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# Effect of Maltodextrin Concentration and Drying Temperature on Quality Properties of Purple Sweet Potato Flour

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**Abstract** The effects of drying temperature (55, 60, and 65°C) and addition levels of maltodextrin (MD) (10, 20, and 30%) on the physicochemical properties and nutritional quality of purple sweet potato flour were investigated. MD-added flours had higher L* values, water soluble index, total phenolic, and anthocyanin contents than untreated flour. However, a*, b* values, water absorption index, and swelling capacity were dependent on the drying temperature and MD concentration. On the other hand, untreated flour had a higher ascorbic acid content compared to the MD-treated flour. Ascorbic acid contents decreased, whereas anthocyanin content was not significantly different, with increasing drying temperatures. MD was positively correlated with phenolic content, anthocyanin, hue angle, and water soluble index. However, there was no correlation between quality parameters and glass transition temperature. The best quality product was obtained when samples were pretreated with MD before drying, regardless of drying temperature.

**Keywords:** sweet potato, maltodextrin, drying, quality attribute, glass transition temperature

## Introduction

Purple-fleshed sweet potatoes have an intense purple color in their storage roots due to the accumulation of anthocyanins (1). The anthocyanins in purple sweet potato are mono- or di-acylated forms of cyanidin and peonidin (2). Purple sweet potato flour anthocyanins are biologically beneficial, by virtue of their free radical scavenging and antimutagenic, anticarcinogenic, and antihypertensive effects (3). Sweet potatoes can be processed into flour, which is less bulky and more stable than the highly perishable fresh root. The flour can be used as a thickener in soup, gravy, fabricated snacks, and bakery products (4). It can also be used to enhance food products through color, flavor, natural sweetness, and supplemented nutrients. Sweet potato flour can substitute for wheat and other cereal flours, especially for individuals diagnosed with celiac disease (5).

Preservation of food by drying is an ancient technique that has been technologically refined in the last century. Dehydrated sweet potato is commonly been obtained by hot air drying, which allows rapid and massive processing, although the processing markedly influences the sensory and nutritional characteristics of the end product. To reduce the drying time and retain the quality of fruits and vegetables, various pretreatment methods (chemical, thermal, and physical) have been investigated (6,7). Among different drying process, freeze- and spray-drying produce the highest product quality. But, the relatively high production cost is a major drawback.

Carbohydrates have been used as wall material to microencapsulate food ingredients. The food industry is currently emphasizing the use of natural rather than synthetic ingredients. Maltodextrins (MDs) are polysaccharides consisted of α (1-4) linked D-glucose produced by acid or enzymatic hydrolysis of corn starch (8). MDs are water-soluble materials that can protect encapsulated ingredients from oxidation (9), and which have been used in different drying regimens including spray-, drum-, and freeze-drying (10). MD also facilitates retention of some food properties such as nutrients, color, anthocyanin, and flavor during drying and storage (10-12). Some studies have explored the use of carrier agents such as MD and gum arabic to protect sensitive compounds like vitamin C in fruit juice and to increase product stability in powder (10-12). But, there are no reports on hot air-drying using MD to produce flour from purple sweet potato. Therefore, the objective of the present study was to investigate the effects of drying temperatures and exposure to different MD concentrations on the physicochemical properties and nutritional qualities of purple sweet potato flour.

## Materials and Methods

**Raw material** Sweet potato (*Ipomoea batatas* L. Lam cv. Sinjami) was purchased from a local farm and stored at 14°C until used. The samples were washed with tap water to remove dirt and soil and peeled with a 27 stainless hand peeler (Han Sung, Gwangju, Korea). Peeled samples were kept in tap water to prevent enzymatic darkening. The samples were then cut into 1 mm thick slices using a slicing machine (Model HFS 350G; Fujee, Suwon, Korea).

**Sample preparation and treatment** Sweet potatoes slices were treated by dipping in 10, 20, and 30%(w/v) maltodextrin (DE 20; Samyang Genex, Seoul, Korea) in water at room temperature for 2 min. Controls were dipped in distilled water at the same temperature and time conditions.

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**Preparation of sweet potato flour** The slices were dried with a drying oven (Dasol Scientific, Seoul, Korea) 55, 60, and 65°C for 7-8 hr. The flour (moisture content 6%) was obtained by milling the dried slices using a FM-681C blender (Hanil, Gwangju, Korea) and sieveing through an 80 mesh screen (Chung-gye-sang-gongsa, Seoul, Korea) to obtain sweet potato flour.

**Proximate compositions of sweet potato flour** Moisture, crude protein, ash, and fat contents of flours were determined by AOAC method (13).

**Hunter color values** The color attributes (Hunter L*, a*, and b* values) were measured with a CM-3500d spectrophotometer (Minolta, Tokyo, Japan). Total color difference was calculated as $\Delta E=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$ (14). The total color difference was calculated for the maltodextrin treated samples as compared to the control sample.

