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Physicochemical Characteristics of Kohlrabi Slices Dehydrated by the Addition of Maltodextrin

- Research Note -

Shu-Mei Wang, Dong-Jin Yu, and Kyung Bin Song†

Department of Food Science & Technology, Chungnam National University, Daejeon 305-764, Korea

Abstract

Kohlrabi (*Brassica oleracea* var. gongylodes L.) slices were dehydrated with maltodextrin (MD) at concentrations of 20, 30, and 40% (w/w), and the dried samples were compared with the freeze-dried and hot-air dried samples regarding various physicochemical qualities. The MD-treated samples had better results than those of freeze-dried or hot-air dried samples in terms of rehydration ratio and color. The total phenolic content of the MD-treated sample was similar to that of the freeze-dried and higher than that of hot-air dried sample. The ascorbic acid content of the MD-treated samples was also higher than that of the hot-air dried one. These results suggest that kohlrabi can be dehydrated with MD instead of hot air.

Key words: kohlrabi, dehydration, maltodextrin, cytorrhysis

INTRODUCTION

Vegetables of Brassicaceae family are widely consumed because of their phytochemicals, such as phenolic compounds and glucosinolates (1). In particular, glycosides of kaempferol and quercetin, and their derivatives, in combination with hydrocinnamic acids, as well as sinapic acid derivatives, are the most important phenolic compounds in the Brassicaceae family (2).

Kohlrabi (*Brassica oleracea* var. gongylodes L.) is a member of Brassicaceae family, and is a good substitute for radishes because it is less bitter and pungent (3). However, kohlrabi deteriorates quickly after harvest, and its shelf life is less than 2 weeks. Thus, controlled atmosphere or modified atmosphere storage methods are usually used to extend the shelf life of kohlrabi (4,5). Otherwise, drying is a common method to preserve the vegetable for a longer storage.

As a dehydration method, molecular press dehydration is based on cytorrhysis phenomenon, which is similar to osmotic dehydration, except for the molecular size of the dehydrating agent such as maltodextrin (6). Dehydration using cytorrhysis occurs outside of plant cell walls since the dehydrating agent cannot penetrate into the cells due to its bigger size than pores of the cell wall (6-8). Therefore, dehydration is more effective, with less loss of the food components. In addition, previous studies have shown that molecular press dehydration gives the dehydrated products better quality in terms of rehydration ratio, color, sensory, and texture than freeze drying or hot-air drying (6).

In the present investigation, the objectives were to investigate the effect of maltodextrin as a dehydrating agent on drying of kohlrabi, and to compare it with freeze drying or hot-air drying in terms of rehydration ratio, ascorbic acid, total phenolic content, and color.

MATERIALS AND METHODS

Materials

Kohlrabi samples were obtained right after harvest in Daejeon, Korea, and stored at 4°C until used. Before the dehydration process, kohlrabi samples were peeled and sliced using a food slicer to ensure a uniform thickness (2±0.5 mm). Maltodextrin DE 14-20 (MD, Shandong Baolingbao Biotech., Shandong, China) was used as a dehydration agent.

Drying process

Kohlrabi slices (100 g) were dehydrated at 25°C in a low density polyethylene bag containing different amount of MD powder (20, 30, and 40 g) with gentle shaking. After dehydration, samples were washed with minimal amount of water to remove the adsorbed MD on the surface, and then placed in an incubator at 25°C to eliminate any remaining water. For freeze-drying, samples were frozen and lyophilized using a freeze dryer (FD-5508, Ilshin Lab Co., Seoul, Korea). For hot-air drying, samples were dried using a hot air dryer (HB-502LP, Hanbaek Co., Bucheon, Korea) at 60°C.

†Corresponding author. E-mail: kbsong@cnu.ac.kr
Phone: +82-42-821-6723, Fax: +82-42-825-2664

Analysis of moisture content

Moisture content of the dehydrated samples was determined according to the method of AOAC (9). The initial moisture content of fresh kohlrabi was 88.71 g/100 g.

Measurement of rehydration ratio

Dried samples (1 g) were immersed in 100 mL distilled water at 25°C for 10, 20, 30, 40, and 50 min. After rehydration, samples were drained for 2 min to remove excess water which is physically entrapped on the surface. All samples were weighed under the same experimental conditions. All measurements were carried out in triplicate and rehydration ratio was calculated as the ratio of grams of water absorbed per sample weight.

