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Short Communication

# Effect of spray drying conditions on physical characteristics of coconut sugar powder

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**Abstract**

The aim of this work was to study the effect of spray drying conditions on quality of coconut sugar powder and their characteristics. Effects of inlet air temperature (120°C, 150°C and 180°C) and maltodextrin concentrations (DE 9-12) at 10%, 20% and 30% (w/v) on physical properties of spray dried coconut sugar powder were investigated. Buchi mini spray dryer, model B-290, was used in this work. Feed rate, air flow and aspirator rate was controlled at 4.5-7.5 ml/min, 357 l/hr and 32 $m^3$/h, respectively. An inlet air temperature of 180°C caused a significant decrease in the moisture content, water activity, bulk density and solubility of the spray dried product. The increased inlet air temperature made the product more flowability or wettability. In addition, increasing of maltodextrin concentrations resulted in increased bulk density (0.43-0.73 g/ml) and flowability (36º-56º), while the solubility (39-103 sec) and wettability (21-55 sec) decreased. However, there were no significant changes in the moisture content (1.92%-3.03%) and water activity (0.20-0.33) of the coconut sugar powder at all the maltodextrin concentrations.



## Introduction

Coconut sugar was derived from coconut inflorescence. Coconut sugar has been used in many food products due to high mineral and its good flavor. Coconut sugar has high in vitamin C and is classified as low glycemic index food (Trinidad *et al*., 2010). However, coconut sugar has a short shelf life due to several reasons such as high initial microbial content, cleanliness during harvesting and high moisture content. A basic method used to retain quality and extend shelf life of coconut sugar is pasteurizing and concentrating for reducing the initial microbial content and moisture content but this may cause loss of good flavor. Currently, the spray drying process is one of drying tools for retaining quality of powder food. The advantage of powder food is long shelf life, lightweight, free flowing and mix with other food product. Which it is the process of making powder food and can retain bioactive compound or flavor (Gharsallaoui *et al*., 2007). However, sugar rich food is difficult to spray dry, due to the fact that sugar is hygroscopic substance and low glass transition temperature value (Muangma, 2009). Therefore, it can adhere to the wall of drying chamber during processing. The stickiness and melting lead to the use of drying aid such as maltodextrin to improve dried powder properties. The aim of this work was to study the effect of spray drying conditions such as inlet air temperature and maltodextrin concentrations (DE 9-12) on physical properties of coconut sugar powder.

## Materials and Methods

### *Coconut sugar preparation*

Coconut sugar (14±1ºbrix) was purchased from Samut Songkhram province (Thailand). The coconut sugar was collected from a coconut tree in the morning and evening. Then it was filtered through cheesecloth to remove adhering dust and insect. Coconut sugar was firstly heated at 100°C for 30 min to obtain pasteurized coconut sugar (20±1ºbrix). The sample was kept frozen at -25°C.

### *Feed solution preparation*

Before the spray drying process, drying aid substance, maltodextrin DE 9-12 purchased from Berli Jucker Public Co. Ltd. (Thailand) was added directly to the pasteurized coconut sugar with

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magnetic stirring until a homogeneous solution was obtained. Maltodextrin (MD) DE 9-12 was varied at 10%, 20% and 30% (w/v), respectively. The total soluble solid of feed solution was adjusted and controlled at 25(±1) °brix by using distilled water.

*Spray drying*

The spray drying process was performed using a laboratory spray dryer (Buchi model B-290, Switzerland). The equipment was operated concurrently using a spray nozzle with an orifice of 0.7 mm in diameter. Feed solution was spray dried at inlet air temperature of 120°C, 150°C and 180°C (±1°C), respectively. The atomizing pressure, feed rate and aspirator rate were kept at 357 l/hr, 4.5-7.5 ml/min and 32 $m^3/h$, respectively. The powder was packed in an air tight zip-lock bag and was then kept in the desiccator. Further analyses were performed to determine overall appearance, color, moisture content, water activity, bulk density, flowability, solubility and wettability.

*Overall appearance*

The overall appearance of the powder was observed for color, adhesion and stickiness characteristics.