**Water solubility index (WSI) and water absorption index (WAI)** WSI and WAI were determined according to the method described by Grabowski *et al.* (14). Sweet potato flour (2.5 g) and 30 mL water were vigorously mixed in a 50-mL centrifuge tube; the mixture was incubated in a water bath at 30°C for 30 min, and centrifuged at 2,090×g for 15 min. The supernatant was collected in a pre-weighed petri dish and the residue was weighed after oven-drying overnight at 105°C. The amount of solids in the dried supernatant as a percentage of the total dry solids in the original 2.5 g sample was an indicator of WSI. WAI was calculated as the weight of the solid pellet remaining after centrifugation divided by the amount of dry sample.

**Swelling capacity (SWC)** SWC was determined according to Lai and Cheng (15) using the equation

$$\text{SWC}=\text{weight of sediment (ws)}/[\text{dry weight of sample}\times(1-\text{ws}\%/100)]$$

**Viscosity** The viscosity was measured by Brookfield viscometer (DV-II+ pro; Brook-field Engineering Laboratories, Middleboro, MA, USA) using spindle No. 4 at 60 rpm. Viscosity was performed using 50 mL sample at room temperature (25±2°C) and value expressed as centipoise (cp).

**Total phenolics** Total phenolics in the sweet potato flours were determined with Folin-Ciocalteu reagent according to a slightly modified method described by Huang *et al.* (16). The sample (0.1 g) was extracted 3 times with 20 mL of 75% methanol and filtered through Whatman No. 2 filter paper. Extracts were combined and concentrated in a rotary vacuum evaporator (Model Heidolph, DE/VV-2011; Rikakikai, Tokyo, Japan) at 40°C; the volume was adjusted to 20 mL with 75% methanol. One mL of extract, 5 mL of distilled water and 2 mL of 10% Folin-Ciocalteau reagent were added to a Falcon tube. After 3 min at room temperature, 2 mL of 7.5% $Na_2CO_3$ solution was added and the sample was diluted to 20 mL with distilled water. Each sample was allowed to stand for 1 hr at room temperature and absorbance was measured at 760 nm using a model UV-1201 spectrometer (Shimadzu, Tokyo, Japan). Total phenolics were calculated on the basis of the calibration curves of gallic acid, and expressed as mg gallic acid/100 g.

**Anthocyanin content** Content of anthocyanins was determined by following the procedures of Giusti and Wrolstad (25) and Huang *et al.* (16). The sweet potato flour (1 g) was treated with 15 mL HCl-methanol (0.15% HCl: methanol=15:85) for 4 hr. The extract was filtered and its absorbance was determined at 530 nm. Anthocynin content (mg/100 g d.w.) was calculated on the basis of the following equation:

$$\text{Anthocynin content}=(A\times Mw\times DF\times 100)/(\varepsilon\times W)$$

where A=absorbance, Mw=molecular weight of cyaniding-3 glucoside chloride ($C_{21}H_{21}ClO_{11}$, 484.84 Da), DF=dilution factor, ε=molar absorptivity (34,300), W=sample weight (g)

**Ascorbic acid** Ascorbic acid content was determined according to the method of Egoville *et al.* (17). Sweet potato flour (1 g) was treated with 20 mL of 0.4% oxalic acid at room temperature for 5 min and filtered through Whatman No. 4 filter paper. The filtrate (1 mL) was mixed with 9 mL of 2,6-dichlorophenolindophenol and the absorbance was read within 15 min at 520 nm against a blank. Ascorbic acid content was calculated on the basis of the calibration curves of ascorbic acid, and was expressed as mg/100 g of ascorbic acid.

**Glass transition temperature ($T_g$)** A differential scanning calorimeter (DSC, S-650; Scinco, Seoul, Korea) equipped with a thermal analysis station was calibrated using mercury. Approximately 5-10 mg of sample was prepared in aluminum pans. The heating program increased the sample temperature from −70 to 120°C at a rate of 10°C/min followed by cooling to 30°C at the same rate. Heating and cooling were performed in an atmosphere of nitrogen gas. An empty pan was used as a reference. Glass transition was analyzed using a DSC equipped with Pyris thermal analysis with Infinity PRO software version 4.2.64 (Scinco). Glass transition was taken at the midpoint of the glass transition range. Thermograms were examined for onset temperature ($T_{gi}$) and end point temperature ($T_{ge}$) of the glass transition region. The glass transition midpoint ($T_{gm}$) value was calculated as the average of the onset and end points values and reported as the glass transition temperature (18).