Determination of ascorbic acid content

Ascorbic acid content of fresh and dried kohlrabi was determined with the 2,6-dichlorophenol indophenol titrimetric method (9). All measurements were performed in triplicate.

Determination of total phenolic content

Total phenolic content of fresh and dried kohlrabi was determined with Folin-Ciocalteau reagent (10). Total phenolic content was expressed as milligrams of gallic acid equivalents per 100 g of the sample. All measurements were done in triplicate.

Color measurement

Color of samples was analyzed using a colorimeter (CR-300 Minolta Camera Co., Osaka, Japan). Samples were placed on a white standard plate and Hunter values (L^*, a^*, b^*) were determined. Each sample was measured 5 times at different locations. Hunter L^*, a^*, and b^* values for the standard plate were L^*=96.65, a^*=-0.18, and b^*=2.10. Chroma value, representing color intensity of the sample, was calculated as $(a^{*2}+b^{*2})^{1/2}$, and the total color difference (ΔE) was defined using the following equation:

$$\Delta E = [(L^* - L_0^*)^2+(a^* - a_0^*)^2+(b - b_0^*)^2]^{1/2}$$

where L^*, a^*, and b^* are the measured values of the dehydrated kohlrabi, and L_0^*, a_0^*, and b_0^* are the values of fresh kohlrabi.

Statistical analysis

Statistical analysis was performed using a SAS program (SAS Institute, Inc., Cary, NC, USA), and mean values were compared with Duncan's multiple range test at the 5% level of significance.

RESULTS AND DISCUSSION

Dehydration of kohlrabi with MD

Cytorrhysis phenomenon was applied to the dehydration of kohlrabi slices, and the higher the MD concentration, the better the dehydration efficiency (data not shown). Regarding the effect of dehydrating agent concentration, osmotic dehydration has the similar results (11,12). However, in the case of osmotic dehydration, dehydration rate is low, since the concentration difference of dehydrating agent between the inside and the outside of the cells is small during dehydration. In the case of molecular press dehydration with MD, dehydration efficiency is better than osmotic dehydration, since the concentration gradient between the inside and the outside of the cell is maintained continuously during dehydration (6). After dehydration with MD, the final moisture contents of the MD (20, 30, and 40%) treated kohlrabi slices were 14.43, 13.02, and 12.89%, respectively.

Rehydration ratio of the dehydrated kohlrabi

Rehydration capacity is a good criterion for determining the quality of the dried vegetables. Rehydration is a diffusion process, where water goes from the outside of the cells into the interior, and the rehydration capacity of samples depends on the type of drying method (13). During the first 10 min of rehydration, all dried kohlrabi samples were rehydrated quickly and the rehydration ratio of all the MD-treated samples were higher than that of the freeze-dried or hot-air dried samples (Fig. 1). Fig. 1 also indicates that the dried samples were rehydrated rapidly at first, but that the rehydration rate slowed down as rehydration proceeded, similar to previous reports (7,8). After 50 min of rehydration, the rehydration ratio of the MD-treated samples was the highest among the samples, and the value of the MD-treated samples increased with the increasing MD concentration. The rehydration ratios of MD-treated (20, 30, and 40%) samples were 22.94, 23.38, and 24.43 g/g, respectively. In addi-

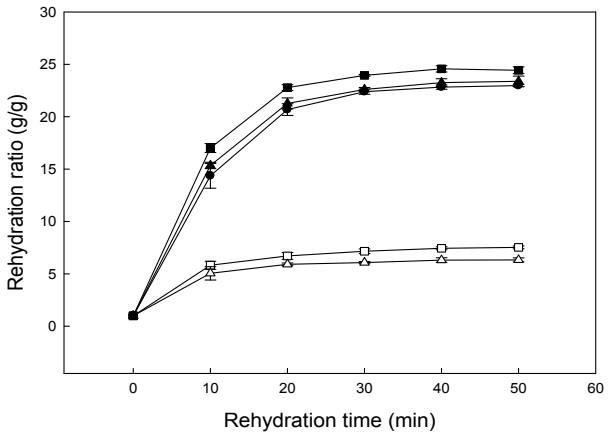

Fig. 1. Rehydration ratio of the dried kohlrabi slices. ●: MD 20%, ▲: MD 30%, ■: MD 40%, △: hot-air drying, □: freeze drying.

