Effects of the pump flow rate and the concentration of maltodextrin (MD) in pineapple spray drying

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***Abstract*— In recent years, the spray drying process have been a popular subject among producers and researchers. Many people wanted to know how to improve the spray drying process, in particular by altering the process parameters. Such process parameters include, but not limited to, the inlet and outlet air temperatures, the inlet and outlet feed temperatures, the rate of atomization and pump flow rate. For this research, the effect of maltodextrin concentration and pump flow rate in pineapple spray drying is investigated. Varying concentrations of Maltodextrin, (15, 20 and 25 %wt) will be mixed with corresponding feed mixture. The feed mixture will be fed into the spray dryer unit at varying flow rate based on the pump flow rate settings at the spray dryer unit. The results will be tabulated. It was noted that changes in the pump flow rate of the spray drying process and the concentration of maltodextrin do affect the drying yield, the powder's moisture content, bulk density and colour.**

Keywords*— *Spray Drying, Pump flow rate, Maltodextrin, Pineapple, Powder

I. Introduction

For this research, the pineapple fruit (Ananas Comusus) juice is used as feed for the process. In many processes involving the spray drying of fruit juices, food additives may be added to the slurry or juice before the juice is fed to the spray dryer. This is to increase the yield of the process. In spray drying processes, particularly involving fruit juices, the type of food additive used is maltodextrin (MD). In the spray drying process, it is used as a food additives to increase the yield of the process and to enhance the quality of the spray dried product.

For this research, the effect of varying maltodextrin (MD) concentration and varying pump flow rate in pineapple spray drying towards the physicochemical properties of the resulting spray dried powder. The physicochemical properties of the powder that will be analyzed in this research include i) Moisture content, ii) Glass temperature (TGA), iii) bulk density and iv) colour of the powder. Apart from that, the duration of the spray drying process will also be analyzedOne way to improve this problem is to use food additives. By adding food additives in the feed slurry, the stickiness of the powder will decrease and the moisture content of the spray dried product will also be reduced. (Wong, Pui, & Ng, 2015) This in turn, will reduced the tendency of the powder to stick to the wall of the drier, thus increasing the yield of the process. Therefore, to improve the yield of the process, food additives is added to emulsion feed. In the spray drying process, food additives can be added together with the solution, or the emulsion, to increase the efficiency of the process. Apart from that, the quality of the yield will improve if food additives are added to the process.

II. Methodology

A. Materials

Fresh pineapple (ananas comosus) were obtained for this research. These pineapple were obtained from the Kedai Nenas Apandi at Meru, Selangor. Preferably, the ripeness of the pineapples obtained were 20% to 40%.

B. Preparation of feed

The pineapple was weighed. The pineapple fruit was cleaned with water. Then, the pineapple was peeled and sliced into small cubes. Then, the pineapple cubes were weighed again and the weight of the pineapple fruit was recorded. The amount of distilled water taken to make to pineapple juice was equal to the weight of the pineapple cubes. The ratio between the volume of distilled water used and the weight of the pineapple fruit was 1:1. Then, using a typical fruit blender, the pineapple fruit was blended together with the addition of the distilled water. The resulting puree was filtered and refrigerated at 4oC in a refrigerator.

C. Addition of Maltodextrin into the feed

For this research, varying amounts of maltodextrin were to be put into the feed slurry of the process. The pineapple puree was mixed with various maltodextrin concentrations of 15 – 25% w/w with 5% w/w intervals. 15 % w/w means for every 100 g of fresh pineapple juice, 15 g of maltodextrin was added. The ratio between the weight of the maltodextrin and the volume of distilled water used to mix with MD is 1:2.

When the maltodextrin concentration was varied, other process parameters like pump flow rate and inlet temperature were kept constant throughout the process. The maltodextrin was mixed and diluted with distilled water and the resulting maltodextrin solution was then stirred using a hot plate stirrer. Then, 500 ml of pineapple juice was weighed. The pineapple juice was mixed and stirred with the maltodextrin solution using the hot plate stirrer. The resulting mixture was stirred for about 15 minutes in a stirrer at 40^{o}C using a hot plate stirrer. After that, the mixture was fed into the spray drier.

