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Microstructure and Antioxidative Activity of Red, White and Extruded Ginseng

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Abstract

The objective of this study was to compare the color and microstructure of powder, redness, brownness, and antioxidative activity in extruded ginseng, white ginseng and red ginseng extracts. The colors of extruded dry ginseng powder (moisture content 30%, barrel temperature 110°C, and screw speed 200 rpm) were similar to those of red ginseng. Intact cell wall structure was examined in dried root ginseng at 70°C (A), white ginseng with skin (D), white ginseng without skin (E), and red ginseng (F) under a scanning electron microscope. The cell wall was not detected in samples B and C (dry ginsengs extruded with 25% and 30% moisture contents, respectively). Intact starch granules were detected in samples A, D, and E under a scanning electron microscope. Melted starch granules were detected in samples B, C, and F. Colors (L, a, b) of 50% EtOH extracts were similar in samples C and F. Browniness and redness of extracts were high in extruded dry ginseng and red ginseng extracts. Extruded dry ginseng (B) showed higher electron donation ability and phenolic content than the other samples.

Key words: extruded ginseng, microstructure, powder color, antioxidative ability, phenolic content

INTRODUCTION

As a member of the *Araliaceae* family and the *Panax* genus, ginseng (*Panax ginseng* C.A. Meyer) is a perennial herb used as an oriental medicine as ginseng radix (1). Ginseng is processed initially into red ginseng and white ginseng, which still maintain their original shape, and secondarily sold as powder, tablet, and capsule in such forms as powder products, drink, and tea etc.

Being a plant structure, the cell wall is affected by mixing, heating and physical changes as the melted product of protein passes through the die exit during the extrusion process. Thus, puffing would occur as the specific volume increases in the superheated steam due to a drastic decrease in pressure, and a textured structure is formed by the bonding of protein chains. This puffing and texturization of protein tissue could be induced by controlling extrusion process variables and feed formulations (2).

When cereal bran containing abundant fiber is processed through extrusion, heat, pressure and shear force affect the substance in the extruder so that physiochemical changes such as cell wall, fiber arrangement and fragmentation occur (3,4). Compared with other heat processing, biopolymers treated through the extrusion process are affected by additional shearing by screw rotation. Thus, the cell wall is destroyed and the biopolymer changes physically and dissociates, bringing about more changes in molecular weight and soluble substance content compared to the other heating process. However, no study was performed on changes of the cell wall during the extrusion process of ginseng.

Excess activated oxygen and free radicals in the body are significantly involved in the development or progression of infection due to tissue damaging effect, carcinogenesis, auto-immune disease, arteriosclerosis, and cerebral disease and are recognized as the most important factors for increasing lipid peroxide in the body (5).

Phenolic content and non-saponin components in red ginseng extract have an anti-lipid peroxidative effect (6), an antiaging effect on skin, and are effective for preventing degenerative changes brought about by activated oxygen (7). Polyacetylene components in ginseng (such as panaxynol, panaxydol, and panaxytrinol) prevent the production of peroxide lipid in mouse liver induced by carbon tetrachloride, and a laboratory study showed that polyacetylene components and tocopherol inhibited lipid peroxidation in liver microsome in a dose-dependent manner (8).

It was reported that the composition fraction obtained from red ginseng and white ginseng showed an antioxidative activity, and that red ginseng had better activity

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compared to white ginseng, when antioxidative activity was investigated using DPPH (α-diphenyl-β-picry-hydrazyl) (9). However, this study was not performed using extruded ginseng. On extruded fresh ginseng, there were studies on the drying process for manufacturing red ginseng (10) and the effect of extrusion process and optimization for manufacturing of red ginseng (11). But no study was performed to compare components in ginseng products prepared by varying the processing process.

In this study, the color microstructure of cell wall and starch granules, DPPH electron donation ability (EDA) of antioxidative ability, and phenolic content of extruded extracts and its powers of white ginseng and red ginseng were compared to those prepared by conventional methods.

MATERIALS AND METHODS

Materials

The material utilized in this study was 4-years-old root ginseng cultivated in the Kumsan region (Korea). High grade chemical reagents were purchased from Sigma.

Preparation of white and red ginseng

White ginseng was prepared with the conventional method. Raw ginseng root was washed, removed its skin and dried at 50°C. The red ginseng sample used in this study was prepared with conventional method. Root ginseng was washed, steamed (90~100°C), dried initially (moisture content 35~40%), stored for maturation, dried for the second time (approximately 16% of moisture content), and formed.

