碩士學位論文

Molecular Press Dehydration of Purple Sweet Potato using Maltodextrin

濟州大學校 大學院

食 品 工 學 科

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2017年 2月

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指導敎授 金 賢 貞

趙 萬 宰

이 論文을 工學 碩士學位 論文으로 提出함

2016年 12月

趙萬宰의 工學 碩士學位 論文을 認准함

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濟州大學校 大學院

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Molecular Press Dehydration of Purple Sweet Potato using Maltodextrin

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A thesis submitted in partial fulfillment of the requirement for the degree of Master of Engineering

2016. 12.

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Dec. 2016

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ABSTRACT

Molecular press dehydration is one of the dehydration methods. Purple sweet potatoes were dehydrated with maltodextrin as a molecular press dehydrating agent with different concentration of 0, 20, 40, 60, 80, and 100% and different dextrose equivalent (DE) of 4-7, 13-17, 16.5-19.5, and 17-20. Molecular dehydration rate of the purple sweet potatoes increased over the time. As the concentration of maltodextrin increased, moisture content after 12 h of dehydration decreased from 64.46 to 66.38, 52.95, 39.70, 34.53, 28.59 and 29.20%, respectively, and as the DE level of maltodextrin increased, moisture content after 12 h of dehydration decreased from 65.79% to 40.78, 36.14, 34.92, and 28.59%, respectively. Total phenolics, total anthocyanins, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activities decreased as the concentration and the DE of maltodextrin increased. The maltodextrins with concentration of 80 and 100% and DE of 16.5-19.5 and 17-20 effectively dehydrated purple sweet potatoes; however, total phenolics, total anthocyanins, DPPH radical scavenging activities, and color measurement values were lowered during dehydration. The DPPH radical scavenging activities were correlated to both total phenolics (r^2=0.96) and total anthocyanins contents (r^2=0.95) of purple sweet potatoes. These results indicated that the purple sweet potatoes were effectively dehydrated with 80% over and the DE of 16.5-20 maltodextrin although there were losses of total phenolics and total anthocyanins.

The quality characteristics of tarts made with dehydrated purple sweet potatoes during storage were studied. The purple sweet potato tarts were evaluated by analyzing moisture content, water activity, total phenolics, anthocyanins, DPPH free radical scavenging activity, color, and sensory

evaluation for 45 days of storage at room temperature. Moisture contents of tart crust made with dehydrated purple sweet potatoes with concentrations of 20, 40, 60, and 80% maltodextrin for 45 days were 8.47, 7.95, 6.96, and 6.24% respectively; however, moisture content of non-treated tart crust was 11.99% ($p<0.05$). Total phenolics, anthocyanins, and DPPH free radical scavenging of dehydrated purple sweet potato tarts were lowered than those of non-treated tart ($p<0.05$). These results indicated that tarts made with molecular press dehydrated purple sweet potatoes effectively controlled moisture content and water activity during storage although total phenolics, anthocyanins, DPPH free radical scavenging activity, color, and sensory evaluation were decreased.

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PART I

Effects of Maltodextrin Concentration and Dextrose Equivalent on the Quality Characteristics of Jeju Purple Sweet Potato (*Ipomoea batatas* L.) during Molecular Press Dehydration

I . Introduction

Molecular press dehydration is a similar method with the osmotic dehydration and related to the cytorrhysis phenomenon occurring outside of the plant cell walls by using a dehydrating agent (Choi *et al.*, 2006; Oparka, 1994). Large polymers used for molecular press dehydration remained outside tissue of the cell because the sizes of the polymers were greater than those of the cell wall while small solutes moved through pores of the cell wall (Lim, 2008). Therefore, molecular press dehydration method dehydrated a larger amount of moisture compared to osmotic dehydration (Yoo and Seo, 2004). Choi and Shin (1999) reported that potato slices were more effectively dehydrated with high molecular solution than with low molecular solution. Lee *et al.* (2009) reported that molecular press dehydrated ginseng had stable color, grain size, and sensory characteristics.

Maltodextrin has been used as an effective dehydrating agent with large molecular size for molecular press dehydration (Lee *et al.*, 2010). In addition, maltodextrin is a rich and chip resource without any restriction to use in foods (Han *et al.*,2013; Downham and Collins, 2000). Because maltodextrin polymers cannot penetrate into the plant cells, molecular press dehydration with

maltodextrin can prevent the change of useful components in the cells as well as other chemical reactions such as oxidation and browning (Torres *et al.*, 2012). Moreover, dehydrated material could remain stable during storage by preventing the spoilage by microorganisms because the material was coated by dehydrated solution, a high concentration of maltodextrin (Yoo, 2005). The recent study reported that high sugar dehydrated solution retarded the spoilage by microorganisms during storage at room temperature and low temperature (Seo *et al.*, 2010). Maltodextrin, a dextrin with less than dextrose equivalent (DE) 25, is usually commercialized to the extent of DE 1 (Sun *et al.*, 2010). The higher DE number of maltodextrin, is the smaller molecular weight and the greater amounts of glucose and maltose (Nagar *et al.*, 2011). Therefore, the levels of maltodextrin DE may differently contribute to the molecular press dehydration.

Purple sweet potatoes contained greater amounts of vitamin C, vitamin E, β-carotene, and anthocyanins than white, yellow, and orange colored potatoes and were known to prevent aging and enhance immune system so that getting much attention to the consumers (Rumbaoa *et al.*, 2009). Anthocyanins in purple sweet potatoes were known to have antioxidant, antibacterial activity, and antihypertensive action (Kim *et al.*, 2010). The recent study reported that purple sweet potatoes had anthocyanins ranged from 20.02 to 40.79 mg/100 g (Ahmed *et al.*, 2011). However, beneficial activities of anthocyanins could be lost during food processing, cooking, and storage (Cevallos-Casals and Cisneros-Zevallos, 2004; Lee and Rhim, 1997). It is necessary to protect anthocyanins in purple sweet potato during food processing. The aim of this study was to investigate the effects of maltodetrin concentration and DE during molecular press dehydration on the quality characteristics of purple sweet potatoes produced in Jeju.

Ⅱ. Materials and Methods

1. Materials

Fresh purple sweet potatoes were provided from Jeju Purple Sweet Potato Farming Association Corporation (Jeju, Korea). Maltodextrin of DE 17-20 (Samyang Genex Co., Seoul, Korea) was used as a dehydrating agent for the investigation of the dehydration rate and moisture content according to the concentration. Maltodextrin of DE 4-7, DE 13-17, and DE 16.5-19.5 for the investigation of the dehydration efficiency according to the DE was purchased from Sigma-Aldrich (St. Louis, MO, USA). Folin-Ciocalteu reagent and DPPH (2,2-diphenyl-1-picrylhydrazyl) were obtained from Sigma-Aldrich (St. Louis, MO, USA).

2. Molecular press dehydration process

Purple sweet potatoes were washed, peeled and ground with a blender (SMX-8000EMT, Hanil, Seoul, Korea). For the investigation of the dehydration rate and moisture content according to the concentration of maltodextrin, maltodextrin of DE 17-20 was added to the purple sweet potatoes at 0%, 20%, 40%, 60%, 80%, and 100%. For the investigation of the quality characteristics by the maltodextrin DE value, maltodextrin of DE 4-7, DE 13-17, DE 16.5-19.5, and DE 17-20 at 80% concentration was added to the purple sweet potatoes (100 g) in LDPE containers and dehydrated for 12 h at 25°C with shaking at 200 rpm (JSSI-100T, JS Research Inc., Gongju, Korea). Dehydrated purple sweet potatoes were separated from the dehydrated solution by centrifugation at 3,000 x g

(H50A-8, Hanil, Seoul, Korea) for 5 min.

3. Dehydration rate

Dehydration rate was determined according to the method of Lee *et al.* (2010) and measured every 2 h for 12 h of dehydration. After mixing the purple sweet potatoes and dehydrating agent, the mixture was centrifuged at 3,000 x g (H50A-8, Hanil, Seoul, Korea) for 5 min. Dehydration rate (%) was calculated by the proportion of the weight of liquid after centrifugation to the weights of purple sweet potato and maltodextrin mixture.

4. Moisture content

Moisture content was determined by the method of AOAC (2005). Approximately 2-5 g of potatoes was taken in a constant weight dish for each treatment and placed in a dry oven (JSOF-150, JS Research Inc., Gongju, Korea) at 105 ± 2°C for 24 h until a constant weight was reached. The purple sweet potatoes was then cooled to room temperature in a desiccator and weighed. The moisture contents were calculated by the differences of weights before and after drying.

5. Determination of total phenolic content

Total phenolic contents of dehydrated purple sweet potatoes were measured by the modified method with Folin-Ciocalteu reagent (Wang *et al.*, 2011). Twenty grams of the dehydrated purple sweet potato was extracted with

200 mL of 80% methanol for 24 h at 15°C and filtered through Whatman No. 1 filter paper (GE Healthcare UK Ltd., Buckinghamshire, UK). One hundred μL of the extract was taken and mixed with 1.5 mL distilled water and 100 μL of 2 N Folin-Ciocalteu reagent was added. After at least 30 sec, 300 μL of 20% Na_2CO_3 solution was added and the mixture was allowed to stand for 1 h at dark. The absorbance was measured at 765 nm using a UV-Vis spectrophotometer (Optizen 2120UV, Mecasys Co., Daejeon, Korea). Standard gallic acid solutions (50-150 mg/L) were prepared in a similar fashion for the construction of the calibration curve. Total phenolic acid contents were expressed as milligram of gallic acid equivalents per 100 g of sample (mg GAE/100 g).

6. Determination of total anthocyanin content

Total anthocyanin content was determined according to the pH-differential method as described by Park *et al.* (2012). The anthocyanin from dehydrated purple sweet potatoes was extracted with 80% ethanol containing 0.1 % citric acid for 12 h. The absorbance was measured at pH 1.0 and pH 4.5 with a UV-Vis spectrophotometer (Optizen 2120UV, Mecasys Co., Daejeon, Korea). The anthocyanin yield (mg/100 g) was then calculated using the following equation and expressed as cyanidin-3-glucoside equivalents:

$$TAC\ (mg/100g) = \frac{A \times MW \times DF \times 20 \times 100}{\varepsilon \times 1}$$

Where,

A = (absorbance at 520 nm - absorbance at 700 nm) at pH 1.0 - (absorbance at 520 nm - absorbance at 700 nm) at pH 4.5

MW = cyanidin-3-glucoside molecular weight (449.2 g)

DF = dilution factor

20 = volume of the final concentrated sample, 20 mL

100 = divided value by 10 g of the sample weight of the extract solution for the change per 100 g of sample

ε = cyanidin-3-glucoside molar absorptivity (26,900 L/cm·mol)

1 = path length in cm.

7. DPPH free radical scavenging activity

For antioxidant activity, the hydrogen electron donating ability was measured by DPPH methods (Liu et al., 2008). One gram of the dehydrated purple sweet potatoes was extracted with 9 mL of 99% methanol. After extraction for 24 h at room temperature, the supernatant was collected by centrifugation at 2,400 x g (Labogene, Gyrozen co., Ltd, Daejeon, Korea) for 20 min. This collected extract (0.2 mL) was mixed with 0.8 mL of 0.4 mM DPPH solution (dissolving in 99% ethanol), and then 2 mL of 99% ethanol was added after 10 sec, and strongly shaken at room temperature for 10 min in a dark room. After allowing standing, the absorbance was measured at 517 nm using a UV-Vis spectrophotometer (Optizen 2120UV, Mecasys Co., Daejeon, Korea). Ethanol was used as a negative control in the same way. Butylated hydroxy anisole (BHA) and ascorbic acid were used for the comparison with samples. The DPPH free radical scavenging activity (%) was calculated by the difference between the absorbance for the control and for the dehydrated purple sweet potatoes.

$$DPPH\ free\ radical\ scavenging\ activity\ (\%) = 1 - \frac{A}{A_0} \times 100$$

Where,

A_0: absorbance of the control

A: absorbance of the sample

8. Color measurement

The color of dehydrated purple sweet potatoes was measured by a colorimeter (UltraScan & EashMatch VIS, Hunter Lab Inc., Reston, VA, USA) after the correction with a white standard plate. The L*(lightness), a*(redness), and b*(yellowness) values were measured at least 3 times and expressed as the average value.

