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ARTICLE

Effects of inlet air temperature and concentration of carrier agents on physicochemical properties, sensory evaluation of spray-dried mandarin (*Citrus unshiu*) beverage powder

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Abstract This study was to investigate the influence of spray drying conditions on the physicochemical characteristics and sensory evaluation of mandarin (*Citrus unshiu*) beverage powder. The results show that moisture content, color, pH, vitamin C, water solubility index and drying yield were significantly affected by the carrier agent concentrations and the inlet air temperatures. However, water activity and water absorption index were not significantly influenced by the spray drying conditions. Sensory evaluation results of taste, color and overall acceptability of mandarin beverage powders added with corn syrup were higher than those added with maltodextrin. As the result of process suitability for spray drying mandarin beverage by using different parameters, it is concluded that 35% corn syrup concentration and 135 °C inlet temperature were suitable to produce mandarin beverage powder with preferable taste and color.

Keywords Mandarin · Spray drying · Citrus fruit · Beverage powder

Introduction

Mandarin is a citrus fruit with a unique taste and color and contains significant amounts of organic acid, vitamin C and vitamin E. In Korea, mandarin comprises up to 30% of total fruit consumption. Among the total mandarin consumption, 20–25% are consumed as processed fruits (Lee et al. 1987). However, it has been constantly noted that there are many problems in the preservation and processing of the mandarin due to its limited production period (Moon et al. 2004). To expand the consumption of the mandarin, it is necessary to develop better technology for preservation and processing. Currently, some processed mandarin products such as mandarin concentrate, drinks, jam, tea, vinegar and yogurt are available, but mandarin is mostly consumed in the form of fresh fruits (Park et al. 2011). Thus, developing new kinds of processed foods using fruits with low marketability is desperately needed.

Spray drying is a technology that evaporates liquid into microscopic drops by spraying the raw material with solid particles followed by contact with hot gas (generally air). The creation of microscopic drops enlarges the surface area and completes the drying process in a few seconds. In spray drying, both drying and pulverization occur simultaneously. The dried powder consists of aggregates of primary particles and takes the general form of a sphere, which enhances the flow of the powder. Due to these properties, it is used in various products including foods, fine chemical products and drugs (Park 1997).

Compared to liquid products, fruit juice powders are easier to transport because they have less volume and weight, more compact packaging and have longer preservation period. The operating parameters play a significant role in the quality of spray-dried food. Thus, it is important to understand the factors that affect the product properties, to optimize the process operating parameters and to create products with better flavor, nutrition and process yield (Phisut 2012). Consequently, this study aimed to investigate the effects of inlet air temperature, type of carrier agents and concentration of carrier agents used as drying

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aids during spray drying on the physicochemical characteristics and sensory evaluation results for mandarin (*Citrus unshiu*) beverage powder.

Materials and methods

Mandarin (*Citrus unshiu*) beverage (50% mandarin juice, vitamin C, citric acid, enzymatically modified stevia glucosyl stevia, fluid fruit sugar, water, Lotte Co., Ltd, Anseong, Korea), maltodextrin MD-20 (Corn Products, Daesang Co., Ltd, Icheon, Korea) with 20 DE and corn syrup (55% maltose, 9% glucose, 17% maltotriose, 19% maltotetraose, Ottogi Co., Ltd, Icheon, Korea) were purchased from a local market.

Spray drying

The spray drying experiments were performed using a pilot-scale spray dryer (MH-8, Mehyun Engineering Co., Ltd, Anyang, Korea), with a rotary disk atomizer. The sample mixture was fed into the main chamber through a peristaltic pump, and the feed flow rate was controlled by the pump rotation speed. Atomizer speed and feed rate were 9860 rpm and 16 mL/min. Different inlet air temperatures and proportions of carrier agents were applied in order to obtain the highest drying yield. Twenty-five to thirty-five percent of maltodextrin was used as the carrier agent when inlet temperatures between 135 and 165 °C were applied, while 30–40% corn syrup was used as the carrier agent when inlet temperatures from 120 to 150 °C were applied.

Drying yield

Drying yield was determined by dividing the weight of the solid mass obtained from the product collector and from the main chamber of the spray dryer by the total mass of solids fed into the spray dryer (Bastos et al. 2012).