D. Sugar level test

For the sugar level test, a refractometer was used. The lense cover was lifted and the lense was rinsed with distilled water. Then, the sugar level of the pineapple juice before the addition of MD was measured. Two drops of the pineapple juice was placed onto the lense of the refractometer. The lense cover was closed and the sugar level of the juice was recorded. Similar steps were made to measure the sugar level of the pineapple juice with MD.

E. pH test

To test the pH of the pineapple juice, a portable pH meter was used. The pH meter's electrode was placed in a buffer with a pH value of 7. Then, the 'measure' button was pressed to start calibrating the pH meter. The electrode was left in the buffer for 1 or 2 minutes to allow the reading to be stabilized. After that, the electrode was placed into the pineapple juice without the addition of MD to measure the pH. Then, the electrode was rinsed with distilled water and stored. Similar steps were taken to measure the pH of the pineapple juice with MD.

F. The Spray Dryer

For this research, a typical laboratory-scale spray drier was used. Firstly, the pump flow rate of the spray drier and the inlet air temperature were adjusted depending on the experiment that would be carried out. If MD concentration in the feed was varied, then the pump flow rate and the inlet air temperature of the process were kept constant at 3 and 180oC respectively. If MD concentration was kept constant throughout the process, the pump flow rate was adjusted to 3, 4 and 5 at the pump flow rate meter. The inlet air temperature was kept constant at 180oC. The pump for the hot air and the feed juice wre switched on. The drying process will commence in the drying chamber. Next, the spray-dried powder will be recovered in a cyclone. The resulting powder was collected from the outlet of the cyclone. The powder was kept in a jar. Table 1 shows the results of each test based on the corresponding spray-dried powders with varying process parameters. The process was repeated three times. The phrase 'pump flow rate' refers to the feed flow rate of the spray drying process.

G. Moisture Content

To determine the moisture content of the powder, an equipment called the moisture analyzer was used. 1 g of spray-dried powder was taken and put into the moisture analyzer. The temperature of the unit was set to 100^{o}C. The powder was left in the moisture analyzer unit for about 10 minutes. After that, the moisture content of the powder sample was recorded.

H. Colour test for the spray dried powder

The colour of the powder was measured using the chromameter. The chromameter was used to measure the lightness, L*, the a* value and the yellowness value, b* of the powder. A few grams of the powder was put into petri dish. The chromameter was held vertical to the petri dish, with the lense of the chromameter being as close as possible to the petri dish containing the powder. The colour of the powder was measured this way.

I. Bulk density

The bulk density of the powder was measured by putting 5 grams of the powder into a measuring cylinder. The measuring cylinder was then tapped until no significant volume change was seen. The volume of the powder was recorded and the bulk density of the powder was determined.

III. RESULTS AND DISCUSSION

A. The effects of pump flow rate in pineapple spray drying

1) Yield

Interestingly, the pump flow rate used during the spray drying process does affect the yield of the process. Contrary to popular beliefs, the higher the pump flow rate used during the spray drying process, the lower the amount of powder formed. The increased in feed flow rate may cause more of the feed juice to make contact with the hot gas at a higher rate. This in turn, may have caused more of the feed juice to be vaporized completely, thus reducing the amount of powder formed.

2) Moisture Content Analysis

For the moisture content of the resulting powder, it was observed that at higher pump flow rates, the resulting spray dried powder will have higher amounts of moisture content. No study had been conducted so far that had elaborated the effects of pump flow rate towards the physical properties of the spray dried powder. Figure 2 shows a graph of moisture content of the powder versus the pump flow rate.

However, one can infer that as the pump flow rate of the spray drying process increases, the contact time of the feed juice with the hot air will decrease. This is because the feed juice is pumped into the drying chamber at a higher rate. When the contact time of the feed juice with the hot air decreases, the amount of water evaporated from the powder particles formed will decrease as well, thus resulting in a higher amount of moisture content in the powder particles.

3) Bulk density

In terms of bulk density, the higher the feed flow rate used in the spray drying process, the higher the bulk density of the resulting spray-dried powder. Figure 3 shows a graph of bulk density of the spray dried powder versus pump flow rate used during the spray drying process.

