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Temperature and Feed Rate Effects Properties of Spray Dried *Hibiscus sabdariffa* Powder

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Abstract:
The present study aims to determine the effects of inlet air temperature and feed rate on the main powder properties during spray drying of roselle extract. A pilot-scale spray dryer was employed for the spray drying process. Parameters analyzed were yield, moisture, color and anthocyanin content. A factorial design with three inlet air temperatures (150, 160 and 170°C) and three feed rate levels (280, 350 and 420 ml/h) were investigated. There was significant ($p<0.05$) effect of inlet air temperature and feed rate on yield, color and moisture content while no remarkable changes in anthocyanin content was observed. Increase in feed rate substantially reduced ($p<0.05$) production of roselle powder. Furthermore, the amount powder was higher with elevated feed rate but lesser with increasing inlet temperature.

Keywords: roselle powder, spray drying, anthocyanin content, physicochemical properties.

Full Length Original Research Paper

INTRODUCTION

Roselle (*Hibiscus sabdariffa L*) is a member of Malvaceae family, commonly found in Middle Eastern countries especially in Malaysia, Indonesia, Thailand and Philippines.[1] It is an annual herb grow up to 180 cm height. The weight and moisture content in roselle has been reported as 35.6 g and 7.7%, respectively.[2] The calyxes are bright red color due to presence of anthocyanin like cyanidin-3-sambubioside, cyanidin-3-glucoside and delphinidin-3-glucoside.[3] It has numerous medicinal properties and used as antioxidant, antiseptic, diuretic and antimutagenic properties.[4-6] The relationship between antioxidant property and anthocyanin activity has been reported in roselle's calyx. Antioxidant capacity of *Hibiscus sabdariffa* extract increased with increasing extraction time and calyxes weight[7,8]. Beside these, it is widely used for making wine, syrup, juice, jam, cakes, ice cream and tea[9,10].

Spray drying technique is an important and routine practice in food industries, used for continuous transformation of feed from a liquid state into dried particulate form by spraying feed into a hot drying medium. The main advantages of spray-drying as compared to other drying methods are minimum increase of material temperature with high rate of drying. There are several factors in spray drying like inlet air temperature and feed rate which affects the properties of powder.[11-13] In order to design a good spray drying control system, the selection of operating parameters is important to ensure the desired quality of final products. It was found that the product with lowest moisture and high quality were obtained when outlet air temperature was in the range of 100-110°C.[14]

The spray dried powder of *Hibiscus sabdariffa* calyces has good reconstitutional characteristics, low water activity, suitable for transportation and improved shelf-life. It can be easily added to other foods. Thus spray drying is the best alternative to obtain colorants and natural flavouring.[15] Although spray drying of food materials are affected by several parameters but inlet air temperature and feed rate are very important parameters. Therefore, this study was conducted to examine the effect of the spray drying temperatures and feed rate on the Roselle extracts (*Hibiscus sabdariffa* L.).

MATERIALS AND METHODS

Sample preparation

Roselle seed (2.5 gm) was collected from Universiti Kebangsaan Malaysia. The seed was extracted with water in 1:4 ratio and obtained extract mixed with 20 % maltodextrin. The extract was spray dried using a Lab Plant SD-50 (England). Air flow temperatures used were 150, 160 and 170 °C, while feed rates were 280 ml/h, 350 ml/h and 420 ml/h. The air flow rate and pressure was 60 m^3/h and 1.5 bar, respectively. All the nine pooled parameters were applied in three replicates.

Yield

The yield of spray dried roselle powder was measured by weighing.

Moisture content

Moisture content was determined using fraigemetric oven drying method according to AOAC.[16]

Anthocyanin content

The anthocyanin content was determined according the procedure described by Wrolstad.[17] It is based on Beer-Lambert law. Absorbance of anthocyanin was measured by UV-Vis spectrophotometer at a wavelength of 510 nm. Shortly, 1ml of roselle extract was added into 25 ml volumetric flasks. It was maintained up to 25 ml with buffer (pH 1.0). Another set of samples were prepared with buffer of pH 4.5. All the samples were kept in the dark for two hr and then absorbance recorded spectrophotometrically at 510 nm. Anthocyanin content was calculated based on the difference in absorbance between the samples at different pH as follows:

Anthocyanin concentration (mg/litre) = $(A/ZL) \times MW \times 10^3 \times DF$

Where: A=absorbance; Z=constant absorbance of cyanidin-3-glucoside pigment (26,900); L=path length (1cm); MW=molecular weight of anthocyanin (449.2); DF=dilution factor (25).