Moisture content

The moisture content of the resulting mandarin beverage powder (3 g) was determined gravimetrically by drying in an oven at 105 °C until constant weight (AOAC Official Methods 18 2005).

Water activity

The water activity of the mandarin beverage powder (5 g) was determined with a thermoconstanter (TH-200, Novasina Co., Ltd, Lachen, Switzerland) (Kim et al. 2004).

Color measurement

The color of the mandarin beverage powder (5 g) was determined using a colorimeter (CM-3500d, Minolta Co., Ltd, Tokyo, Japan). The results were expressed as L^*, a^* and b^* values (Kim and Choi 2008).

pH

Five grams of mandarin beverage powder with 45 mL of distilled water was mixed with a homogenizer (T25 BASIC, IKA® Works, INC., Wilmington, NC, USA) and centrifuged (Union32R plus, Hanil Scientific Co., Ltd, Gimpo, Korea) at 2016*g* force for 15 min. Then, the pH of the supernatant was measured using a pH meter (Model 8000, ORION, Rockford, IL, USA) (Kim et al. 2003).

Water solubility index (WSI) and water absorption index (WAI)

WSI and WAI were determined according to the method described by Anderson (1982). A small sample of dry powder (2.5 g) was added to 30 mL of water at 30 °C in a 50-mL centrifuge tube, stirred intermittently for 30 min, and then centrifuged for 10 min at 2016*g* force. The supernatant was carefully poured off into a Petri dish and oven-dried overnight. The amount of solid in the dried supernatant as a percentage of the total dry solids in the original 2.5 g sample gave an indication of the WSI. Wet solid remaining after centrifugation was dried in an oven (105 °C) overnight. WAI was calculated as the weight of dry solid divided by the amount of dry sample.

Vitamin C content

Vitamin C content was determined according to the method described by Doner and Hickts (1981) with slight modifications. Mandarin beverage powder (2 g) was mixed with 100 mL of 5% metaphosphoric acid solution and extracted by vortexing at room temperature for 1 min. The mixture was centrifuged for 15 min at 2016*g* force, and the supernatant was filtered using a 0.45-μm PVDF syringe filter; 20 μL of this sample was injected into the HPLC (PU-980 PUMP and UV-970 detector, Jasco Co., Ltd, Tokyo, Japan). Vitamin C was separated by an ODS C18 column (4.6 × 250 mm, YMC Inc., Kyoto, Japan) using a mobile phase of acetronitrile:0.05 M KH_2PO_4 (60:40 v/v) (A) and water (B), at a flow rate of 1 mL/min. The detection wavelength was 254 nm.

Sensory evaluation

A sensory evaluation was conducted with 50 semi-trained panelists who were students at the Department of Food

Science and Technology, Chonnam National University, Korea. Mandarin beverage powder was evaluated for color, flavor, taste and overall acceptability using the seven-point hedonic scale method. The scale ranged from 1 to 7, with 1 representing ‘dislike very much’ and 7 representing ‘like very much.’

Statistical analysis

All experiments were conducted twice, and all the measurements were taken in triplicate (unless stated otherwise) and presented as mean ± standard deviation. The statistical significance of the data obtained was analyzed by one-way analysis of variance (ANOVA) followed by Duncan’s multiple range test using SPSS version 18.0. The level of significance was set at $p < 0.05$.

Results and discussion

Drying yield

The drying yields for the spray-dried mandarin beverage powder are shown in Fig. 1. When maltodextrin was used as the carrier agent, the drying yield ranged from 40.84 to 70.27%. The maximum yield was obtained when inlet air temperature reached 150 °C and the maltodextrin concentration was 30%. When corn syrup was used as the carrier agent, the drying yield ranged from 41.11 to 60.89% and reached a maximum when the inlet air temperature reached 135 °C and the corn syrup concentration was 35%. According to Tonon et al. (2008), there is positive relationship between inlet temperature and the process yield, or in other words, the efficiency of heat and mass transfer processes is higher at higher inlet air temperatures. This result is similar to the result reported by Cai and Corke (2000). Meanwhile, it has been reported that the increase of inlet air temperature reduces the drying yield. One possible explanation for such result is that the melting of powder and the cohesion wall at higher temperature might have reduced the amount of powder production and yield (Dolinsky et al. 2000; Dolinsky 2001; Chegini and Ghobadian 2007). The drying yield for mandarin beverage powder was found to be lower when the inlet temperature was increased to a certain degree.

