

건조과정 중 갈변에 의한 양파가루의 항산화 특성 연구

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Enhancement of Antioxidant Activity of Onion Powders by Browning during Drying Process

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Abstract Drying process was applied to increase the antioxidant activity of onion powder: freeze-drying or air-drying at 50, 70, and 90°C and onion extracts were obtained from each powder using water or aqueous ethanol (50%) at 25°C and 60°C. In the color analysis, the freeze-dried powders showed higher *L** and lower *a** and *b** values than did the air-dried ones. The browning index of powders air-dried at 90°C was significantly higher than that of freeze-dried powders or those air-dried at temperatures below 90°C. Phenolic content in the extracts was 4.02-23.12 mg gallic acid equivalent/g sample, and was the highest in the extract from the sample air-dried at 90°C, regardless of the extraction condition. The highest antioxidant activity, measured by 2,2-azinobis-3-ethylbenzothiazoline-6-sulfonic acid and 1,1-diphenyl-2-picrylhydrazyl methods, was found in the powder air-dried at 90°C, which induced browning. These findings indicate that antioxidant activity depends more on browning during drying than on extraction conditions.

Keywords: onion powder, air-drying, browning index, phenolic content, antioxidant activity

Introduction

Onion (*Allium cepa* L.) is a popular vegetable consumed worldwide due to its unique flavor and functional properties resulting from residual polyphenols. It is specifically recognized as the major dietary source of quercetin in the form of aglycone or O-glycosylated derivatives (1). The quercetin has also been reported to have many health-promoting functions based on its strong antioxidant activity (2), which includes cholesterol-reducing (3), allergy-suppressing (4), blood circulation (5), and blood sugar-reducing functions (6).

Onion is, however, readily spoiled during storage due to the residual enzymatic action and/or microbial contamination. Dehydration is one of the common processes to minimize the spoilage as well as to reduce bulk handling and enable off-season use (7). Dried onion powders have been used in various processed foods like soups, sauces, salad dressing, sausages, and meat products (8) with superior storage stability and convenience (9). Different methods for drying using air (8), steam (10), freezing

(11,12), sun, oven, and microwave (13) have been reported. Thermal treatments for drying, however, often cause significant changes in chemical and biological functions of onions, which may cause the changes in taste, color, and nutrient components. Mota *et al.* (8) reported that the nutrient composition of onion was highly susceptible to the temperature for drying. Pérez-Gregorio *et al.* (12) reported that freeze-drying has a positive effect on the levels of total flavonols and anthocyanins in red onions because of the change in the tissue structure during freeze-drying.

In addition, onion extracts have been reported to possess many biological activities including antioxidant, anti-carcinogenic, anti-mutagenic, and prebiotic activities (14) or anti-browning effect (15). Despite the studies on the functionality of onion extracts (12,16,17), few studies have been reported on the effects of extraction and drying process in association with the physical and physiological properties of onion products.

Recently, since the positive correlations between browning and antioxidant properties have been reported in food systems including onion (11,18-22), more researches about processing condition inducing browning in foods are needed for improving functionality. In this study, onion powders using different processes for drying were prepared and onion extracts were obtained from each onion powder under different extraction conditions. Physical properties of the onion powders and antioxidant activity of the onion extracts were then compared.

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Materials and Methods

Materials

Onions harvested at Mun-Kyeong (Gyeongsangbuk-do, Korea) in 2014 were purchased from a local market. Gallic acid, Folin-Ciocalteu phenol reagent, 1, 1-diphenyl-2-picrylhydrazyl (DPPH), 2, 2-azinobis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS), 3, 5-dinitrosalicylic acid (DNS), L-ascorbic acid, and D-glucose were purchased from Sigma-Aldrich Co. (St. Louis, MO, USA).

Preparation of onion powders

After removing roots and stems, the onion bulbs peeled and washed with tap water. Only onion pulp were sliced to a width of 1-2 cm, and then dried using a freeze-dryer (Eyela FDU-2100, Tokyo Rikakikai Co., Tokyo, Japan) at -80°C for 3 days (FDOP) or a convection oven (MOV-212F, Sanyo Electric, Osaka, Japan) at 50°C for 24 h, 70°C for 12 h, or 90°C for 9 h (50OP, 70OP, and 90OP, respectively). The dried onion slices were ground to powders using a grinder (JL-1000, Hibell, Seoul, Korea), and the onion powders were stored in sealed bags at -20°C before analysis.

