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Comparison of Physicochemical Properties of Extruded Ginseng Samples

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Abstract

This study compared the physicochemical properties of root hair of white ginseng (WG), root hair of tissue cultured mountain ginseng (MG), root hair of red ginseng (RG) and extruded ginseng samples. The comparison of crude ash and total sugar resulted insignificant differences between extruded and raw samples. MG had a higher content of crude ash, crude protein, amino acids and polyphenolic compound than WG and RG; the total sugar and reducing sugar were highest in RG. Crude fat and acidic polysaccharide in RG and WG were similar to and higher than MG. Crude saponin of treated samples WG1 (moisture content 25%, barrel temperature 110°C) and WG3 (moisture content 35%, barrel temperature 110°C) were 9.80% and 9.73%, respectively, which were the highest among ginseng samples. In conclusion, the extrusion process can be applied to red ginseng manufacturing, and some characteristics of MG were higher than in RG and WG.

Key words: root hair of ginseng, extrusion process, physicochemical properties

INTRODUCTION

Panax ginseng is a popular herbal supplement using worldwide and has many health benefits owing to the presence of high level of ginsenosides in it. Ginsenosides are the main active compounds in ginseng which are reported to function in the easing of pain, cardio-protection, immunomodulation, anti-fatigue, as well as in hepato-protective physiology and pharmacological effects (1). Various strategies using plant *in vitro* systems have been successfully exploited not only to improve the production of secondary metabolites, such as natural food ingredients, but also to study their biosynthesis and metabolism (2). Root suspension culture of *P. ginseng* in bioreactors is viewed as a primary alternative method for large-scale production of ginsenosides (3). This method is less expensive and time consuming and allows for more control of experimental conditions than field grown plants. Therefore, root suspension culture of ginseng in bioreactors is viewed as a primary alternative method for large-scale production.

Heat treatment is a process typically used to enhance nutritional, hygienic, physicochemical and other characteristics of grain, that is, to improve nutritional value of some ingredients, upgrade sensory properties (for example, improves "mouthfeel" of treated corn), meet microbiological requirements of the product (4,5) and inactivate heat-unstable anti-nutrients, if any. Heat treatments most commonly used for grain processing are extrusion, micronisation, hydro-thermal treatment, toasting and others. When raw ginseng is heat treated, chemical changes occur in the ginseng compositions to produce active substances that do not exist in raw ginseng.

Extrusion is a process of high pressure, high shear, heat, mixing, cutting, crushing, and pressing. Extrusion technology has been reported for starch pretreatment, however, it has little been tried to the processing of ginseng root. Researchers have been performing experiments on using extrusion technology as pretreatment of ginseng for further treatments such as release of ginseng active components and red ginseng production in Korea (6).

The objective of this study was to compare the physiochemical properties of root hair of red ginseng, raw and extruded samples of root hair of white ginseng and tissue cultured mountain ginseng. We investigated the component changes before and after extrusion process at the condition of barrel temperature 110/140°C and moisture content: 25% and 35%.

MATERIALS AND METHODS

Materials

Root hair of red ginseng and white ginseng were purchased from a local market (Chungcheongnam-do, Korea), which were produced in 2007. Root hair of cultured mountain ginseng was purchased from CBN BIOTECH company (Chungcheongbuk-do, Korea). High

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grade reagents used in this study were purchased from Sigma (St. Louis, USA).

Extrusion process

A THK31T (Incheon Machinery Co., Korea) co-rotating intermeshing twin-screw extruder was used. The screw geometrical features were the following: length 768 mm and diameter 32 mm (L/D=24:1), screw speed 200 rpm, feed rate 100 g/min. The die dimension was 3 holes of circular shape with a diameter of 1 mm. Barrel temperature was adjusted to 110°C and 140°C. The moisture content of dried ginseng used for extrusion was adjusted to 25% and 35%. The extrudate was directly dried in an oven at 50°C for 8 hr. The dried extrudate was ground and sieved through 500 μm mesh and kept at 4°C.

