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Physicochemical properties of spray-dried cantaloupe powder and rheological behaviour of cake icing

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Abstract

Cantaloupe is an excellent source of carotenoids, phenolics, flavonoids, carbohydrates, and minerals. Fresh cantaloupe is a seasonal fruit, highly perishable, and has a short shelf life. In the present work, the physicochemical properties of spray-dried cantaloupe powder with various Arabic gum (AG) concentrations (5 - 15%), and its food application in cake icing were evaluated. Results showed that spray-dried cantaloupe powder with 10% AG exhibited the best quality in terms of moisture content, hygroscopicity, hue, water solubility index, and total carotenoid content. A rheological test was then conducted on the cake icing incorporated with spray-dried cantaloupe powder with 10% AG at a powder-to-icing ratio of 1:10, and in temperature between 15 and 35°C. Steady shear flow of cake icing incorporated with spray-dried cantaloupe powder fit the Power Law model. The flow behaviour index of the icing was 0.134, and showed no significant difference ($p < 0.05$) with the control sample. The cake icing incorporated with spray-dried cantaloupe powder showed higher b^* value (yellowness) as compared to the control sample. This indicated that spray-dried cantaloupe powder with 10% AG has the potential to produce cake icing with a natural colorant and high in antioxidants, with no significant effect on the flow behaviour index of the produced cake icing.

Introduction

At present, many people are going for simple and health-promoting food products. Fruit powders are one of the convenient foods to promote health benefits in food products (Salehi, 2019). The incorporation of fruit powders in cakes, breads, cake icing, and beverages can produce final products that are rich with various nutrients such as vitamins, polyphenols, fibres, minerals, and natural colorants.

Melon (*Cucumis melo* L.) is one of the most widely cultivated and consumed fruits around the world. Melon's close relative cantaloupe (*Cucumis melo* L. *reticulatus* cv. Glamour) is grown as a seasonal fruit commodity in tropical regions. It is a popular dietary choice, and contains biologically active compounds such as phenolic compounds, β-carotene, and vitamin C. In the yellow-orange colour of cantaloupe flesh, there are natural pigments present known as carotenoids (Sangamithra *et al.*, 2015). Carotenoids are the main group of natural pigments which are responsible for the red, orange, and yellow colours of fruits and vegetables. The carotenoids in cantaloupe play a significant role as antioxidants that can prevent and protect against serious human health diseases such as cancers, cardiovascular diseases, cataracts, and macular degeneration (Song *et al.*, 2017).

Cantaloupe is highly perishable, and spoils over short storage time. Dehydration is one of the methods to preserve cantaloupe by reducing its moisture content to suppress microbial growths and enzymatic reactions (Wong and Lim, 2016). There are various methods to dry fruits such as convective, freeze, spray, foam mat, microwave, and vacuum drying. Spray drying is one of the drying methods that has been widely used to produce fruit powders (Darniadi *et al.*, 2018; González *et al.*, 2019). Fruit powders have many advantages and economic benefits over the liquid products, for example, due to

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their reduced weight or size, they require lesser packaging space, easier handling and transportation, and have a longer shelf life.

Spray drying is also a general technique to encapsulate heat-sensitive compounds by using carrier agents that serve as a coating or wall material. The wall material protects the encapsulated material not only from heat, but also from surrounding environment, as well as oxidation. The addition of carrier agents can also prevent stickiness, low yield, and flowability problems caused by the sugars and organic acids present in fruit pulps (Pereira *et al.,* 2019). Among the common carrier agents used is Arabic gum (AG) due to its good functional properties such as high solubility and low viscosity (Ferrari *et al.,* 2013). The use of AG in spray drying had been investigated in many food products such as tamarind pulp (Bhusari *et al.,* 2014), Cagaita fruit (Daza *et al.,* 2016), jussara pulp (Santana *et al.,* 2016), and roselle fruit (Archaina *et al.,* 2019). To the best of our knowledge, scarce information exists on spray-dried cantaloupe powder using various AG concentrations, and its application in food products such as icing. Therefore, the objective of the present work were (1) to investigate the influence of AG concentrations on the physicochemical properties of spray-dried cantaloupe fruit powder, and to (2) evaluate the effect of temperature on the rheological properties of cake icing incorporated with spray-dried cantaloupe powder.

