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Contributed Paper

Study of Spray Drying of Pineapple Juice Using Maltodextrin as an Adjunct

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ABSTRACT

A number of pineapple powder specimens were produced using a spray dryer under various drying conditions. Fresh pineapple juices were added with maltodextrin (MD) at 15, 20 and 25% before exposing to the drying temperatures at 130, 150 and 170^{o}C with the feed rate 0.020, 0.022 and 0.035 litre per minute respectively. Then, the qualities of pineapple powders and reconstituted pineapple powders were investigated in the aspects of moisture content, solubility, color, pH and the consumer acceptance. The results indicated that the pineapple juice should be added with MD at 15% and dried at 150^{o}C. Furthermore, the moisture content and solubility of the pineapple powder produced under this condition were 5.1% and 6.2 minutes respectively while its solution had the lightness 58.8, redness 5.2, yellowness 25.1 and pH 3.5.

Keywords: spray drying, pineapple, pineapple powder, instant pineapple juice, maltodextrin.

1. INTRODUCTION

Pineapple is the most important fruit of Thailand and many developing countries due to its export values. Generally, the pineapples are exported as the canned-fruit, concentrated juice and dried pineapple slices. Although there are a number of pineapple products in the market, the food industry still keeps developing new product from pineapple. The benefit of new product development is the elevation of the fresh pineapple demand and consequently help reducing the pineapple loss caused by the microorganisms, chemical and enzymatic reactions during the peak of harvesting season [1,2]. Pineapple powder is an interesting product because of its long shelf life at ambient temperature, convenience to use and low transportation expenditure. Pineapple powder can be consumed as an instant juice powder or a flavoring agent. So far, there have been merely few studies about the production of pineapple powder.

Some researchers claimed that drying of fruit juice could produce the fruit powder that reconstituted rapidly to a fine product resembling the original juice [2]. It is because the product temperature is rarely raised above 100^{o}C during drying process [3]. Nonetheless, there are some difficulties in drying the fruit juice with high sugar content like pineapple due to their thermoplasticity and hygroscopicity at high temperatures and humidities causing their packaging and utilization in trouble [3-5]. These characteristics are attributed to low molecular weight sugars such as fructose, glucose and sucrose and organic acids such as citric, malic and tartaric that are the major solids in fruit juices [4]. The low glass transition temperature (T_g), high hydroscopy, low melting point, and high water solubility of these solids lead to a highly sticky product when spray dried [6]. These solids normally have low glass transition temperatures. Additionally, Roos and Karel [7] stated that these materials are very hygroscopic in amorphous state and loose free flowing character at high moisture content.

The thermoplasticity and hygroscopicity problems occurring in drying the fruit juice with high sugar content can be overcome by adding some carriers such as maltodextrin (MD) and Arabic gum [2,5,8]. The drying carriers or adjuncts are high molecular weight compounds that have high T_g; as a result, they can raise the T_g value of feed and the subsequent powder [9]. According to Cano-Chauca *et al.* [5], MD is a carrier which is the most popular in spray drying due to its physical properties such as high water solubility. Gabas *et al.* [2] described that MD consists of b-D-glucose units linked mainly by glycosidic bonds and are typically classified by their dextrose equivalent (DE). Bhandari *et al.* [8] and Silva *et al.* [10] pointed out that MD could improve the stability of fruit powder with high sugar content because it reduced stickiness and agglomeration problems during storage. Also, Shrestha *et al.* [9] indicated that the increasing amount of MD could increase the product recovery and the lightness of the orange juice powder.

Spray drying is a technique widely used in the food industry to produce food powder due to its effectiveness under the optimum condition [5]. The spray drying parameters such as drying air temperature and feed rate are influential to the attributes of spray-dried food such as particle size, bulk density, moisture content, average time of wettability and insoluble solids [11-13]. For instance, Greenwald and King [11] pointed out that the increased air temperature resulted in higher bulk density of spray-dried products. On the other hand, Chegini and Ghobadian [13] concluded that the raise of drying air temperature increased the particle size, average time of wettability and insoluble solids but decreased the bulk density and moisture content of the orange juice powder.

Due to the lack of research about spray dried pineapple juice, this study was carried out with the following objectives; (1) to study the feasibility of producing the spray-dried pineapple powders and (2) to determine the optimal quantity of MD and drying condition for spray drying of pineapple juice.