The content of moisture content, crude ash, crude protein and crude fat were determined according to the AOAC methods (7).

Crude saponin

Crude saponin contents were analyzed according to the water-saturated butanol extraction method of Ando et al. (8) and Namba et al. (9). Briefly, 50 mL of water-saturated butanol solution was added to 5 g of sample. The mixture was refluxed and extracted at 80°C for 1 hr and filtered. The mixture was refluxed and extracted twice by adding 50 mL of water-saturated butanol solution to the remaining solution. The filter paper was washed by pouring 10 mL of water-saturated butanol. The water-saturated butanol solution layer was extracted by adding 50 mL of distilled water. The supernatant liquor was concentrated. After vacuum concentration, 50 mL of ethyl ether was added to the sample, which was then refluxed and extracted. After the ether was removed, the residue was dried at 105°C for 2 hr and weighed.

Total sugar

Total sugar was analyzed according to the Phenol-H_2SO_4 method (10), using D-glucose as a standard. 1 mL of 70% ethonal solution was added into 10 g of sample. The mixture was refluxed and extracted at 80°C for 2 hr and was massed up to 200 mL. The solution was filtered through filter paper (Whatman No.2). 1 mL of the filtrate was mixed with 1 mL of 5% phenol solution, and 5 mL of concentrated sulfuric acid was added. After standing for 15 min at room temperature, the absorbence was measured at 550 nm.

Reducing sugar

Reducing sugar was analyzed according to the Dinitrosalicylic acid (DNS) method (11), using D-glucose as a standard. 50 mL of distilled water was added to 2 g of ginseng sample. The mixture was extracted at room temperature for 10 min and then filtered through filter paper (Whatman No.1) and brought to 100 mL. 1 mL of this solution was mixed with 3 mL of DNS solution. The mixing solution was heated in boiling water for 5 min and then was cooled on ice for 15 min. The cooling solution was massed up to 25 mL with distilled water and then the absorbence was detected at 550 nm.

Amino acids

The content of amino acids was measured according to the Ninhydrin method (12), using leucine as a standard. 50 mL of distilled water was added into 0.5 g of ginseng sample. The mixture was shaken and then was filtered through filter paper (Whatman No.1) to 100 mL. 0.2 mL of sample solution was mixed with 0.4 mL of ninhydrin reagent and then was heated for 20 min at 100°C. This solution was mixed with l mL of solvent (acetone : 0.1 M sodium phosphate : distilled water, 4:2:4) after the solution was cooled on ice quickly. The absorbence was detected at 570 nm.

Acidic polysaccharide

Acidic polysaccharide was analyzed by the Carbazole-sulfuric method (13), using galacturonic acid as a standard. 25 mL of distilled water was added to 0.5 g of sample. The mixture was centrifuged at 4°C, 9000 rpm for 10 min. 0.5 mL of the supernatant liquor was mixed with 0.25 mL of 0.1% carbazole ethanol and 3 mL of concentrated sulfuric acid and then held at 80°C for 5 min and was placed at room temperature for 15 min for cooling. The absorbence of the solution was detected at 525 nm wavelength.

Polyphenolic compound

The Folin-Denis method (7) was modified to quantify polyphenolic compound colorimetrically. 5 mL of DMSO was added to 0.5 g of sample, and this mixture was extracted at room temperature for 1 hr and then centrifuged at the condition of 9000 rpm, 15°C and 15 min. 0.5 mL of the supernatant was mixed with 6.5 mL of distilled water and 0.5 mL of Folin-Ciocalteu's reagent. After the mixture was placed at room temperature for 3 min, 1 mL of saturated Na_2CO_3 solution and 1.5 mL of distilled water was added into the mixture and then was stored in the dark for 1 hr. The absorbence of the mixture was measured at 725 nm and converted to phenolic contents according to the calibration curve from various concentrations of gallic acid (as gallic acid equivalents (GAE)/mg of extract).