This observation is similar to the one made by (Al-Asheh, Jumah, Banat, & Hammad, 2003). They had discovered that as the higher the feed flow rate used during the tomato spray drying process, the lower the total solids of the tomato powder, the lower bulk density of the spray dried powder. According to (Jumah, Tashtoush, Shaker, & Zraiy, 2000), the reason as to why the bulk density of the powder increases as the feed flow rate used increases is because of the powder particles having a higher water content. Powder having a higher water content consequently has a higher bulk density.

According to (Chegini & Ghobadian, 2007), as the feed flow rate increases, the bulk density of the resulting spray dried powder will decrease. This observation cannot be referred to as this particular study is based data obtained from spray drying process of various types of food, whereas the observation made by (Al-Asheh et al., 2003) is based on tomato spray drying process which uses food that is closely related to type of food used in the spray drying process conducted in this research.

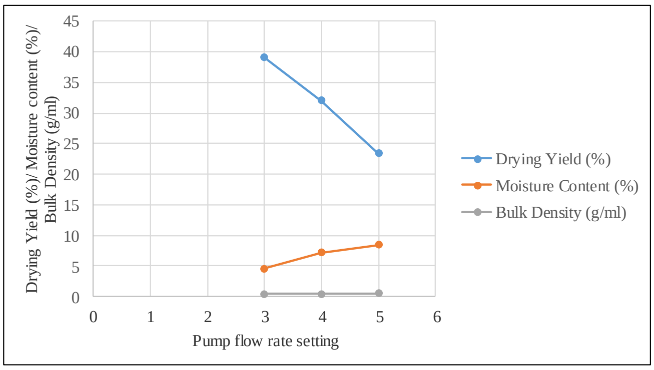

Fig. 1: A graph showing the effect of different pump flow rate setings on the various physical properties of the spray dried powder

4) Colour

In terms of the colour of the powder, it was observed that the higher the feed flow rate used during the spray drying process, the lower the lightness of the powder's colour. This observation can be contributed by the higher processing temperature that is caused by the friction between the feed and the hot air inside the chamber. The higher pump flow rate of the spray drying process, the higher the friction that will occur between the feed and the hot air inside the chamber, the higher the temperature inside the drying chamber. According to (Abonyi et al., 2002), colour degradation of the powders can be influenced by high process temperatures. Lightness, L value describes the lightness of the colour. The range of values for L values spans from 0 for black to 100 for white. (Caparino et al., 2012) Figure 2 shows a graph of L (lightness) versus pump flow rate.

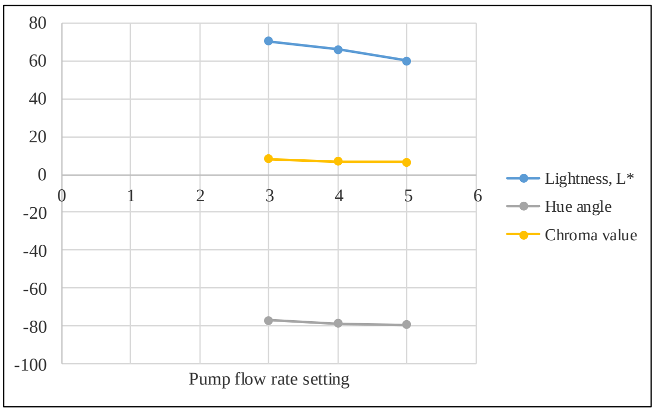

Fig. 2: A graph showing the effect of different pump flow rate on the colour of the spray dried powder

As the pump flow rate used during the spray drying process decreases, the yellowness of the pineapple powder decreases. The yellowness value, often expressed as b*, is used to represent the yellowness (0-60) or bluenesss (0- -60) of a colour. (Caparino et al., 2012)

Also, the higher the pump flow rate used during the spray drying process, the lower the hue angle of the resulting spray dried powder. The hue angle, H is determined by using $H = \tan^{-1}\frac{a}{b}$. Hue is a colour element in which the colour red, yellow, blue and green is recognized. (Caparino et al., 2012) Figure 2 shows a plotted graph of the hue angle of the powder versus pump flow rate during the spray drying process.