Materials and methods

Materials

Cantaloupe samples were purchased from a commercial farm (Jeram, Kuala Selangor, Selangor, Malaysia), and refrigerated at 4°C. Methylcellulose (pharmaceutical grade) was purchased from Scienfield Expertise PLT (Shah Alam, Selangor, Malaysia), and food grade Arabic gum (AG) was purchased from Markaids (Malaysia) Sdn. Bhd. (Petaling Jaya, Selangor, Malaysia). Chemicals and solvents were purchased from Fisher Scientific Sdn. Bhd. (Shah Alam, Selangor, Malaysia) and BT Science Sdn. Bhd. (Cheras, Selangor, Malaysia), and of analytical grade.

Sample preparation

Cantaloupe samples were washed, peeled, sliced, and blanched in boiling water (100°C) for 1 min to inactivate the enzyme. Then, the blanched slices were blended into purée using a kitchen blender, and the purée was packed in polyethylene bags and frozen (-24°C) until further analysis. Arabic gum (AG) was used as a carrier agent (Suhag and Nanda, 2016; de Araujo Santiago *et al.,* 2016; Braga *et al.,* 2018). Various AG concentrations (5 - 15% w/w) were added to the purée. Next, the mixture of purée and AG was homogenised using a blender. The homogenised feed mixtures were spray-dried in a pilot scale spray drier (Niro A/S, GEA, Germany) at an inlet air temperature of 170°C, outlet air temperature of 90°C, and 900 m^3/min air flow rate (Solval *et al.,* 2012). Spray-dried powders were collected and sealed in aluminium-laminated polyethylene bags.

Proximate analysis

Official methods of AOAC (2005) were used to determine the moisture content, total protein, fat, total ash, total carbohydrate, and energy of cantaloupe purée.

Moisture content and water activity

The moisture content was determined using moisture measurement of AOAC (2005), while the water activity was determined using a water activity analyser (Decagon Devices, Inc., model 3TE, USA).

Hygroscopicity

The hygroscopicity was determined according to Cai and Corke (2000). Approximately, 1 g of powder was weighed into a crucible, and placed in an airtight desiccator at 25°C with a saturated NaCl solution (75% RH) for 1 w, following which the hygroscopicity was calculated using Eq. (1):

$$Hygroscopicity\ (\%) = [(WI\% + MC\%) \times 100] \div (100 + WI\%) \quad \text{(Eq. 1)}$$

where,

$$\text{WI\%} = \frac{(\text{Weight of sample after equilibrium} - \text{Weight of sample})}{\text{Weight of sample}} \times 100$$

MC% = moisture content of the powder

Colour

The colour values were determined according to Darniadi *et al.* (2018) using a chromameter (Konica Minolta, CR-410, Japan) in terms of L^*, a^*, and b^* values. The chroma and hue angle values were calculated using Eq. (2) and Eq. (3), respectively.

$$\text{Chroma} = \sqrt{(a^{*2} + b^{*2})} \quad \text{(Eq. 2)}$$

$$\text{Hue angle} = \arctan\left(\frac{b*}{a*}\right) \quad \text{(Eq. 3)}$$

Bulk density, tap density, cohesiveness, and flowability

The bulk density was determined manually by pouring 2.5 g of powder into 10 mL graduated measuring glass cylinder, and calculated using Eq. (4):

$$\text{Bulk density } (\rho_B) = \frac{\text{Mass of cantaloupe powder,g}}{\text{Volume of cantaloupe powder,cm}^3}$$

(Eq. 4)

The tapped density was measured by placing 2.5 g powder in 10 mL graduated measuring glass cylinder, and the tapped volume was measured after the sample was gently dropped onto a rubber mat until the volume of powder no longer reduced. Subsequently, the tap density was calculated using Eq. (5):

$$\text{Tap density } (\rho_T) = \frac{\text{Mass of cantaloupe powder,g}}{\text{Final tapped volume,cm}^3}$$

(Eq. 5)

The cohesiveness and flowability was determined in terms of HR (Hausner ratio) and CI (Carr index), respectively (Saifullah *et al.,* 2016). Based on HR, the cohesiveness was considered low (HR < 1.2), intermediate (1.2 < HR < 1.4), and high (HR > 1.4). Based on CI, the flowability was considered very good (CI < 15%), good (< 15% < CI < 20%), fair (20% < CI < 35%), bad (35% < CI < 45%), and very bad (CI > 45%). HR was calculated using Eq. (6):

$$\text{Hausner ratio (HR)} = \frac{\rho_T}{\rho_B} \quad \text{(Eq. 6)}$$

where, ρ_T = tapped density, and ρ_B = bulk density.

