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Effect of Maltodextrin Concentrations at different drying temperatures on the Physical and Drying Properties of the Spray-dried Pink Guava Powder

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ABSTRACT

Pink guava is easily perishable fruit with attractive pink color and a unique flavor. Thus, the production of pink guava powder through spray drying is seen as a better alternative to increase its shelf life and preserve its quality. Thus, this research investigated the effect of different parameters on the physical and drying properties of the spray-dried pink guava powder. The pink guava juice was spray-dried with the inlet air temperature of 150ºC to 170ºC and the carrier agent of 10% to 20% of maltodextrin was added. Although, there was no significant interaction (MDC×T) on the physical and drying properties, all properties were individually affected at $p<0.01$ by the drying temperature and MD concentration. The most remarkable result was found in 15% of the MDC at 150ºC where lower particle size led to the highest bulk density 492kg/m^3) that was mostly desired, and the drying rate of about at 307gm/hr increased the powder yield by 15%. In the case of color attributes, the higher color ratio a*/b* and lower color change that indicates better color retention than the others were found in 10% and 15% MDC at 150ºC. However, the powder produced with 15% of MDC at 150ºC was found to be more satisfactory because of the moderate moisture content within the target range of below 5%, the highest bulk density, maximum production of 60% and significant color attributes.

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INTRODUCTION

The production and preservation of different types of seasonal fruits have raised global concern owing to their enormous production and high perishability. As a typical instance, pink guava (*Psidium guajava*), belonging to the family of Myrtacea, is produced abundantly in tropical and sub-tropical regions (Shruthi *et al*., 2013) and they are spoilt a lot due to over-ripening or the lacking of initiatives of proper preservation technique. However, literature shows that spray drying is an economic and quality-ensuring technique which involves atomizing the feed solution into liquid droplets in hot air stream to obtain dehydrated powder particles (Turchiuli *et al*., 2011).

Fruit juices are very sensitive and susceptible to different spray drying parameters especially at higher inlet temperature, where it shows the issue of stickiness that leads to wall deposition, lower product yield and operating difficulties. Fruits are naturally sugar-rich foods which contain high content of low molecular weight of sugar that is responsible for stickiness difficulty (Bhandari *et al*., 1997; Patil *et al*., 2014). The most common way to deal with the stickiness difficulty during spray drying of sugar-rich foods especially pink guava juice is the supplement of drying agents into the spray sample (Cabral *et al*., 2009). Maltodextrin, as a drying agent, contributes to the retention of food properties like color, flavor and nutrients both in the spray drying and storage. It offers a good and mutual combination between cost and efficiency (Rodríguez-Hernández *et al*., 2005).

The quality of the final product depends on the spray drying parameters like the feed to drying aid ratio, feed concentration, atomizer speed, flow rate, inlet and outlet air temperature and so on. Higher bulk density with lower moisture content is more significant in spray drying. This is because, higher bulk density reduces the packaging and shipping costs and increases the flowability and lower moisture content specifically less than 5% ensures higher stability of the powder product during packaging and storage (Sahin-Nadeem *et al*., 2013; Sinija and Mishra, 2008). Nonetheless, literature shows that the physical properties like moisture

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content, bulk density and particle size are very much affected by the drying temperature and drying agent (Igual *et al*., 2014; Tonon *et al*., 2008; Amerie and Maa, 2006). In turn, the drying indices such as the drying ratio, drying rate, productivity and yield percentage have great significance in the industry to measure the drying performances. The productivity is the most considerable matter to maximize the production yield by controlling the drying rate. Also, it has been reported that drying rate causes the changes in the moisture content, particle size and bulk density (Sahin-Nadeem *et al*., 2013, Chong *et al*., 2014). Color is another key feature of the powder product since it reveals the sensual attraction and the excellence of the powders (Quek *et al*., 2007). Without proper visual attraction, even a functional food will not be acceptable to the consumers. The color-indicating attributes such as lightness (L*), color ratio (a*/b*), chroma (c*), Hue angle (h*) and color difference (ΔE) are mostly influenced by higher inlet temperature and the Maltodextrin level. The heat and air-sensitive samples may be degraded by the thermal effect, oxidative reaction and non-enzymatic browning reaction (Mishra *et al*., 2013; Sahin-Nadeem *et al*., 2013; Cai and Corke, 2000). However, pink guava juice has unique and attractive pink color that is very sensitive to heat, air and light. Several works have been done on pink guava products like, pink guava juice, puree, paste and dehydrate slices. However, it still has some limitation in literature or there is insufficient information on the commercial scale on spray-dried pink guava powder basically with regard to the physical properties, drying indices and color attributes.