9. Statistical analysis

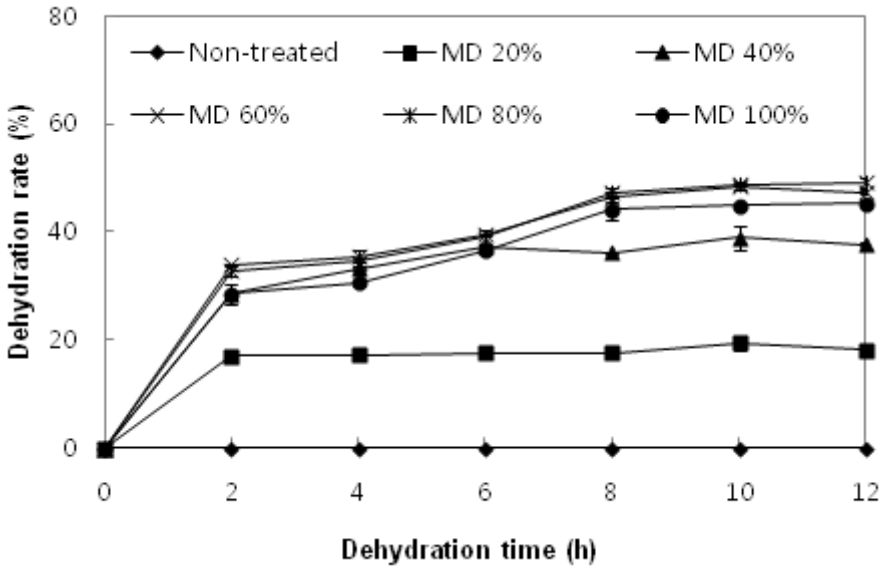
All experiments were performed in triplicate. Data were determined by one-way analysis of variance (ANOVA) followed by Duncan's multiple range test using SPSS (PASW Statistics 18, SPSS Inc., Chicago, USA). Significant differences were considered at $p<0.05$.

Ⅲ. Results and Discussion

1. Effect of maltodextrin concentration on dehydration rate and moisture content

For the determination of optimum maltodextrin concentration during molecular press dehydration of purple sweet potato, the dehydration rate and moisture content of purple sweet potatoes dehydrated with 0%, 20%, 40%, 60%, 80%, and 100% maltodextrin are shown in Fig. 1. Purple sweet potatoes were dehydrated with the dehydration rate of 20% or more. Dehydration rate of purple sweet potatoes with 0% maltodextrin was not changed for 12 h. As the concentration of maltodextrin increased to 20%, 40%, 60%, 80%, and 100%, dehydration rates of purple sweet potatoes rapidly increased to 17.09%, 28.61%, 34.03%, 32.75%, and 28.50%, respectively, after 2 h of dehydration. The dehydration rates of molecular press dehydrated purple sweet potatoes with concentrations of 20%, 40%, 60%, 80%, and 100% maltodextrin after 12 h were 18.17%, 37.72%, 47.35%, 49.14%, and 45.33%, respectively. Moisture content of purple sweet potato with 0% maltodextrin was 64.60% and was not much changed during dehydration. As the concentration of maltodextrin increased to 20%, 40%, 60%, 80%, and 100%, the moisture contents decreased to 52.95%, 39.70%, 34.53%, 28.59%, and 29.20% after 12 h of dehydration, respectively. As the concentration of dehydrating agent increased, the amount of dehydrated moisture increased because of the pressure at outside of the cell walls by molecular press dehydration. These results showed the same trends as reported by Kim *et al.* (2008), Kim *et al.* (2009), and Kim *et al.* (2009) that as the concentration of maltodextrin increased, moisture content of green peppers, gingers, and carrots decreased.

(A)



(B)

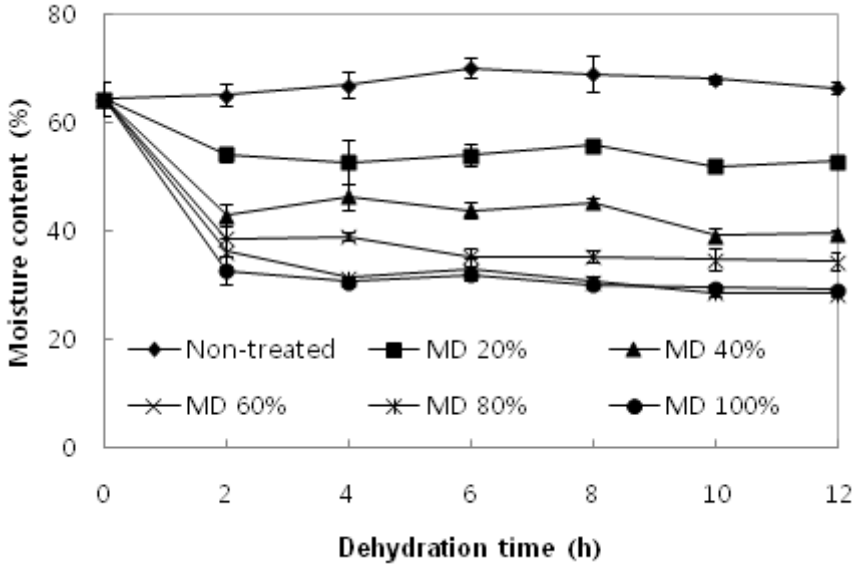


Fig. 1. Dehydration rate (A) and moisture content (B) of purple sweet potato during molecular press dehydration with different concentration of maltodextrin (MD). Mean±SD.

The dehydration rate of purple sweet potatoes increased and moisture content decreased as the concentration of maltodextrin as a dehydrating agent increased during molecular press dehydration. When purple sweet potatoes dehydrated by molecular press method with 60 and 80% maltodextrin, there was no significant difference observed about dehydration rate ($p>0.05$). The dehydration rate of purple sweet potatoes with 100% maltodextrin was rather low and low moisture content of purple sweet potatoes with 80% maltodextrin was lower than those with 60% maltodextrin. Therefore, the 80% of maltodextrin was added for the determination of maltodextrin DE level effect on the quality characteristics of purple sweet potatoes during molecular press dehydration.

2. Effect of maltodextrin dextrose equivalent (DE) on dehydration rate and moisture content

Dehydration rate of purple sweet potatoes dehydrated with different levels of maltodextrin DE is shown in Fig. 2 (A). As the DE of maltodextrin increased from DE 4-7 to DE 13-17, DE 16.5-19.5, and DE 17-20, the dehydration rates after 2 h of dehydration rapidly increased from 11.50% to 25.57%, 24.46%, and 28.50%, respectively. Dehydration rates of purple sweet potatoes dehydrated with DE 4-7, DE 13-17, DE 16.5-19.5, and DE 17-20 maltodextrin after 12 h were 12.55%, 42.84%, 42.81%, and 45.33%, respectively. In particular, dehydration rate of DE 4-7 maltodextrin was significantly lower than those of other DE maltodextrins ($p<0.05$). Because of the low hydrolysis degree of starch to DE 4-7 maltodextrin, a large molecular size of DE 4-7 maltodextrin slowed down the absorption of moisture compared with DE 13-17, DE 16.5-19.5, and DE 17-20 maltodextrins (Lee *et al.*, 2010). Dehydration rates of purple sweet potatoes dehydrated with DE 13-17 and DE 16.5-19.5 maltodextrin were not significantly different after 12 h. The DE 17-20 maltodextrin dehydrated purple sweet potato

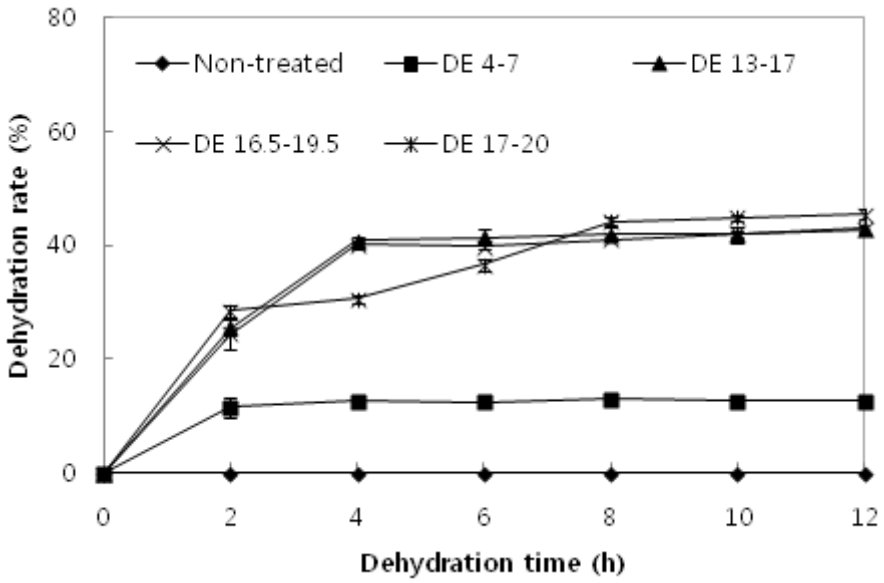
with greater dehydration rates than other DE 13-17 and DE 16.5-19.5 maltodextrins. This agreed with the study by Lee *et al.* (2010) that molecular press dehydration of ginger was effectively dehydrated with DE 16.5-19.5 maltodextrin.

Change in moisture content of molecular press dehydrated purple sweet potatoes according to the DE levels of maltodextrin at 80% is shown in Fig. 2 (B). Moisture content of the purple sweet potato without maltodextrin was 66.47% and not much changed after 12 h of dehydration. Purple sweet potatoes quickly lost their moisture and the moisture contents of sweet potatoes dehydrated with DE 4-7 to DE 13-17, DE 16.5-19.5, and DE 17-20 were 40.59%, 37.59%, 38.58%, and 36.23%, respectively, after 2 h. As the dehydration time increased to 12 h, the moisture contents of purple sweet potatoes dehydrated with DE 4-7, DE 13-17, DE 16.5-19.5, and DE 17-20 were 40.78%, 36.14%, 34.92%, and 28.59%, respectively. Moisture content of purple sweet potato dehydrated with DE 4-7 maltodextrin which was large molecular size was higher than those dehydrated with other DE of maltodextrin. Purple sweet potato was effectively dehydrated with the DE 17-20 maltodextrin. The DE levels of maltodextrin affected the loss of moisture in purple sweet potatoes during molecular press dehydration.