**Scanning electron microscopy (SEM)** Flour granule morphology was examined using SEM. Sample was mounted on an aluminium specimen holder by double-sided tape. The specimen holder was loaded in an Emitech K550 sputter coater (Emitech, East Grinstead, UK). The sample was coated with gold palladium, with a thickness of about 15 nm and viewed using an S-2400 instrument (Hitachi, Tokyo, Japan) operated at an accelerating voltage of 10 KV.

**Statistical analyses** All measurements were performed in triplicate for each sample. Data were analyzed using SPSS for Windows Version 14.0 (SPSS, Chicago, IL, USA). One-way analysis of variance (ANOVA) was carried out to determine the overall effect of treated untreated and drying temperatures on each of the assays. Significant differences between the means were estimated using Duncan's multiple range tests. Differences were considered to be significant at $p<0.05$.

## Results and Discussion

**Physicochemical properties** Proximate compositions of sweet potato flour prepared with different MD concentrations and drying temperatures are shown in Table 1. Moisture, ash, and fat contents of sweet potato flour ranged from 5.16-6.81, 2.49-3.32, and 0.77-1.8%, respectively, which were similar to those reported previously (19). Moisture and ash contents of flours from untreated and MD-treated sweet potatoes were similar to each other. During drying, ash content increased with increasing drying temperature. The increased ash content could also be due increased overall sweet potato solid. There were no significant differences in fat and protein of treated and untreated flours among different MD concentration and drying temperatures. The protein content in sweet potato flour is generally low, ranging from 1.0-8.5% (19). Consistent with this, presently protein content ranged from 2.16-3.22%.

**Hunter color values** Hunter color parameters, L*, a*, b*, and ΔE have been widely used to describe color change during dehydration of fruit and vegetables products. These values of sweet potato flours were measured with different MD concentrations and drying temperatures (Table 2). MD-treated flours had higher L* values than did the untreated flours. This observation was similar to that obtained previously (14). L* values slightly decreased with increasing MD concentration. In terms of drying temperatures, all flours had higher L* values at 60°C; with increased drying temperature L* decreased. This variation may be due to the changes of total phenolic content. Rocha and Morais (20) found levels of phenols to be associated with the color change, particularly lightness. L* values were positively correlated with MD and phenolic content. Hunter a* and b* values were dependent on drying temperature and MD concentrations. The changes of a* and b* values may be attributable to formation of polymeric anthocyanin (2). Presently, all flours showed color values similar to those reported by Yang and Gadi (2). The color values for MD-treated flours could be best described by the change in total color difference (ΔE) values. The lower total ΔE values may be due to loss of phenolic and anthocyanin content. The ΔE values were highly correlated with phenolic and anthocyanin contents.

**WAI, WSI, SWC, and viscosity** WAI, WSI, SWC, and viscosity of sweet potato flours are shown in Table 3. MD-treated flours had lower WAI than untreated flours. WAI of untreated flours decreased with increasing drying temperatures. On the other hand, MD-treated flours had lower WAI at 60°C compared to that at 55°C except for 30% MD-treated flour; WAI was lower at 55°C, with WAI subsequently increasing with increasing drying temperature. The variation in WAI could be due to differences in the degree of engagement of hydroxyl groups to form hydrogen and covalent bonds between starch chains. The increase in WAI is associated with the loss of starch crystalline structure (21). MD-treated flours had higher WSI than that untreated flours. This variation may be attributed to the fact that MD has superior solubility (22). WSI of MD-treated flours increased with increasing MD concentration and drying temperatures for all flours. However, untreated flours had lower WSI at 60°C than at 55°C, with WSI subsequently increasing with increasing drying temperature. According to Eliasson and Gudmundsson (23), the low solubility at low temperature can be attributed to the semi-crystalline structure of the starch granules and the hydrogen bonds formed between hydrogen groups in the starch molecules. As the temperature increases, the solubility increases due to the disruption of starch granules and exposure of hydrophilic groups. Presently, WAI and WSI were negatively and positively correlated with MD, respectively. SWC depends on MD concentration and drying temperature. All samples had lower SWC at 60°C, except for 30% MD-treated flour; SWC was lower at 55°C and increased with increasing drying temperature. Low SWC is caused by the presence of a large number of crystallites, which increase granular stability, thereby reducing the extent of granular swelling. When starch is gelatinized at a certain temperature, the molecular organization is disrupted within the granules and the starch-water interactions increase, resulting in a substantial increase in swelling (21,23). MD-treated flours had higher viscosity than untreated flours. Viscosity increased with increasing MD concentration. This may be due to the interaction between MD and polysaccharides present in sweet potato. However, viscosity decreased at a higher drying temperature for all samples due to the intermolecular interaction and hydration of molecules.