2. MATERIALS AND METHODS

2.1 Raw Materials

The ripe pineapples (*Ananas comosus*) of the "Smooth cayenne" variety were obtained at the local market nearby Kasetsart University, Bangkok, Thailand. The pineapples were peeled, cut, crushed and hydraulically pressed to squeeze out the juice. The soluble solid content, color and pH of the fresh pineapple juice were measured by refractometer, color meter and pH meter respectively.

Aqueous solutions of MD were prepared by dispersing MD that had dextrose equivalent (DE) 10, pH 4.7, and moisture content 5.2% into 200 gram of hot water. The solution was mixed with 900 gram of the fresh pineapple juice using the blender. The amounts of MD filled into the hot water were 165, 220 and 275 grams in order to provide MD content 15, 20 and 25% of the combination of hot water and pineapple juice 1,100 gram. The MD content 15, 20 and 25% of the feed mixture can be approximately converted to be the ratios of pineapple juice (based on total soluble solids) and MD (based on dry weight) at 65:35, 50:50 and 40:60 (pineapple juice:MD) by weight respectively.

2.2 Drying Experiment

The samples prepared by the procedure described in the previous section were dried in a "NIRO" small-scale spray dryer model "Mobile Minor 2000". The schematic diagram of the dryer was shown in Figure 1. The drying experiments were carried out using the full factorial design of three MD content levels (15, 20 and 25%) and three drying air temperatures (130, 150 and 170°C). The feed rate was controlled at 0.020, 0.022 and 0.035 litre per minute (lpm) for the drying air temperatures 130, 150 and 170°C respectively in order to keep the temperature of the outlet drying air at approximately 90°C. At the end of drying, the pineapple powders were collected, weighed, and kept in the sealed container for the quality determination. The total weight value of powder collected from each drying run was used for the calculation of powder recovery.

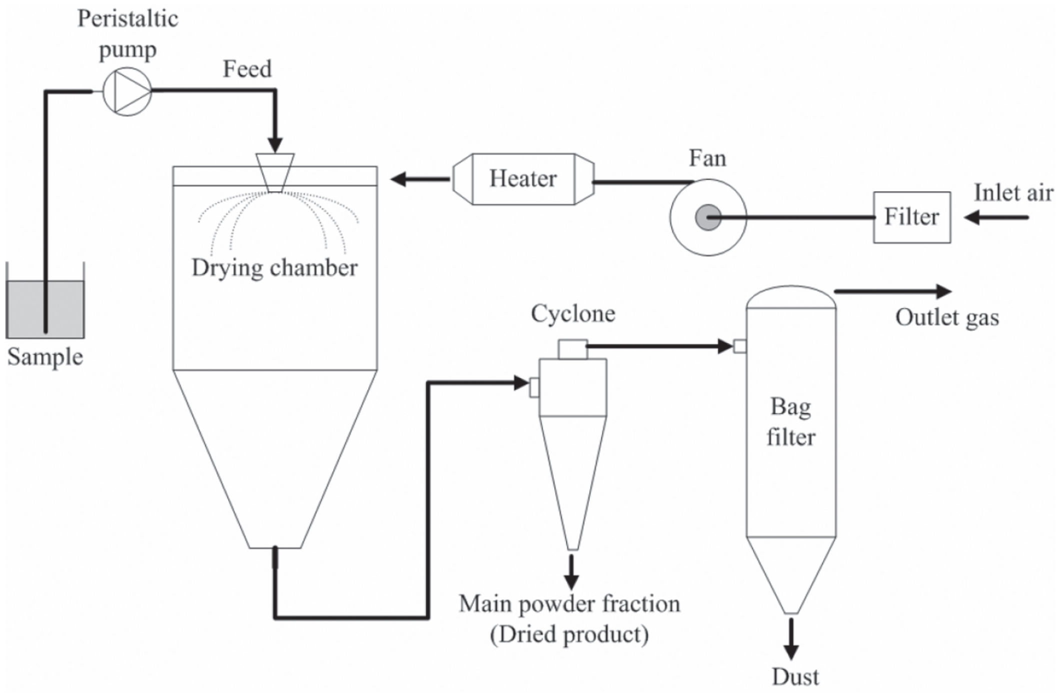

Figure 1. A schematic diagram of the spray dryer.

2.2 Quality Determination

The soluble solid content, color and pH of the fresh pineapple juice were measured by "ATAGO" hand refractometer, "Minolta" color meter model CM-3500d and "JENCO" pH meter respectively.