3. Effect of maltodextrin concentration on total phenolic and anthocyanin contents

Total phenolic content of molecular press dehydrated purple sweet potatoes at different concentration of maltodextrin as a dehydrating agent is shown in Fig. 3 (A). Total phenolic content of purple sweet potatoes without maltodextrin were not significantly changed during dehydration of 12 h and these were 210.91 mg GAE/100 g. The phenolic contents of purple sweet

(A)



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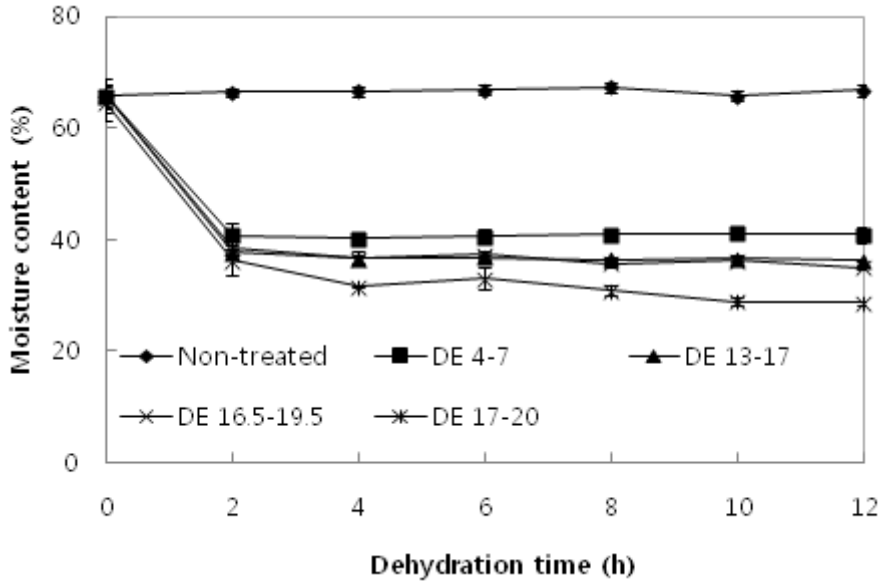


Fig. 2. Dehydration rate (A) and moisture content (B) of purple sweet potato during molecular press dehydration with different dextrose equivalent (DE) of maltodextrin. Mean±SD.

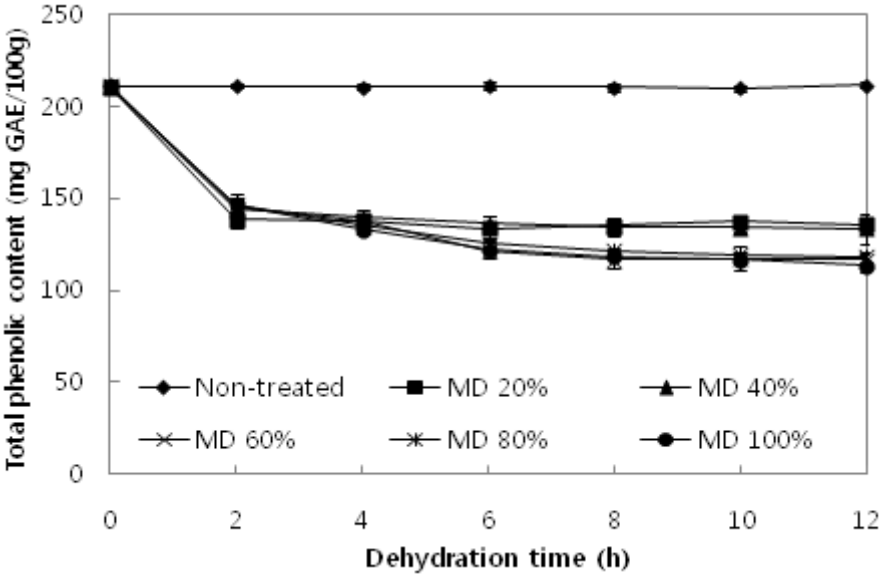
potatoes were decreased during molecular press dehydration with maltodextrin at all concentration. The contents of dehydrated purple sweet potatoes with 20%, 40%, 60%, 80%, and 100% after 12 h reduced from 210.91 to 137.59, 133.52, 116.88, 118.14, and 113.57 mg GAE/100 g, respectively. As the concentration of maltodextrin increased, total phenolics decreased. Total phenolic contents of purple sweet potatoes dehydrated with the maltodextrin concentration of 60, 80, and 100% were not significantly different for 12 h of dehydration ($p>0.05$).

The change in total anthocyanin contents of purple sweet potato during molecular press dehydration with different concentration of maltodextrin is shown in Fig. 3 (B). Purple sweet potato treated with maltodextrin contained 20.77 mg/100 g anthocyanin which was not changed for 12 h. Total anthocyanin contents in purple sweet potatoes rapidly decreased during dehydration of 2 h. The anthocyanin contents of purple sweet potatoes dehydrated with 20%, 40%, 60%, 80%, and 100% after 2 h were 13.63, 12.57, 12.56, 8.59, and 8.49 mg/100 g, respectively. After 12 h of dehydration, they reduced 20.77 to 10.24, 7.56, 6.15, 6.16, and 6.12 mg/100 g, respectively. As the concentration of maltodextrin increased, total anthocyanins decreased. There were no significant difference with 60, 80, and 100% of maltodextrin ($p>0.05$).

4. Effect of maltodextrin dextrose equivalent on total phenolic and anthocyanin contents

Total phenolic content of molecular press dehydrated purple sweet potatoes at different DE levels of maltodextrin as a dehydrating agent is shown in Fig. 4 (A). Total phenolic content of purple sweet potatoes without maltodextrin were not significantly changed during dehydration of 12 h and these were 210.75 mg GAE/100 g. The phenolic contents of purple sweet

(A)



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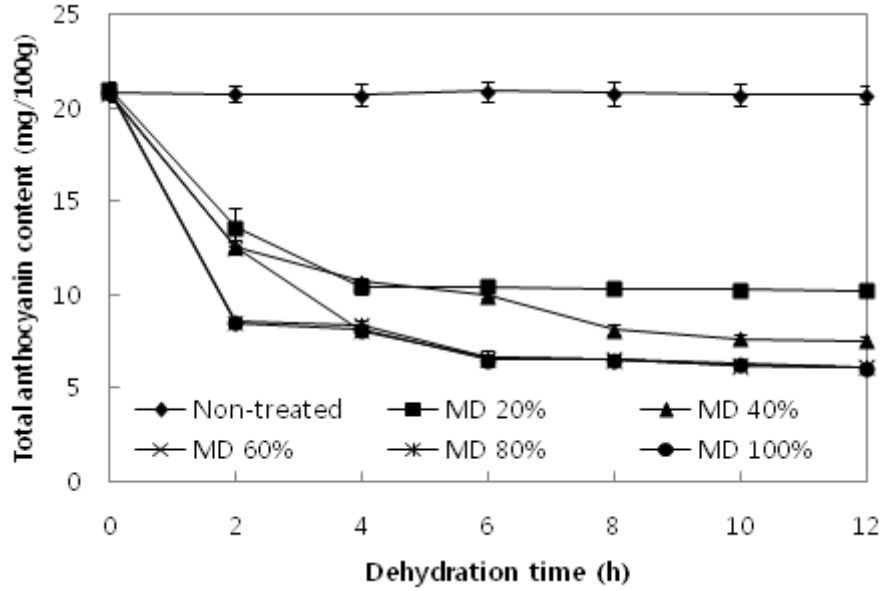
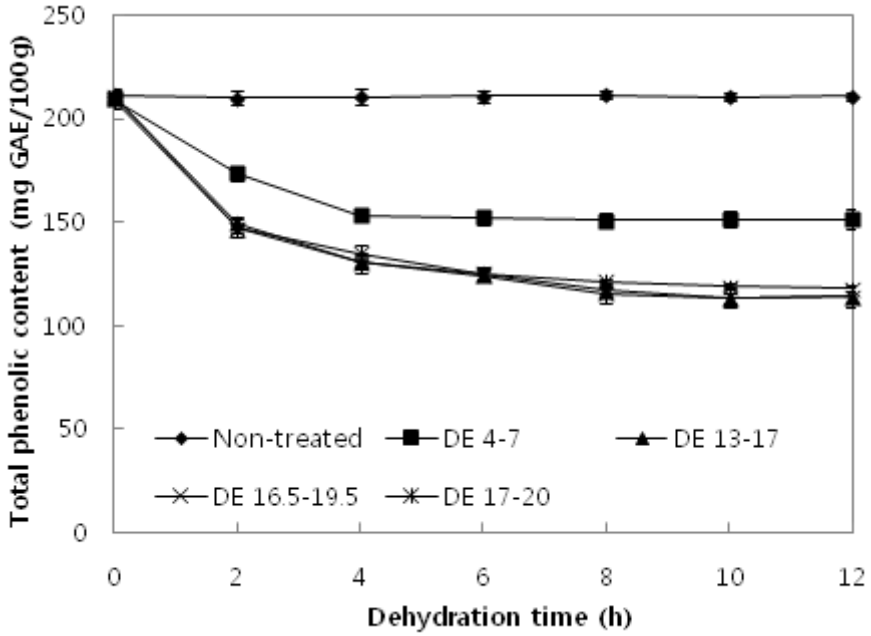


Fig. 3. Total phenolic (A) and anthocyanin (B) contents of purple sweet potato during molecular press dehydration with different concentration of maltodextrin (MD). Mean±SD.

potatoes were decreased during molecular press dehydration with maltodextrin at all DE levels. The contents of dehydrated purple sweet potatoes with DE 4-7, DE 13-17, DE 16.5-19.5, and DE 17-20 after 12 h reduced from 210.75 to 151.48, 114.28, 114.07, and 118.14 mg GAE/100 g, respectively. As the DE levels of maltodextrin increased, total phenolics decreased. Total phenolic contents of purple sweet potatoes dehydrated with the maltodextrin DE levels of 13-17, 16.5-19.5, and 17-20 were not significantly different for 12 h of dehydration ($p>0.05$). Because of low dehydrated rate and high moisture content of molecular press dehydrated purple sweet potato with DE 4-7 maltodextrin, the loss of total phenolics was reduced compared to other maltodextrins. The phenolic compounds as recognized antioxidants (Manach *et al.,* 2004), was not protected by molecular press dehydration in purple sweet potatoes.