**Anthocyanin contents** The anthocyanin content of the flours with treatment of different MD concentrations and drying temperatures ranged from 35.98-41.18 mg/100 g (Table 4). The content of anthocyanin was much similar than that of steamed or kneaded flours (16). MD-treated flours had higher anthocyanin contents than untreated flours. These results are consistent with a previous study (24) that reported anthocyanin from pomace was increased by encapsulation with DE 20 MD. The same study further reported that MD could stabilize the anthocyanin pigment due to reduction of water activity. Presently, anthocyanin content increased with increasing drying temperatures for all samples, even though the values were not significantly different. This might be due to much higher amounts of acylated anthocynins present in flour samples. Giusti and Wrolstad (25) indicated that acylated anthocynin exhibits unusual stability in neutral or weakly acidic media. Acylation improves the stability of anthocyanins through intermolecular copigmentation (25). Anthocyanin was highly correlated with MD and color L* values.

**Total phenolic content** The total phenolic content of sweet potato flours ranged from 9.55-12.24 mg/100 g (Table 4). The phenolic contents of the flours were comparable to that of raw sweet potato flour, and steamed and kneaded sweet potato flour (16). MD-treated flours had higher total phenolic content as compared to untreated flour. Possible explanations for this difference are interference of MD with phenolic compounds during analysis (24) and that, in

**Table 1. Effect of MD concentration and drying temperatures on proximate analysis of sweet potato flour**

| Drying temperature (°C) | 55 | | | | 60 | | | | 65 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MD concentration (%) | 0 | 10 | 20 | 30 | 0 | 10 | 20 | 30 | 0 | 10 | 20 | 30 |
| Moisture (%) | $^{1)AB}6.15^{a2)}$ | $^{A}6.81^{a}$ | $^{B}5.74^{b}$ | $^{AB}6.39^{a}$ | $^{AB}5.72^{a}$ | $^{AB}5.43^{b}$ | $^{B}5.16^{c}$ | $^{A}6.17^{a}$ | $^{A}5.20^{a}$ | $^{A}5.69^{b}$ | $^{A}5.68^{a}$ | $^{A}6.18^{a}$ |
| Ash (%) | $^{B}2.84^{c}$ | $^{AB}2.80^{b}$ | $^{B}2.75^{c}$ | $^{C}2.49^{c}$ | $^{A}3.14^{b}$ | $^{C}2.87^{c}$ | $^{B}2.96^{b}$ | $^{AB}3.05^{b}$ | $^{AB}3.27^{a}$ | $^{A}3.13^{a}$ | $^{A}3.32^{a}$ | $^{B}3.21^{a}$ |
| Protein (%) | $^{A}2.25^{a}$ | $^{A}2.53^{a}$ | $^{A}2.63^{a}$ | $^{A}2.79^{ab}$ | $^{A}2.70^{a}$ | $^{A}2.40^{a}$ | $^{A}2.95^{a}$ | $^{A}3.05^{a}$ | $^{AB}2.48^{a}$ | $^{B}2.18^{a}$ | $^{A}3.22^{a}$ | $^{B}2.16^{a}$ |
| Fat (%) | $^{A}1.72^{a}$ | $^{A}1.54^{a}$ | $^{A}1.76^{a}$ | $^{A}1.80^{a}$ | $^{A}1.44^{a}$ | $^{A}1.28^{a}$ | $^{A}1.75^{a}$ | $^{A}1.55^{a}$ | $^{A}1.16^{a}$ | $^{A}0.84^{a}$ | $^{A}0.77^{a}$ | $^{A}1.31^{a}$ |

1)Means followed by different uppercase letters in each row are significantly different among drying temperatures ($p<0.05$).
2)Means followed by different lowercase letters in each row are significantly different among flour samples ($p<0.05$).

**Table 2. Effect of MD concentration and drying temperatures on Hunter color values of sweet potato flour**

| Drying temperature (°C) | 55 | | | | 60 | | | | 65 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MD concentration (%) | 0 | 10 | 20 | 30 | 0 | 10 | 20 | 30 | 0 | 10 | 20 | 30 |
| L* | $^{1)A}43.31^{a2)}$ | $^{A}45.58^{c}$ | $^{A}44.37^{b}$ | $^{B}45.40^{c}$ | $^{C}47.36^{a}$ | $^{C}51.35^{c}$ | $^{C}49.76^{b}$ | $^{C}49.44^{b}$ | $^{B}42.75^{a}$ | $^{B}49.28^{c}$ | $^{B}48.80^{b}$ | $^{B}48.08^{b}$ |
| a* | $^{B}19.18^{c}$ | $^{B}18.84^{b}$ | $^{A}19.39^{c}$ | $^{A}18.16^{a}$ | $^{A}18.84^{b}$ | $^{A}18.14^{a}$ | $^{B}19.65^{c}$ | $^{B}19.67^{c}$ | $^{C}21.30^{d}$ | $^{B}18.85^{a}$ | $^{C}20.08^{c}$ | $^{B}19.53^{b}$ |
| b* | $-^{C}6.87^{b}$ | $-^{B}6.06^{c}$ | $-^{B}7.15^{a}$ | $-^{C}5.56^{d}$ | $-^{B}7.29^{a}$ | $-^{B}6.08^{c}$ | $-^{C}6.43^{b}$ | $-^{B}5.87^{d}$ | $-^{A}7.98^{a}$ | $-^{A}6.44^{d}$ | $-^{A}7.67^{b}$ | $-^{A}6.44^{d}$ |
| ΔE | - | $^{A}2.47^{a}$ | $^{B}1.14^{b}$ | $^{A}2.09^{b}$ | - | $^{A}4.21^{a}$ | $^{B}2.68^{b}$ | $^{C}2.08^{b}$ | - | $^{A}7.13^{a}$ | $^{B}6.17^{a}$ | $^{B}5.63^{a}$ |