CI was calculated using Eq. (7):

$$\text{Carr index (CI)} = 100 \times \frac{\rho_T - \rho_B}{\rho_T} \quad \text{(Eq. 7)}$$

Total carotenoid content

The extraction of carotenoids was carried out according to Khoo *et al.* (2008). Briefly, 1 g of spray-dried cantaloupe powder was weighed and mixed with 10 mL of ethanol (95:5 v/v). The mixture was stirred for 30 min with a magnetic stirrer at 500 rpm. The mixture was filtered with filter paper, and was added with 10 mL of hexane. The step was repeated several times until lipid substances were extracted completely. Later, the pooled hexane was evaporated using a rotary vacuum evaporator at 39°C. The lipid layer on the flask was dissolved in 10 mL hexane to determine the total carotenoid content (TCC) using UV-Vis spectrophotometer at 450 nm, and calculated using Eq. (8):

$$\text{Carotenoid content } \left(\frac{\text{ug}}{\text{g}}\right) = \frac{\text{A} \times \text{V(ml)} \times 10^4}{\text{A}_{1\text{cm}}^{1\%} \times \text{P(g)}}$$

(Eq. 8)

where, A = absorbance, V = total extract volume, P = sample weight, and $\overline{A_{1cm}^{1\%}}$ = 2592 (β-carotene extinction coefficient in hexane).

Total phenolic and total flavonoid contents

One gram of spray-dried cantaloupe powder was extracted using 10 mL of ethanol-water (50:50 v/v) at room temperature for 2 h with a magnetic stirrer. The sample was then centrifuged at 5,000 rpm for 10 min, and the extracts were stored at -24°C until further analysis.

TPC was determined according to Koh *et al.* (2017). Gallic acid calibration curve in the range of 10 - 100 µg/mL ($y = 0.0094x + 0.1559$ with R^2 of 0.9905) was constructed. TPC was expressed as mg gallic acid equivalent (mg GAE) per 100 g dry weight of the sample as a mean of three replicates.

TFC was determined according to López-Vargas *et al.* (2013). Quercetin calibration curve in the range of 10 - 100 µg/mL ($y = 0.0018x + 0.0025$ with R^2 of 0.9993) was constructed. TFC was expressed in mg quercetin (QE)/100 g of the sample as a mean of three replicates.

Application of spray-dried cantaloupe powder into cake icing

Spray-dried cantaloupe powder with the concentration of AG that showed overall good qualities in terms of physicochemical properties was chosen for further study in cake icing as food application.

Preparation of cake icing

Spray-dried cantaloupe powder with 10% AG was selected to be incorporated into cake icing. The cake icing was produced using 500 g of krimwell and 250 g of icing sugar. Krimwell was whipped for 10 min at high speed, then the icing sugar was added slowly, and whipped for another 10 min. Based on a preliminary study, the ratio of spray-dried cantaloupe powder and cake icing was set at 15 g:150 g, as the cake icing generated a nice light yellow-orange colour.

Colour of cake icing

Colour (L^*, a^*, and b^*) of cantaloupe cake icing was analysed using a chromameter (Konica Minolta, CR-410, Japan).

Rheology of cake icing

The rheological analysis was done in triplicate. Flow behaviour of icing (60 ± 1 °Brix) was analysed using a dynamic controlled stress rheometer at three temperatures of 15, 25, and 35°C at shear rate ranging from 1 to 300 s^{-1}. The rheometer was attached with a 35-mm parallel plate probe at 1 mm gap.

Effect of temperature on consistency coefficient

The rheological data from the experiment were fit into an existing model such as Power law (Ostwald-de-Waele) as shown in Eq. 9 (Dutta *et al.,* 2006).

$$\text{Power law: } \sigma = k\gamma^{n} \quad \text{(Eq.9)}$$

where, σ = shear stress (Pa), k = consistency coefficient ($Pa.s^n$), γ = shear rate (s^{-1}), and n = flow behaviour index.

The Arrhenius equation that is used to describe the effect temperature on consistency coefficient was as shown in Eq. 10 (Dutta *et al., 2006):*

$$K = A\exp^{(\frac{E_a}{RT})} \quad \text{(Eq. 10)}$$

where, A = constant, E_a = activation energy (J/mol), R = gas constant (J/mol/K), and T = absolute temperature (K).

Statistical analysis

All tests were performed in triplicate. The means and standard deviations of the results were then reported. The results were analysed using Minitab Statistical Software (Minitab Inc., v. 18, Pennsylvania). Tukey's test was used to identify the significant differences of the mean values at 95% significance level ($p < 0.05$).