Carrier agent concentration was found to have negative effect on drying yield due to the mixture viscosity, which increased exponentially with this variable. When viscosity increases, more solids are created, and these solid pastes in the main chamber wall of the spray dryer cause a reduction in the drying yield (Cai and Corke 2000). With the same principle, the higher the solid content, the higher the number of solids in the mixture, and thus, more solid paste is present in the main chamber wall, causing lower drying yield (Tonon et al. 2008). In this research, the drying yield with both carrier agents was found to be lower when the carrier agent concentration was increased to a certain degree. Chopda and Barrett (2001) regarded 50% of powder recovery following the drying of guava fruit juice as a successful drying process. The yield for dried mandarin beverage powder in this study was 70%, which is higher than that of previous studies. Chopda (2001) reported that the higher the amount of solid in the mixture, the higher the amount of solids available for contact with and for sticking to the chamber wall, thus the lower the process yield. However, the mandarin beverage powder in this study did not stick to the main chamber wall, indicating relatively low solid content compared to the guava fruit juice.

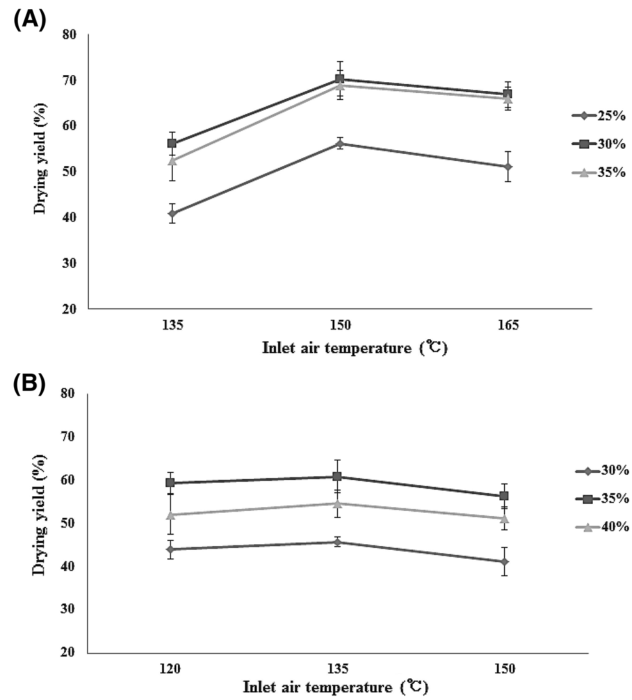

Fig. 1 Drying yield of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried at different inlet temperatures. (**A**) When maltodextrin was used as carrier agent; (**B**) when corn syrup was used as carrier agent

Moisture content

Table 1 shows the moisture content for the mandarin beverage powders treated with different amounts of carrier agents and spray-dried at different inlet air temperatures. The moisture content ranged from 0.92 to 1.74 and 1.22 to 1.92% with maltodextrin and corn syrup, respectively. This was in agreement with Fazaeli et al. (2012), who reported that higher inlet temperature activated heat transfer to the particle and accelerated moisture evaporation. Similar results were observed in experiments conducted on other

Table 1 Moisture content of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried at different inlet temperatures (%)

	135 °C	150 °C	165 °C
Maltodextrin			
25%	1.74 ± 0.04^{Aa}	1.44 ± 0.07^{Ba}	1.25 ± 0.12^{Ca}
30%	1.60 ± 0.19^{Ab}	1.27 ± 021^{Bb}	1.23 ± 0.02^{Ba}
35%	1.30 ± 0.07^{Ac}	1.10 ± 0.20^{Bc}	0.92 ± 0.06^{Cb}
	120 °C	135 °C	150 °C
Corn syrup			
30%	1.92 ± 0.03^{Aa}	1.65 ± 0.08^{Ba}	1.40 ± 0.04^{Ca}
35%	1.88 ± 0.08^{Ab}	1.57 ± 0.11^{Bb}	1.38 ± 0.07^{Ca}
40%	1.59 ± 0.13^{Ac}	1.45 ± 0.14^{Bc}	1.22 ± 0.06^{Cb}