*Color analysis*

The color characteristics of the powder were analyzed by Hunter Lab (Color Quest, USA). The results were expressed as $L^*$, $a^*$, $b^*$, $C^*$ and $h^*$ value, where $L^*$ mean lightness and darkness, positive and negative values of $a^*$ mean redness (+) and greenness (-), positive and negative values of $b^*$ mean yellowness (+) and blueness (-). Hue angle measures the property of the color and it is calculated according to the Equation 1. $h^*$ (hue angle) values indicated as 0°, 90°, 180°, 270° and 360° mean red, yellow, green, blue and purple color, respectively. $C^*$ (chroma) means color intensity.

$$\text{hue} = \tan^{-1} (b^*/a^*) \qquad (1)$$

*Moisture content determination*

The moisture content of dried samples was determined according to AOAC (2000) by oven drying at 105°C for 24 hr, as followed. An aluminum can was heated to 105+1°C and cooled down in a desiccator to room temperature before weighing. Approximately 3 g of the sample was weighed into the can. The sample was heated to 105+1°C for 24 hr (or until constant weight was reached), transferred to a desiccator, and was weighed soon after it had reached room temperature. The wet basis moisture content was calculated, as followed. Moisture content of each sample was measured in duplicate and the average value was taken.

%moisture content (wet basis) = [weight of sample and aluminum can before drying (g)-weight of sample and aluminum can after drying (g)/ weight of sample (g)]x100.

*Water activity determination*

Approximately 2 g of sample was placed in a plastic cup. Water activity of the sample was then determined by using a water activity meter (AquaLab 4TE, USA). The temperature was maintained at 24°C (±1°C).

*Bulk density determination*

The bulk density was analyzed followed by the method of Goula and Adamopoulos (2008). The powder, 10 g, was added in 100 ml cylinder. Cylinder was tapped until the volume of powder attained a constant level. The bulk density of the powder was calculated by measuring the ratio of mass of the powder (g) to the volume occupied by the powder (ml).

*Flowability testing*

The flowability testing of the powder was determined according to the method of Muangma (2009) by pouring 30 g of the powder from a funnel (diameter 1 cm) to the surface plate (kept the height from the funnel to the surface about 20 cm). The angle of repose was measured. The powder with repose angle up to 35° is free flowing material, 35-45° is fairly cohesive, and 45-55° is cohesive while >55° is very cohesive material.

*Solubility testing*

The solubility testing was adapted from Tulardilok (2009). Powder (3 g) was added to 250 ml of distilled water at room temperature. The solution was agitated in a 400 ml glass beaker with magnetic stirrer (size 1 cm) at speed level 2. The time (s) required for the powder to dissolve completely was recorded.

*Wettability testing*

The wettability testing was adapted from Dacanal and Menegalli (2010). Powder (3 g) was placed in a beaker containing 80 ml of distilled water the surface of water (height from the start point to the surface of water was about 10 cm). Time (s) was recorded for the powder to become completely wetted.

*Statistical analysis*

All experiments were conducted in triplicate. The data were expressed as mean±SD. The analysis of variance was performed. The least significant difference at $p<0.05$ was calculated using the Duncan Multiple Range Test in SPSS software.

## Results and Discussion

*Appearance and color of coconut sugar powder*

Coconut sugar powder obtained from spray drying technique had a white color at all conditions and was non-sticky and non-melting. The overall appearance of the sample is similar in color. Increasing of inlet air temperature caused a significant change of $L^*$, $a^*$, $b^*$ and $C^*$ ($p<0.05$) but no significant changes in $h^*$ ($p>0.05$). At the highest inlet air temperature, the powder has become darker and has more redness and yellowness compared at the powder produced with the low inlet air temperature. This can be explained that caramelization occurred when spray drying at higher inlet air temperature. This finding is consistent with Jittanit *et al.* (2010) who reported that the decrease of lightness of pineapple powder could be the resulting of non-enzymatic browning reactions occurred during the spray drying. It was also found that high maltodextrin concentrations caused a significant change of $L^*$ but no significant effect on $a^*$, $b^*$, $C^*$ and $h^*$ ($p>0.05$).

*Moisture content and water activity ($a_w$)*

The moisture content and water activity of the powder ranged from 1.92%-3.03% (wet basis) and 0.20-0.33, respectively (Figure 1). Moisture content and water activity of the powder decreased with an increase of inlet air temperature. It can be explained that high inlet air temperature provides the good driving force for moisture removal which increased the rate of heat transfer from hot air to the particle (Goula and Adamopoulos, 2008). These results are consistent with Fazaeli *et al*. (2012) who reported that the moisture content of the black mulberry powder decreased with the increase of inlet air temperature. However, the increase of maltodextrin concentrations had no effect on the moisture content and water activity of the powder. This may be because the feed solution was controlled at 25ºbrix at all conditions, which cause the same rate of water evaporation during spray drying process and similar moisture content of the powder was obtained.