Moisture, color, and browning index of onion powders

The moisture content of onion powder was measured by the AOAC method (23) by drying at 105°C and presented by dry basis %.

The color of the onion powders was measured using a colorimeter (CR-10, Konica Minolta Sensing Inc., Osaka, Japan). Total color difference (ΔE) was calculated as follows:

$$\Delta E^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

where, L_1 , a_1 , b_1 are the values of control (fresh onion), and L_2 , a_2 , and b_2 are the values of each dried onion.

The browning index was determined using the method of Baloch *et al.* (24), with minor modifications. Onion powder (0.5 g, dry base) was mixed with 20 mL of distilled water and 5 mL of 10% trichloroacetic acid. The mixture was kept at room temperature for 2 h and then centrifuged at 2600 g for 15 min. The supernatant was filtered (Whatman No. 1) and the browning index was measured at 420 nm using 2% trichloroacetic acid solution as a blank.

Preparation of onion powder extracts

For extraction, dried onion powders (1.5 g, dry base) were dispersed in 30 mL of distilled water or an aqueous ethanol (50% alcohol) at different temperatures (25 and 60°C) for 2 h. The dispersions were centrifuged at 2600 g for 15 min, and the supernatants were filtered, evaporated under a reduced pressure at 60°C to remove ethanol, and then freeze-dried. The pH of extracts was measured by a pH meter (Model 440, Corning Inc., New York, USA) before freeze-drying. The recovery yield was calculated as the percent solids in the extracts based on the solids of powders.

Total phenolic content in onion extracts

The total phenolic content (TPC) was determined using the method of Cho *et al.* (25) and expressed as gallic acid equivalent (GAE).

Reducing sugar content in extracts

The reducing sugar content in the onion powder extracts was determined using DNS reagent following the method of Miller (26).

Radical scavenging activity assessed by DPPH and ABTS

The DPPH radical scavenging activity and ABTS radical scavenging activity were measured according to the method of Brand-Williams *et al.* (27) and Re *et al.* (28), respectively. Vitamin C (ascorbic acid, $20 \mu\text{g/mL}$) was used as a positive control.

Statistical analysis

All experiments were carried out in triplicate, and statistical analyses were performed using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA). Statistical differences were tested using one-way analysis of variance (ANOVA) and Duncan's multiple-range tests at a significant level at 0.05. The critical p -values were set at 0.05 and a probability value of $p < 0.05$ was considered statistically significant.

Results and Discussion

Color and browning of onion powder by drying

Moisture contents of the air-dried onion powders varied from

Table 1. Moisture content, color and browning index of fresh onion and onion powders

Samples	Moisture content (dry basis%)	Color			ΔE	Browning Index
		L value	a value	b value		
FO	91.71±0.69	79.0±0.2 ^b	-2.2±0.2 ^d	15.9±0.5 ^c	0	-
FDOP	13.98±0.11	82.0±0.5 ^a	1.7±0.2 ^d	21.5±0.2 ^d	6.4±0.2 ^a	0.083±0.002 ^d
50OP	4.21±0.11	73.3±0.6 ^c	5.0±0.3 ^c	28.1±0.1 ^b	14.3±0.1 ^b	0.136±0.004 ^c
70OP	3.94±0.14	63.2±0.3 ^d	11.1±0.5 ^b	30.4±0.6 ^a	25.4±0.8 ^c	0.755±0.005 ^b
90OP	3.55±0.04	43.7±0.4 ^e	13.4±0.4 ^a	23.8±0.4 ^c	39.5±0.4 ^d	1.218±0.001 ^a

FO: fresh onion; FDOP: freeze-dried onion powder; 50OP, 70OP, and 90OP: air-dried onion powders at 50, 70 and 90°C for 24, 12 and 9 h, respectively. Values in the same column with different letters (a-e) mean significant difference ($p < 0.05$).