Values represent mean ± SD

[a–c] Means followed by different letters in each column are significantly different ($p < 0.05$)

[A–C] Means followed by different letters in each row are significantly different ($p < 0.05$)

Table 2 Water activity of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried at different inlet temperatures

	135 °C	150 °C	165 °C
Maltodextrin			
25%	0.15 ± 0.00^{NS}	0.16 ± 0.01	0.16 ± 0.00
30%	0.15 ± 0.01	0.15 ± 0.00	0.16 ± 0.01
35%	0.15 ± 0.00	0.15 ± 0.01	0.16 ± 0.00
	120 °C	135 °C	150 °C
Corn syrup			
30%	0.16 ± 0.00^{NS}	0.16 ± 0.00	0.16 ± 0.00
35%	0.16 ± 0.01	0.16 ± 0.00	0.16 ± 0.00
40%	0.17 ± 0.00	0.16 ± 0.00	0.17 ± 0.01

Values represent mean ± SD

[NS] Not significant at $p < 0.05$

fruit juice powders such as watermelon juice, tomato juice, acai juice and pineapple juice (Quek et al. 2007; Goula and Adamopoulos 2008; Tonon et al. 2008; Jittanit et al. 2010; Tonon et al. 2011). Hence, the moisture content in the mandarin beverage powders decreased with increasing inlet temperature because higher inlet temperature accelerated moisture evaporation. When the carrier agents were added to the feed before spray drying, the total amount of solid content increased, while the amount of water available for evaporation decreased, eventually decreasing the moisture content of the resulting powder. Thus, increasing the amount of carrier agents leads to reduced moisture content of processed powder (Quek et al. 2007). The results indicate that the moisture content of mandarin beverage powders decreased when the carrier agent concentration increased.

Water activity

The water activity of the powder was 0.15–0.16 when maltodextrin was used as the carrier agent and 0.16–0.17 when corn syrup was used as the carrier agent (Table 2). Both powders treated with different carrier agents, maltodextrin and corn syrup, showed no significant differences, despite changes in inlet temperature and carrier agents' concentration. Water activity is different from moisture content since the former measures the availability of free water in a food system, which is responsible for biochemical reactions. In contrast, the moisture content rears to the water composition in a food system. In general, food with water activity under 0.6 is considered microbiologically stable. Hence, any spoilage is due to chemical reactions rather than microorganisms (Quek et al. 2007). From the above results, these value ranges are much lower than the minimum condition in which microorganisms such as germs, yeast and mold can grow, thereby confirming the microbiological stability of the spray-dried powders.

Color

The effects of different levels of carrier agents and inlet temperature on the color of the spray-dried mandarin beverage powder are shown in Table 3. When maltodextrin was used as a carrier agent, the L^*, a^* and b^* values ranged from 83.13 to 87.28, 3.44 to 5.55 and 32.52 to 36.87, respectively. As the levels of maltodextrin increased, the L^* value also increased, while the a^* and the b^* values decreased. Moreover, the a^* value increased as the temperature of the inlet air increased. When corn syrup was used as the carrier agent, the L^*, a^* and b^* values ranged from 82.31 to 85.49, 4.58 to 5.79 and 34.58 to 36.47, respectively. As inlet air temperature up, the $L^*$and b^* values decreased, while the a^* value increased. The above association between the color and carrier agent concentration is also affected by the color of the carrier agents. With the increase of the white-colored maltodextrin powder, the L^* value increased, while the a^* value and b^* value decreased. On the other hand, the use of the colorless and transparent corn syrup liquid did not affect the color of the mandarin beverage powder. The change in color following changes in inlet air temperature is a result of non-enzymatic browning reactions such as caramelization and Maillard reactions that occur during the drying process (Jittanit et al. 2010). Since the color of the product differs as the amount of carrier agent and the temperature of the inlet air changes, careful design taking into consideration the drying condition for mandarin beverage powder is required to maintain the color as one of the quality characteristics.