1)Means followed by different uppercase letters in each row are significantly different among drying temperatures ($p<0.05$).
2)Means followed by different lowercase letters in each row are significantly different among flour samples ($p<0.05$).

**Table 3. Effect of MD concentration and drying temperatures on WAI, WSI, SWC, and viscosity of sweet potato flour**

| Drying temperature (°C) | 55 | | | | 60 | | | | 65 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maltodextrin concentration (%) | 0 | 10 | 20 | 30 | 0 | 10 | 20 | 30 | 0 | 10 | 20 | 30 |
| WAI | $^{1)C}2.45^{c2)}$ | $^{B}2.34^{b}$ | $^{B}2.36^{bc}$ | $^{A}2.22^{a}$ | $^{B}2.40^{b}$ | $^{A}2.23^{b}$ | $^{A}2.19^{a}$ | $^{B}2.30^{c}$ | $^{A}2.39^{b}$ | $^{C}2.37^{c}$ | $^{B}2.34^{b}$ | $^{C}2.33^{c}$ |
| WSI (% ) | $^{B}34.65^{a}$ | $^{A}34.72^{a}$ | $^{A}35.77^{b}$ | $^{A}36.94^{c}$ | $^{A}32.56^{a}$ | $^{B}37.44^{c}$ | $^{A}37.50^{b}$ | $^{C}40.69^{d}$ | $^{C}38.96^{a}$ | $^{C}39.62^{b}$ | $^{C}39.68^{ab}$ | $^{B}41.66^{a}$ |
| SWC | $^{B}3.76^{d}$ | $^{A}3.59^{b}$ | $^{B}3.67^{c}$ | $^{A}3.52^{a}$ | $^{A}3.57^{b}$ | $^{A}3.59^{b}$ | $^{A}3.46^{a}$ | $^{B}3.89^{c}$ | $^{C}3.88^{ab}$ | $^{B}4.00^{c}$ | $^{C}3.86^{a}$ | $^{B}3.93^{b}$ |
| Viscosity (cp) | $^{A}84.567^{c}$ | $^{A}93.10^{b}$ | $^{A}94.53^{b}$ | $^{A}118.90^{a}$ | $^{B}36.667^{b}$ | $^{B}36.70^{b}$ | $^{B}37.33^{b}$ | $^{B}49.43^{a}$ | $^{C}27.76^{b}$ | $^{B}34.43^{ab}$ | $^{B}35.13a^{b}$ | $^{C}$ 38.86$^{a}$ |

1)Means followed by different uppercase letters in each row are significantly different among drying temperatures ($p<0.05$).
2)Means followed by different lowercase letters in each row are significantly different among flour samples ($p<0.05$).

**Table 4. Effect of MD concentration and drying temperatures on anthocyanin content, total phenolic, and ascorbic acid content of sweet potato flour**

| Drying temperature (°C) | 55 | | | | 60 | | | | 65 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maltodextrin concentration (%) | 0 | 10 | 20 | 30 | 0 | 10 | 20 | 30 | 0 | 10 | 20 | 30 |
| Anthocyanin (mg/100 g) | $^{1)A}35.98^{a2)}$ | $^{A}38.99^{b}$ | $^{A}39.38^{b}$ | $^{A}39.90^{b}$ | $^{A}36.87^{a}$ | $^{A}36.84^{ab}$ | $^{A}39.74^{ab}$ | $^{A}41.04^{ab}$ | $^{A}36.68^{a}$ | $^{A}40.20^{b}$ | $^{A}39.91^{b}$ | $^{A}41.18^{b}$ |
| Total phenolic (mg/100 g) | $^{B}9.74^{a}$ | $^{A}11.76^{c}$ | $^{B}11.97^{c}$ | $^{A}11.10^{c}$ | $^{C}10.04^{a}$ | $^{A}11.50^{d}$ | $^{A}11.16^{b}$ | $^{B}11.37^{c}$ | $^{A}9.55^{a}$ | $^{B}12.24^{b}$ | $^{B}12.11^{b}$ | C12.23$^{b}$ |
| Ascorbic acid (mg/100 g) | $^{B}22.08^{c}$ | $^{B}20.35^{b}$ | $^{B}21.17b^{c}$ | $^{A}18.42^{a}$ | $^{B}20.92^{b}$ | $^{B}19.65^{ab}$ | $^{B}20.43^{b}$ | $^{A}18.24^{a}$ | $^{A}14.47^{c}$ | $^{A}11.90^{ab}$ | $^{A}12.20^{b}$ | $^{B}10.92^{a}$ |

[1] Means followed by different uppercase letters in each row are significantly different among drying temperatures ($p<0.05$).