Therefore, the objectives of this study are to investigate the physical properties such as moisture content, particle size and bulk density with its drying indices as the drying ratio, drying rate, productivity and powder yield percentage of pink guava powder spray-dried with different levels of MDC at different inlet temperatures. Apart from this, the color analysis was included to observe its attractive color retention during the spray processing.

Nomenclature

MD	Maltodextrin
MDC	Maltodextrin concentration
T	Temperature
MDC×T	Interaction between maltodextrin concentration and temperature
L*	Lightness
c*	Chroma
h*	Hue angle
a*/b*	Color ratio
ΔE	Color difference

Methodology:

1.1. Raw materials:

Commercial pink guava juice was collected from Sime Darby Beverages Sdn. Bhd., Malaysia. Maltodextrin DE 10 was chosen as a drying aid for spray drying.

1.2. Spray feed preparation and spray drying:

The pink guava juice was diluted with the same amount of distilled water, and total soluble solid content was controlled at the brix content of 5.5±0.1°Bx to make the viscosity optimal. After proper mixing, it was sieved with a 250µm sieve to reduce undesirable larger particles and then maltodextrin added to the juice sample in the concentrations of 10%, 15% and 20% (w/v) and homogenized at 5000 rpm for 8 minutes prior to the proper mixing (Carrillo-Navas *et al*., 2011) by using Homogenizer Wise Mix, HG-15A, Malaysia. The total soluble solid content was measured with a refractometer (Pocket Refractometer, ATAGO, Tokyo, Japan) at 25ºC before spray drying and 300ml sample was taken to spray dry in every case.

The spray drying was carried out with spray dryer Lab Plant SD-05 (West Yorkshire, UK) comprising of spray chamber of 1050mm×620mm×500 mm and 0.5 mm standard diameter nozzle with co-current flow. Drying was conducted at inlet air temperatures of 150°C, 160°C, and 170°C with controlled conditions at the feed flow rate of 350 mL/h, feed temperature and room temperature of 25±1°C and relative humidity of 55±1% in the room. During the spray drying, the outlet air temperature, air flow rate and the compressor air pressure were noted at 90±2ºC, 47±2m^3/hr and 2.1±1bar accordingly. After setting each temperature, the sample was spray dried and the powder produced was collected in a plastic zip bag (LDPE) and kept inside the desiccator until it cooled down. After cooling, the powders were weighed and stored at 4°C in the dark for further analysis.

1.3. Analysis of powder properties:

1.3.1. Moisture content:

The moisture content analysis was carried out followed by the method of AOAC, 1990. One gram of sample was carefully measured and dried in an oven at 70°C until constant weight was obtained and the analysis triplicated. The final moisture content was calculated as the total weight of moisture loss to the total weight of powder sample ratio.

1.3.2. Particle size:

The particle size was determined using a laser light diffraction instrument, Mastersizer 2000 (Malvern Instruments, Malvern, U.K.) (Tze *et al*., 2012). A small powder sample was placed into the optical bench and the data acquisition was recorded automatically. The particle size was found as the mean diameter, which is generally used to characterize a particle. The analysis was performed in triplicate.

1.3.3. Bulk density:

The bulk density was measured according to Sahin-Nadeem *et al.* (2013). Two grams of powder were carefully measured and taken into a 10 mL graduated cylinder (rest on plane surface) and the bulk variations noted down. The bulk density of the powder was calculated by the relationship of the mass of the powder sample to the powder volume ratio.

1.3.4. Drying ratio, drying rate, productivity and yield:

The drying properties such as drying ratio, drying rate and the productivity by the way of Cai and Corke, (2000) with slight modification and the powder yield followed by León-Martínez *et al.* (2010) were calculated and these were mentioned as the following equations 1, 2, 3 and 4, respectively. The drying ratio was calculated as the powder solid content to the feed solid content ratio.

$$Drying\ ratio, D_o = (M_f + 1)/(M_p + 1) \quad (1)$$

$$Productivity, P_o = F_r / D_o \quad (2)$$

$$Drying\ rate, D_r = F_r / P_o \quad (3)$$

Where M_f = moisture content of feed on dry basis, M_p = moisture content of powder on dry basis and F_r = feed rate (g/hr).

$$Powder\ Yield, Y = \frac{(W_2 - W_1) - X_{wb}(W_2 - W_1)}{F_V T_S} \times 100 \quad (4)$$

where, X_{wb} is the moisture content (wb), F_v is the feed volume, T_s is the total solid content, and W_1 and W_2 are the weights of the powder bottle before and after spray-drying, respectively.