Table 1. Contents of moisture content, crude ash, crude fat, and crude protein in ginseng samples

Samples[1)]	Moisture content (%)	Crude ash (%)	Crude fat (%)	Crude protein (%)
MG	5.70±0.11[2)]	8.52±0.02	0.98±0.003	23.24±0.07
MG1	9.18±0.11	8.41±0.04	0.57±0.007	23.01±0.10
MG2	8.09±0.17	8.56±0.07	0.77±0.007	22.95±0.03
MG3	10.53±0.12	8.34±0.06	0.82±0.007	22.64±0.03
MG4	10.24±0.06	8.50±0.06	0.73±0.010	22.77±0.06
WG	4.83±0.05	5.14±0.02	1.20±0.008	13.40±0.06
WG1	6.92±0.05	5.24±0.02	0.35±0.006	12.99±0.05
WG2	6.69±0.07	5.41±0.08	0.20±0.010	13.03±0.01
WG3	7.13±0.16	5.20±0.05	0.25±0.004	12.80±0.04
WG4	7.75±0.07	5.28±0.10	0.17±0.007	12.79±0.21
RG	7.58±0.10	5.00±0.05	0.90±0.001	12.89±0.11

[1)]RG: Root hair of red ginseng, MG: Root hair of tissue cultured mountain ginseng, MG1: Extruded by root hair of tissue cultured mountain ginseng (MG) (moisture content: 25%, barrel temperature: 110°C), MG2: Extruded by root hair of tissue cultured mountain ginseng (MG) (moisture content: 25%, barrel temperature: 140°C), MG3: Extruded by root hair of tissue cultured mountain ginseng (MG) (moisture content: 35%, barrel temperature: 110°C), MG4: Extruded by root hair of tissue cultured mountain ginseng (MG) (moisture content: 35%, barrel temperature: 140°C), WG: Root hair of white ginseng, WG1: Extruded by root hair of white ginseng (WG) (moisture content: 25%, barrel temperature: 110°C), WG2: Extruded by root hair of white ginseng (WG) (moisture content: 25%, barrel temperature: 140°C), WG3: Extruded by root hair of white ginseng (WG) (moisture content: 35%, barrel temperature: 110°C), WG4: Extruded by root hair of white ginseng (WG) (moisture content: 35%, barrel temperature: 140°C).
[2)]Mean±standard deviation.

RESULTS AND DISCUSSION

The content of moisture content, crude ash, crude fat and crude protein

As shown in Table 1, the content of crude ash in MG (8.52%) was higher than WG (5.14%) and RG (5.00%) significantly. The contents of crude ash in MG1-MG4 were 8.41, 8.56, 8.34, and 8.47%, respectively. In WG1-WG4, the crude ash content was 5.22, 5.50, 5.20, and 5.28%, respectively.

The contents of crude fat in MG, WG and RG were 0.98, 1.20, and 0.90% respectively, and were decreased after extrusion. In MG, the content of crude fat was 0.98%, while the crude fat in MG1～MG4 was 0.57, 0.77, 0.82, and 0.73%, respectively. The crude fat content decreased about 17～42% after extrusion. While in root hair of white ginseng, the crude fat content decreased 71～86% after extrusion. The crude fat in root hair of white ginseng had a greater loss than the root hair of tissue cultured mountain ginseng, which was because the lipids formed complexes with starch and protein (14), so the crude fat decreased. Also, the crude fat decreased with the decrease in the barrel temperature and moisture content.

Table 1 also showed that the content of protein in MG was 23.24%, which was significantly higher than in WG (13.40%) and RG (12.89%). After extrusion, the content of protein decreased 1～3% in comparison to raw material of MG, and decreased 3～5% in extruded WG. The decrease in protein was lower, when higher moisture content (35%) was applied than with the lower moisture content (25%). Protein content in RG (12.89%) was similar to extruded WG (12.79～13.40%).