[2] Means followed by different lowercase letters in each row are significantly different among flour samples ($p<0.05$).

**Table 5. Pearson's correlation coefficient of among quality attributes[1]**

| | Temperature | L | a | b | Hue | Phenol | WSI | WAI | SWC | Anthocyanin | Vitamin C | $T_g$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maltodextrin | | 0.35* | -0.11 | 0.34* | 0.32* | 0.63*** | 0.48** | -0.44** | 0.45 | 0.77*** | -0.41** | -0.07 |
| Temperature | | -0.04 | 0.31 | -0.46** | 0.01 | 0.11 | 0.13 | 0.11 | 0.19 | 0.06 | -0.17 | -0.17 |
| L | | | -0.32* | 0.049*** | 0.31 | 0.48** | 0.28** | -0.34** | -0.04 | 0.78*** | -0.04 | -0.05 |
| a | | | | -0.42** | 0.24 | 0.11 | 0.44 | -0.08 | 0.23 | -0.09 | -0.25 | -.000 |
| b | | | | | -0.27** | -0.07 | -0.58*** | -0.72 | -0.55*** | -0.04 | -0.46 | 0.18 |
| Hue | | | | | | 0.54*** | 0.41** | -0.37 | 0.02 | 0.80*** | -0.11 | -0.04 |
| Phenol | | | | | | | 0.16 | -0.07 | 0.07 | 0.44* | -0.18 | 0.16 |
| WSI | | | | | | | | -0.33* | 0.06 | 0.44** | -0.32* | 0.02 |
| WAI | | | | | | | | | 0.03 | -0.15 | -0.08 | -0.27 |
| SWC | | | | | | | | | | 0.25 | -0.32* | -0.18 |
| Anthocyanin | | | | | | | | | | | -0.146 | -0.12 |
| Vitamin C | | | | | | | | | | | | 0.21 |

[1] WSI, water solubility index; WAI, water absorption index; SWC, swelling capacity; $T_g$, glass transition temperature; *$p<0.05$, **$p<0.01$, ***$p<0.001$.

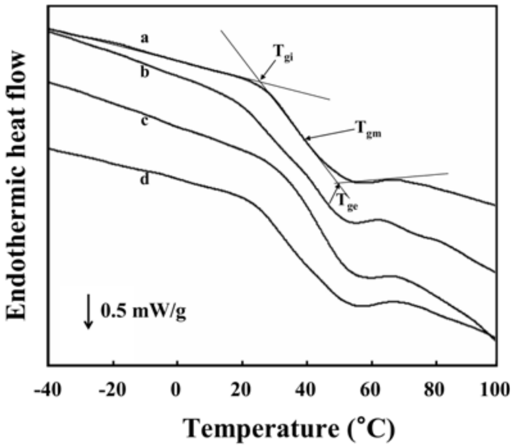


**Fig. 1. DSC thermographs showing the glass transition temperature ($T_g$) of air-dried at 55°C sweet potato flour with increasing levels of maltodextrin concentration.** a, 0%; b, 10%; c, 20%; and d, 30%.

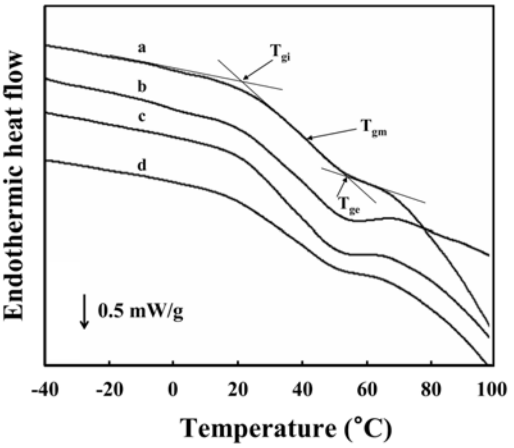


**Fig. 2. DSC thermographs showing the glass transition temperature ($T_g$) of air-dried at 60°C sweet potato flour with increasing levels of maltodextrin concentration.** a, 0%; b, 10%; c, 20%; and d, 30%.