The change in total anthocyanin contents of purple sweet potato during molecular press dehydration with different DE of maltodextrin is shown in Fig. 4 (B). Purple sweet potato treated with maltodextrin contained 21.22 mg/100 g anthocyanin which was not changed for 12 h. Total anthocyanin contents in purple sweet potatoes rapidly decreased during dehydration of 2 h. The anthocyanin contents of purple sweet potatoes dehydrated with DE 4-7, 13-17, 16.5-19.5, and 17-20 after 2 h were 14.56, 14.02, 13.74, and 8.59 mg/100 g, respectively. After 12 h of dehydration, they reduced to 4.30, 5.09, 4.22, and 9.97 mg/100 g, respectively. As the DE levels of maltodextrin increased, total anthocyanins decreased. There were no significant difference with DE 13-17, 16.5-19.5, and 17-20 of maltodextrin ($p>0.05$). During the molecular press dehydration with maltodextrin, purple sweet potatoes lost over 50% of their anthocyanins. When the anthocyanin contents of dehydrated solution were measured, the lost anthocyanins in purple sweet potatoes during dehydration were remained in the dehydrated solution (data not shown). The similar result reported by Chun *et al.* (2012) showed that total anthocyanins from blue berries were lost

(A)



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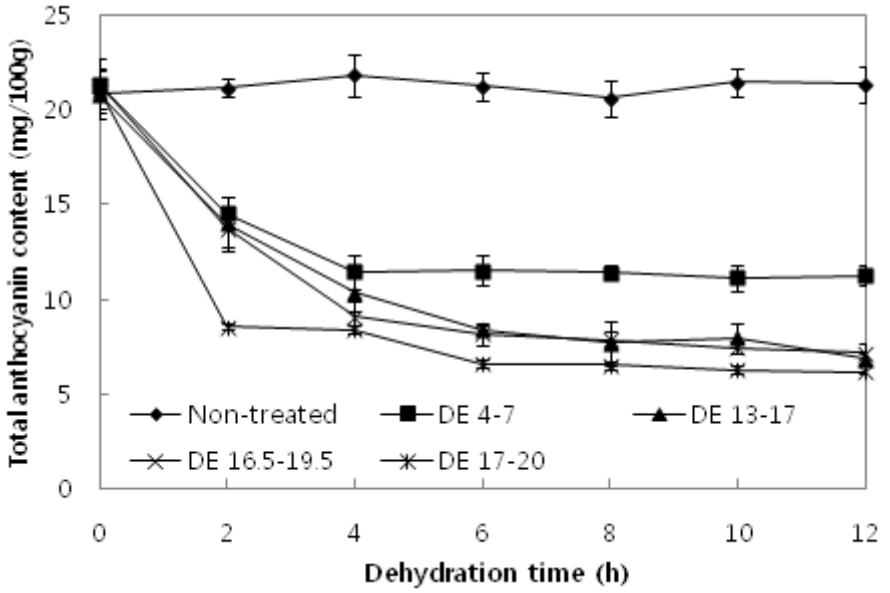


Fig. 4. Total phenolic (A) and anthocyanin (B) contents of purple sweet potato during molecular press dehydration with different dextrose equivalent (DE) of maltodextrin. Mean±SD.

during molecular press dehydration and remained in molecular press dehydrated solution. Dehydrated solution contained useful components including total phenolics and anthocyanins flowed out from purple sweet potato during molecular press dehydration. Therefore, these results indicated that the dehydrated solution with natural pigments including anthocyanins after molecular press dehydration of purple sweet potato could further be applied to develop natural food products.

5. Effect of maltodextrin concentration on DPPH free radical scavenging activity

For the antioxidant activities of molecular dehydrated sweet potatoes, DPPH free radical scavenging activity of molecular press dehydrated purple sweet potatoes at different concentration of maltodextrin as a dehydrating agent is shown in Fig. 5. DPPH free radical scavenging activity of purple sweet potatoes without maltodextrin was 89.39% and not much changed after 12 h. The antioxidant capacity of BHA (10% concentration) was 89.90% for 12 h and the antioxidant capacity of ascorbic acid (10% concentration) was 94.43% for 12 h. DPPH free radical scavenging activity of molecular press dehydrated purple sweet potatoes with 20%, 40%, 60%, 80%, and 100% maltodextrin after 2 h of dehydration rapidly decreased from 74.50%, 71.02%, 71.36%, 65.36%, and 63.19%, respectively. DPPH free radical scavenging activity of molecular press dehydrated purple sweet potatoes with 20%, 40%, 60%, 80%, and 100% maltodextrin after 12 h were 53.96%, 52.74%, 48.22%, 48.48%, and 48.74%, respectively. As the concentration of maltodextrin increased, DPPH free radical scavenging activities decreased. DPPH free radical scavenging activity of purple sweet potatoes dehydrated with the maltodextrin concentration of 60%, 80%, and 100% maltodextrin were not significantly different for 12 h of dehydration ($p>0.05$). The antioxidant capacity of purple sweet potatoes without maltodextrin was

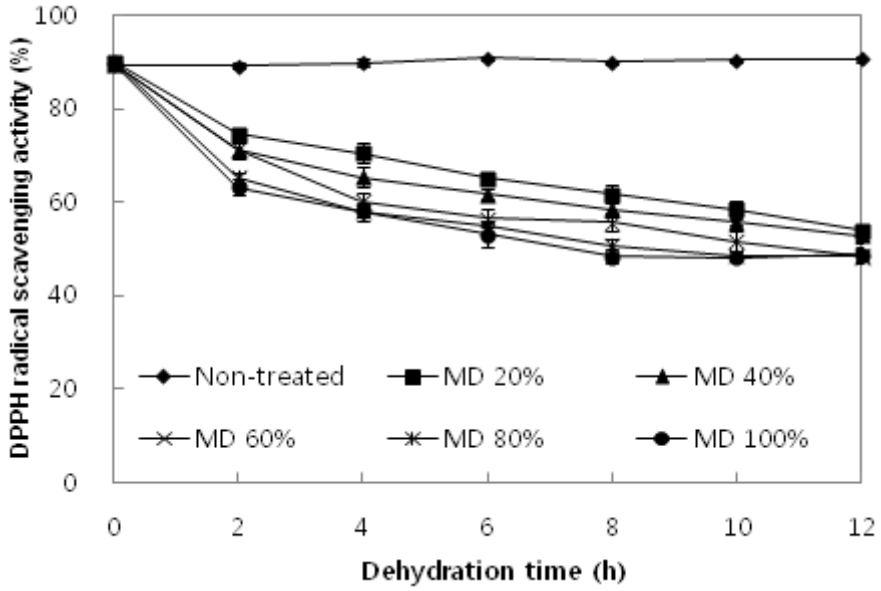


Fig. 5. DPPH radical scavenging activity of purple sweet potato during molecular press dehydration with different concentration of maltodextrin (MD). Mean±SD.

similar to BHA, but it was lower than ascorbic acid. The antioxidant capacity of molecular press dehydrated purple sweet potato was decreased during dehydration.

6. Effect of maltodextrin dextrose equivalent on DPPH free radical scavenging activity

For the antioxidant activities of molecular dehydrated sweet potatoes, DPPH free radical scavenging activity of molecular press dehydrated purple sweet potatoes at different DE levels of maltodextrin as a dehydrating agent is shown in Fig. 6. DPPH free radical scavenging activity of purple sweet potatoes without maltodextrin was 88.85% and not much changed after 12 h. The antioxidant capacity of BHA (10% concentration) was 87.39% for 12 h and the antioxidant capacity of ascorbic acid (10% concentration) was 95.14% for 12 h. DPPH free radical scavenging activity of molecular press dehydrated purple sweet potatoes with DE 4-7, DE 13-17, DE 16.5-19.5, and DE 17-20 maltodextrin after 2 h of dehydration rapidly decreased from 77.50%, 68.26%, 68.25%, and 65.36%, respectively. DPPH free radical scavenging activity of molecular press dehydrated purple sweet potatoes with DE 4-7, DE 13-17, DE 16.5-19.5, and DE 17-20 maltodextrin after 12 h were 56.86%, 47.90%, 45.57%, and 48.48%, respectively. As the DE levels of maltodextrin increased, DPPH free radical scavenging activities decreased. DPPH free radical scavenging activity of purple sweet potatoes dehydrated with the maltodextrin DE levels of 13-17, DE 16.5-19.5, and DE 17-20 maltodextrin were not significantly different for 12 h of dehydration ($p>0.05$). The antioxidant capacity of purple sweet potatoes without maltodextrin was higher than BHA, but it was lower than ascorbic acid. The antioxidant capacity of molecular press dehydrated purple sweet potato was decreased during dehydration. On the other hand, the antioxidant capacity of

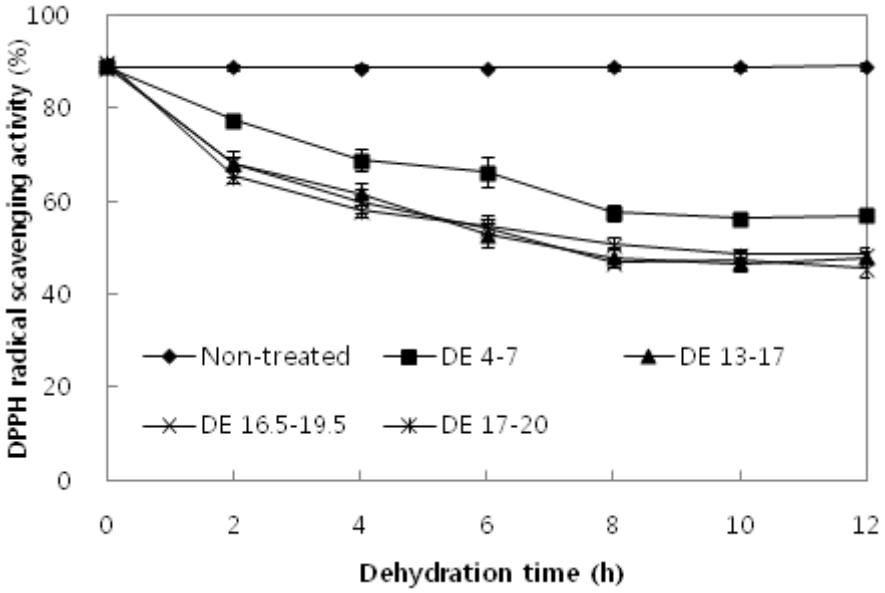


Fig. 6. DPPH radical scavenging activity of purple sweet potato during molecular press dehydration with different dextrose equivalent (DE) of maltodextrin. Mean±SD.

dehydrated solution was increased during dehydration (data not shown). The DPPH radical scavenging activities were correlated to both total phenolics (r^2=0.96) and anthocyanins contents (r^2=0.95) of purple sweet potatoes. These results indicated that the antioxidant capacity decreased during dehydration because of the loss of phenolics and anthocyanins.

7. Effect of maltodextrin concentration on color

Changes in color of molecular press dehydrated purple sweet potatoes at different concentration of maltodextrin as a dehydrating agent are shown in Table 1. The color of purple sweet potatoes without maltodextrin after 12 h changed from L* value 40.34, a* value 25.90, and b* value -8.83 to 34.69, 6.55, and 2.95, respectively. L* value of molecular press dehydrated purple sweet potatoes with 20%, 40%, 60%, 80%, and 100% maltodextrin after 12 h were 28.66, 26.93, 26.96, 26.99, and 26.95, respectively. a* Value of molecular press dehydrated purple sweet potatoes with 20%, 40%, 60%, 80%, and 100% maltodextrin after 12 h were 7.21, 7.06, 6.98, 5.36, and 4.91, respectively and b* value were 2.04, 1.60, 1.43, 1.03, and 1.01, respectively. These results indicated that L* value, a* value and b* value of molecular press dehydrated purple sweet potatoes for 12 h were lower than purple sweet potato without maltodextrin.

8. Effect of maltodextrin dextrose equivalent on color

Changes in color of molecular press dehydrated purple sweet potatoes at different DE levels of maltodextrin as a dehydrating agent are shown in Table 2. The color of purple sweet potatoes without maltodextrin after 12 h changed from L* value 40.34, a* value 25.90, and b* value -8.83 to 34.69, 6.55, and 2.95,

Table 1. Color changes of dehydrated purple sweet potato during molecular press dehydration with different concentration of maltodextrin (MD)

Color	Dehydrating agent (maltodextrin)	Dehydration time		
		0 h	2 h	12 h
L*	Non-treated	40.34[a]±3.58[1)]	35.58[a2)]±1.44	34.69[a]±0.79
	MD 20%		28.78[b]±0.84	28.66[b]±0.56
	MD 40%		27.00[c]±0.28	26.93[c]±0.60
	MD 60%		26.95[c]±0.49	26.96[c]±0.66
	MD 80%		27.22[bc]±0.83	26.99[c]±0.64
	MD 100%		26.69[c]±1.17	26.95[c]±0.53
a*	Non-treated	25.90[a]±0.50	6.66[b]±0.27	6.55[a]±0.32
	MD 20%		7.49[a]±0.31	7.21[a]±0.38
	MD 40%		7.03[ab]±0.20	7.06[a]±0.27
	MD 60%		7.01[ab]±0.09	6.98[a]±0.14
	MD 80%		5.44[c]±0.63	5.36[b]±0.57
	MD 100%		5.04[c]±0.53	4.91[b]±0.38
b*	Non-treated	-8.83[a]±0.47	2.71[a]±0.29	2.95[a]±0.16
	MD 20%		2.07[b]±0.38	2.04[b]±0.23
	MD 40%		1.60[b]±0.07	1.60[c]±0.08
	MD 60%		1.59[b]±0.08	1.43[c]±0.19
	MD 80%		1.04[c]±0.39	1.03[d]±0.25
	MD 100%		1.08[c]±0.17	1.01[d]±0.12

[1)] Values are mean±SD.