1.3.5. Color analysis:

The color of the final product was measured carefully using a color reader (CR-10; Konica Minolta Sensing Ltd., Japan). In order to obtain the L*(lightness), a*(green/red), and b*(blue/yellow), c*(chroma, indicating color intensity), h*(hue angle, indicating color property), the lens of the color reader was placed on the powder (Tze *et al.*, 2012). The ratio of a*/b* was also used for color determination. Total color variation or change between the sample before spray drying and the final product was determined using the following equation:

$$\Delta E = \sqrt{(L_o^* - L^*)^2 + (a_o^* - a^*)^2 + (b_o^* - b^*)^2} \quad (5)$$

where L_o^*, a_o^*, b_o^* and L^*, a^*, b^* are the values of the sample before spray drying and the values of the final product after spray drying, respectively (Kha *et al*., 2010).

1.4. Statistical analysis:

The data were analyzed through the analysis of variance (ANOVA) and Duncan's multiple range test using SAS 9.3 TS L1M2 (SAS, 2014). All the measurements were conducted in triplicate and evaluated as the mean value with standard deviations. The diagrams of the mean value and error bars were generated by using Microsoft excel version of 2010.

RESULTS AND DISCUSSIONS

2.1. Effect on the physical properties of spray-dried pink guava:

The effect of MD concentrations at different inlet air temperatures on physical attributes of spray-dried pink guava powder has been mentioned in Fig. 1.1. Both of the factors were highly significant on the final product in terms of the final moisture content, particle size and bulk density at $p<0.01$. The moisture content of pink guava powder was observed in the range of 2.03% to 3.26% which is within the target range of the spray drying process. According to the finding of Sinija and Mishra, (2008), the instant tea powder has moisture content less than 5%, showing more stability in both the packaging and storage. From Fig 1.1, the powder moisture content sharply reduced with the increasing MDC from 10% to 15% and then the reduction became very slow at 20% of MDC. On the other hand, the increasing temperature caused rapid reduction of the moisture content from 150°C to 170ºC and produced very low moist powder (below 2.5%) at 170ºC with different levels of MDC. Kha *et al.* (2010) and Mishra *et al.* (2013) reported a similar trend on the moisture content reduction due to the higher temperature gradient, causing rapid water evaporation with greater rate of heat transfer, and higher MD concentration affected to increase the total solids of the feed and reduce the amount of water evaporation.

The mean particle size of the powder was found to be almost similar (around 11µm) at lower temperature of 150ºC with the level of 10-20% of MDC. The changes of the drying temperature from 150°C to 170ºC caused rapid increment of the particle size except for 15% of MDC where the particle size trend was quite constant until 160ºC and then rose mildly at 170ºC. The slow upward trend of 15% of MDC may be owing to the significant interaction between the two factors (MDC &T) observed and the lower particle sizes produced. According to the report of Nijdam and Langrish, (2006), the size of the particle became more shrunk at lower temperature, which resulted in smaller particle. Higher feed concentration is responsible for higher feed viscosity, creates greater droplets and consequently produces greater sizes of the powder particle (Master, 1979). It was observed that the very low moist power provided higher particle size of the powder that was undesirable. This is because, due to the faster drying, the powder particle cannot be shrunk properly leading to a creation of a hole inside the powder particle. This has the probability of quality degradation through oxidation.

In the case of bulk density, the trend of bulk density was reverse to the trend of the particle size. It decreased with the higher temperature and rose with the increasing MD concentration except for 20% MD where it fell down. Similar results had been proved by Kha *et al*. (2010); Bae & Lee, (2008) documenting the rise of the total feed solid content.