For each drying batch of pineapple powders, the moisture content and the solubility were measured. The moisture content was determined by the oven method using 2 g of powder and 105°C drying temperature for 2 h. After that, the sample was cooled in desiccator, weighed, redried 2 h, and repeated process until change in weight between successive dryings at 2 h intervals was not over 2 mg. The weight loss after drying in the oven was used to calculate the moisture content of pineapple powder, expressed on wet basis (WB). To determine the solubility, the methods of Al-Kahtani and Hassan [14] and Sommanas [15] were applied. The powder sample and distilled water were transferred into a 500 mL beaker with the proportion 37 g of powder per 100 g of distilled water. This ratio was based on the average production yield (the feed 137 g could produce 37 g of powder). After transferring the specified amount of powder sample and distilled water into the beaker, a magnetic bar was dropped and then the beaker was located on the “FISHER” hot plate stirrer model 210T setting at speed level 5 while the heater was not turned on. The measurement was conducted in the room controlling temperature at 25°C. The stopwatch was started since turning on the hot plate stirrer and stopped when the powder in the beaker entirely dissolved. This recorded time, namely solubility was indicated in the unit of minute.

An aliquot of pineapple powder from each drying run was reconstituted at the proportion 37 g of powder per 100 g of distilled water in order to make them to be comparable with the fresh juice. The pH and color of the solutions were measured. Furthermore, the solutions were exposed to the sensory evaluation and compared with the fresh pineapple juice in aspects of appearance, color, aroma, taste and overall liking. The sensory was evaluated using 9-point hedonic scale test by 22 panelists who were the undergraduate students in the faculty. The Figure 2 illustrates the throughout procedure from the raw material preparation until the solutions of pineapple powder were exposed to the color and pH measurements and the sensory test.

The soluble solid content, color, pH and solubility were measured in three replications while the moisture content was measured in duplicate. The software package of Statistica 5.5 StatSoft™ (supplied by StatSoft, Inc. Tulsa, OK 74104 USA) was used for statistical analysis.

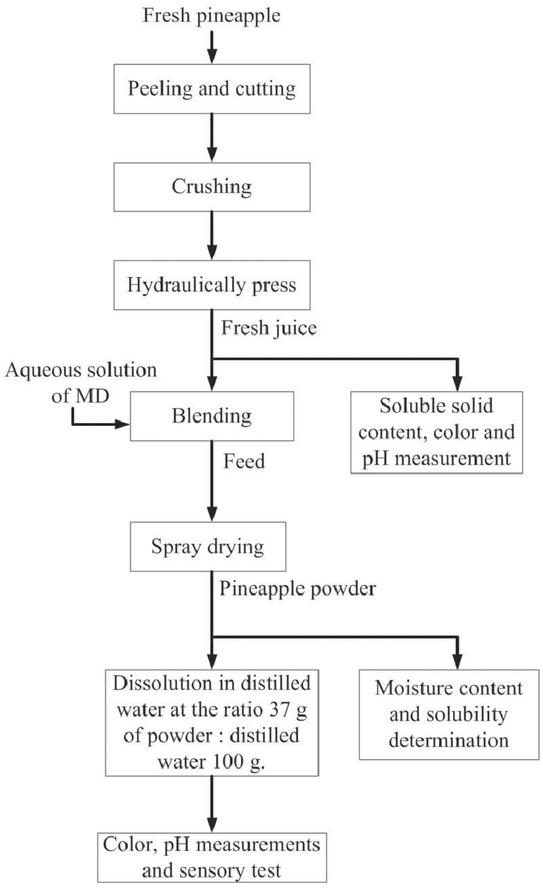

Figure 2. A schematic diagram of the experiments.

3. RESULTS AND DISCUSSION

3.1 Fresh Pineapple Juice

The measurement of soluble solid content, color and pH of the fresh pineapple juices revealed that their soluble solid contents ranged 11-12°Brix while the mean of lightness (L*, +), redness (a*, +) and yellowness (b*, +) were 61.3, 3.3 and 18.8 respectively. The average of pH of the fresh pineapple juices in this study was 2.3.

3.2 Pineapple Powder Appearance

From the drying experiment, the appearances of pineapple powders from all treatments were white color and not agglomerate (powdery). However, the intensity of the pineapple aroma of the powder was declining along the increase of MD content. In addition, the preliminary experiments implied that when using the MD contents at 5 and 10%, the powder product would be sticky and agglomerated (toffee). These sticky and agglomerated products would seize on the surface of the dryer especially in the drying chamber and cyclone.