Preparation of extruded dry ginseng

The L/D ratio of the corotating twin-screw extruder (THK 31, Incheon Machinery Co., Korea) used in this study was 25:1. Fig. 1 shows its screws configuration. The die holes were circular shape with a diameter of 3.0 mm. Water was injected into the barrel around the feed section to control moisture content. Barrel temperature was adjusted using an electric heater and circulated cold water. The ginseng used for preparing extruded ginseng was the same as that used to conventionally prepared white and red ginseng. Root hair was removed. The sample ginseng was cut using a lab-scale chopper (Hwajin Precision Co., Seoul). It was sorted according to its size by using 4.75 mm aperture sieve (Chunggye Sangsa Co., Seoul), dried at 70°C to adjust moisture to less than 12%. Distilled water was injected during the extrusion process to adjust the moisture content from 25 to 30%. After extrusion-cooking, the sample was finally dried at 50°C to adjust the moisture content to less than 12%. Extruded ginseng was ground using a lab-scale chopper (FM680, Hanil Co., Korea), and sorted according to its size (425~10,000 μm) for analysis. Barrel temperature was adjusted at 80/110/110/60°C (barrel sections: 1/2/3/4). The screw speed was 200 rpm. Feed rate was fixed at 111.7 g/min. The moisture content of dried ginseng used for extrusion was adjusted at 25% and 30%.

Powder color

Powder color of white, red, and extruded ginseng was examined at the size of less than 425 μm using a Chroma meter (CR-200 76003134, Minolta, Japan). Using D65 as the standard light, the measured values were expressed in Hunter color values. L value ranged from 100 (white) to 0 (black), a value ranged from +60 (red) to -60 (green), and b value ranged from +60 (yellow) to -60 (blue). The standard L, a, and b values used at this time were 97.67, -0.57, and 2.70, respectively.

Color of extracts

Color of extract was observed using Chroma colorimeter (Minolta, CR-21, Japan). After placing 3 g of powder sample in a 100 mL Erlenmeyer flask, 70 mL of a 50% ethanol solution was placed into the flask and stirred for 10 sec with 30 min intervals for 5 hr. Then, the mixture was left for 20 hr and filtered. The flask and residue solution were washed with 100 mL of 50% ethanol. Placed 50 mL of aliquot into Chroma colorimeter and Hunter color values were read at D_{65}. The

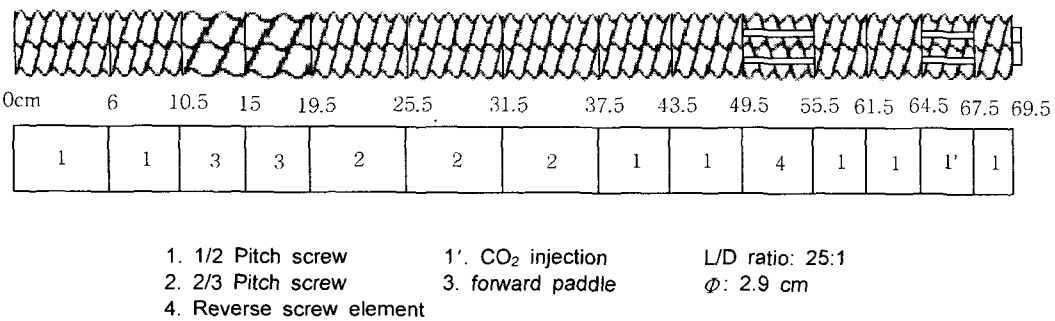

Fig. 1. Screw configuration of model (THK31).

standard value used at this time was the same as that used for the measurement of powder color.

Microstructure

After screening particles according to sizes (355~425 μm), microstructure was observed in which the cell wall was observed at 500x and the starch structure at 2,000x using Digital Scanning Microscopy (DSM 960, ZEISS, Germany).

DPPH electron donation ability (EDA)

To evaluate antioxidative ability of each sample, EDA was measured using DPPH at 517 nm. For 2 g of each sample, 20 mL of 60% ethanol was added. Then, extraction was undergone in a water bath at 80°C for 1 hr. The 0.5 mL of this extract solution was placed into 5 mL of 5×10^{-4} M DPPH solution (After 12 mg of DPPH dissolved completely in 100 mL of ethanol and after then 100 mL of distilled water was added) and stirred for 10 sec. Absorbance change was read at 517 nm for 10 min (12).