Table 3 Color of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried at different inlet temperatures

	Maltodextrin				Corn syrup		
	25%	30%	35%		30%	35%	40%
*L**							
135 °C	83.85 ± 0.48^{Bc}	85.70 ± 0.30^{Ab}	87.28 ± 0.09^{Ba}	120 °C	85.43 ± 0.81^{NSa}	85.49 ± 0.34^{a}	85.44 ± 0.16^{a}
150 °C	85.03 ± 0.17^{Ab}	84.60 ± 0.28^{Bb}	87.97 ± 0.50^{Aa}	135 °C	83.28 ± 0.15^{Bb}	83.56 ± 0.17^{ABb}	83.73 ± 0.15^{Ab}
165 °C	83.13 ± 0.24^{Cb}	84.86 ± 0.34^{Ba}	85.16 ± 0.08^{Ca}	150 °C	82.42 ± 0.13^{Bc}	82.87 ± 0.23^{Ac}	82.31 ± 0.18^{Bb}
*a**							
135 °C	5.11 ± 0.17^{Ba}	3.75 ± 0.13^{Bb}	3.44 ± 0.10^{Cc}	120 °C	4.95 ± 0.19^{Ac}	4.58 ± 0.31^{Bc}	4.88 ± 0.23^{ABc}
150 °C	5.13 ± 0.10^{Ba}	4.82 ± 0.14^{Ab}	3.83 ± 0.16^{Bc}	135 °C	5.14 ± 0.14^{NSb}	5.11 ± 0.18^{b}	5.20 ± 0.19^{b}
165 °C	5.55 ± 0.17^{Aa}	4.84 ± 0.19^{Ab}	4.40 ± 0.08^{Ac}	150 °C	5.43 ± 0.11^{Ba}	5.79 ± 0.20^{Aa}	5.33 ± 0.84^{Ca}
*b**							
135 °C	34.61 ± 0.32^{Ba}	34.36 ± 0.30^{Ba}	32.66 ± 0.31^{NSb}	120 °C	36.47 ± 0.21^{Aa}	36.25 ± 0.12^{Ba}	36.46 ± 0.24^{Aa}
150 °C	36.87 ± 0.80^{Aa}	36.72 ± 0.56^{Aa}	32.52 ± 0.81^{b}	135 °C	35.65 ± 0.32^{NSb}	35.61 ± 0.26^{a}	35.61 ± 0.78^{b}
165 °C	35.76 ± 0.85^{ABa}	35.64 ± 0.91^{Aa}	32.82 ± 0.68^{b}	150 °C	34.77 ± 0.55^{Ac}	34.58 ± 0.17^{Bb}	34.75 ± 0.88^{Abc}

Values represent mean ± SD

[a–c] Means followed by different letters in each row are significantly different ($p < 0.05$)

[A–C] Means followed by different letters in each column are significantly different ($p < 0.05$)

[NS] Not significant at $p < 0.05$

pH

The pH of the mandarin beverage powders treated with different amounts of carrier agents and spray-dried at different inlet air temperatures ranged from 3.14 to 3.24 and 3.07 to 3.23% (Table 4). The pH increased with increasing inlet air temperature and amounts of carrier agents. The pH of the powders with maltodextrin and corn syrup was 4.85 and 4.25, respectively. It can be concluded that higher amounts of carrier agent affected the resulting mandarin beverage powder. Hence, pH in the mandarin beverage powders increased with increasing amounts of carrier agents. According to Chung et al. (2009), the change in pH is closely related to the acid content. It was reported that heat treatment under high temperature over a long period of time accelerates the decrease in the acid content, thus increasing the pH values in the mandarin beverage powders. A similar result was observed, with some acids lost due to evaporation during drying and the pH increasing as the concentration of carrier agents increased (Mahendran 2010).