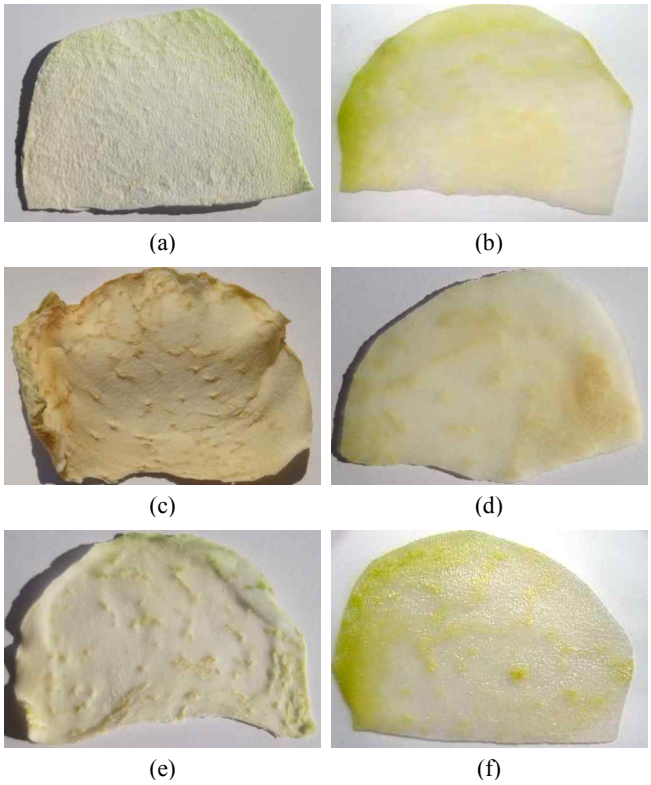

Fig. 2. Photos of the dried kohlrabi before and after rehydration. Freeze-dried kohlrabi before (a) and after (b) rehydration, Hot-air dried kohlrabi before (c) and after (d) rehydration, MD-treated kohlrabi before (e) and after (f) rehydration.

tion, photos of the kohlrabi samples before and after rehydration also represent that the MD-treated sample preserved the quality of the fresh kohlrabi (Fig. 2).

The rehydration ratios of freeze-dried and hot-air dried samples after 50 min of rehydration were 7.53 and 6.34 g/g, respectively, which were lower than those of the MD-treated samples. This difference might be due to the following reasons: during the process of freeze drying, cells would collapse, causing the solute matrix to lose its shape (14), for hot-air drying, water is lost rapidly because of high drying temperature, which makes cells shrink and the tissues because damaged, leading to a lower diffusion of water through the surface during rehydration (15).

Ascorbic acid content and total phenolic content

Functional components of Brassica vegetables are mainly ascorbic acid, phenolic compounds, and glucosinolates (1,16-18). It is well known that most of the biological functions of Brassica vegetables are related to their antioxidative properties (19,20), and ascorbic acid and phenolic compounds are the major antioxidants (20). Therefore, in the present investigation, the contents of ascorbic acid and phenolic compounds in the kohlrabi were determined (Table 1).

Table 1. Ascorbic acid content and total phenolic content (TPC) of the dehydrated kohlrabi slices

	Ascorbic acid content (mg/100 g)	TPC (mg GAE/100 g)
Control[1)]	$432.03 \pm 1.30^{a2)}$	346.88 ± 1.69^{a}
Freeze drying	423.91 ± 3.09^{b}	342.73 ± 0.85^{a}
Hot-air drying	260.51 ± 0.40^{f}	258.96 ± 2.38^{c}
MD 20%	398.43 ± 3.39^{c}	345.88 ± 1.66^{a}
MD 30%	389.70 ± 1.71^{d}	333.53 ± 4.16^{b}
MD 40%	395.87 ± 1.74^{c}	331.76 ± 1.66^{b}

[1)]Raw kohlrabi.
[2)]Any means in the same column followed by different letters are significantly different ($p<0.05$).