According to Fazaeli *et al*. (2012), higher inlet air temperatures resulted in lower dense powder, which is due to the higher drying temperature that causes faster particle to dry with less droplet shrinkage providing lower dense powder. However, it was similar with the work of shishir *et al*. (2014), whereby when the bulk density was found to be higher for 15% of MDC at 150°C and 160ºC, the particle size was lower under the same conditions. In the commercial aspect, higher bulk density is more desirable to reduce the packaging and transportation expenses while the low dense powder having higher and irregular particle size and shapes, blocks more air within the powder particles which causes oxidative degradation and reduces the storage stability. Therefore, it was found that the higher dense powder showed lower particle size and moderate moisture content especially for the powder produced with 15% MD at 150ºC that was desired as the highest bulk density (492kg/m^3) with acceptable particle size (10.93µm) and moisture content of around 2.84%.

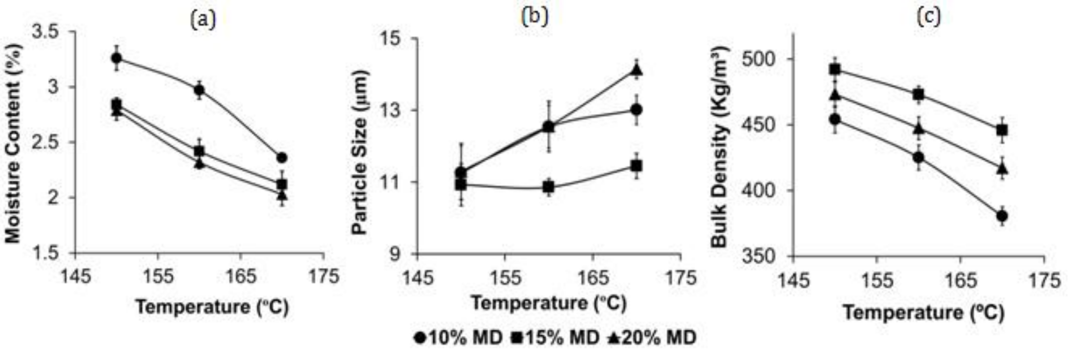

Fig. 1.1: Effect of MD concentrations at different inlet temperature on (a) moisture content, (b) particle size and (c) bulk density

2.2. Effect on drying properties of spray-dried pink guava:

The drying properties like drying ratio, drying rate, productivity and powder yield percentage are the most important indices in the spray drying process to measure the drying performances, increase the productivity and reduce the drying expenditures. The effect of MD concentration at different drying temperatures on the drying properties, was highly significant in the level of $p<0.01$, and this has been presented in Fig. 1.2 and 1.3. The drying ratio significantly ($p<0.01$) decreased with the increasing MD concentrations due to the increment of total soluble solid content on the feed and it increased very smoothly with the increasing temperature. It coincided with the changes of the moisture content at different levels of MDC. This is owing to the fact that the calculated drying ratio depends on the feed sample moisture content and final product moisture content. Therefore, the increase in the inlet temperature and MDC level reduced the moisture content and led to the changing drying ratio. Similar results were found according to the findings of Cai and Corke, (2000).

The drying rate during the spray process has an intimate effect on the physical properties of powder produced such as the final moisture content, particle size and bulk density. According to Fig. 1.2, the changes of the drying rate were similar to those of the drying ratio. It was significantly ($p<0.01$) decreased with the increasing feed concentration because of the higher feed solid content that caused the liquid feed to be more dense and to produce larger feed droplets in the spray chamber and increase the spray drying time. On the other hand, it was increased gently with the increasing drying temperature due to faster drying. This is similar to the observation of Cai and Corke, (2000). The higher drying rate was found at 10% MDC and this refers to the faster water evaporation that was responsible for the production of lower moist powder with higher and irregular particle size and lower bulk density resulting in lower grade powder product.

Higher productivity and higher percentage of powder recovery are the essential requirements in the drying technology. In Fig. 1.3, the drying conditions' effect on productivity and powder yield against the drying rate were shown. The trend of productivity was in a reverse with the tendency of the drying rate that was not in line with the observation of Cai and Corke, (2000). The higher MD concentration sharply increased the productivity whereas the higher temperature lowered the productivity mildly. However, according to Igual *et al.* (2014), the productivity linearly increased with the increasing drying aid concentration, but it was found to be quite unchangeable with the increasing temperature. Since faster drying rate happened due to higher inlet temperature, the feed with lower MDC became burned and transformed into sticky powder that stuck on the drying chamber wall. Thus, productivity was reduced with the higher drying rate. Similar observation was found in powder yield where it was reduced with higher drying temperature and higher drying rate. Nonetheless, when the MDC level was increased from 10% to 15%, the powder yield rose from around 50% to around 60% that was preferable, although it was found in a sharp fall at 20% MDC. Shrestha *et al*., (2007) proved that the increase of MDC led to higher powder yield. The fall of the powder yield percentage after 15% MDC is due to the higher Maltodextrin concentration that tends to increase the feed viscosity which produced larger feed droplets and it made it hard to dry easily. Thus, higher MDC of 20% provided lower powder production.