*Bulk density*

Bulk density of all powder samples were in the range of 0.43-0.73 g/ml (Figure 2). Increasing of inlet

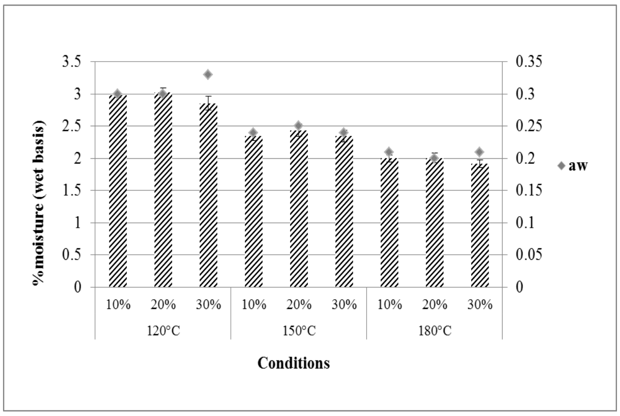


Figure 1. % moisture (wet basis) and water activity ($a_w$) of coconut sugar powder; error bars represent the standard deviation of the minimum and maximum value

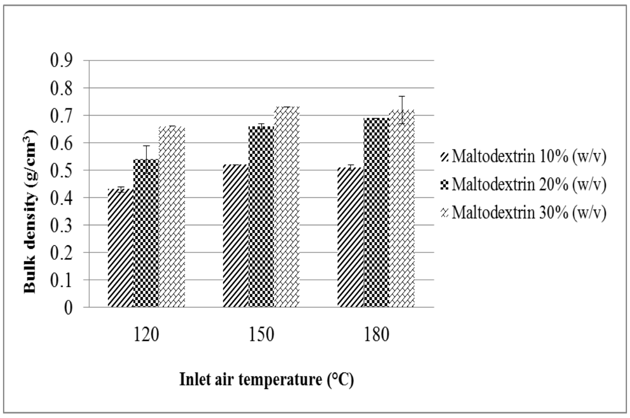


Figure 2. Bulk density (g/ml) of coconut sugar powder; error bars represent the standard deviation of the minimum and maximum value

air temperature caused a decreased in the bulk density. This could be due to the faster evaporation and more porous structure or fragmented structure of the dried powder which is implying a lower shrinkage of the droplets and giving lower density of the powder (Fazaeli *et al*., 2012). Increasing of maltodextrin concentrations lead to increase in the bulk density of powder. This effect may cause a decreased in the volume of air trapped in the particles causing less dense and porous structure.

*Flowability*

The flowability of all powder samples were in the range of 36º-56º indicating fairly cohesive to cohesive particle (Figure 3). It was found that the flowability increased with increase of inlet air temperature. The powder produced from inlet air temperature of 180ºC had a lower degree of angle repose than that produced at 120ºC and 150ºC at the same maltodextrin concentration. This can be explained that high inlet air temperature affects residual moisture of the powder which exhibited a higher angle of repose. Increase of cohesion lead to reduction of the flowability (Chauhan and Patil,

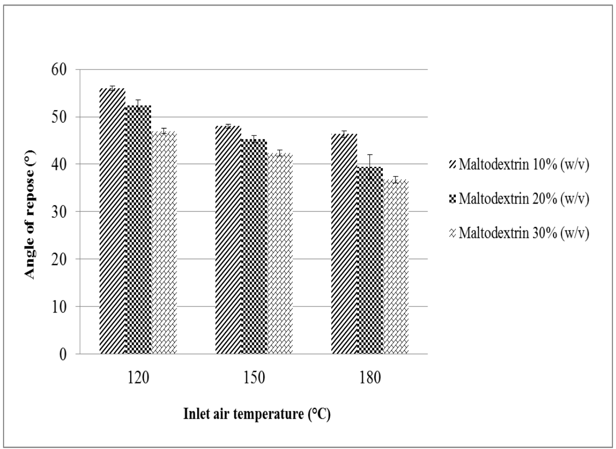


Figure 3. Flowability (°) of coconut sugar powder; error bars represent the standard deviation of the minimum and maximum value