In the course of extrusion, due to the effect of high temperature and mechanical forces, proteins lose their globular structure. There occurs cleavage of bonds responsible for the 2nd and 3rd order structure of proteins, due to polypeptide chains becoming straightened and extended (15,16), and unfolded protein structures subjected to the effect of mechanical forces form layered structures.

The content of crude saponin

Fig. 1 shows the results of crude saponin analysis which indicated that crude saponin content increased after extrusion-cooking. The amount of crude saponin was

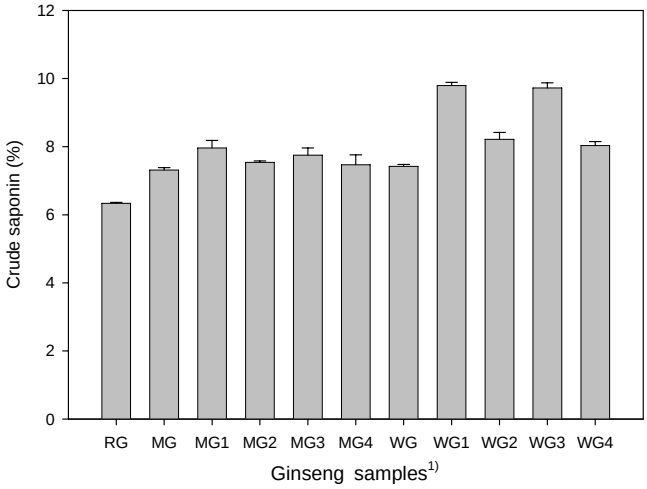

Fig. 1. Comparison of contents of crude saponin in ginseng samples. [1)]Refer to the samples in Table 1.

higher in sample WG (7.42%) and MG (7.31%) than RG (6.34%), and crude saponin in extruded ginseng was higher than that of the commercial red ginseng (RG). After extrusion, the content of crude saponin was increased more in WG1 and WG3 than other extruded samples. Extruded ginseng at the moisture content of 25% and 35% and at a temperature of 110°C contained analogous crude saponin. Furthermore, at the temperature of 140°C, the crude saponin content was analogous too. Nevertheless, at the same moisture content (whether 25% or 35%), crude sapoin in extruded samples at a temperature of 110°C was higher than at 140°C, indicating that the content of crude saponin was not significantly affected by the moisture content of ginseng samples during the extrusion process, but was affected by the barrel temperature.

The content of crude saponin was 7.42% in WG, 9.8% in WG1 and 8.21% in WG2, showing that the crude saponin was increased during the extrusion process while decreased with increasing the temperature from 110°C to 140°C. The same trend for crude saponin was observed in MG: the content was 7.31% in MG, 7.96% in MG1 and 7.54% in MG2, respectively. Meanwhile, in WG3 and WG4, MG3, and MG4 the same results were obtained.

These results suggest that the molecular structure of saponin was changed by the extrusion process so that the release of crude saponin became easier with changing the temperature through the extrusion process. Ha et al. (17) also reported that the content of crude saponin was changed by the drying and extrusion process. Furthermore, compared with the crude saponin content of 7.42% in WG, the content of crude saponin in RG was 6.34%, which was lower than WG. This result was different with the results that crude saponin content of puffing red ginseng tail root was increased by 26.5% compared to non-puffing (18). This result may have been caused by the different production methods for RG and WG.

The degree of deformation applied to the plant cell tissue with shear stress by extrusion cooking is determined according to the screw dimension, and the shear stress affected by the changing shear rate (19-22). The results showed that more crude saponin was contained in the extruded ginseng with a lower moisture content. During the extrusion process, the amount of crude saponin increased, which was probably due to the shear stress and pressure arising from the thermal and mechanical energy dissipated as the raw ginseng passed through the screw inside the extruder barrel.