The lightness, the yellowness and the hue angle values obtained can be used to determine the chroma value of the pineapple powder. The chroma is colour characteristic which differentiates between bright and dull colours. It is expressed as $C^* = \sqrt{a^2 - b^2}$. (Caparino et al., 2012) Figure 6 shows a graph of chroma value of the powder versus the pump flow rate used.

B. The effects of maltodextrin (MD) concentration in pineapple spray drying

1) pH level of the feed juice

In terms of pH level of the feed juice, it was observed that across all concentrations of maltodextrin (MD), the pH level of the feed juice will increase when it is added with maltodextrin. Figure 7 shows a bar chart of pH level of the feed juice before and after the addition of maltodextrin of varying concentrations.

2) Sugar level of the feed juice

For the sugar level of the feed juice, it was observed that the sugar level of the feed juice increases when maltodextrin (MD) is added to the feed juice. This is because maltodextrin has high sugar level content. As MD is added to the pineapple juice, the overall sugar level of the feed mixture will increase.

3) Yield of the spray drying process

In terms of yield of the spray dried powder, supposedly the higher the concentration of maltodextrin used in preparing the feed juice, the higher the yield of the spray drying process, especially in pineapple spray drying. However, in the present research, the higher the concentration of maltodextrin in feed, the lower the percentage of yield of the process.

According to (Wong, Pui, & Ng, 2015), the best maltodextrin concentration for spray drying pineapple juice is 15wt%. They observed that as the concentration of maltodextrin increases, the yield of the pineapple spray drying process also increases but only up to a certain point. If more maltodextrin is added beyond this point, the yield of the process will start to decrease. Similar observation can be made with the present research here, as the highest amount of yield produced from the process is achieved when 15wt% concentration of maltodextrin (MD) is used.

Figure 3 shows a graph of maltodextrin concentration with yield of the process. Based on the graph, it can be concluded that as the concentration of maltodextrin increases, the yield of the spray drying process decreases.

4) Moisture content of the resulting spray dried powder

In the present research, it was observed that the higher the concentration of maltodextrin used, the higher the amount of moisture content present in the spray dried powder. This contradicts most of the observations made by many researchers. For instance, according to (Wong et al., 2015), they concluded that as the concentration of maltodextrin increases, the moisture content present in the resulting spray dried powder will decrease. Similar observation have been made by (Caliskan & Nur Dirim, 2013).

Based on a study conducted by (Jittanit, Niti-att, & Techanuntachaikul, 2010), it was observed that the addition of food carriers like maltodextrin to the feed slurry for a spray drying process will reduce the hygroscopicity of the resulting spray-dried powder. As the hygroscopicity of the powder decreases, less water molecules is retained into the particles in the powder, thus lowering the amount of moisture present in the spray dried powder. According to (Tontul & Topuz, 2017), adding maltodextrin into the feed of a spray drying process will decrease the hygroscopicity of the spray dried product.

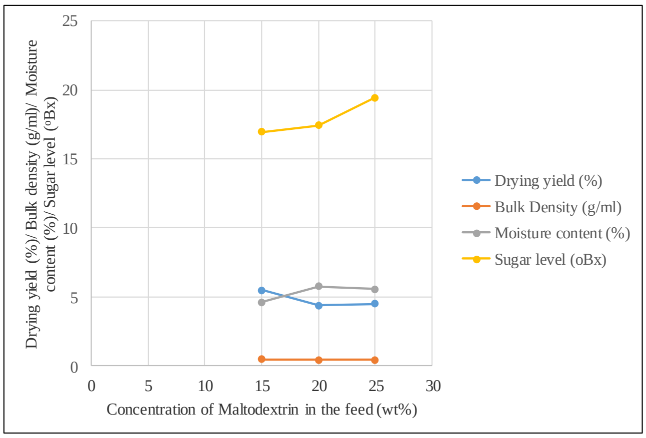

Fig. 3: A graph showing the effects of the maltodextrin concentration on the physical properties of the pineapple feed juice and the spray dried powder.

Figure 3 shows a graph of maltodextrin concentration versus the moisture content of the spray dried powder. Based on the data, it was observed that the higher the concentration of maltodextrin used, the higher the moisture content of the powder.