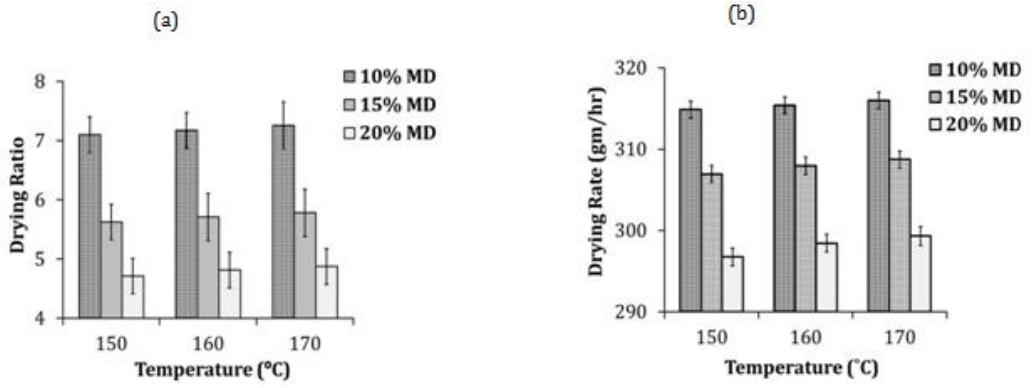

Fig. 1.2: Effect of MD concentrations at different inlet temperatures on (a) drying ratio (b) drying rate.

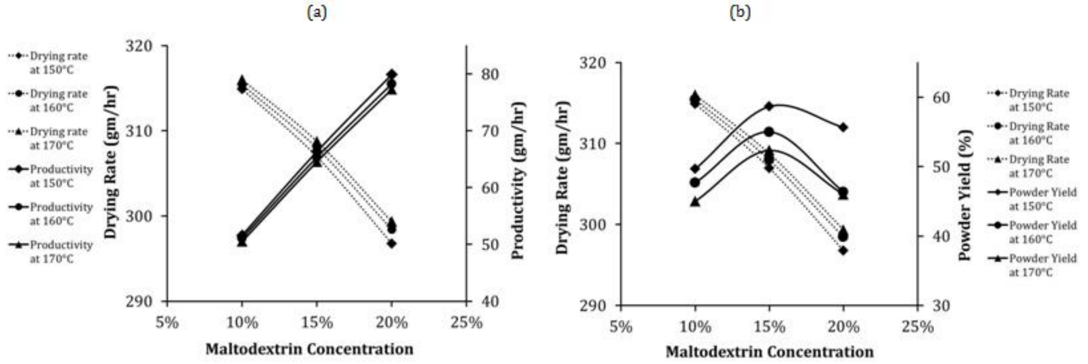

Fig. 1.3: Effect of Maltodextrin concentrations on (a) drying rate and productivity (b) drying rate and powder yield at different inlet temperatures

2.3. Effect on color attributes of spray-dried pink guava:

The influences of MD concentrations and inlet air temperatures were significant on the color attributes of spray dried powder (Table 1.1). The lightness of the powder was significantly (p<0.01) impacted by different levels of MD concentrations and inlet temperatures. With the rising temperature and MD concentration, the lightness generally increased. Similar observation was proved by Caliskan and Dirim (2013); Mishraa *et al*. (2013). Higher degree of lightness of spray-dried powder reflects that the color attributes were declined due to oxidation and thermal degradation (Sousa *et al*., 2008). As another justification, the higher MDC, physically in white color, covered the pink color of the powder product, resulted in higher degree of lightness. In case of Hue angle and chroma, MD concentrations at different drying temperatures affected the powder significantly at p<0.01. There was an almost linear upward trend found with the rising drying temperature and MD concentration. However, the lowest hue angle indicating better color property (around 70°) was found at 150ºC for 10% and 15% of MDC.