Table 4 pH of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried at different inlet temperatures

	135 °C	150 °C	165 °C
Maltodextrin			
25%	3.16 ± 0.01^{Bb}	3.17 ± 0.01^{Bb}	3.24 ± 0.01^{ANS}
30%	3.16 ± 0.01^{Bb}	3.23 ± 0.01^{Aa}	3.23 ± 0.01^{A}
35%	3.17 ± 0.02^{Ba}	3.22 ± 0.01^{Aa}	3.24 ± 0.01^{A}
	120 °C	135 °C	150 °C
Corn syrup			
30%	3.07 ± 0.01^{Cb}	3.09 ± 0.01^{Bc}	3.17 ± 0.01^{Ab}
35%	3.08 ± 0.01^{Ca}	3.14 ± 0.01^{Bb}	3.23 ± 0.01^{Aa}
40%	3.09 ± 0.01^{Ca}	3.15 ± 0.01^{Ba}	3.23 ± 0.01^{Aa}

Values represent mean ± SD

[a, b] Means followed by different letters in each column are significantly different ($p < 0.05$)

[A, B] Means followed by different letters in each row are significantly different ($p < 0.05$)

[NS] Not significant at $p < 0.05$

Water solubility index (WSI) and water absorption index (WAI)

The effects of different amounts of carrier agents and inlet air temperatures on the mandarin beverage powders on WSI are shown in Table 5, and the effects on WAI are shown in Table 6. When maltodextrin was added, WSI ranged from 90.88 to 93.42% and WAI ranged from 0.04 to 0.06%. When corn syrup was added, WSI ranged from 87.31 to 91.21%, while WAI ranged from 0.05 to 0.06%. In both cases, WSI increased as the temperature of the inlet air increased and decreased as the amount of carrier agents increased. According to the research by Fazaeli et al. (2012), the bulk density and solubility of powder are inversely proportional. Also, the higher the dry temperature

Table 5 WSI of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried in different inlet temperatures (%)

	135 °C	150 °C	165 °C
Maltodextrin			
25%	91.57 ± 0.05^{Ba}	93.07 ± 0.66^{Aa}	93.42 ± 0.16^{Aa}
30%	91.40 ± 0.47^{Bab}	92.55 ± 0.21^{ABb}	93.03 ± 0.14^{Aab}
35%	90.88 ± 0.64^{Bb}	92.15 ± 0.59^{Ab}	92.68 ± 0.02^{Ab}
	120 °C	135 °C	150 °C
Corn syrup			
30%	88.73 ± 0.13^{Ba}	90.19 ± 0.21^{Aa}	91.21 ± 0.24^{Aa}
35%	87.31 ± 0.14^{Bb}	90.48 ± 0.19^{ABa}	90.53 ± 0.09^{Aab}
40%	87.61 ± 0.33^{Bb}	89.35 ± 0.37^{Ab}	90.08 ± 0.65^{Ab}

Values represent mean ± SD

[a, b] Means followed by different letters in each column are significantly different ($p < 0.05$)

[A, B] Means followed by different letters in each row are significantly different ($p < 0.05$)

Table 6 WAI of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried at different inlet temperatures (%)

	135 °C	150 °C	165 °C
Maltodextrin			
25%	0.06 ± 0.01^{NS}	0.04 ± 0.01	0.04 ± 0.00
30%	0.05 ± 0.00	0.05 ± 0.00	0.05 ± 0.00
35%	0.05 ± 0.00	0.04 ± 0.00	0.04 ± 0.00
	120 °C	135 °C	150 °C
Corn syrup			
30%	0.05 ± 0.00^{NS}	0.05 ± 0.01	0.06 ± 0.00
35%	0.06 ± 0.00	0.06 ± 0.00	0.05 ± 0.00
40%	0.06 ± 0.00	0.05 ± 0.01	0.05 ± 0.00

Values represent mean ± SD

[NS] Not significant at $p < 0.05$

is, the lower the density and the higher the solubility become. Similar result is found in number of studies (Chegini and Ghobadian 2005; Goula and Adamopoulos 2010). Since evaporation rate increases with increasing temperature, products dry and become a more porous or fragmented structure, resulting in less shrinkage of the droplets, hence the less dense powder. Fazaeli et al. (2012) reported that the bulk density increased with increasing moisture content. Therefore, increasing inlet air temperature increased the moisture content of mandarin beverage powder and decreased the solubility.