[2)] Different letters in the same column are significantly different at $p<0.05$.

Table 2. Color changes of dehydrated purple sweet potato during molecular press dehydration with different dextrose equivalent (DE) of maltodextrin

Color	Dehydrating agent (maltodextrin)		Dehydration time		
			0 h	2 h	12 h
L*	Non-treated		40.34[a]±3.58[1)]	35.58[a2)]±1.44	34.69[a]±0.79
	DE	4-7		32.06[b]±0.66	30.72[b]±0.34
		13-17		27.86[c]±0.75	26.72[c]±0.35
		16.5-19.5		26.71[c]±0.36	26.89[c]±0.38
		17-20		27.22[c]±0.83	26.99[c]±0.64
a*	Non-treated		25.90[a]±0.50	6.66[b]±0.27	6.55[b]±0.32
	DE	4-7		9.99[a]±0.37	9.56[a]±0.27
		13-17		5.24[c]±0.65	5.23[c]±0.33
		16.5-19.5		5.71[c]±0.19	5.20[c]±0.36
		17-20		5.44[c]±0.63	5.36[c]±0.57
b*	Non-treated		-8.83[a]±0.47	2.71[a]±0.29	2.95[a]±0.16
	DE	4-7		2.87[a]±0.34	2.78[a]±0.36
		13-17		1.17[b]±0.39	1.05[b]±0.19
		16.5-19.5		1.27[b]±0.08	1.05[b]±0.25
		17-20		1.04[b]±0.39	1.03[b]±0.25

[1)] Values are mean±SD.

[2)] Different letters in the same column are significantly different at $p<0.05$.

respectively. L* value of molecular press dehydrated purple sweet potatoes with DE 4-7, DE 13-17, DE 16.5-19.5, and DE 17-20 maltodextrin after 12 h were 30.72, 26.72, 26.89, and 26.99, respectively. a* Value of molecular press dehydrated purple sweet potatoes with DE 4-7, DE 13-17, DE 16.5-19.5, and DE 17-20 maltodextrin after 12 h were 9.56, 5.23, 5.20, and 5.36, respectively and b* value were 2.78, 1.05, 1.05, and 1.03, respectively. These results indicated that L* value of molecular press dehydrated purple sweet potatoes for 12 h were lower than purple sweet potato without maltodextrin; however, a* value and b* value of molecular press dehydrated purple sweet potatoes and purple sweet potato without maltodextrin were not significantly different for 12 h. The change of color in purple sweet potatoes during molecular press dehydration was possibly caused by enzymatic browning reaction occurring often in fruits and vegetables by the enzyme, polyphenoloxidase (Manohan and Wai, 2012).

Ⅳ. Conclusion

Maltodextrin was effective in dehydrating purple sweet potato as a dehydration, especially at 80% concentration. As the DE of 80% maltodextrin increased, dehydration rate of molecular press dehydrated purple sweet potatoes increased; however, moisture content, total phenolics, anthocyanins, and DPPH radical scavenging activity decreased during molecular press dehydration. These studies indicated that molecular press dehydration was the great method to dehydrate moisture from purple sweet potatoes even though their antioxidants activities related to total phenolic and anthocyanins decreased. It needs further study to provide the optimum conditions for molecular press dehydration to maintain the quality characteristics of purple sweet potatoes.

PART Ⅱ

Quality Characteristics of Tarts Made with Molecular Press Dehydrated Purple Sweet Potatoes during Storage

Ⅰ. Introduction

Baking products are not suitable for main cooking but they are perfect for refreshments and have emerged as rapidly expanding market items over the past years (Sloan, 1998; McWatters *et al.*, 2005; Mondal and Datta, 2008). In particular, tart, a baked product consisting of a filling over a pastry base with an open top, has been consumed by many people whilst enjoying their brunch and dessert (Boyle and Kolbe, 2002). Not only bakeries but also food manufacturers have produced tarts with the expansion of brunch and dessert markets (Worosz, 2006; Thornsbury and Martinez, 2012). As a filling material in tarts, purple sweet potatoes have been increasingly used because of their taste and health benefits imparted by the presence of phenolic compounds and anthocyanins (Konczak-Ilsam *et al.*, 2003; Kano *et al.*, 2005; Yang, 2012). However, sometimes, the purple sweet potatoes as a filling in tarts caused the degradation of tart quality because of high moisture content (Sanguinetti *et al.*, 2009). Because of the movement of moisture from the filling to a tart crust during storage, the crust loses its crunchy taste. Henceforth, it is necessary to control moisture contents of purple sweet potato tarts during storage.

Molecular press dehydration is one of the dehydration methods, which is based on the cytorrhysis phenomenon occurring outside of the plant cell walls

using a dehydrating agent with large molecular size (Yoo and Seo, 2003). Because the size of solute molecule is greater than pore size of cell wall, solute molecule is pressed which leads to collapse of the cell walls (Choi and Shin, 1999; Choi *et al.*, 2006). This dehydration method has been continuously employed to dehydration of raw materials for food preparation. Kim MH et al. (2008) reported effective dehydration of green peppers employing maltodextrin as a dehydrating agent in high concentrations. Lee HS et al. (2010) reported that molecular press dehydrated ginger indicated great dehydration rate, high recovery rate, stable color, and sensory characteristics. To control moisture content of purple sweet potatoes prior to baking tarts, they were dehydrated by molecular press dehydration with a dehydrating agent, maltodextrin. And the effect of treatment on the quality characteristics of purple sweet potato tarts during storage was investigated.

Ⅱ. Materials and Methods

1. Materials

Purple sweet potatoes were provided by Jeju Purple Sweet Potato Farming Association (Jeju, Korea). The maltodextrin (Samyang Genex Co., Seoul, Korea) was used as dehydrating agent. Folin-Ciocalteu reagent and DPPH (a,a-diphenyl-2-picryl-hydrazyl) were purchased from Sigma-Aldrich (St. Louis, MO, USA) to determine total phenolic content and DPPH free radical scavenging activity.

2. Molecular press dehydration of purple sweet potatoes

Purple sweet potatoes were molecular press dehydrated as follows. Washed purple sweet potatoes were peeled and ground with a blender (SMX-8000EMT, Hanil, Seoul, Korea). They were mixed with maltodextrin at concentrations of 0%, 20%, 40%, 60%, and 80% (w/w) and dehydrated at 25°C for 12 h in a shaking incubator (JSSI-100T, JS Research Co., Gongju, Korea). Dehydrated purple sweet potatoes were separated from the dehydrated solution by filtering and used for the preparation of tart filling.

3. Preparation of purple sweet potato tarts

Tart filling was prepared by mixing dehydrated purple sweet potato, butter, sugar, treha (Hayashibara Co., Okayama, Japan), eggs, and salt. Tart

crust dough was made with 48% wheat flour (soft flour, Samyang Co., Seoul, Korea), 22% margarine (Ottogi Co., Ahnyang, Korea), 15% butter (Seoul Dairy Co., Seoul, Korea), 9.6% sugar (CJ Cheiljedang Co., Seoul, Korea), 5.4% eggs (Hanaro mark, Jeju, Korea), and salt (purified salt, Hanju Co., Ulsan, Korea). The entire mixture of purple sweet potato filling and dough were put into a tart molding machine (System one SO-2A, Masdac Co., Saitama, Japan) to form the shape of a tart. Molded tarts were then baked in a baking oven (FDO-7102, Daeyung Bakery Machinery Ind. Co., Seoul, Korea) for 30 min at 190-200°C. After cooling down the baked tarts, they were individually packaged in plastic bags. All experiments were performed for storage period of 0, 3, 7, 10, 15, 20, 30, and 45 days at room temperature.

4. Moisture content and water activity of tarts

Tarts were separated into purple sweet potato filling and tart crust. The moisture content of tart filling and crust was determined by the method of AOAC (2005).

Water activities of tart filling were measured by water activity meter (HP23-AW-A, Rotronic AG, Zurich, Switzerland). Water activity was measured at least 20 times and expressed as the average value.

5. Determination of total phenolic content

Total phenolic content of tart filling was measured following the modified method of Rumbaoa RGO et al. (2009) using Folin - Ciocalteau reagent. The absorbance was measured at 765 nm using a UV-Vis spectrophotometer (Optizen 2120UV, Mecasys Co., Daejeon, Korea). As a standard, gallic acid (Sigma-Aldrich

Co.) solutions were prepared in varying concentrations (50-150 mg/L) in a similar manner to construct a calibration curve. Total phenolic acid content was expressed as milligram of gallic acid equivalents per 100 g of sample (mg GAE/100 g).

6. Determination of total anthocyanin content

Total anthocyanin content was measured according to the pH-differential method as described by Park HM et al. (2012). The absorbance was measured at pH 1.0 and pH 4.5 with a UV-Vis spectrophotometer (Mecasys Co.). Total anthocyanin concentration (TAC, mg/100 g) was then calculated using the following equation and expressed as cyanidin-3-glucoside equivalents:

$$TAC\ (mg/100g) = \frac{A \times MW \times DF \times 20 \times 100}{\varepsilon \times 1}$$

Where,

A = (absorbance at 520 nm - absorbance at 700 nm) at pH 1.0 - (absorbance at 520 nm - absorbance at 700 nm) at pH 4.5

MW = cyanidin-3-glucoside molecular weight (449.2 g)

DF = dilution factor

20 = volume of the final concentrated sample (20 mL)

100 = divided value by 10 g of the sample weight of the extract solution for the change per 100 g of sample

ε = cyanidin-3-glucoside molar absorptivity (26,900 L/cm·mol)

1 = path length in cm.

7. DPPH free radical scavenging activity

To compare the antioxidant capacity of tart during storage, hydrogen electron donating abilities of tart filling were determined by DPPH method (Liu YN et al. 2013). Subsequently, the absorbance was measured at 517 nm using a UV-Vis spectrophotometer (Mecasys Co.). Ethanol (Daejung chemicals & metals Co., Shiheung, Korea) was used as a control in the same way. Butylated hydroxyanisole (BHA, Sigma-Aldrich Co.) and ascorbic acid (Sigma-Aldrich Co.) levels were measured for comparison. DPPH free radical scavenging activities (%) were calculated by the difference in absorbance between the control and the tart filling sample.

$$DPPH\ free\ radical\ scavenging\ activity\ (\%) = 1 - \frac{A}{A_0} \times 100$$

Where, A_0: absorbance of the control and A: absorbance of the sample.

8. Color measurement

The color of tart filling was measured by a colorimeter (UltraScan VIS Spectrophotometer, Hunter Lab Inc., Reston, VA, USA) after correcting the color with a white and black standard plate. L* (lightness), a* (redness), and b* (yellowness) values were measured and expressed as the average value. The total color difference (ΔE) was defined using the following equation:

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

9. Sensory evaluation

Sensory evaluation was conducted with 10 panelists at Department of

Food Bioengineering in Jeju National University, who were explained about the objective of the study and valuation basis. When the sensory evaluation was performed, panelist rinsed their mouth with water after evaluating a single sample. Samples given with any number were conducted to ensure the objectivity of the study and to increase the accuracy. Evaluation details included characteristic of appearance, color, flavor, texture, and overall acceptability. Nine points evaluation was conducted with a range from very poor (1 point) to excellent (9 points) and a high preference gave a high score.