The color ratio a*/b* was affected significantly at p<0.01 for the spray-dried juice powder; and went lower with the greater temperature and higher MD concentration. This was similar to Mishraa *et al*. (2013). In fact, a* symbolizes the redness of the pink guava pigment. Since the redness (a*) decreased during the spray process with higher temperature that caused thermal degradation and higher amount of MD that covered the pigment, the color ratio a*/b* was reduced. However, the most significant a*/b* value that refers to better color ratio was observed at 150ºC for 10% and 15% of the MDC. The color change between the sample and final product before and after drying was significantly impacted at the level of p<0.01. It was a calculated value from L*, a*, b* of the sample and the final product. According to Table 1.1, higher MD concentration caused greater change (around 2 to 3) of the color difference between the sample before spray drying and the final powder product after spray drying, while temperature led to change at about 0.5 to 1.0. More color change indicates more color degradation. The higher temperature caused faster drying and rapid pigment oxidation. Another probable reason lies in the big surface area of the spray chamber that leads to the oxidative degradation. Also, higher MDC may be the reason to increase the color difference that hid the color. Kha *et al*. (2010) reported, that an upward trend of color change had been observed with the growing temperature while a slight rise was found with higher MD concentration. Therefore, the most significant color change was found at 15% MDC and 150ºC, 10% with 150ºC and 160ºC were more acceptable.

Table 1.1: Color analysis of spray dried pink guava powder.

MDC	Temperature (°C)	L*	c*	h*	a*/b*	ΔE
10%	150	72.86 ± 0.55^{d}	26.50 ± 0.10^{f}	70.00 ± 0.55^{d}	0.373 ± 0.021^{a}	34.25 ± 0.09^{f}
	160	73.21 ± 0.15^{e}	27.10 ± 0.10^{d}	70.96 ± 0.37^{c}	0.343 ± 0.007^{b}	34.42 ± 0.21^{f}
	170	73.86 ± 0.32^{c}	27.30 ± 0.26^{c}	71.86 ± 0.57^{ab}	0.326 ± 0.001^{c}	35.59 ± 0.58^{cd}
15%	150	73.26 ± 0.35^{d}	26.73 ± 0.21^{e}	70.06 ± 0.20^{d}	0.362 ± 0.004^{a}	34.96 ± 0.38^{f}
	160	73.83 ± 0.20^{a}	27.30 ± 0.20^{c}	71.40 ± 0.52^{bc}	0.336 ± 0.012^{bc}	35.27 ± 0.29^{de}
	170	74.20 ± 0.10^{c}	27.66 ± 0.15^{a}	72.10 ± 0.20^{a}	0.321 ± 0.005^{cd}	35.61 ± 0.09^{cd}
20%	150	74.76 ± 0.15^{b}	26.93 ± 0.15^{d}	71.23 ± 0.20^{bc}	0.340 ± 0.005^{bc}	35.86 ± 0.06^{bc}
	160	75.26 ± 0.15^{ab}	27.56 ± 0.15^{ab}	71.90 ± 0.36^{ab}	0.327 ± 0.006^{c}	36.29 ± 0.24^{ab}
	170	75.60 ± 0.36^{a}	27.86 ± 0.05^{a}	72.46 ± 0.32^{a}	0.315 ± 0.007^{d}	36.65 ± 0.38^{a}
Significant interaction						
MDC		**	**	**	**	**
T		**	**	**	**	**
MDC×T		*	NS	NS	NS	NS
* Significant at p<0.05, ** Significant at p<0.01, NS- Non-significant, [a] Values are mean ± standard error						

Conclusion:

The present work was carried out to investigate the influence of MD concentration at different inlet air temperatures on spray-dried pink guava juice powder properties in terms of its physical properties, drying indices and color attributes. Both of the factors had a significant effect on the powder properties. The powder produced with 15% MDC at 150ºC was found to be more convenient than the others where the moisture content of 2.84% indicates more stability with the highest bulk density (492kg/m³) that was more desired and with the maximum yield of 60% ensured. In the aspect of color attributes, a significant level of lightness (L*), also higher color ratio (a*/b*) refer to the presence of color compound and lower color difference (ΔE) indicating lesser amount of loss of color compounds found in15% MDC at 150ºC.

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