Total phenolic content

The Folin-Denis method (13) was modified to quantify total phenolic content colorimetrically. Extraction was done using 20 mL of extraction solvent added onto 2 g of each sample prepared at 80°C for 1 hr. Then, it was filtered and diluted 20 folds for analysis. After a mixture of 1 mL of sample and 1 mL of Folin was prepared and left for 3 min at room temperature, 1 mL of 10% $NaHCO_3$ solution was added into the mixture, which was left at room temperature for 1 hr. Absorbance was read at 700 nm.

RESULTS AND DISCUSSION

Color of powder and extract

Table 1 shows lightness (L), redness (a) and yellowness (b) in extruded dry ginseng, white ginseng, and red ginseng powder. L value was 81.02 in dried ginseng root (sample A) and 59.31 and 70.45 in extruded dry ginseng at 25% and 30% moisture content (samples B and C, respectively) in which sample C showed lower value. L value was 86.89 and 87.36 in white ginseng with skin (sample D) and white ginseng without skin (sample E), respectively. It was 79.95 in red ginseng (sample F). Thus, sample E showed the highest L value.

Redness (a) was +0.78, +7.99, and +2.91 in samples A, B, and C, respectively. As in the case of lightness, high a-value was associated with low moisture content. It was -1.15, -1.72, and +1.16 in samples D, E and F, respectively. Thus, the sample D showed the lowest a-value. Yellowness (b-value) was +21.59, +27.44 and +25.44 in samples A, B, and C, respectively, in which sample B showed the highest b value. It was +13.63, +14.02 and +23.54 in samples D, E, and F, respectively, in which sample D showed the lowest b-value.

Table 1. Hunter color values of samples flour

Sample[1)]	Hunter color values		
	L	a	b
A	81.02	+0.78	+21.59
B	59.31	+7.99	+27.44
C	70.45	+2.91	+25.89
D	86.89	- 1.15	+13.63
E	87.36	- 1.72	+14.02
F	75.95	+1.16	+23.54

[1)]A: Dried whole root ginseng slice at 70°C.
B: Extruded dry whole root ginseng slice (A). (moisture content: 25%, barrel temperature: 110°C, screw speed: 200 rpm)
C: Extruded dry whole root ginseng slice (A). (moisture content: 30%, barrel temperature: 110°C, screw speed: 200 rpm)
D: White ginseng with skin.
E: White ginseng without skin.
F: Red ginseng.

Powder color was most similar in red ginseng (F) and extruded dry ginseng with 30% moisture content (C). Extruded dry ginseng with a similar powder color to red ginseng can be processed by controlling process variables such as moisture content and barrel temperature during the extrusion process.

Table 2 shows extract colors observed in ginseng samples extracted with 50% ethanol. L value was 97.30, 88.04 and 96.44 in dried ginseng not extruded (A), extruded dry ginseng at 25% moisture content (B) and extruded dry ginseng at 30% moisture content (C), respectively. Thus, it was the high in sample A, but the lowest in sample B. It was 98.69 and 99.14 in white ginseng with skin (D) and white ginseng without skin (E), respectively. It was 97.27 in red ginseng (F). Thus, the highest value was achieved by sample E.

Redness (a) value was -0.81, -0.27 and -1.99 in samples

Table 2. Hunter color values of 50% ethanol extracts from ginseng samples

Treatment[1)]	Hunter color values		
	L	a	b
A	97.30	-0.81	+5.80
B	88.04	-0.27	+45.31
C	96.44	-1.99	+13.98
D	98.69	-0.73	+3.64
E	99.14	-0.59	+2.61
F	97.27	-1.70	+9.97

[1)]Refer to comment in Table 1.

A, B, and C, respectively. It was -0.73, -0.59 and -1.70 in samples D, E and F, respectively. Thus, it was the lowest in sample F. Yellowness (b) value was +5.80, +45.31, and +13.98 in samples A, B, and C, respectively. It was the lowest in sample A and highest in sample B. It was +3.64, +2.61, and +9.97 in samples D, E, and F, respectively, showing the lowest value in of all samples in sample E.