Results and discussion

Proximate and physicochemical properties of fresh cantaloupe purée

Physicochemical properties of fresh cantaloupe purée were moisture content (93.22%), protein (0.77 g/100 g), total fat (0.09 g/100 g), total carbohydrate (5.27 g/100 g), ash (0.66 g/100 g), energy (25.00 kcal/100 g), water activity (0.97), and colour parameter such as lightness, redness, yellowness, chroma, and hue (71.51, 15.39, 39.18, 42.10, and 68.58, respectively), as shown in Table 1. Similar results of moisture, protein, and lipid were reported in United States Department of Agriculture (USDA) nutrient database (USDA, 2019). The fresh cantaloupe purée contained total phenolic content (55.28 mg GAE/100 g), total flavonoid content (5.74 mg QE/100 g), and total carotenoid content (0.71 µg/g), which were lower than the values reported by Wulandari *et al.* (2017) of 89.82 mg GAE/100 g, 11.00 mg QE/100 g, and 86.50 mg/100 g, for TPC, TFC, and TCC respectively.

Moisture content and water activity

Table 2 shows that the moisture content of spray-dried cantaloupe powder ranged from 1.46 to 1.88 g/100 g, which was almost similar to another study (Edris *et al.,* 2016). The value was below 4.0%, which is within the minimum specification for powders applied in food. The moisture content of spray-dried cantaloupe powder significantly decreased with the addition of AG. This might be due to the increase in the concentration of AG which increased the total feed solids, thus reducing the total moisture (Tuan Azlan *et al.,* 2020). A similar finding was reported by Bhusari *et al.* (2014) and Caliskan and Dirim (2016) who worked with tamarind pulp powder and spray-dried sumac extract powder, respectively.

All powders exhibited water activity values around 0.45 a_w. This indicated that the powders were stable against chemical reaction and microbial activity. In addition, spray-dried cantaloupe powders produced with different AG concentrations showed no significant change in water activity values. Largo Avila *et al.* (2015) who investigated spray-dried sugarcane juice powder reported a similar finding, where the powders produced with different levels of carrier agent had no significant difference in their water activities.

Hygroscopicity

Table 2 represents the effect of AG on the hygroscopicity of the spray-dried cantaloupe powders. AG showed significant influence ($p < 0.05$) on the hygroscopicity of the powders. Spray-dried cantaloupe powders produced with 10 and 15% AG showed the lowest hygroscopicity. A similar finding was reported by Daza *et al.* (2016) who studied spray-dried Cagaita fruit extract powder. The addition of AG into the spray drying process led to a significant decrease in

Table 1. Proximate and physicochemical properties of fresh cantaloupe purée.

Parameter	Mean ± SD
Moisture content (%)	93.22 ± 0.05
Protein (g/100 g)	0.77 ± 0.04
Total fat (g/100 g)	0.09 ± 0.01
Total carbohydrate (g/100 g)	5.27 ± 0.07
Ash (g/100 g)	0.66 ± 0.03
Energy (kcal/100 g)	25.00 ± 0.00
Water activity (a_w)	0.97 ± 0.01
Colour *L**	71.51 ± 0.57
Colour *a**	15.39 ± 0.14
Colour *b**	39.18 ± 0.69
Chroma	42.10 ± 0.62
Hue	68.58 ± 0.47
Total phenolic content (mg GAE/100 g)	55.28 ± 0.20
Total flavonoid content (mg QE/100 g)	5.74 ± 0.62
Total carotenoid content (µg/g)	0.71 ± 0.06

Table 2. Moisture content, hygroscopicity, and water activity of spray-dried cantaloupe powders produced with different concentrations of Arabic gum (0 - 15% AG).

Sample	Moisture content (g/100 g)	Hygroscopicity (g/100 g)	Water activity (a_w)
SD_AG 5	2.46 ± 0.03^a	23.83 ± 0.28^a	0.45 ± 0.01^a
SD_AG 10	1.88 ± 0.13^b	18.26 ± 0.80^b	0.45 ± 0.04^a
SD_AG 15	1.75 ± 0.12^b	19.46 ± 0.72^b	0.43 ± 0.05^a

Values are means ± SD of triplicate determination. Means with different lowercase superscripts in the same column are significantly different ($p < 0.05$). SD = spray dried, AG = Arabic gum.

hygroscopicity. This might due to high amount of sugar such as fructose, glucose, and sucrose contained in cantaloupe purée, which will cause the powders to be sticky and affect the flowability. Adding AG to the fruit purée decreases the hygroscopicity due to its high molecular weight property, and increases the glass transition temperature, thus validating its capability as a carrier agent for spray drying (Suhag and Nanda, 2016; Seerangurayar *et al.,* 2018).