The content of total sugar

Fig. 2 shows that the content of total sugar in RG (261.04 mg/g) was obviously higher than MG (121.24 mg/g), and higher than WG (225.03 mg/g). The total sugar contents of MG1-MG4 were 122.42, 127.33, 128.09, and 125.63 mg/g respectively, and WG1-WG4 were 247.39, 245.68, 252.4, and 237.08 mg/g separately (Fig. 2). These results showed that total sugar content was not changed by the extrusion process, and it was not significantly affected by the moisture content or die temperature.

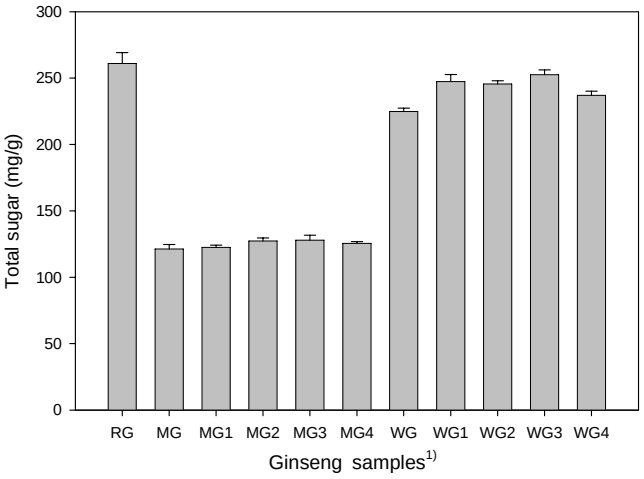

Fig. 2. Comparison of contents of total sugar in ginseng samples. [1)]Refer to the samples in Table 1.

The content of reducing sugar

As shown in Fig. 3, the content of reducing sugar in RG (98.60 mg/g) was significantly higher than MG (52.60 mg/g) and WG (37.52 mg/g). Furthermore, reducing sugar content was decreased after extrusion (Fig. 3). It was decreased with the increase in the barrel temperature and moisture content. Simultaneously, the decrease of reducing sugar in extruded MG was higher than

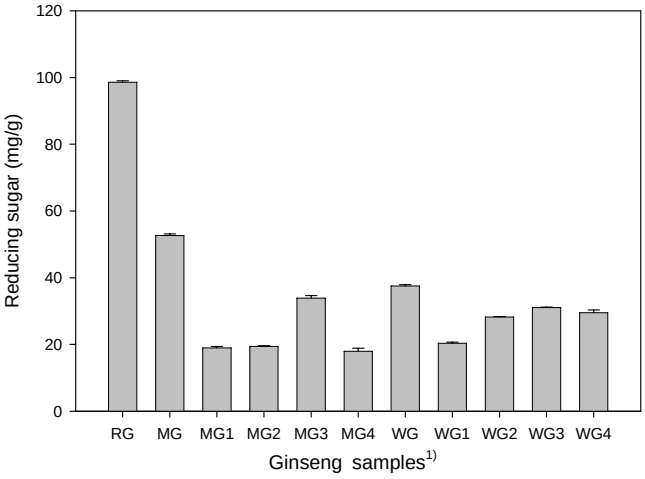

Fig. 3. Comparison of contents of reducing sugar in ginseng samples. [1)]Refer to the samples in Table 1.

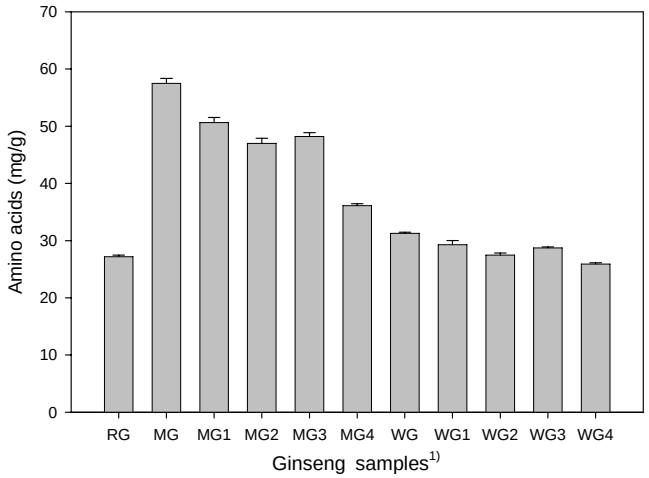

Fig. 4. Comparison of contents of amino acids in ginseng samples. [1)]Refer to the samples in Table 1.