Red ginseng (F) and extruded ginseng (C) showed similar color values in 50% ethanol extract. Thus, similar colors would be obtained in red ginseng extract prepared by the conventional method as well as prepared by the extrusion process.

Microstructure

Figs. 2~5 show the microstructure of cell wall and starch granules in dried, extruded, white, and red ginseng to observe the change in microstructure during the extrusion process. The cell wall was present in dry ginseng (sample A) before extrusion but not in extruded dry ginseng (sample B) with 25% moisture content (Figs. 2 and 3). This was probably the cell wall structure due to changing as a result of shear force coming from screw rotation along with heating and applying pressure inside the barrel during the extrusion process. This result is similar to the finding (14) that the soluble fiber content increases due to cell wall damage when the by-product of tofu (i.e., dried soy pulp) was put through the extrusion process.

On the other hand, the cell wall was also present in red ginseng (F) manufactured by steaming and heating and white ginseng with skin (D). This result suggests that the cell wall does not change by heating, but changes during the extrusion process due to heat energy and mechanical energy coming from shear force and pressure when the sample passes through the barrel.

Figs. 4 and 5 show the microstructure of starch granules in not extruded dried ginseng (A) and ginseng extruded at 25% moisture content (B) as observed under SEM. Starch granules were present in not extruded dry ginseng (A). Gelatinized starch during the extrusion process was present in ginseng extruded at 25% moisture (B). Starch granules also present in white ginseng, but was not present in red ginseng (F) treated by steaming and drying.

Antioxidative activity

As shown in Fig. 6, the reducing agent DPPH was used to measure oxidative free radical reaction, typical of antioxidative agents, by evaluating electron donation ability (EDA) of extract with time. EDA was highest in B>F>C>A>E>D, showing the highest value in the extruded dry ginseng at 25% moisture content.

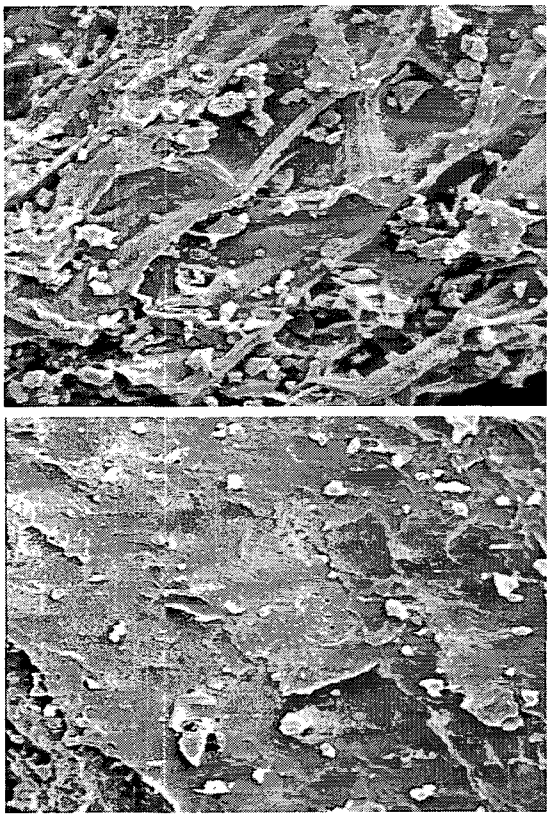

Fig. 2. Scanning electron microphotoghraph of cell wall structure for dried (top) and extruded ginseng (bottom).