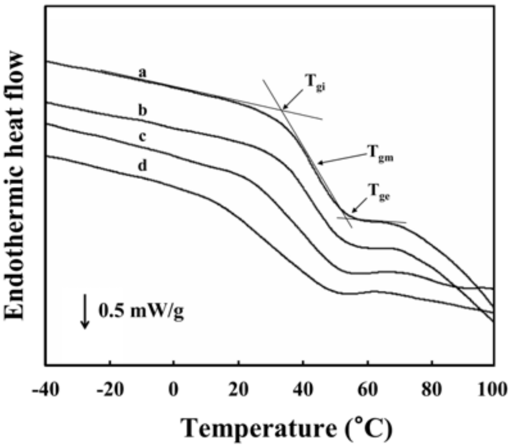
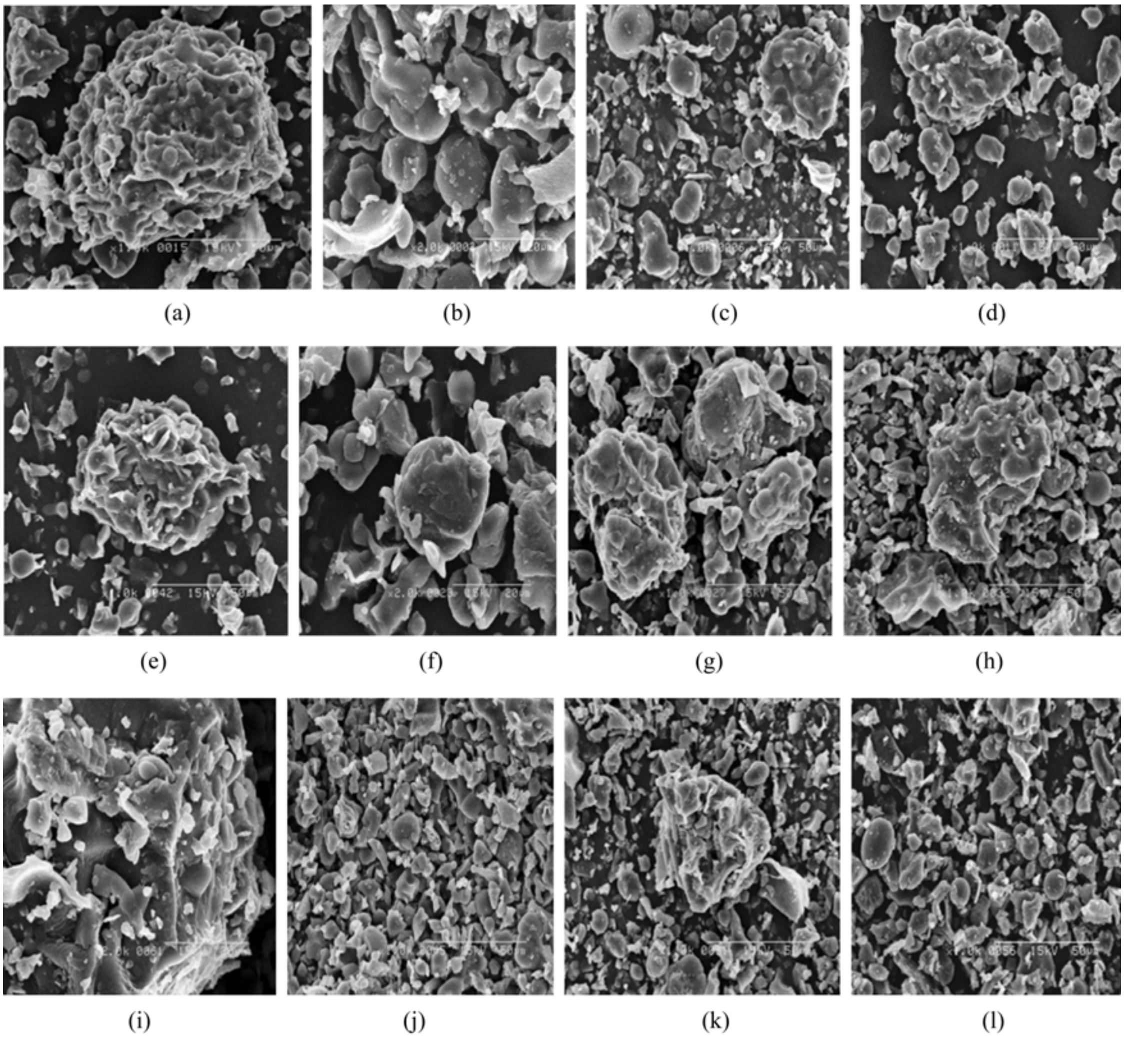


**Fig. 3. DSC thermographs showing the glass transition temperature ($T_g$) of air-dried at 65°C sweet potato flour with increasing levels of maltodextrin concentration.** a, 0%; b, 10%; c, 20%; and d, 30%.