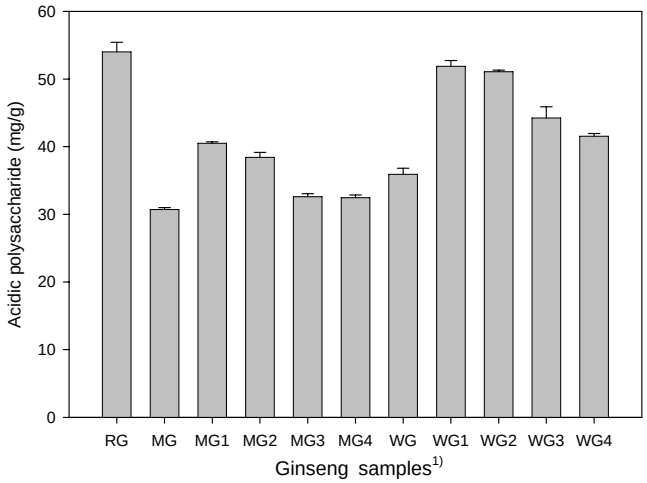

Fig. 5. Comparison of contents of acidic polysaccharide in ginseng samples. [1)]Refer to the samples in Table 1.

extruded WG. It has been previously reported that during the drying process, reducing sugar generally decreases due to the browning reaction (Maillard reaction), since reducing sugars react with amino acids (23). Thus, after extrusion, the content of reducing sugars decreased. These results were consistent with the report of Kim et al. (24) and Filipovic et al. (25).

Compared with RG, the content of total sugar and reducing sugar in WG and MG was lower (Fig. 2, 3). In WG, the total sugar content is higher than MG, while reducing sugar content is lower.

Amino acid content

As shown in Fig. 4, the order of amino acid content in raw ginseng was RG (27.16 mg/g)< WG (31.28 mg/g) < MG (57.46 mg/g). The content of amino acids decreased after extrusion. Also, the amino acids decreased more in MG than WG after extrusion. Compared with WG, there were 6.39% amino acids lost in WG1, 12.21% lost in WG2, 8.22% lost in WG3 and 17.23% lost in WG4 respectively, and there were 11.89% amino acids less in MG1, 18.22% less in MG2, 16.15% less in MG3 and 37.14% less in MG4 respectively than in MG. Comparing the extruded samples, the amino acids at die temperature 140°C and moisture content of 35% was the lowest.

Ilo and Berghofer (26) indicated that during extrusion cooking, the raw materials underwent many chemical and structural transformations that led to a variety of unique products. The processing conditions used in extrusion cooking were known to favor the Maillard reaction (27) of amino groups with reducing sugars, which led to amino acid loss and formation of color compounds. Csapo and Varga-Visi (28) also reported that amino acids were lost after extrusion processing.

The content of acidic polysaccharide

According to this research (Fig. 5), RG (54.00 mg/g) contained more acidic polysaccharide than WG (35.91 mg/g) and MG (30.71 mg/g). Furthermore, the yield of acidic polysaccharide was increased by the extrusion process. The content of acidic polysaccharide in extruded ginseng was higher than raw ginseng. The content of acidic polysaccharide in extruded WG was higher than extruded MG, while lower than RG. The acidic polysaccharides in WG1 (51.87 mg/g) and WG2 (51.07 mg/g) were similar to RG (54.00 mg/g).