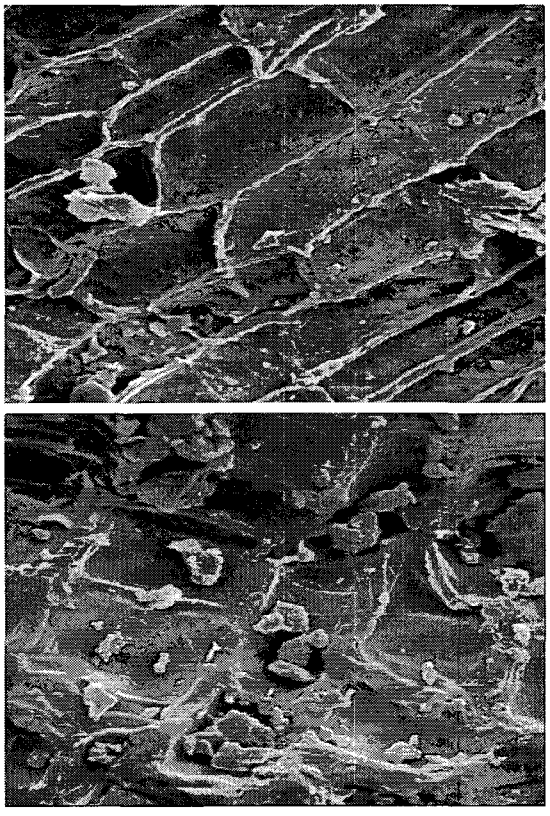

Fig. 3. Scanning electron microphotoghraph of cell wall structure for white ginseng (top) and red ginseng (bottom).

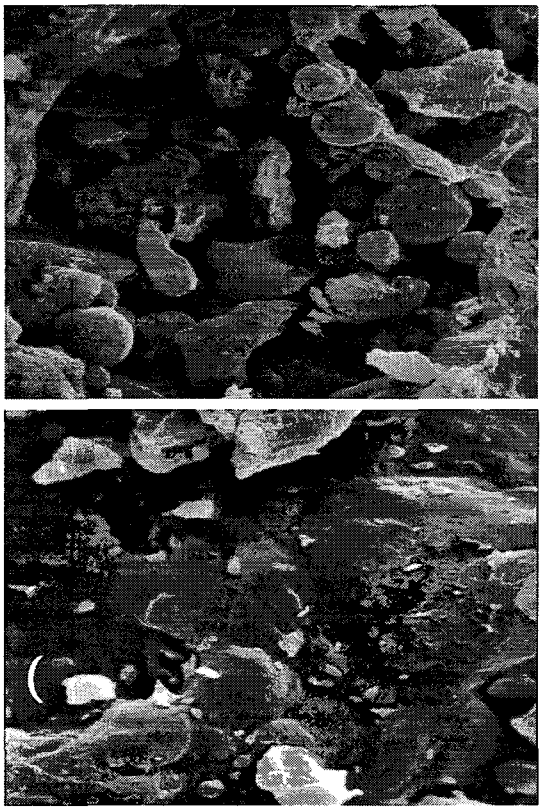

Fig. 4. Scanning electron microphotoghraph of starch granule structure for dried (top) and extruded ginseng (bottom).

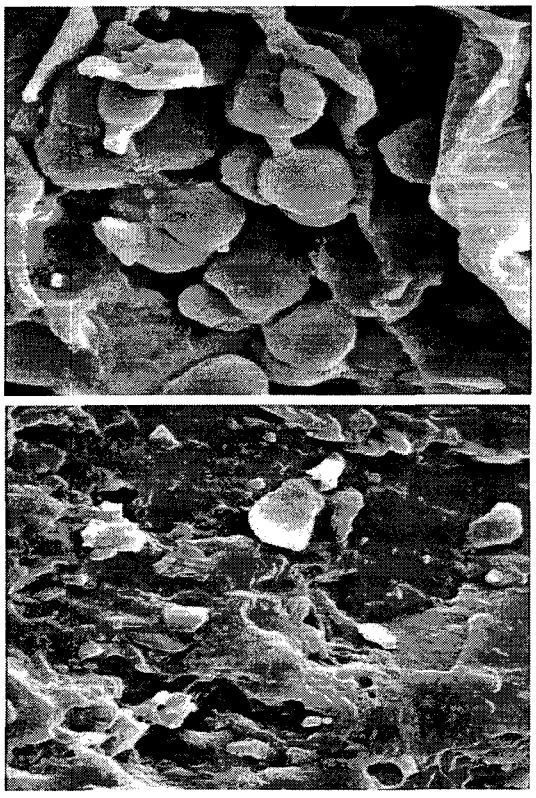

Fig. 5. Scanning electron microphotoghraph of starch granule structure for white ginseng (top) and red ginseng (bottom).