untreated samples, some phenolic compounds were more hydrolyzed or oxidized than in treated samples because dispersions were prepared in the presence of ambient oxygen. Shahidi and Han (9) reported that water-soluble MD protects encapsulated ingredients from oxidation. Presently, total phenolic content was unaltered or slightly decreased with increasing MD concentration. The changes of total phenolic content may be attributed to the destruction of active compounds. Total phenolic content decreased at a higher drying temperature for untreated flour, whereas it increased for MD-treated flours. This may reflect changes in the phenolic composition and contents that might occur upon MD addition and drying. Laine *et al.* (26) demonstrated that phenolic compounds such as flavonols may form complexes with polysaccharides such as starch, and that the affinity of phenolics to polysaccharides depends on water solubility, molecular size, conformational mobility, and shape of the polyphenol. Total phenolic content highly correlated with MD.

**Ascorbic acid content** MD concentrations and drying temperatures affected the ascorbic acid content of sweet potato flours are shown in Table 4. The ascorbic acid content of sweet potato flours ranged from 10.92-22.08 mg/100 g, similar to previously reported values (16). Untreated flours had a higher retention of ascorbic acid than MD-treated flours. The ascorbic acid content was unaltered or slightly decreased with increased MD concentration. These results agree with a previous study (14) that reported MD addition decreased the overall sweet potato solids, decreasing the amount of vitamin C. Drying of sweet potato flour decreased the ascorbic acid decreased. It is well-known that ascorbic acid is relatively unstable to heat, oxygen, and light. Drying temperatures had a detrimental effect on the retention of ascorbic acid since heated air inherently exposes the products to oxidation, reducing their ascorbic acid content (27).

**Glass transition temperature ($T_g$)** The thermograms of air-dried untreated and MD-treated sweet potato flours at 55, 60, and 65°C are shown in Fig. 1-3. The $T_g$ of treated and untreated flours were approximately 37.5-38.5°C. However, presently, the values of glass transition temperature for all flour samples were lower than those previously reported (14). This may be due to the use of different operating conditions and variety of sweet potato. Since no clear differences were observed between $T_g$ of samples obtained with and without MD and using different drying temperatures beyond those due to variable moisture content. Small difference of $T_g$ values for MD pre-treated samples can be explained by gain solutes. Telis and Sobral (28) observed only small differences between $T_g$ of fresh and osmotically-treated tomato, and attributed this result to the short time adopted for the osmotic treatment, which led to low solute gain. Similarly, Del Valle *et al.* (29) suggested the same behavior was responsible for small differences in $T_g$ resulting from osmotic treatment of apple cylinders in sucrose solutions. Slade and Levine (30) reported that the addition of sugar resulted in increased mobility of starch mixtures leading to decreased $T_g$ of the amorphous starch-sugar-water matrix. There were no relationship between $T_g$



(a) (b) (c) (d)

(e) (f) (g) (h)

(i) (j) (k) (l)

**Fig. 4. Microstructure of sweet potato flours treated with different concentrations of MD and drying temperatures.** Air-dried at 55°C (a, b, c, d), 60°C (e, f, g, h), and 65°C (i, j k, l) after treatment with different concentration of MD (0, 10, 20, and 30%, respectively).

and quality attributes in sweet potato flours. To the best of our knowledge, this is the first report indicating the effect of different MD concentrations and hot air drying temperatures on $T_g$ in purple sweet potato flour.

**Microstructure** Scanning electron micrographs (SEM) of sweet potato flour prepared with different concentrations of MD and drying temperatures are presented in Fig. 4. SEM micrographs showed that the particle size of without MD-treated flours at 55, 60, and 65°C were approximately 9.79, 18.67, and 9.53 μm respectively. On the other hand, 10, 20, and 30% MD-treated flours particle size ranged from 21.48 to 10.59, from 17.31 to 15.43 and from 15.94 to 11.59 μm approximately. The granules from the MD-treated flour were more disrupted than those of untreated flour. This variation might be attributed to the interaction between MD and polysaccharides present in sweet potatoes. At higher drying temperatures, MD-treated flour was more disrupted as compared to lower drying temperatures. This could weaken molecular interactions at elevated temperature. These results agreement with the observations of Grabowski *et al.* (14), who reported that potato starch granules are disrupted through interaction between MD and polysaccharides present in sweet potatoes.

In conclusion, the addition of various levels of maltodextrin and different drying temperature on the physicochemical and nutritional properties of sweet potato flours were investigated in this study. These results indicate a potential influence of MD treatment on quality characteristics of sweet potato flours as compared to untreated flour. Therefore, the nutrient composition of MD-treated flour could be used to make a higher quality product that would be more attractive to product developers and consumers. Further studies will be aimed at increasing the retention of nutrients during storage.

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