3.3 Moisture Content, Solubility and Powder Recovery

The outcomes of moisture content, solubility and powder recovery determinations for the pineapple powders are presented in Table 1. The results showed that the moisture contents of the powders were in the range of 4.0-5.8%. These moisture levels are close to the moisture content of dried-tea powder that ranged 3-5% [16]. The increasing drying temperatures and MD content resulted in the lower moisture product. The high drying air temperature leaded to the high temperature gradient at the surface of feed drops. This directly expedited the heat transfer rate and also the moisture evaporation from the liquid drops in the drying chamber resulting in the low moisture level of dried product. Furthermore, the MD has the capability to hurdle the sugars in the fruit powder that have highly hygroscopic nature from absorbing the humid in the surrounding air [9]. Nevertheless, in this study the feed rates were diverse for different drying temperatures in order to keep the temperature of the outlet drying air at approximately 90°C. At this outlet temperature level, the powder products were usually not burnt or humid. At elevated drying temperature, the feed was supplied to the drying chamber at a higher rate to avoid the product burn. On the other hand, at lower drying temperature, the feed rate was reduced; otherwise, the powder might be too wet. Thus, the effect of the drying temperature on the moisture content of pineapple powder was partially reimbursed by the feed rate increase.

Regarding the solubility in Table 1, the effect of drying temperature was unclear. However, it was found that at the same drying temperature the solubility in minute would be reduced when raising the concentration of MD. This result can be explained by the discovery of Shrestha *et al.* [9]. They found that the addition of MD content raised the T_g of powder; however, the increase in T_g was not linear. Thus, the agglomeration of MD rich powder will be obstructed; as a consequence, the specific surface area of the powder was high in this case leading to the faster solubility (lower value of solubility in minute) of the powder.

The values in Table 1 indicate that all drying conditions provided high powder recovery in the range 72.7-86.6%. High powder recovery values were due to the addition of MD contents $\geq$ 15% that resulted in the non-sticky products and subsequently low amount of product seized in the drying chamber and cyclone. Besides, there was a trend of less powder recovery along the increasing MD contents. This occurrence might be explained by the method applied for the powder collection. In this study, all the powder was collected at the cyclone; nonetheless, the drying chamber was periodically knocked by the hard-rubber hammer during the experiment in order to keep the remaining powder on the drying chamber surface and its accessories as minimum as possible. As a result, although the powder recovery was high for every drying run, there were higher amount of powder stuck in the drying system for the drying conditions that had more solids in the feed (added higher MD) because of the limitation of the hammer force applied in this powder collection method. On the other hand, if at the end of drying run, all the powder on the drying chamber surface was manually swept and combined with those collected at the cyclone, the trend of powder recovery might change.

Table 1. The moisture contents, solubility and powder recovery of the pineapple powders.

Drying condition		Moisture content (%)	Solubility (minute)	Powder recovery (%)
Drying temperature (°C)/Feed rate (lpm)	MD content (%)			
130/0.020	15	5.8 ± 0.1^{a}	6.2 ± 0.2^{a}	86.6
	20	4.4 ± 0.1^{b,c}	2.7 ± 0.7^{b,e}	75.9
	25	4.3 ± 0.3^{b}	1.9 ± 0.3^{c}	72.9
150/0.022	15	5.1 ± 0.3^{d}	6.2 ± 0.1^{a}	86.6
	20	5.2 ± 0.4^{d}	4.4 ± 0.2^{d}	81.3
	25	4.5 ± 0.0^{b,c}	3.1 ± 0.1^{e}	80.0
170/0.035	15	4.8 ± 0.2^{c,d}	4.6 ± 0.3^{d}	81.4
	20	4.2 ± 0.2^{b}	1.9 ± 0.1^{c}	73.2
	25	4.0 ± 0.2^{b}	2.4 ± 0.2^{b,c}	72.7

Note: lpm = litre per minute.
Moisture content and solubility values are mean ± standard deviation.
Means with the same superscript within same column are insignificant different ($P < 0.05$).