10. Statistical analysis

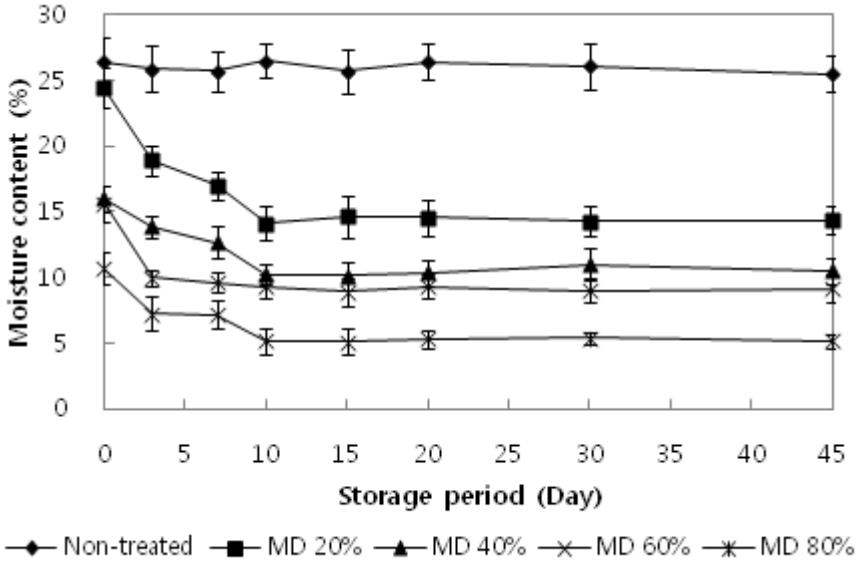
All experiments were performed in triplicate. Data were determined by one-way ANOVA followed by Duncan's multiple range test using SPSS Statistics (ver. 18.0, SPSS Inc., Chicago, IL, USA). Significant differences were considered at $p<0.05$.

Ⅲ. Results and Discussion

1. Moisture content and water activity

Changes in moisture contents of tart filling and a tart crust made with purple sweet potato dehydrated with 0%, 20%, 40%, 60%, and 80% maltodextrin as a dehydrating agent are shown in Fig. 1. Purple sweet potatoes dehydrated using more than 20% maltodextrin controlled the moisture content of tart filling and tart crust low during storage of 45 days. No major changes in moisture content of purple sweet potato in the tart filling without maltodextrin was observed from 0 days (26.39%) to 45 days (25.48%), which signifies maintenance of high moisture content. Furthermore, moisture content of tart crust non-treated by maltodextrin increased gradually from 0 days (10.47%) to 45 days (13.18%). As the concentration of maltodextrin used in the molecular press dehydration increased to 20%, 40%, 60%, and 80%, moisture content of purple sweet potato tart filling on 0 days exhibited a decreasing pattern as 24.39%, 15.96%, 15.59%, and 10.67%, respectively. Under similar conditions, moisture content of tart crust exhibited a decreasing trend as 4.10%, 4.77%, 4.64%, and 3.98%, respectively. Moisture content of tart filling made with molecular press dehydrated purple sweet potatoes in the presence of 20%, 40%, 60%, and 80% maltodextrin gradually decreased to 14.34%, 10.48%, 9.11%, and 5.12% after 45 days, respectively. Under similar conditions, moisture content of tart crust gradually increased to 8.47%, 7.95%, 6.96%, and 6.24% after 45 days, respectively. The higher concentration of maltodextrin used in molecular press dehydration led to lower moisture contents of tart filling and tart crust. Tarts made with molecular press

(A)



(B)

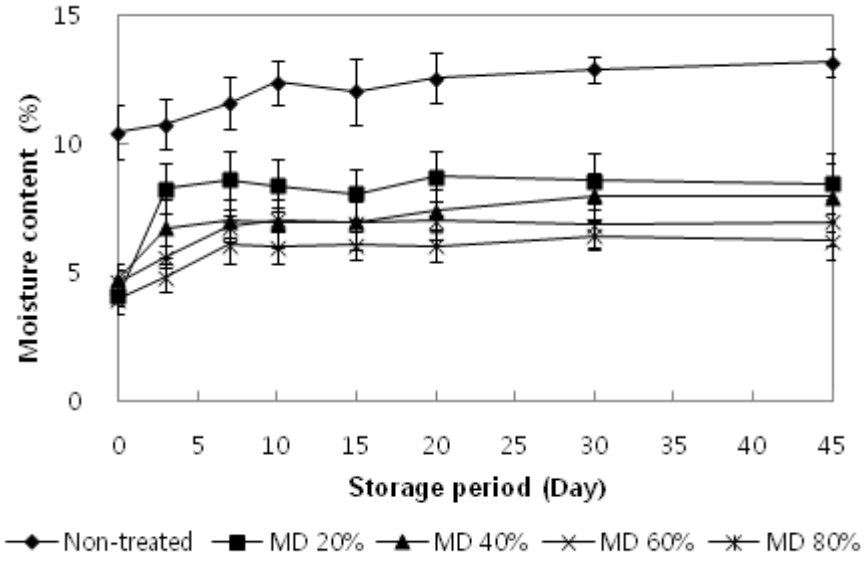


Fig. 7. Changes in moisture contents of tart filling (A) and tart crust (B) made with molecular press dehydrated purple sweet potatoes with different concentration of maltodextrin (MD) during storage. Mean±SD.

dehydrated purple sweet potatoes helped to keep moisture contents low during storage. Previously, the green peppers, gingers, and carrots were effectively dehydrated by maltodextrin and the moisture contents were kept low (Kim MH et al. 2008, Kim MH et al. 2009, Kim MK et al. 2009). Therefore, these results suggested that merchandise made with molecular press dehydration efficiently maintained low moisture contents during storage.

Water activity of tart fillings made with purple sweet potato dehydrated with 0%, 20%, 40%, 60%, and 80% maltodextrin as a dehydrating agent was changed during storage for 45 days as shown in Table 1. Water activity of tart fillings made with molecular press dehydrated purple sweet potato were lower as compared to the water activity of tart filling made without dehydration during storage for 45 days. As the concentration of maltodextrin used in the molecular press dehydration increased to 20%, 40%, 60%, and 80%, water activity of tart fillings of purple sweet potato for 0 days decreased to 0.890, 0.847, 0.833, and 0.752, respectively. After 45 days of storage, the water activity gradually decreased to 0.753, 0.744, 0.713, and 0.715, respectively. These results indicated that tart made with molecular dehydrated purple sweet potatoes was possibly stored for a long time with expected crusty texture.

2. Total phenolic and anthocyanin contents

Total phenolic content in tarts made with purple sweet potato dehydrated with 0%, 20%, 40%, 60%, and 80% maltodextrin as a dehydrating agent is shown in Fig. 2 (A). Total phenolic content of tart made with non-treated purple sweet potato was 412.46 mg GAE/100 g on 0 days and no significant change in total phenolic content (408.74 mg GAE/100 g) for 45 days of storage was observed. However, total phenolic content of tarts made with molecular press dehydrated purple sweet potatoes exhibited a decreasing

Table 3. Change in water activities of tart made with molecular press dehydrated purple sweet potatoes with different concentration of maltodextrin (MD) during storage

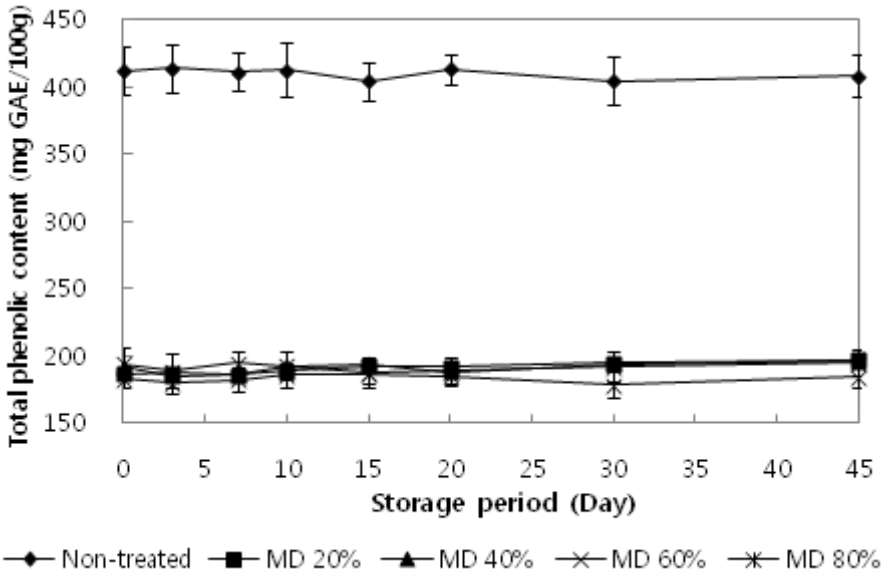
Tart	Storage							
	0 day	3 day	7 day	10 day	15 day	20 day	30 day	45 day
Non-treated	0.869±0.015[1)b2)D3)]	0.881±0.013^{aC}	0.885±0.012^{aC}	0.886±0.012^{aBC}	0.890±0.013^{aBC}	0.895±0.013^{aB}	0.890±0.017^{aBC}	0.915±0.013^{aA}
MD 20%	0.890±0.010^{aA}	0.855±0.019^{bB}	0.830±0.012^{bC}	0.793±0.015^{bD}	0.787±0.012^{bD}	0.772±0.020^{bE}	0.757±0.016^{bF}	0.753±0.013^{bF}
MD 40%	0.847±0.014^{cA}	0.788±0.013^{cB}	0.759±0.014^{cC}	0.744±0.014^{cD}	0.741±0.016^{cD}	0.742±0.015^{cD}	0.740±0.014^{cD}	0.744±0.012^{cD}
MD 60%	0.833±0.011^{dA}	0.737±0.013^{dB}	0.729±0.014^{dBC}	0.732±0.015^{dBC}	0.727±0.017^{dCD}	0.722±0.013^{dCD}	0.719±0.015^{dDE}	0.713±0.014^{dE}
MD 80%	0.752±0.020^{eA}	0.686±0.013^{eC}	0.663±0.020^{eE}	0.673±0.013^{eD}	0.689±0.012^{eC}	0.686±0.012^{eC}	0.718±0.015^{dB}	0.715±0.015^{dB}

[1)] Values are mean± SD.

[2)] Means with different small letters within a column indicate significant difference at $p<0.05$.

[3)] Means with different capital letters within a row indicate significant difference at $p<0.05$.