After extrusion, the contents of acidic polysaccharide in MG1～MG4 were 40.50, 38.43, 32.60, and 32.45 mg/g respectively, and in WG1-WG4 were 51.87, 51.07, 44.24, and 41.54 mg/g respectively, which indicated that at the same moisture content but different barrel temperatures, the acidic polysaccharides were close. Moreover, the content of acidic polysaccharide at a moisture content of 25% was higher than 35%. From this research, we concluded that the acidic polysaccharide increased with the decrease of moisture content and barrel temperature.

Previous reports also showed the same: acidic polysaccharide was increased 2～3% by extrusion process (29). After extrusion, the content of acidic polysaccharide was increased compared with white ginseng (30). Acidic polysaccharide increased with the increase in heating temperature and time (31).

The content of polyphenolic compounds

As shown in Fig. 6, the concentrations of total polyphenolic compounds in RG, WG and MG were 1.62, 2.14, and 4.79 mg garlic acid equivalent/g respectively. Compared to the content of commercial red ginseng, the polyphenolic compound content in raw ginseng (MG and WG) was higher, while the content in extruded samples

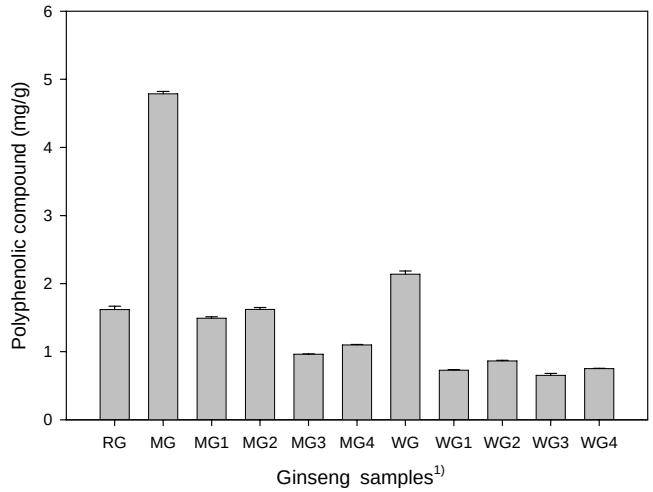

Fig. 6. Comparison of contents of polyphenolic compound in ginseng samples. [1)]Refer to the samples in Table 1.

was lower. After extrusion, the content of polyphenolic compounds decreased substantially. At a die temperature of 110°C and moisture content of 35%, the content of polyphenolic compounds was 0.65 mg and 0.96 mg garlic acid equivalent/g in WG3 and MG3, and was the lowest in extruded samples. The content of polyphenolic compounds decreased with increasing moisture content and decreaing die temperature.

Polyphenolic compounds are plant secondary metabolites of biological and pharmacological significance, exerting antioxidant (32,33), antiallergic (34) and antigonadotropic effects (35). Whereas, this study indicated that the polyphenolic compounds decreased after extrusion. In the future, a suitable temperature and moisture content should be found for preserving polyphenolic compounds.

CONCLUSION

This research compared the physicochemical properties of root hair of red ginseng, root hair of white ginseng, root hair of tissue cultured mountain ginseng and extruded samples of raw ginseng at different temperatures (110°C and 140°C) and moisture contents (25% and 35%). Compared with RG and WG, the contents of crude ash, crude protein, amino acids and polyphenolic compound in MG were the highest. The content of crude saponin and acidic polysaccharide increased after extrusion and increased with decreased moisture content and barrel temperature. The content of crude fat, reducing sugar, amino acids and polyphenolic compounds also decreased. Furthermore, crude fat and polyphenolic compounds decreased with the decrease in the barrel temperature. However, reducing sugar and amino acids decreased with increased barrel temperature and moisture content. The content of crude ash, crude protein and total sugar was unchanged after extrusion.

In a short, most bioactive components in MG were higher than RG and WG. There is a good rational for using root hair of tissue cultured mountain ginseng. The content of some components changed after extrusion, and the application of the extrusion process to the processing of red ginseng could probably shorten the processing.

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