Determination of colour

The colour of spray dried *Hibiscus sabdariffa* samples was determined by using chromameter (Minolta CR-200, Japan). The values for L (brightness), a (redness) and b (yellowness) were obtained. Before analysis calibration was done using a white tile.

Data analysis

All the data obtained were analyzed for two-way ANOVA and Duncan Test using a Statistical Software (SAS).

Results and Discussion

Yield

Table 1 shows the yield (g) of roselle powder from 300 ml roselle extract with different combinations of air flow temperature and feed rate. There was significant differences ($p<0.05$) in the yield for both inlet air temperature and feed rate. The yield was decreased with increasing feed rate from 280 ml/h to 420 ml/h at each air flow temperature. The highest yield was found at 150°C inlet air temperature and feed rate of 280 ml/h whereas the 150°C and 420 ml/h exhibited lowest yield. At inlet air temperature of both 150 and 160°C, increase in feed rate from 280 ml/h to 350 ml/h and 420 ml/h leads to a significant decrease ($p<0.05$) in yield of roselle powder. However, at 420 ml/h and 350 ml/h no remarkable changes was observed ($p>0.05$). At 170 °C, yield was lower at feed rate 280 ml/h, 350 ml/h and 420 ml/h. A higher feed rate caused an increase in the drying load as sample is sucked into the drying chamber and sprayed at a faster rate. Consequently, higher amount of extract was not dried due to accumulation in drying chamber resulting in decreased yield.

For the feed rate of 280 ml/h, different temperatures (150, 160 and 170 °C) did not show any remarkable effect on the yield of *Hibiscus sabdariffa* powder. However, at 350 ml/h, increasing the temperature from 160 to 170 °C caused a substantial increase ($p<0.05$) in yield, but there was no significant difference ($p>0.05$) between 150 to 160 °C. At the feed rate of 420 ml/h, increased temperature from 150 to 160 and 170 °C resulted in higher product.

According to Filkova and Mujumdar, temperature is not much effective at lower feed rate because of low drying rate [18]. Hence, the drying capacity is sufficient to dry all the particles. However, at higher feed rate like 420 ml/h, the drying load increased and a low inlet air temperature produces low drying capacity, resulting in lesser yields.

Table 1: Yield (g) of *Hibiscus sabdariffa* powder at different inlet air temperature and feed rate

Feed rate (ml/h)	Inlet air temperature (°C)		
	150	160	170
280	23.457^{a}	23.000^{a}	21.713^{ab}
350	19.603^{bc}	17.953^{c}	22.330^{ab}
420	13.923^{d}	17.407^{c}	17.087^{c}

$^{a-d}$Mean with different letters indicate significant difference ($p<0.05$)

Moisture content

Table 2 shows the effect of inlet air temperature and feed rate on the moisture content in *Hibiscus sabdariffa* powder produced from 300 ml roselle extract. At inlet air temperature of 150°C, there was marginal effect on moisture content at different feed rates (280, 350 and 420 ml/h). Similar result was observed at 160 °C. However, at 170°C, there was large increase ($p<0.05$) in the moisture content of samples produced at 420 ml/h feed rate.

Table 2: Moisture content (%) of *Hibiscus sabdariffa* powder at different inlet air temperature and feed rate.

Feed rate (ml/h)	Inlet air temperature (°C)		
	150	160	170
280	8.015^{ab}	7.281^{bcd}	6.601^{d}
350	8.022^{ab}	7.768^{ab}	6.960^{cd}
420	8.334^{a}	8.032^{ab}	7.483^{bc}

$^{a-d}$Mean with different letters indicate significant difference ($p<0.05$).