3.4 Color and pH of the Reconstituted Specimens

As mentioned earlier, the pineapple powders were reconstituted with distilled water at the proportion 37 g of powder per 100 g of distilled water in order to make the solutions that were similar to the fresh juice. The results of color and pH determination for the solutions comparing to the fresh juice are illustrated in Table 2. It showed that the pH of the solutions were significantly higher than those of the fresh sample at 5% significant level. This result was unsurprising because the pH value of MD applied in this study was 4.7 while the fresh juice pH was 2.3. Furthermore, there were only slight differences in the pH among the reconstituted specimens. If deeming the proportion of juice (based on total soluble solids) and MD (based on dry weight) in this study (65:35, 50:50 and 40:60), it is clear that MD contents were not very difference between powder samples. Moreover, these powders were reconstituted with distilled water before measuring pH; as a result, the effects of different proportions of juice and MD contents on the pH values were also diluted.

Regarding the color, it appeared that the lightness, redness and yellowness of the solutions of pineapple powders were significantly different from the fresh juice for almost all cases. In general, the solutions had the less lightness than the fresh sample but the redness and yellowness were higher. The cause of the lower lightness was that a small proportion of powder could not dissolve in the solution. Another reason for the lightness decrease could be the non-enzymatic browning reactions occurring during the spray drying [17]. For the higher redness and yellowness of the solutions, it may be also as a result of some non-enzymatic browning reactions such as caramelization and Maillard reactions happening during the drying process. These reactions could take place because of the high sugar content in the pineapple juice and heat supplied to the juice in the drying chamber [18]. Furthermore, the MD concentration is another cause of the color difference between the fresh and the reconstituted pineapple juices. However, the color difference among reconstituted samples did not have obvious trend because for these samples the spray-dried powders were diluted in distilled water. Moreover, the effect of drying temperature on the product color was not apparent because the feed rates were also increased at higher drying temperature.

Table 2. The color and pH of the solutions of pineapple powders comparing to the fresh pineapple juice.

Drying condition		Color				pH
Drying temperature (^{o}C)/Feed rate (lpm)	MD content (%)	L*	a*	b*	ΔE*	
130/0.020	15	$57.3 \pm 0.1^{a,e}$	4.8 ± 0.1^{a}	24.3 ± 0.3^{a}	7.0	$3.5 \pm 0.1^{a,c,d}$
	20	52.6 ± 1.5^{b}	$6.3 \pm 0.7^{b,e}$	$25.6 \pm 0.5^{b,c}$	11.4	$3.5 \pm 0.0^{a,c,d}$
	25	67.8 ± 0.8^{c}	3.7 ± 0.2^{c}	23.0 ± 0.6^{f}	7.8	$3.6 \pm 0.0^{a,b,d}$
150/0.022	15	$58.8 \pm 1.7^{a,d}$	$5.2 \pm 0.3^{a,d}$	$25.1 \pm 0.7^{a,b}$	7.1	$3.5 \pm 0.1^{a,c}$
	20	$57.2 \pm 1.6^{a,e}$	$6.0 \pm 1.3^{e,f}$	26.4 ± 1.7^{c}	9.1	$3.5 \pm 0.1^{a,c,d}$
	25	$54.8 \pm 1.5^{b,e}$	6.9 ± 0.3^{b}	26.7 ± 0.3^{c}	10.8	3.4 ± 0.1^{c}
170/0.035	15	52.4 ± 1.4^{b}	$5.6 \pm 0.3^{d,f}$	24.2 ± 0.6^{a}	10.6	$3.6 \pm 0.1^{b,d}$
	20	73.1 ± 0.7^{f}	2.1 ± 0.0^{g}	18.2 ± 0.3^{e}	11.9	3.7 ± 0.1^{b}
	25	47.3 ± 1.9^{g}	6.9 ± 0.2^{b}	$25.6 \pm 0.1^{b,c}$	15.9	3.7 ± 0.1^{b}
Fresh pineapple juice		61.3 ± 2.1^{d}	3.3 ± 0.2^{c}	18.8 ± 0.3^{e}	-	2.3 ± 0.1^{e}

Note: lpm = litre per minute, L* = lightness, a* = redness, b* = yellowness
L*, a*, b* and pH values are mean ± standard deviation.
Means with the same superscript within same column are insignificant different ($P < 0.05$).

$$\Delta E^* = \sqrt{\left(L^*_{sample} - L^*_{fresh\ juice}\right)^2 + \left(a^*_{sample} - a^*_{fresh\ juice}\right)^2 + \left(b^*_{sample} - b^*_{fresh\ juice}\right)}$$