Podsedek (20) has reported that the ascorbic acid content of the edible part of Brassica vegetables was in the range of 17～186 mg/100 g, and the total phenolic content was 15～337 mg GAE/100 g. However, in the present investigation, the ascorbic acid content and total phenolic content of fresh kohlrabi were 432.03 mg/100 g and 346.88 mg GAE/100 g, respectively, which were higher than those in the report of Podsedek (20). For the hot-air dried kohlrabi, they were 260.51 mg/100 g and 258.96 mg GAE/100 g, respectively, and the low contents were mainly due to the destruction of ascorbic acid and phenolic compounds during hot-air drying (21). In contrast, the freeze-dried samples had the similar ascorbic acid and total phenolic contents to those of the fresh kohlrabi, while the MD-treated kohlrabi had higher contents than those of hot-air dried samples, but lower contents than those of the freeze-dried ones. This could be due to the fact that some of the ascorbic acid and phenolic compounds came out as the exudates during dehydration process. However, it should be noted that MD treatment is a better method for dehydration of kohlrabi, considering the cost and processing time of freeze drying.

Color measurement

Discoloration of plant tissue is usually related to pigment destruction, enzymatic or oxidative browning, and Maillard reaction (22). Color parameters of the MD-treated samples were better than those of other dried samples, indicating that color can be preserved well by the MD treatment (Table 2). Similar results have been reported for the dried strawberry, persimmon, ginger, and other vegetables treated with MD (6-8). In particular, dehydration of vegetables and fruit with MD can avoid enzymatic browning, since direct exposure of cell components to the air is prevented by covering the tissues with dehydrating agents (6). Therefore, the MD-treated samples had less damage on the color of the samples than other drying methods.

In contrast, color parameters of the freeze or hot-air

Table 2. Hunter color value of the dehydrated kohlrabi slices

	Color parameter				
	L^*	a^*	b^*	⊿E	Chroma
Control[1)]	89.57±0.02[b2)]	-2.03±0.01[b]	11.21±0.01[c]	0.00±0.00	11.39±0.01[c]
Freeze drying	92.20±0.03[a]	-2.37±0.01[e]	7.47±0.00[f]	4.59±0.01[b]	7.83±0.01[f]
Hot-air drying	85.48±0.05[f]	-1.39±0.01[a]	14.53±0.01[a]	5.30±0.03[a]	14.60±0.02[a]
MD 20%	90.65±0.10[b]	-2.18±0.02[c]	8.72±0.01[e]	2.71±0.04[c]	8.99±0.00[e]
MD 30%	89.17±0.10[c]	-2.25±0.01[d]	10.07±0.03[d]	1.23±0.05[e]	10.32±0.03[d]
MD 40%	87.89±0.08[d]	-2.36±0.02[e]	11.69±0.03[b]	1.78±0.08[d]	11.93±0.03[b]

[1)]Raw kohlrabi.
[2)]Any means in the same column followed by different letters are significantly different ($p<0.05$).

dried samples were altered, compared to the fresh sample. Lightness value (L^*) of 92.20 in the freeze-dried sample was higher compared to the control of 89.57, while redness (a^*) and yellowness (b^*) values were lower than the control. The results indicate that the freeze-dried sample is brighter than the fresh sample, but plant cells can be damaged during freeze drying process, resulting in a change in color (23). In addition, the hot-air dried sample, different from the freeze-dried sample, has lower lightness and higher redness and yellowness, compared to the control. Hunter L^*, a^*, and b^* values for the hot-air dried sample were 85.48, -1.39, and 14.53 respectively, while the control had 89.57, -2.03, and 11.21. These results indicate that hot-air drying causes a dark color, the result of Maillard reaction and pigment destruction (24).

Color change can be explained by the total color difference (ΔE) and chroma value as shown in Table 2. ΔE value of the MD-treated samples was less than 3.0, but ΔE values for the freeze and hot-air dried sample were 4.59 and 5.30, respectively, indicating a significant difference compared to the control. Also, the chroma value of the freeze-dried sample (7.83) was significantly lower than the control (11.39), while the value of the hot-air dried sample (14.60) was significantly higher.

In summary, MD can be used as an effective dehydrating agent for drying kohlrabi. In particular, considering the rehydration ratio and color of the dried kohlrabi, the quality of the MD-treated kohlrabi was well-maintained, compared with the freeze-dried or hot-air dried sample. Regarding the ascorbic acid and total phenolic content, the MD-treated and the freeze-dried samples had similar values with those of fresh kohlrabi. In addition, the MD concentration used (20～40%) did not affect the quality of the dehydrated product very much. Therefore, taking the cost of MD into consideration, these results suggest that kohlrabi can be dehydrated with 20% MD.

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