There was no evident change in moisture content at 150°C when feed rate increased from 280 to 420 ml/h. This is because of low drying capacity. However, at 170°C drying capacity was high which resulted lower moisture content in *Hibiscus* *sabdariffa* powder. These results coincide with previously published data.[19,20] It has been reported that increased feed rate resulted in higher moisture content due to the increase load in drying chamber.

At a feed rate of 280 ml/h, there was trivial change in moisture content when temperature increased from 150 to 160°C. However, significant decrease in moisture content was occurred when the temperature increased from 150 to 170°C. Similarly, at feed rates of 350 and 420 ml/h, increasing the temperature from 150°C to 170°C resulted in a large reduction in moisture content. Higher inlet air temperature produced higher drying capacity. Exposure of particles with hotter air lead to dried particles thus, lowers moisture. Jumah et al reported that higher inlet air temperature caused a decrease in moisture content of sample[20].

Anthocyanin content

Anthocyanin is the largest group of water soluble natural pigment from plants provide red, blue and violet colours to flowers, fruits, vegetables, juices, liquor and jams. It is an active compound, which is sensitive to pH, temperature, light, oxygen, enzyme and sulphur dioxide. Anthocyanin was reported to be destroyed by high heat during processing and storage of food.[21]

Table 3 shows the effect of hot inlet air temperature and feed rate on the anthocyanin content in roselle powder produced from 300 ml of extract. It was found that the increase in feed rate from 280ml/h to 420ml/h at inlet air temperatures of 150, 160 and 170°C showed no significant effects (p>0.05) on anthocyanin content. Different inlet air temperatures (150, 160 and 170 °C) at each feed rate of 280, 350 and 420ml/h also did not show any significant effects on anthocyanin content. However, anthocyanin content of samples treated at 150°C and 420 ml/h was significantly (p<0.05) higher than those treated at 170 °C/250 ml/h. The lower anthocyanin content at higher temperature is might be due to exposure to heat.

Table 3: Anthocyanin content (mg/L) in *Hibiscus sabdariffa* at different inlet air temperature and feed rate

Feed rate (ml/h)	Inlet air temperature (°C)		
	150	160	170
280	31.641^{abc}	30.697^{bc}	30.663^{c}
350	31.889^{ab}	31.128^{abc}	30.949^{abc}
420	32.145^{a}	31.827^{abc}	31.339^{abc}

a-c Mean with different letters indicate significant difference (p<0.05)

Anthocyanin is sensitive to temperature [21]. Usually, manufacturers use high temperature short time (HTST) processing methods for *Hibiscus sabdariffa* to maintain natural characteristic of anthocyanin in food products.[22] Based on these results, any inlet air temperature and feed rate employed in this study did not show any adverse effect on the content of anthocyanin in roselle powder.

Table 4 shows L values of roselle extract spray dried at different air flow temperature and feed rate. There was substantial decrease (p<0.05) in L values of *Hibiscus sabdariffa* powder at inlet air temperature of 150 °C and 420 ml/h to 280 ml/h. However, no changes were found between 350 ml/h and 420 ml/h. At 160°C, L values were not altered by different feed rates. Similar result was also obtained at 170 °C.

At higher feed rate particles dried in a shorter time period so the exposure of particles with high temperature is less; hence sample powder is in bright colour. Whereas the time of exposure is long in case of low feed rate which resulted dark colour powder.[20] The effect of inlet air temperature was insignificant on L value of roselle powder when feed rate was 280 ml/h. At 350 ml/h feed rate, L values decreased remarkably with increasing inlet temperature from 150°C to 160°C. However, no change was occurred from 160°C to 170°C. At 420 ml/h, there was significant change in L value with increasing air flow temperature.

Table 4: L values of *Hibiscus sabdariffa* powder at different air flow temperature and feed rate

Feed rate (ml/h)	Inlet air temperature (°C)		
	150	160	170
280	70.783[c]	70.817[c]	70.413[c]
350	72.590[a]	71.050[bc]	71.247[abc]
420	72.260[ab]	71.757[abc]	71.527[abc]

[a-c]Mean with different letters indicate significant difference ($p<0.05$).