3.5 Sensory Evaluation

The outcome of hedonic scale test is shown in Table 3. The limit score for each item was 9.0 indicating that the sample was favored extremely. The sensory evaluation was found that both drying temperature and MD content affected the characteristics of the solutions. As regards to the appearance and aroma, almost all of the solutions of pineapple powders showed higher score than the fresh juice. It might be the consequence of the higher sugar content in the solutions due to the MD integration. For the color, all solutions were preferred when comparing with the fresh one. It should be due to the stronger redness and yellowness of the samples after exposing to the spray drying process. In term of the taste, the solutions of pineapple powders produced with 15-20% MD were favored but those with 25% MD were not when comparing to the fresh one. The cause was that if adding MD ≥ 25%, the taste of MD would dominate and worsen the favorite of sample [17]. The overall liking score revealed that the solutions of pineapple powders produced from the feed with 15% MD at drying temperature 150^{o}C was the most accepted sample.

Table 3. The sensory test results of the solutions of pineapple powders and fresh pineapple juice.

Drying condition		Score (maximum = 9.0)				
Drying temperature (°C)/Feed rate (lpm)	MD content (%)	Appearance	Color	Aroma	Taste	Overall liking
130/0.020	15	4.9 ± 0.9^{a}	$4.2 \pm 0.7^{a,b,c,d}$	$5.2 \pm 0.9^{a,b,c,d}$	5.0 ± 1.0^{a}	$4.4 \pm 0.8^{a,b}$
	20	3.6 ± 0.8^{b}	$4.9 \pm 0.9^{e,f}$	$4.8 \pm 1.0^{e,f}$	3.8 ± 0.8^{b}	2.4 ± 1.2^{c}
	25	3.2 ± 0.9^{b}	$3.9 \pm 0.7^{d,g,h}$	$4.6 \pm 1.1^{d,g,h}$	3.3 ± 0.9^{b}	3.5 ± 0.8^{d}
150/0.022	15	5.6 ± 0.9^{c}	5.2 ± 0.9^{e}	4.7 ± 0.9^{e}	5.6 ± 0.9^{c}	5.6 ± 1.0^{e}
	20	4.6 ± 0.8^{a}	$4.7 \pm 0.9^{f,i}$	$4.8 \pm 1.0^{f,i}$	4.8 ± 1.1^{a}	$5.2 \pm 0.9^{e,f}$
	25	3.1 ± 1.0^{b}	$3.8 \pm 0.8^{c,g}$	$4.0 \pm 0.9^{c,d,h}$	3.5 ± 0.8^{b}	$3.9 \pm 0.8^{b,d}$
170/0.035	15	4.7 ± 1.0^{a}	$4.2 \pm 0.7^{b,c,h,i}$	$3.0 \pm 0.7^{b,h,i}$	3.6 ± 0.9^{b}	$4.0 \pm 0.9^{b,d}$
	20	5.0 ± 0.9^{a}	$4.6 \pm 1.0^{b,f}$	$4.6 \pm 0.7^{b,f}$	$5.2 \pm 1.0^{a,c}$	$4.9 \pm 0.9^{a,f}$
	25	3.7 ± 0.8^{b}	$3.7 \pm 0.8^{a,g}$	$3.1 \pm 0.7^{a,g}$	2.6 ± 0.9^{d}	2.6 ± 1.3^{c}
Fresh pineapple juice		3.3 ± 0.9^{b}	3.5 ± 1.0^{g}	3.9 ± 0.9^{g}	3.6 ± 0.9^{b}	3.7 ± 1.0^{d}

Note: lpm = litre per minute.
Sensory score values are mean ± standard deviation.
Means with the same superscript within same column are insignificant different ($P < 0.05$).

4. CONCLUSIONS

From the results, it showed the practicability of producing the pineapple powders from the mixture of fresh pineapple juice and the aqueous solutions of MD by applying the spray drying method. After reconstituting the pineapple powder in the distilled water, it was found that a number of samples obtained the sensory test scores not less than the fresh counterpart in aspects of appearance, color, aroma, taste and overall liking. Obviously, the drying air temperature and MD content had significant influence on the product quality. The pineapple juice added with MD at 15% and dried at 150°C achieved the highest overall liking score. The pineapple powder made under this condition had the moisture content and solubility 5.1% and 6.2 minutes respectively. Moreover, its solution has the lightness 58.8, redness 5.2, yellowness 25.1 and pH 3.5. These results are useful for the fruit powder producers and researchers.

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