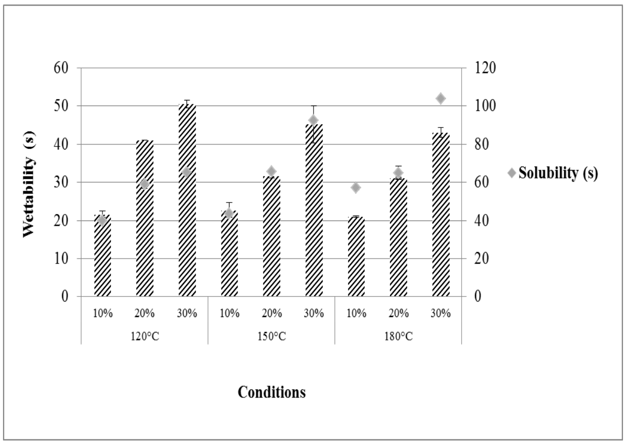


Figure 4. Solubility (s) and wettability (s) of coconut sugar powder; error bars represent the standard deviation of the minimum and maximum value

2013). Increasing of maltodextrin concentrations in feed solution resulted in a significant increasing of powder flowability ($p<0.05$). This can be explained that high sugar content in feed solution causes the powder absorbed moisture rapidly, which caused decreased in the flowability of powder. Therefore, addition of maltodextrin, which has low hygroscopic property, could alter the surface stickiness of low molecular weight sugars such as glucose, sucrose, fructose and organic acids. The powder with low the flowability are difficultly to sink when poured on liquid surface because of their inherent cohesion (Shittu and Lawal, 2007). However, apart from the moisture content, the flowability of powder has been found to be related to particle size and the chemical composition of the powder (Buma, 1971).

*Solubility*

The solubility of powder varies from 39-103 sec (Figure 4). The relation between the solubility and inlet air temperature and maltodextrin concentrations was demonstrated in Figure 4. It was found that the solubility decreased as a resulting of the increase of inlet air temperature. It can be explained that high inlet air temperature the hard shell may be form on the outer surface area of the powder. This may be prevented water molecules from diffusing through to inside of particle (Chegini and Ghobadian, 2005). In addition, particle size, porous structure and moisture content of the powder are also another factor affecting on solubility (Goula and Adamopoulos, 2008). These results also showed that the solubility of powder decreased with increase of maltodextrin concentrations. This case can be explained that high maltodextrin concentrations lead to high bulk density of the powder, the powder is less porous. This results directly affect the reduction on water absorption of the powder was reduced.

*Wettability*

Wettability is the ability of the powder to overcome the surface tension between themselves and water or a time required to give the powder wet completely. In order to attain high wettability values, high porosity or large pores for bigger particles are desirable (Caliskan and Dirim, 2013). The wettability of powder varied from 21-50 sec (Figure 4). The wettability of the powder increased with increasing of inlet air temperature. This indicated that the inlet air temperature had significant effect on the wettability of powder ($p<0.05$).

It may be due to several reasons such as the decreased of residual moisture content, porous structure and particle size of the powder. These results are consistent with Chegini and Ghobadian (2005) reported that increasing of inlet air temperature caused increase in the wettability of orange juice powder. It can be explained that low moisture content in powder can absorb water molecule rapidly. Increasing of maltodextrin concentrations led to a significant decrease in the wettability ($p<0.05$). This can be explained that maltodextrin acts as a bulking agent that affects porous structure by making less porous powders and high bulk density. These results are similar to Ferrari *et al*. (2012) reported that blackberry powder produced with maltodextrin showed the lowest wettability.

## Conclusion

The effects of inlet air temperature and maltodextrin concentrations are important factors on physical properties of coconut sugar powder. The results founded that the overall appearance of all conditions of coconut sugar powder from spray drying is similar. Increasing of inlet air temperature increased the darkness, redness and yellowness of the powder and lead to reduction in the moisture content, water activity, bulk density and solubility except wettability. Moreover, high maltodextrin concentrations lead to increase of lightness, bulk density and flowability of the powder while solubility and wettability decreased. The use of a maltodextrin could reduce the stickiness of the powder which is the main problem during spray drying of pasteurized coconut sugar or sugar rich food. It was suggested that inlet air temperature at 120°C and maltodextrin concentrations at 20% (w/v) is the optimum condition for produce coconut sugar powder due to good appearance and good solubility. However, the results from this research can be used to develop instant coconut sugar beverage and apply to related food products.

## Acknowledgements

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