(A)



(B)

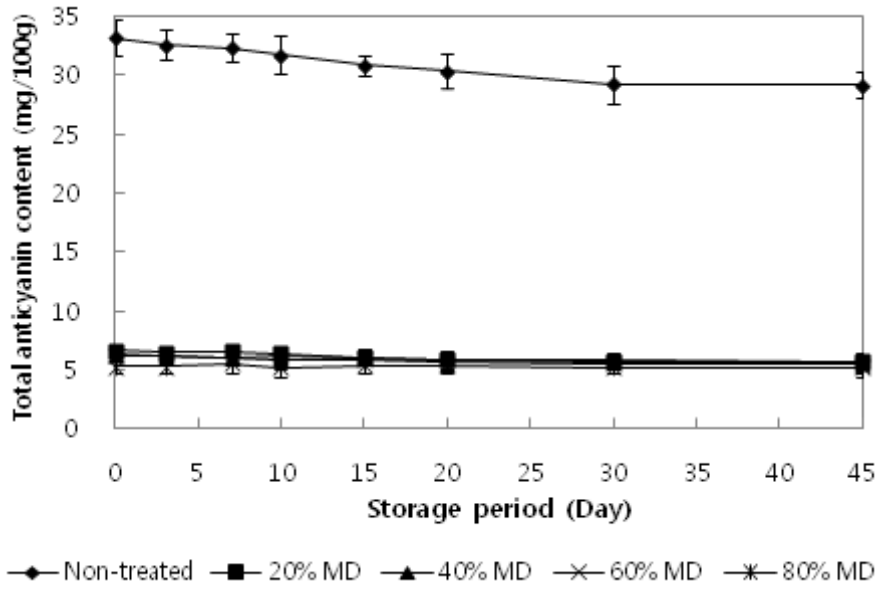


Fig. 8. Changes in total phenolic (A) and anthocyanin (B) contents of tarts made with molecular press dehydrated purple sweet potatoes with different concentration of maltodextrin during storage. Mean±SD.

range of 183.22 to 194.43 mg GAE/100 g on 0 days. These results exhibited similar trends as reported by Wang SM et al. (2011), which stated the occurrence of total phenolic content in purple sweet potatoes during molecular press dehydration.

Total anthocyanin content in tarts made with purple sweet potato dehydrated with 0%, 20%, 40%, 60%, and 80% maltodextrin as a dehydrating agent is shown in Fig. 2 (B). Purple sweet potato tart prepared without dehydration of purple sweet potato by maltodextrin contained 33.16 mg/100 g of anthocyanin on 0 days and the content decreased significantly to 29.20 mg/100 g after 45 days of storage. These results were in concordance with the reports of Brownmille C et al. (2008) and Hager A et al. (2008), which stated that over half of total anthocyanins in blue berries purees and black raspberry juice was lost after 6 months of storage.

Total anthocyanin content of purple sweet potato tarts made with molecular press dehydration with 20%, 40%, 60%, and 80% maltodextrin was 6.68, 6.29, 6.20, and 5.31 mg/100 g on 0 days, respectively. In addition, these values decreased to 5.68, 5.61, 5.47, and 5.17 mg/100 g after 45 days of storage ($p>0.05$). Anthocyanins in purple sweet potatoes were discharged into molecular press dehydrated solution during molecular press dehydration (Chun HH et al. 2012). Because of low stability of anthocyanins, enormous loss was noted during the process of dehydration and storage.

3. DPPH free radical scavenging activity

Changes in DPPH free radical scavenging activity of tarts made with purple sweet potato dehydrated with 0%, 20%, 40%, 60%, and 80% maltodextrin as a dehydrating agent are shown in Fig. 3. The DPPH free radical scavenging activity of tarts made with non-treated purple sweet potatoes was 88.45% on 0

days and 83.61% after 45 days of storage. The antioxidant capacities of BHA (10%) and ascorbic acid (10%) were in the range of 86.61-90.90% and 94.23-95.24% from 0 days to 45 days, respectively. The antioxidant capacity of non-treated purple sweet potato tart was similar to the activities of BHA. However, the DPPH free radical scavenging activity of purple sweet potato tarts made with molecular press dehydration with 20%, 40%, and 60% maltodextrin was 77.44%, 74.36%, and, 73.58%, respectively, on 0 days and 75.33%, 73.58%, and 71.71%, respectively, after 45 days of storage. The tart made with the purple sweet potato dehydrated with 80% maltodextrin showed no change in the DPPH free radical scavenging activity during storage. There were no significant differences in the antioxidant activities of purple sweet potato tarts during storage. The DPPH free radical scavenging activity of tarts made with molecular press dehydrated purple sweet potatoes significantly decreased with increasing the concentration of maltodextrin from 20%, 40%, and 60% to 80%. Although the total phenolic and anthocyanin contents were significantly low in tarts made with maltodextrin dehydrated purple sweet potatoes, no major difference in the DPPH free radical scavenging activity was observed in tart made with non-treated purple sweet potato. This result was similar to the results of Lee HS et al. (2009) study, which demonstrated loss of antioxidant capacities of green peppers treated with maltodextrin as a dehydrating agent.

4. Color

Change in the color of tarts made with purple sweet potatoes dehydrated with 0%, 20%, 40%, 60%, and 80% maltodextrin as a dehydrating agent is shown in Table 2. The lightness (L*) of tart made with non-treated purple sweet potatoes changed from 21.54 to 22.32 after 45 days of storage. The L* value of tarts made with molecular press dehydrated purple sweet potatoes

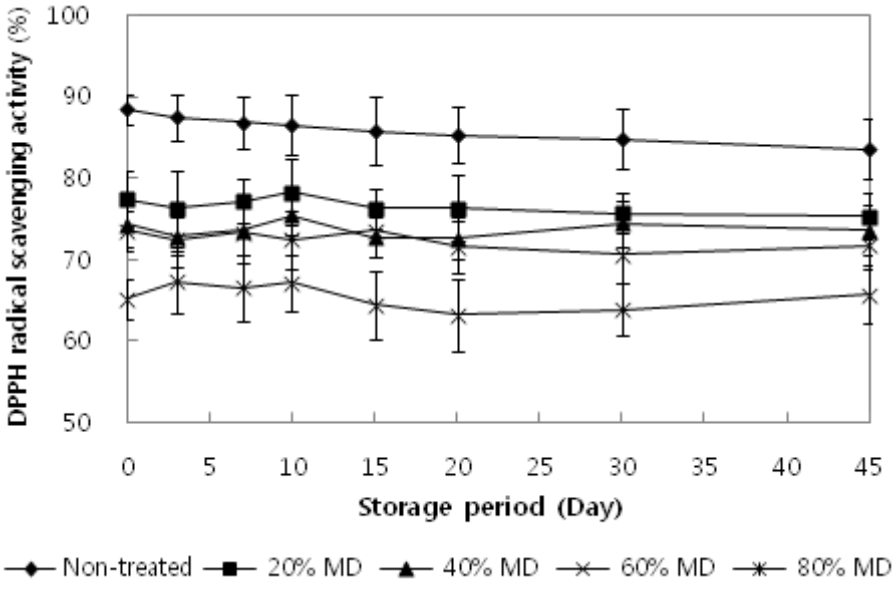


Fig. 9. Changes in DPPH radical scavenging activities of tarts made with molecular press dehydrated purple sweet potatoes with different concentration of maltodextrin (MD) during storage. Mean±SD.

increased from 17.69 to 19.67, 21.24, and 21.33 as maltodextrin concentration increased from 20% to 40%, 60%, and 80%, respectively. However, the ⊿E value of tarts made with molecular press dehydrated purple sweet potatoes was significantly different with that of tart made with non-treated purple sweet potato. The redness (a*) and yellowness (b*) of purple sweet potatoes were greatly lost compared to the non-treated tart during molecular dehydration process, which led to an increase in the ⊿E values.

5. Sensory evaluation

Sensory evaluation of tarts made with purple sweet potatoes dehydrated with 0%, 20%, 40%, 60%, and 80% maltodextrin as a dehydrating agent is shown in Table 3. Sensory evaluation of tarts included appearance, color, flavor, texture, and overall acceptability and measured at 0 and 45 days. Appearance, color, flavor, texture, and overall acceptability of tart made with non-treated purple sweet potato had scores of 7.2, 7.2, 7.5, 7.0, and 7.2 and changed to 6.7, 6.8, 6.0, 6.3, and 6.9, respectively, after 45 days of storage. All the sensory values of tarts made with molecular press dehydrated purple sweet potatoes were significantly lowered as compared to the tarts made without molecular press dehydration. The molecular press dehydration by maltodextrin led to reduction in the sensory quality of tarts although the moisture content and water activity were low, the resultant effect was seen as maintenance of crustiness of shell of tart.

Table 4. Color changes of cross section of tarts made with molecular press dehydrated purple sweet potatoes with different concentration of maltodextrin (MD) during storage

	Tart	Storage							
		0 day	3 day	7 day	10 day	15 day	20 day	30 day	45 day
L*	Non-treated	21.54±1.33[1)a2)A3)]	22.15±1.05^{aA}	21.62±1.47^{aA}	22.28±1.08^{aA}	21.77±1.26^{aA}	21.93±1.85^{aA}	22.11±1.08^{aA}	22.32±1.11^{aA}
	MD 20%	17.69±1.90^{cA}	17.41±1.16^{bAB}	16.67±1.65^{dAB}	16.56±0.83^{dB}	17.10±1.27^{cAB}	17.12±1.96^{cAB}	16.53±1.33^{dB}	17.27±1.67^{dAB}
	MD 40%	19.67±2.52^{bA}	18.29±1.75^{bB}	18.86±1.45^{cAB}	18.57±1.10^{cAB}	19.74±1.46^{bA}	19.64±1.41^{bA}	18.41±2.14^{cB}	18.98±1.02^{cAB}
	MD 60%	21.24±1.14^{aAB}	21.68±1.56^{aB}	20.27±2.73^{bB}	21.16±1.24^{bAB}	21.24±1.13^{aAB}	21.42±1.05^{aAB}	20.37±2.45^{bB}	20.85±1.16^{bAB}
	MD 80%	21.33±2.25^{aA}	20.99±2.82^{aA}	21.79±1.48^{aA}	21.04±1.61^{bA}	21.24±1.50^{aA}	21.18±1.74^{aA}	21.08±0.87^{abA}	21.46±1.12^{bA}
a*	Non-treated	8.18±0.81^{bC}	8.13±0.76^{bC}	8.27±1.19^{aC}	8.18±1.07^{bC}	8.44±0.85^{aBC}	8.97±0.81^{aAB}	9.21±1.00^{aA}	9.15±0.54^{aA}
	MD 20%	4.60±0.78^{dAB}	4.62±0.41^{dAB}	4.83±0.91^{cA}	4.68±0.58^{dAB}	4.51±0.74^{cAB}	4.94±1.22^{cA}	4.64±0.57^{dAB}	4.16±0.55^{cB}
	MD 40%	5.67±0.74^{cA}	5.82±0.46^{cA}	5.82±1.58^{bA}	5.72±0.47^{cA}	5.53±0.53^{bA}	5.67±0.39^{bA}	5.52±0.75^{cA}	5.91±0.50^{bA}
	MD 60%	8.93±0.70^{aA}	8.71±1.25^{aAB}	8.87±0.70^{aAB}	8.96±0.58^{aA}	8.54±0.67^{aAB}	9.03±0.83^{aA}	8.28±1.51^{bB}	8.93±0.45^{aA}
	MD 80%	5.17±1.09^{cA}	5.10±1.07^{cA}	5.85±0.91^{bA}	5.68±0.84^{cA}	5.74±0.89^{bA}	5.75±0.41^{bA}	5.84±1.48^{cA}	5.88±1.64^{bA}
b*	Non-treated	-3.73±0.87^{dA}	-3.49±0.65^{aA}	-3.46±0.97^{dA}	-3.57±0.74^{dA}	-3.27±0.77^{dA}	-3.36±0.73^{dA}	-3.47±0.62^{dA}	-3.49±0.68^{dA}
	MD 20%	4.03±0.99^{bcAB}	4.07±0.75^{cAB}	3.80±1.70^{cAB}	3.59±0.30^{cAB}	3.49±0.84^{cB}	4.23±0.62^{bA}	4.12±0.42^{bAB}	4.05±0.75^{bcAB}
	MD 40%	4.61±1.24^{bA}	4.57±0.75^{bA}	4.86±1.72^{bA}	4.54±0.69^{bA}	4.42±0.69^{bA}	4.45±0.62^{bA}	4.49±0.60^{bA}	4.81±0.53^{bA}
	MD 60%	5.67±1.55^{aAB}	5.69±1.08^{aAB}	5.93±1.22^{aA}	5.39±0.89^{aAB}	5.40±1.27^{aAB}	5.10±0.89^{aB}	5.77±1.10^{aAB}	5.38±0.80^{aAB}
	MD 80%	3.57±0.42^{cAB}	3.80±0.48^{cAB}	3.68±0.62^{cAB}	3.37±0.80^{cB}	3.52±0.48^{cB}	3.63±0.50^{cAB}	3.97±0.84^{cA}	3.68±0.65^{cAB}
ΔE	Non-treated	1.79 ±1.01^{cB2}	1.97±0.75^{cAB}	2.30±0.83^{cAB}	2.09±0.92^{cAB}	2.11±0.78^{cAB}	2.48±0.77^{dA}	2.18±0.51^{dAB}	2.02±0.84^{dAB}
	MD 20%	10.41±1.02^{aAB}	10.49±0.76^{aAB}	10.54±1.42^{aAB}	10.32±0.49^{aAB}	10.13±0.84^{aB}	10.70±0.90^{aAB}	10.82±0.65^{aA}	10.71±0.70^{aAB}
	MD 40%	10.20±1.12^{aAB}	10.26±0.52^{aAB}	10.45±1.59^{aA}	10.09±0.58^{aAB}	9.83±0.64^{aAB}	9.83±0.53^{bB}	10.32±0.58^{bAB}	10.18±0.53^{bAB}
	MD 60%	10.43±1.56^{aAB}	10.57±1.02^{aAB}	10.97±1.58^{aA}	10.16±0.91^{aAB}	10.16±1.27^{aAB}	9.88±0.87^{bB}	10.86±1.03^{aA}	10.14±0.80^{bAB}
	MD 80%	9.23±0.87^{bAB}	9.60±0.97^{bA}	8.98±0.69^{bB}	8.75±0.59^{bB}	8.84±0.61^{bB}	8.95±0.42^{cB}	9.24±0.71^{cAB}	9.02±0.54^{cB}