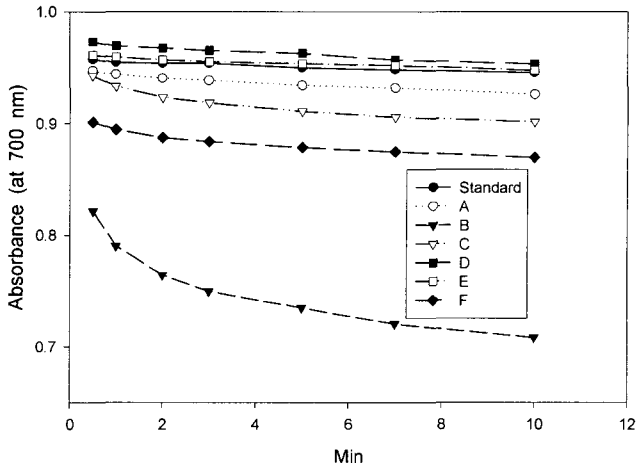

Fig. 6. Change of absorbance by the hydrogen donor properties of ginseng samples. Samples are the same as in Table 1.

According to Choi and Oh (15), electron donation is used as a measurement to evaluate not only the degree of fatty acid oxidation in food by donating electrons to free radicals, but also the degree of aging inhibition due to free radicals in the body. Recently, it has been used to screen for natural antioxidants and their effectiveness.

It was reported that electron donation increases the reducing action of red ginseng extracts except those with strong polarity (16,17). We found that reducing ability was increased. These results concur with the results of previous studies reporting that reducing ability was increased as browning reaction was promoted by reaction time in brown soluble substance of ginseng extracts (18) and that reducing ability was significantly increased in red ginseng with promotion of Maillard reaction compared to that of white ginseng (19). Compared to red ginseng, these results suggest that better antioxidative effect can be obtained by controlling the extrusion process.

Fig. 7 shows total phenolic content in ginseng samples. It was 0.238%, 0.700% and 0.373% in samples A, B, and C, respectively, showing the highest value in ginseng sample extruded at 25% moisture content. Total phenolic content was 0.243, 0.232, and 0.385% in samples D, E, and F, respectively.

It has been reported that phenolic content in ginseng gives antioxidative, antifatigue, and antiaging effects and that Korean red ginseng contains more than 10 types of natural phenolic components including maltol, salicylic acid, and vanillic acid (20,21), showing the similar results of this study obtained by using EDA. Thus, better antioxidative effect can be obtained by extruded ginseng compared to red ginseng by controlling moisture content.

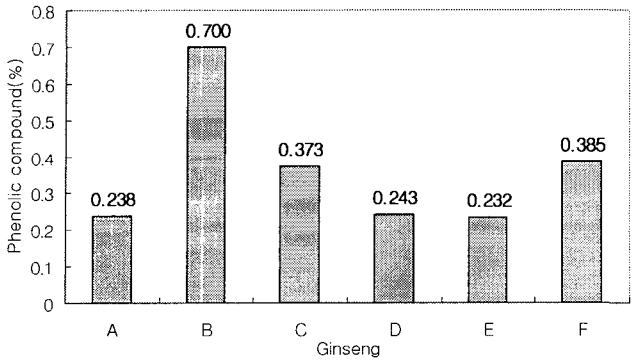

Fig. 7. Contents of phenolic compound in ginseng samples. Samples are the same as in Table 1.

CONCLUSION

To manufacture red ginseng using the extrusion process, dry ginseng extruded at 25% and 30% moisture contents, lab-prepared white ginseng powder, and red ginseng powder were compared using their color, microstructure, red color and brown color of extracts, and antioxidative ability as basis for observation. Powder colors were similar in red ginseng and extruded dry ginseng. The cell wall was present in dry ginseng root, but not in extruded dry ginseng. It was also present in red ginseng obtained by steaming, heating, and drying white ginseng. Starch granules were present in dry ginseng, but only melted starch granules were present partially in extruded dry ginseng after the extrusion process. Starch granule structure was similar in the dry white ginseng which not heated and non-extruded sample. But melted and gelatinized starch granules were present in red ginseng powder as in the case of all extruded ginseng samples.

Colors were similar in 50% ethanol extracts of red ginseng and extruded fresh ginseng. EDA was the highest in dry ginseng extruded at 25% moisture content, followed by red ginseng and white ginseng respectively. Total phenolic content was 0.238%, 0.700% and 0.373% in dry ginseng, ginseng extruded at 25% moisture content and 30% moisture content, respectively, showing the highest value in ginseng extruded at 25% moisture content. Thus, extruded ginseng has better colors and antioxidative effect than that of red ginseng and can be created by controlling moisture content and other extrusion process.

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