WSI decreased as the carrier agent concentration increased. This can be because of the low moisture content of products or the high amount of air in the particles, as maltodextrin and corn syrup are skin-forming materials. Goula and Adamopoulos (2010) made similar observations. As the concentration of carrier agent increased, the powder solubility also increased. This may be because superior water solubility of maltodextrin and corn syrup makes them suitable to be used in the process of spray drying (Grabowski et al. 2006; Goula and Adamopoulos 2010). The concentration of maltodextrin and corn syrup affects the size of the powdered particles and eventually decreases the solubility of the mandarin beverage powders.

WAI had very low values and did not show any significant differences as the inlet temperature and the amount of carrier agents increased. This was because low hygroscopicity of maltodextrin had confirmed its efficiency as a carrier agent. The low WAI values of the mandarin beverage powders could be due to the high values of WSI. Ineffective separation during centrifugation was observed to result in lower WAI values.

Vitamin C

The vitamin C contents of mandarin beverage powders treated with different amounts of carrier agents and spray-dried at different inlet air temperatures are shown in Table 7. When maltodextrin was added, vitamin C content ranged from 83.84 to 105.37 mg/100 g. Vitamin C content ranged from 86.77 to 108.91 mg/100 g when corn syrup was used as an agent. Vitamin C contents decreased as the inlet temperature and the amount of carrier agents increased. The research conducted by Nicoleti et al. (2004) demonstrated that the degradation of ascorbic acid during drying was influenced the most by temperature, followed by the moisture content, oxygen, pH and light. Moreover, the addition of carrier agents reduced the overall amount of mandarin beverage powder solid and thus the amount of vitamin C in the powders (Grabowski et al. 2008).

Sensory evaluation

Sensory evaluation of mandarin beverage powders treated with different amounts of carrier agents and spray-dried at different inlet air temperatures was conducted, and the results are shown in Table 8. When maltodextrin was used as the carrier agent, the color ranged from 5.3 to 6.1 and decreased as inlet temperature and maltodextrin concentration increased. The flavor and taste ranged from 5.1 to 5.4 and 4.4 to 4.8, respectively, showing no significant difference. Overall acceptability was from 4.8 to 5.6, decreasing as inlet temperature and maltodextrin concentration increased. The higher the maltodextrin content, the less preferred the powder was.

Table 7 Vitamin C content of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried at different inlet temperatures (mg/100 g)

	135 °C	150 °C	165 °C
Maltodextrin			
25%	105.37 ± 0.17^{Aa}	104.05 ± 1.63^{Aa}	99.12 ± 0.46^{Ba}
30%	101.37 ± 1.55^{Ab}	91.95 ± 4.65^{ABab}	86.63 ± 8.79^{Bb}
35%	95.03 ± 1.25^{Ac}	84.48 ± 2.22^{Bc}	83.84 ± 0.44^{Bb}
	120 °C	135 °C	150 °C
Corn syrup			
30%	108.91 ± 3.31^{Aa}	107.60 ± 2.01^{Aa}	101.13 ± 0.48^{Ba}
35%	105.92 ± 1.33^{Aa}	95.63 ± 0.98^{Bb}	91.08 ± 0.60^{Cab}
40%	100.40 ± 0.71^{Ab}	89.62 ± 2.97^{Bc}	86.77 ± 1.69^{Bc}

Values represent mean ± SD

$^{a–c}$ Means followed by different letters in each column are significantly different ($p < 0.05$)

$^{A–C}$ Means followed by different letters in each row are significantly different ($p < 0.05$)

Using corn syrup as a carrier agent, the color ranged from 5.4 to 6.4, decreasing as inlet air temperature increased. The flavor ranged from 4.9 to 5.2, showing no significant difference. Taste ranged from 5.1 to 6.3, increasing as the corn syrup concentration increased. Overall acceptability ranged from 5.6 to 6.5, decreasing as the inlet air temperature increased and increasing as corn syrup concentration increased.

The sweetness of maltodextrin was not high enough to affect the overall taste of the dried product. Corn syrup was preferred over maltodextrin due to its higher sweetness and colorlessness, which was able to maintain the original color of the mandarin beverage. Based on the results for taste, color and overall preference, corn syrup is a better option than maltodextrin as a carrier agent during spray drying of mandarin beverage.