Table 5 represent the effect of air flow temperature and feed rate on a value of roselle powder produced from 300 ml of extract. It was found that reduction of feed rate from 420 ml/h to 280 ml/h caused a significant decrease ($p<0.05$) in a value of the *Hibiscus sabdariffa* powder produced at 150 °C. However, there was no change in a value between feed rates of 280 ml/h to 350 ml/h, and 350 ml/h to 420 ml/h. Similar results were obtained when feed rate was increased from 280 ml/h to 420 ml/h at 160 °C and 170 °C inlet air temperature.

Table 5: Values (a) of *Hibiscus sabdariffa* powder at different inlet air temperature and feed rate.

Feed rate (ml/h)	Inlet air temperature (°C)		
	150	160	170
280	+32.540[bc]	+31.850[cd]	+31.223[d]
350	+33.270[ab]	+32.327[bc]	+31.900[cd]
420	+33.633[a]	+33.057[ab]	+32.330[bc]

[a-d]Mean with different letters indicate significant difference ($p<0.05$).

At a feed rate of 280 ml/h, the values of a were almost same at 150°C and 160°C. However, there was a significant decrease ($p<0.05$) when air flow temperature increased from 150°C to 170°C. Similar results were obtained for a value when air flow temperature was increased from 150°C to 170°C at 350 ml/h and 420 ml/h feed rates. The value is degree of the redness in roselle extract contributed by the anthocyanin pigment. However, the values for the different combinations of inlet air temperature and feed rate did not show similar trends on anthocyanin content. In Table 3, 150°C/420 ml/h and 170°C/280ml/h represented lowest and highest exposure of temperature, respectively. The 150°C/420ml/h produced highest degree of redness (a value) which corresponds to the highest anthocyanin content. Similarly 170°C/280 ml/h produced lowest degree of redness with least anthocyanin content. Therefore, it is possible that destruction of anthocyanin pigment may associated with the reduction in degree of redness. It was also found that the different inlet air temperature and feed rates used in this study did not have any significant effect on anthocyanin content. Thus, the destruction of anthocyanin pigment may not be the only factor that contributed the changes of a value in *Hibiscus sabdariffa* powder. Other factors that might influence are the other pigments that contribute in the degree of redness of roselle powder.[8]

Table 6 shows the effect of air flow temperature and feed rate on the b value of roselle powder produced from 300 ml of extract. At 150°C, there was trivial effects ($p>0.05$) on b values when feed rate was increased from 280 ml/h to 350 ml/h and subsequently to 420 ml/h. Similar results were observed with inlet air temperature of 160 and 170 °C. Different inlet air temperatures showed that at a feed rate of 280 ml/h, b values increased largely

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($p<0.05$) when temperature increased from 150 °C to 170 °C. However there was no change found between 150 °C to 160 °C. At feed rate of 350 and 420 ml/h, there was no remarkable change ($p>0.05$) in b values with increasing inlet air temperature.

Table 6: Values (b) of *Hibiscus sabdariffa* powder at different air flow temperature and feed rate

Feed rate (ml/h)	Inlet air temperature (°C)		
	150	160	170
280	$+3.547^{bc}$	$+3.927^{ab}$	$+4.080^{a}$
350	$+3.530^{bc}$	$+3.857^{ab}$	$+3.943^{ab}$
420	$+3.333^{c}$	$+3.680^{abc}$	$+3.713^{abc}$

$^{a-c}$Mean with different letters indicate significant difference ($p<0.05$).

At the feed rate of 280 ml/h, b value increased with elevated inlet air temperature due to the exposure of particles at high temperature, which caused browning process in the samples. The higher degree of yellowness was observed at large heat exposure. However, at higher feed rates (350 and 420 ml/h), the effect of increased temperature was not obvious probably due to the increased feed rate resulted in higher drying load.

Conclusion

From the obtained results we can conclude that both inlet air temperature and feed rate significantly affect yield, moisture content, colour and anthocyanin of spray dried roselle extract. Increased feed rate in spray drying caused a significant decrease in yieldwith high moisture content. L value and a value of roselle powder also increased with increased feed rate. Elevated inlet air temperature produced significantly high yield at feed rate of 420ml/h. However, increased inlet air temperature resulted in reduced moisture content and a value. Reduction of the degree of redness may be contributed in part by the degradation of anthocyanin.

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