 150℃ for 30 min. 0.11 ppb of benzopyrene, which is about 10 times higher, was produced in roasted red ginseng under 170℃ for 30 min. However, this figure is much lower than the 2.0 ppb of black ginseng powder, which is the benzopyrene limit suggested by Ministry of Food and Drug Safety (Seong *et al*., 2018). Since fresh

Table 3. Total ginsenoside content and composition of ginseng powder under different roasting conditions.

Roasting		Panaxadiol (PD)						Panaxatriol (PT)					Total[2] (㎎/g)	PD/PT
Temp. (℃)	Time (min)	Rb1	Rb2	Rb3	Rc	Rd	Rg3	Re	Rf	Rg1	Rg2	Rh1		
Control[1]		1.37±0.12^{c}	0.71±0.03^{bcd}	0.14±0.01^{a}	0.74±0.06^{abc}	0.06±0.003^{b}	0.02±0.002^{de}	1.98±0.16^{a}	0.84±0.08^{c}	2.27±0.09^{a}	0.28±0.02^{ab}	0.02±0.001^{g}	8.43±0.51^{ab}	0.56±0.01^{e}
140	10	1.51±0.05^{bc}	0.76±0.07^{abc}	0.13±0.01^{ab}	0.72b±0.08^{c}	0.08±0.037^{b}	0.03±0.004^{d}	1.70±0.29^{b}	0.94±0.03^{b}	1.73±0.37^{b}	0.28±0.11^{ab}	0.03±0.001^{fg}	7.90±0.22^{bc}	0.69±0.04^{de}
	20	0.89±0.14^{ef}	0.55±0.06^{cde}	0.08±0.01^{cde}	0.46±0.08^{e}	0.05±0.003^{b}	0.02±0.008^{e}	0.98±0.13^{e}	0.51±0.02^{e}	1.20±0.17^{cd}	0.12±0.03^{de}	0.02±0.001^{g}	4.87±0.31^{e}	0.72±0.11^{de}
	30	1.06±0.27^{de}	0.35±0.04^{de}	0.07±0.02^{de}	0.41±0.24^{ef}	0.40±0.020^{a}	0.03±0.003^{d}	1.17±0.09^{d}	0.66±0.11^{d}	1.25±0.39^{c}	0.14±0.02^{cde}	0.03±0.003^{g}	5.57±0.11^{e}	0.70±0.13^{de}
160	10	0.85±0.15^{fg}	0.27±0.04^{e}	0.06±0.01^{d}	0.39±0.24^{ef}	0.56±0.008^{a}	0.03±0.001^{d}	1.19±0.14^{d}	0.64±0.12^{d}	1.25±0.31^{c}	0.11±0.04^{de}	0.03±0.001^{g}	5.37±0.34^{e}	0.68±0.06^{de}
	20	1.47±0.04^{bc}	0.86±0.07^{abc}	0.11±0.02^{bc}	0.81±0.02^{abc}	0.43±0.036^{a}	0.03±0.004^{d}	1.28±0.08^{d}	0.86±0.05^{c}	1.68±0.19^{b}	0.13±0.01^{cde}	0.04±0.004^{f}	7.69±0.44^{bc}	0.93±0.07^{bcd}
	30	1.36±0.11^{c}	0.95±0.00^{ab}	0.11±0.03^{abc}	0.78±0.03^{abc}	0.17±0.013^{b}	0.02±0.001^{de}	1.19±0.04^{d}	0.67±0.07^{d}	1.31±0.26^{c}	0.14±0.01^{cde}	0.03±0.005^{fg}	6.73±0.27^{d}	1.03±0.13^{abc}
180	10	1.70±0.14^{a}	0.85±0.06^{abc}	0.12±0.60^{abc}	0.91±0.05^{ab}	0.38±0.031^{a}	0.03±0.004^{d}	1.49±0.23^{c}	1.12±0.06^{a}	2.43±0.54^{a}	0.16±0.04^{cd}	0.07±0.002^{e}	9.25±0.44^{a}	0.77±0.18^{cde}
	20	1.63±0.12^{ab}	1.09±0.21^{a}	0.13±0.02^{ab}	0.92±0.02^{a}	0.05±0.0016^{b}	0.05±0.001^{c}	1.26±0.09^{d}	0.81±0.03^{c}	1.36±0.06^{c}	0.18±0.01^{c}	0.11±0.007^{c}	7.60±0.16^{c}	1.04±0.12^{abc}
	30	1.16±0.05^{d}	0.63±0.04b^{cd}	0.09±0.04^{cd}	0.68±0.01^{cd}	0.04±0.01^{b}	0.05±0.010^{c}	0.74±0.17^{f}	0.47±0.08^{e}	0.91±0.11^{de}	0.09±0.05^{e}	0.10±0.003^{d}	4.96±0.24^{e}	1.19±0.30^{ab}
200	10	1.03±0.12^{def}	0.91±0.02^{abc}	0.11±0.02^{abc}	0.69±0.02^{cd}	0.07±0.036^{b}	0.05±0.008^{c}	0.78±0.04^{f}	0.51±0.02^{e}	0.81±0.10^{e}	0.14±0.03^{3cde}	0.12±0.005^{c}	5.22±0.57^{e}	1.21±0.18^{ab}
	20	0.70±0.07^{g}	0.65±0.05^{bcd}	0.09±0.05^{cd}	0.53±0.05^{de}	0.06±0.026^{b}	0.15±0.010^{b}	0.43±0.13^{g}	0.43±0.02^{e}	0.33±0.06^{f}	0.24±0.02^{b}	0.24±0.006^{a}	3.86±0.33^{f}	1.25±0.50^{a}
	30	0.36±0.08^{h}	0.26±0.06^{e}	0.05±0.02^{e}	0.28±0.16^{f}	0.05±0.020^{b}	0.17±0.007^{a}	0.20±0.02^{h}	0.26±0.03^{f}	0.15±0.01^{f}	0.30±0.02^{a}	0.20±0.002^{b}	2.27±0.32^{g}	1.07±0.36^{ab}

[1]Control; dried (60 ℃, 16 hours) ginseng powder. Each value represents the mean ± SD (n = 3). [2] Total; Rb1 + Rb2 + Rb3 + Rc + Rd + Rg3 + Re + Rf + Rg1 + Rg2 + Rh1. Different letters within columns indicate significant differences by Duncan's Multiple Range Test (DMRT, $p < 0.05$).

ginseng was roasted at 160℃ for 30 min and 180℃ for 10 min in this experiment, benzopyrene will be detected at a lower concentration compared to red ginseng. However, additional experiments related with benzopyrene are required under this condition in practice.

Our results confirmed that the physicochemical properties of 4-year-old ginseng roots changed according to the roasting conditions. Based on a comprehensive analysis of the results, the optimum roasting conditions to minimize the reduction in total ginsenosides, yield, and proximate composition and maximize the polyphenol content and antioxidant activity are 160℃ for 30 min or 180℃ for 10 min. Although this was set to optimal condition, further review of this process is needed to assess stability and the optimum roasting conditions may vary based on the type of ginseng used and the presence of other materials.

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