The effects of different inlet air temperatures, carrier agents and amounts of carrier agents on the physicochemical and sensory characteristics of mandarin beverage powder were studied. Increasing the inlet air temperature led to increases in the a^* value, pH and WSI and decreases in the moisture content, L^* value, b^* value and vitamin C content. Increasing the carrier agent concentration led to increases in the L^* value and pH and decreases in the moisture content, a^* value, b^* value, WSI and vitamin C content. Water activity and WAI showed no significant differences among the samples. Sensory evaluation results for taste, color and overall preference of mandarin beverages powders treated with corn syrup were higher than for those treated with maltodextrin. From evaluating the process suitability of spray-dried mandarin beverage using different parameters, it was concluded that the use of corn syrup, which appeared to be a suitable carrier agent with acceptable taste and color, at drying conditions of 135 °C inlet temperature and 35% concentration, was a better option for the preparation of mandarin powder. However, the drying yield using corn syrup was 10% lower than using maltodextrin. Thus, further research is required to develop appropriate methods to increase the drying yield and improve the taste and color.

Table 8 Sensory characteristics of mandarin (*Citrus unshiu*) beverage powder added with different levels of maltodextrin and corn syrup and spray-dried at different inlet temperatures

	Maltodextrin					Corn syrup			
	Color	Taste	Flavor	Overall acceptability		Color	Taste	Flavor	Overall acceptability
135 °C					*120 °C*				
25%	6.1 ± 0.7^{a}	4.6 ± 0.7^{NS}	5.1 ± 0.8^{NS}	5.6 ± 1.2^{a}	30%	6.4 ± 1.0^{a}	5.2 ± 1.5^{bc}	5.0 ± 0.9^{NS}	5.7 ± 1.5^{b}
30%	6.1 ± 0.5^{a}	4.4 ± 0.7	5.2 ± 0.6	5.6 ± 1.7^{a}	35%	6.2 ± 1.0^{a}	5.7 ± 0.5^{b}	4.9 ± 0.7	6.1 ± 1.2^{a}
35%	5.8 ± 0.7^{b}	4.6 ± 0.5	5.1 ± 0.7	5.4 ± 1.5^{a}	40%	6.3 ± 0.6^{a}	6.0 ± 0.6^{a}	5.1 ± 0.7	6.5 ± 1.7^{a}
150 °C					*135 °C*				
25%	5.8 ± 1.0^{b}	4.6 ± 0.8	5.3 ± 1.0	5.5 ± 1.0^{a}	30%	5.7 ± 0.8^{b}	5.1 ± 0.7^{c}	5.1 ± 0.9	5.8 ± 1.2^{b}
30%	5.6 ± 0.9^{b}	4.5 ± 0.7	5.3 ± 0.7	5.1 ± 1.4^{b}	35%	5.9 ± 0.6^{b}	5.5 ± 0.8^{b}	5.1 ± 0.7	6.1 ± 1.2^{a}
35%	5.5 ± 0.9^{b}	4.7 ± 1.0	5.1 ± 1.0	5.1 ± 1.6^{b}	40%	5.8 ± 0.7^{b}	6.3 ± 1.0^{a}	5.2 ± 0.8	6.4 ± 1.0^{a}
165 °C					*150 °C*				
25%	5.6 ± 1.2^{b}	4.8 ± 0.8	5.4 ± 0.8	5.4 ± 1.3^{a}	30%	5.5 ± 0.7^{c}	5.1 ± 0.8^{c}	5.2 ± 0.9	5.6 ± 1.8^{b}
30%	5.5 ± 0.8^{b}	4.5 ± 0.7	5.2 ± 0.5	5.0 ± 2.0^{b}	35%	5.4 ± 1.1^{c}	5.6 ± 0.6^{b}	5.1 ± 0.5	6.0 ± 1.2^{b}
35%	5.3 ± 0.8^{c}	4.6 ± 0.9	5.2 ± 0.6	4.8 ± 1.8^{b}	40%	5.5 ± 0.5^{c}	6.1 ± 1.0^{a}	4.9 ± 0.9	6.1 ± 0.9^{a}

Values represent mean ± SD

$^{a–c}$ Means followed by different letters in each column are significantly different ($p < 0.05$)

^{NS} Not significant at $p < 0.05$

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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