Table 2. Yield, pH, total phenolic and reducing sugar contents of onion powder extracts

Samples	Extract condition	Yield	pH	Total phenolic contents (mg GAE/g sample)	Reducing sugar contents (mg/100 mL)
FDOP	25 DW	72.0±0.9	5.30±0.02 ^a	4.02±0.01 ^d	75.60±0.33 ^a
50OP		68.7±0.1	5.08±0.01 ^b	4.98±0.09 ^c	65.37±0.40 ^c
70OP		67.7±0.5	4.57±0.02 ^c	7.85±0.23 ^b	70.29±1.14 ^b
90OP		72.3±0.5	4.34±0.01 ^d	22.10±0.46 ^a	42.07±3.19 ^d
FDOP	25 EtOH	72.3±0.5	5.23±0.03 ^a	4.26±0.23 ^d	70.68±0.13 ^b
50OP		74.0±0.1	5.13±0.05 ^a	5.92±0.33 ^c	75.39±0.35 ^a
70OP		76.7±0.9	4.50±0.13 ^b	9.75±0.21 ^b	67.29±0.57 ^c
90OP		76.3±0.5	4.22±0.02 ^c	23.12±0.72 ^a	50.56±1.36 ^d
FDOP	60 DW	72.0±0.9	4.83±0.01 ^a	6.58±0.40 ^c	76.78±0.27 ^b
50OP		65.7±0.5	4.74±0.01 ^b	4.45±0.11 ^d	83.22±0.13 ^a
70OP		64.7±0.1	4.47±0.01 ^c	8.32±0.07 ^b	73.16±1.29 ^c
90OP		69.3±0.1	4.20±0.02 ^d	21.76±0.61 ^a	45.73±1.20 ^d
FDOP	60 EtOH	71.0±0.5	5.26±0.02 ^a	6.81±0.40 ^c	76.91±1.23 ^a
50OP		69.0±0.5	5.22±0.01 ^a	5.03±0.17 ^d	69.24±0.57 ^b
70OP		72.0±0.9	4.58±0.04 ^b	9.64±0.13 ^b	70.90±0.98 ^b
90OP		73.3±0.1	4.21±0.04 ^c	22.01±0.57 ^a	41.98±0.67 ^c

FDOP: freeze-dried onion powder; 50OP, 70OP, and 90OP: air-dried onion powders at 50, 70 and 90°C for 24, 12 and 9 h, respectively. Values in the same column with different letters (a-d) mean significant difference ($p < 0.05$).

3.55 to 4.21% depending on drying temperature and time. The freeze-dried samples contained a higher amount of moisture than the air-dried samples (Table 1). The color characteristics were significantly different among the dry onion powders indicating the susceptibility on drying methods and conditions. The FDOP showed a higher L^* value and lower a^* and b^* values than the air-dried samples, indicating that the air drying induced more changes on the color. As the temperature increased for air-drying, the L^* value decreased whereas the a^* value increased, consistent with a report published elsewhere (17). Total color differences (ΔE^*), which indicate the color difference between fresh and dried onion powder were presented in Table 1. The ΔE^* of air-dried onion powder was higher than that of freeze-dried one, and the value increased dramatically with drying temperature increase. Regarding the browning index, the FDOP showed the much lower value (0.083) than those of air-dried samples. It was increased from 0.136 to 1.218 as the drying temperature increased, indicating that the browning was facilitated by increasing drying temperature (29). The values between color difference (ΔE) and browning index of onion powders was closely correlated ($R^2=0.9614$).

Characteristics of onion powder extracts

The extraction yields of solids from the onion powders either in water and alcohol solutions were shown in Table 2, which ranged from 64.7-76.7%. The highest yield was obtained when onion powders dried at 70 or 90°C were extracted at 25°C in aqueous alcohol solution.

The pH values of the onion powder extracts were in a range between 4.20 and 5.30 depending on the drying conditions. The pH of the freeze-dried samples was higher than those of the air-dried ones, and the higher temperature for drying resulted in

the lower pH, indicating that the browning induced by the thermal drying caused the pH decrease for the onion extracts. Similarly, Kehrberg and Johnson (30) reported that pH decrease during maillard reaction has been attributed to the reaction of the basic amino groups with reducing sugars.

The total phenol contents (TPC) of the onion powder extracts are shown in Table 2. It ranged from 4.02 to 23.12 mg GAE/g depending on the drying and extraction conditions. More importantly, the drying temperatures instead of methods for extraction appeared the major determining factor for the TPC. Especially when the drying temperature increased from 70 to 90°C for air-drying, the TPC increase was substantial. The increase in TPC by heating may reflect the production of phenolic compounds in dry onion powders. Air-drying at a high temperature could induce production and/or thermal release of polyphenols from plant matrices, which could result in an increase of antioxidant activity (31). In onion powder, because the release of polyphenol aglycones increased by hot air drying (32), so it could be assured that high temperature air-drying could deactivate some enzymes, which would destroy the antioxidants in food, and this could avoid the loss of phenolic acids, resulting in increase of polyphenol. Similar result was reported by Chang *et al.* (33).