[1)] Values are mean± SD.

[2)] Means with different small letters within a column indicate significant difference at $p<0.05$.

[3)] Means with different capital letters within a row indicate significant difference at $p<0.05$.

Table 5. Sensory evaluation of tarts made with molecular press dehydrated purple sweet potato with different concentration of maltodextrin (MD)

Sensory evaluation	Tart	Storage	
		0 day	45 day
Appearance	Non-treated	7.2±0.9[1)a2),AB3)]	6.7±1.1^{aB}
	MD 20%	3.2±1.2^{bA}	3.9±1.6^{bA}
	MD 40%	4.1±1.5^{bA}	4.5±0.8^{bA}
	MD 60%	4.1±1.3^{bA}	3.8±1.1^{bA}
	MD 80%	3.9±0.9^{bA}	3.2±1.2^{bA}
Color	Non-treated	7.2±0.9^{aA}	6.8±0.9^{aA}
	MD 20%	2.9±1.0^{cA}	3.5±1.7^{bA}
	MD 40%	4.2±1.5^{bA}	3.3±0.9^{bA}
	MD 60%	4.3±1.5^{bA}	4.0±1.2^{bA}
	MD 80%	4.2±1.5^{bA}	3.7±1.3^{bA}
Flavor	Non-treated	7.5±1.0^{aA}	6.0±1.7^{aB}
	MD 20%	3.8±1.3^{bA}	4.0±1.2^{bA}
	MD 40%	4.5±2.0^{bA}	4.8±1.0^{abA}
	MD 60%	4.7±1.8^{bA}	4.7±1.6^{abA}
	MD 80%	4.4±1.5^{bA}	4.5±1.6^{bA}
Texture	Non-treated	7.0±0.9^{aA}	6.3±1.8^{aA}
	MD 20%	4.1±1.6^{bA}	3.9±1.0^{bA}
	MD 40%	4.1±1.5^{bA}	3.0±1.4^{bA}
	MD 60%	4.3±1.5^{bA}	4.0±1.4^{bA}
	MD 80%	3.3±1.5^{bA}	2.8±1.5^{bA}
Overall acceptability	Non-treated	7.2±1.1^{aA}	6.9±1.4^{aA}
	MD 20%	3.4±1.4^{bA}	3.4±1.2^{bA}
	MD 40%	3.4±1.3^{bA}	3.2±1.1^{bA}
	MD 60%	4.0±0.9^{bA}	3.6±1.3^{bA}
	MD 80%	3.2±1.4^{bA}	2.6±1.1^{bA}

1) Values are mean±SD.

2) Means with different small letters within a column indicate significant difference at $p<0.05$.

3) Means with different capital letters within a row indicate significant difference at $p<0.05$.

Ⅳ. Conclusion

Tarts made with molecular press dehydrated purple sweet potatoes with 20%, 40%, 60%, and 80% maltodextrin resulted in maintenance of low moisture content, which prevented movement of moisture towards the shell of tart. However, loss in total phenolic and anthocyanin contents was noted during molecular press dehydration with maltodextrin and these compounds directly affected the loss of DPPH free radical scavenging activity of purple sweet potatoes. The lightness of color in tarts made with 60% or 80% maltodextrin molecular press dehydrated sweet purple potatoes was not changed as compared to the tart made with non-treated purple sweet potatoes. The redness (a*) and yellowness (b*) of purple sweet potatoes were greatly lost as compared to the non-treated tart during molecular dehydration. Sensory evaluation of tarts with molecular press dehydrated purple sweet potatoes had a low score with respect to appearance, color, flavor, texture, and overall acceptability. Molecular press dehydration was observed as an effective process to reduce moisture content of tarts and in maintaining consistent quality of tart crust and water activity of purple sweet potatoes; however, decrease in total content of phenolics and anthocyanins, and sensory quality was observed.

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국 문 요 약

분자압축탈수는 고분자물질을 과일와 채소 등의 섞어주면 세포벽에 압력을 가하여 열이 없는 상태에서 수분을 탈수시키는 방법이다. 탈수제인 말토덱스트린을 이용하여 자색고구마에 0, 20, 40, 60, 80, 100% 농도별로 탈수하였고, DE 4-7, DE 13-17, DE 16.5-19.5, DE 17-20의 포도당 당량별로 탈수하였다. 자색고구마의 탈수율은 시간이 지날수록 증가하였다. 말토덱스트린의 농도가 증가할수록 12시간 후 수분함량은 64.46%에서 각각 66.38, 39.70, 34.53, 28.59, 29.20%로 감소하였고, 말토덱스트린의 포도당 당량이 증가할수록 12시간 후 수분함량은 65.78%에서 각각 66.74, 40.78, 36.14, 34.92, 28.59%로 감소하였다. 총페놀함량, 총안토시아닌함량, DPPH 자유라디칼 소거능은 말토덱스트린의 농도와 포도당 당량이 증가할수록 감소하였다. 말토덱스트린 80%, 100%의 농도와 DE 16.5-19.5, DE 17-20의 포도당 당량에서 가장 효과적으로 자색고구마가 탈수되었다. 그러나 총페놀함량, 총안토시아닌, DPPH 자유라디칼 소거능, 색상 값은 탈수되는 동안 낮아졌다. DPPH 자유라디칼 소거능은 자색고구마의 총페놀함량(r^2=0.96)과 총안토시아닌함량(r^2=0.95)과 높은 상관관계가 있었다. 이 결과에서 자색고구마는 분자압축탈수가 일어나는 동안에 총페놀함량과 총안토시아닌함량은 줄어들었지만, DE 16.5-20인 말토덱스트린을 80% 이상 첨가하였을 때 가장 효과적으로 분자압축 탈수 되었다.

분자압축 탈수된 자색고구마를 이용하여 만든 타르트의 품질특성을 연구하였다. 자색고구마타르트는 45일 동안 실온에 보관하며 수분함량, 수분활성도, 총페놀함량, 총안토시아닌함량, DPPH 자유라디칼 소거능, 색상, 관능평가에 의해 분석하여 평가하였다. 20, 40, 60, 80%의 말토덱스트린으로 탈수된 자색고구마로 만든 타르트 껍질의 45일 후 수분함량은 각각 8.47, 7.95, 6.96, 6.24%이었다. 그러나 말토덱스트린으로 처리되지 않은 자색고구마로 만든 타르트 껍질의 수분함량은 11.99%였다($p<0.05$). 말토덱스트린으로 탈수된 자색고구마로 만든 타르트는 말토덱스트린으로 처리되지 않은 자색고구마로 만든 타르트보다 총페놀함량, 총안토시아닌, DPPH 자유라디칼 소거능이 낮았다($p<0.05$). 이 결과 분자압축탈수된 자색고구마로 만든 타르트는 저장하는 동

안에 수분함량과 수분활성도는 효과적으로 관리할 수 있지만 총페놀함량, 총안토시아닌, DPPH 자유라디칼 소거능, 색상, 관능평가는 감소하였다.

ACKNOWLEDGEMENT

새로운 도전을 위해 대학원에 입학한 게 엊그제 같은데 벌써 이렇게 시간이 흘러 감사의 글을 쓰게 되었습니다. 돌이켜 보면 조교생활을 같이하면서 대학원 생활을 병행해야 되기 때문에 부족한 점이 많았고, 이 때문에 힘이 들기도 했지만 항상 힘이 되어준 감사한 분들이 계셨기 때문에 여기까지 올 수 있었다고 생각합니다.

먼저 본 학위 논문이 완성될 수 있도록 배려해주시고 항상 따뜻하게 격려해주시면서 부족한 저를 아낌없이 지도해주신 김현정 교수님께 진심으로 감사합니다. 또한 바쁘신 와중에도 많이 부족했던 논문을 일일이 확인해주시고 세심하게 지도해주신 고영환 교수님과 천지연 교수님께도 정말 감사드립니다. 조교를 병행하며 부족했던 저에게 많은 가르침과 격려를 해주신 임상빈 교수님, 박은진 교수님께 감사의 마음을 전하며, 학부 때부터 지금까지 부족한 저에게 가르침과 격려를 해주신 송대진 교수님, 김수현 교수님, 강영주 교수님, 하진환 교수님께도 정말 감사드리며 건강하시길 기원합니다.

대학원 생활을 하며 만난 인연으로 많은 힘이 되어주신 고재필 선생님, 한지령 선생님, 신철민 선생님, 강은옥 선생님, 김경민 선생님, 오화정 선생님, 이수경 선생님, 김재원 선생님, 김소연 선생님, 고미옥 선생님, 고정연 선생님, 김효진 선생님, 신호빈 선생님, 김동신 선생님에게도 감사의 마음을 전합니다.

마지막으로 항상 믿음과 사랑으로 지켜봐 주시고 부족한 저를 격려해주신 어머니, 동생 성재와 공부하는 사위를 항상 응원해주신 장인어른, 장모님, 처남, 처제에게도 감사의 말씀을 드립니다. 항상 내게 든든한 힘이 되어준 제 아내 유정이와 사랑스러운 딸 효빈이에게도 감사의 마음을 전합니다.

이 논문이 완성되기까지 수많은 분들의 도움이 없었다면 불가능했을 것입니다. 도움을 주신 분들에게 부끄럽지 않도록 좀 더 배려하고 배풀 수 있는 사람이 되도록 노력하겠습니다. 감사합니다.