5) Bulk density of the resulting powder

In terms of bulk density, as the concentration of maltodextrin increases, the bulk density of the spray dried powder decreases. According to (Fazaeli, Emam-Djomeh, Kalbasi Ashtari, & Omid, 2012), increasing the concentration of maltodextrin in orange juice will decrease the bulk density of the resulting spray dried powder. Also, according to (Caparino et al., 2012), increasing the concentration of maltodextrin in tomato pulps will decrease the bulk density of the resulting spray dried powder. (Caparino et al., 2012) also have discovered that in mango spray drying, the addition of maltodextrin in the feed slurry will result in spray dried powders that have increased porosities and thus lower bulk densities.

According to (Goula & Adamopoulos, 2008), maltodextrin contains skin-forming material which by using it as a food carrier will help inhibit accumulation and trapping of air inside the particles of the powders. This will result in the particle becoming less dense and more porous. Figure 3 shows a graph of maltodextrin concentration versus bulk density of the resulting spray dried powder.

6) Colour of the resulting powder

Figure 4 shows a graph of maltodextrin concentration used versus the lightness value, L*, of the powder. It is observed that in this present research, the higher the concentration of maltodextrin, the lower the value of lightness, L* of the powder, the lighter the colour of the powder.

Based on a research conducted by (Caliskan & Nur Dirim, 2013), it was observed that the colour values (L*, a* and b*) of the spray dried sumac extract powder are heavily influenced by the amount of maltodextrin added to the feed of the process.

Figure 4 shows a graph of concentration of maltodextrin versus the yellowness of the spray-dried powder. Based on the data, it was concluded that the higher the concentration of maltodextrin used in the feed of the process, the lower the yellowness value of the powders. A lower value of b* indicates a lower amount of yellowness in regards to the colour of the powder.

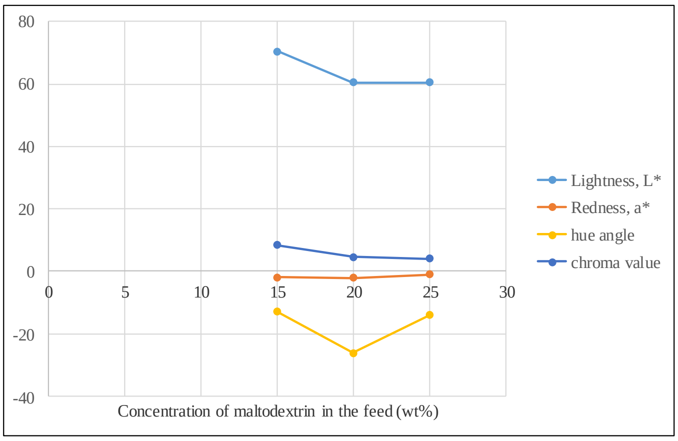

Fig. 4: A graph showing the effects of different maltodextrin concentration on the colour of the spray dried powder

Figure 4 shows a graph of maltodextrin concentration versus the hue angle of the resulting spray dried powder. It can be concluded that the higher the concentration of maltodextrin used, the lower the hue angle value for the spray dried powder.

Figure 4 shows a graph of maltodextrin concentration versus the chroma value. The chroma is colour characteristic which differentiates between bright and dull colours and it is expressed as $C^* = \sqrt{a^2 - b^2}$. (Caparino et al., 2012) Table 3 shows the average values of all analysis made to the feed juice and the spray dried powders based on spray drying processes that were in triplicates.

IV. Conclusion

In conclusion, this present research is a success as it has achieved its primary objectives. The effect of pump flow rate and maltodextrin (MD) concentration in pineapple spray drying have been investigated. The physical properties of the resulting spray dried powders have also been analyzed. It was observed that as the pump flow rate of the spray drying process increases, the yield of the process decreases, the resulting spray dried powders have higher moisture content, higher bulk densities and have darker appearance in colour. As the concentration of maltodextrin increases, the pH of the feed juice increases slightly, the sugar level of the feed juice increases significantly, the drying yield of the process decreases and the resulting spray dried powder have higher moisture content, have lower bulk densities and have generally darker appearance in colour.

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