The reducing sugar contents of onion powder extracts were varied according to the drying and extraction conditions (Table 2). Like the TPC, the reducing sugar content in the extracts was more susceptible to the drying temperature than the drying methods or extraction conditions. Among the air-dried samples, the temperature increased from 70 to 90°C resulted in significant decreases in reducing sugar content, whereas that from 50 to 70°C caused relatively minor decreases. The sugar degradation with formation of phenolic compounds proved that there was Maillard browning reactions during drying process (8).

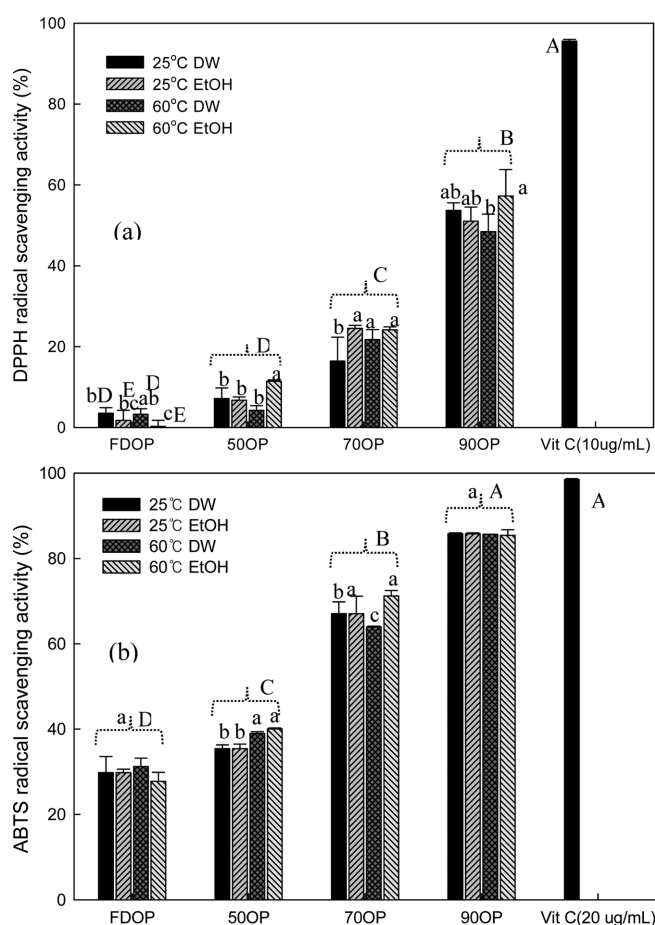


Fig 1. (a) DPPH and (b) ABTS radical scavenging activity (%) of onion powder extracts; FDOP: freeze-drying, 50OP: 50°C hot-air drying, 70OP: 70°C hot-air drying, and 90OP: 90°C hot-air drying. Bars with different letters (A-E, in samples with different drying condition at same extraction, and a-c, in samples with same drying condition at different extraction) indicate significant ($p < 0.05$) differences.

The antioxidant activity of onion powder extracts was evaluated by measuring their ABTS and DPPH radical scavenging activities and the results are shown in Fig 1. (a) and (b), respectively. The extraction conditions for onion powder extracts did not affect the ABTS and DPPH radical scavenging activity; however, the drying process before extraction, especially the drying temperature for onion powder, significantly affected the results. For the DPPH radical scavenging activity, the extracts from 90OP had the highest activity (about 60% for a concentration of 1.0 mg/mL), although the highest activity of 90OP was lower than that of vitamin C (at a concentration of 10 µg/mL). The ABTS radical scavenging activity of onion extracts showed a similar trend to the DPPH radical scavenging activity, and the activity was comparable to that of vitamin C (at a concentration of 20 µg/mL).

Conclusion

The drying process before extraction, especially the drying temperature for onion powder preparation, significantly affected

the properties of powders such as pH, color or browning index. Air-dried one, especially at the highest temperature (90°C) had the strongest antioxidant activity, resulting from the highest TPC and the lowest reducing sugar content. It seems that the increased polyphenol contents was due to the liberation from matrix as well as melanoidins produced via Maillard reaction. Extraction conditions, including solvents and temperature after drying, however, little affected the ABTS and DPPH radical scavenging activity of onion powder.

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