Bulk density, tap density, cohesiveness, and flowability

Table 3 shows the effect of AG on bulk and tap density. The bulk and tap density had a significant difference in the spray-dried cantaloupe powders produced with various AG concentrations. The bulk density of spray-dried cantaloupe powders decreased with AG concentrations. The highest bulk and tap density was found in the sample with 5% AG. This might be due to the highest moisture content present in the powder that caused a higher bulking weight in the powder (Santhalakshmy *et al.,* 2015).

Table 3 also shows the effect of AG on flowability and cohesiveness. HR was in the range of 1.48 to 1.55, while CI was in the range of 32.37 to 35.66. There was no significant change of AG concentrations on HR and CI. The reported HR values showed high cohesiveness, while the CI values showed between fair and bad flowability. A similar finding was reported by Saikia *et al.* (2015) where spray-dried watermelon and carambola had high cohesiveness and bad flowability. Caliskan and Dirim (2016) also reported that spray-dried sumac powder at 20% maltodextrin produced a powder with high cohesiveness and bad flowability.

Colour

Fresh cantaloupe purée had lower L^* with higher a^* and b^* values as compared to spray-dried cantaloupe powder. Table 4 shows the colour characteristics of the spray-dried cantaloupe powder produced with different concentrations of AG. Generally, the colour parameters of spray-dried cantaloupe powders were not significantly affected by AG concentrations. For L^* values, there was no significant change with increasing AG concentrations. The sample produced with 15% AG had the highest a^* value and lowest b^* values, thus indicating that it had more redness and less yellowness in the sample. The use of AG significantly decreased b^* values, hue, and chroma values, while increasing a^* values thus producing less yellow powder. This result can be related to the non-enzymatic reaction between the reducing sugar of cantaloupe fruit and protein fraction of AG. Chroma values decreased with increasing AG concentration, and thus, the saturation of spray-dried cantaloupe powder colour decreased. This result was similar to Bhusari *et al.* (2014) who reported that the chroma values of tamarind pulp powder was affected by the addition rate of the carrier agent such as maltodextrin, AG, and whey protein concentrate.

Particle size

The particle size distribution of spray-dried cantaloupe powder produced with various AG concentrations is presented in Table 5. The particle size of spray-dried cantaloupe powder ranged from 34.01 to 48.50 µm. Spray-dried powders often have a smaller particle size (< 50 µm). Similar findings were observed in spray-dried honey powder and *Nigella sativa* oil (Shi *et al.,* 2013; Mohammed *et al.,* 2017). Spray-dried cantaloupe powder produced with 15% AG had significantly higher particle size as compared to the other samples. This might be due to the viscosity emulsion. As explained by Jinapong *et al.* (2008), the particle size of soymilk powder was significantly affected by the concentration of the

Table 3. Density and flowability of spray-dried cantaloupe powders produced with different concentrations of Arabic gum (0 - 15% AG).

Sample	Bulk density (g/cm^3)	Tap density (g/cm^3)	Hausner ratio	Carr index
SD_AG 5	0.58 ± 0.01^a	0.91 ± 0.02^a	1.55 ± 0.02^a	35.66 ± 0.73^a
SD_AG 10	0.44 ± 0.01^b	0.65 ± 0.02^b	1.48 ± 0.03^a	32.37 ± 1.46^a
SD_AG 15	0.43 ± 0.01^b	0.66 ± 0.01^b	1.55 ± 0.04^a	35.10 ± 1.81^a

Values are means ± SD of triplicate determination. Means with different lowercase superscripts in the same column are significantly different ($p < 0.05$). SD = spray dried, AG = Arabic gum.

Table 4. Colour properties of spray-dried cantaloupe powders produced with different concentrations of Arabic gum (0 - 15% AG).

Sample	Colour				
	L^* value	a^* value	b^* value	Hue	Chroma
SD_AG 5	78.95 ± 0.74^a	4.11 ± 0.06^{ab}	27.11 ± 0.29^a	81.42 ± 0.20^a	27.42 ± 0.28^a
SD_AG 10	80.74 ± 1.03^a	3.78 ± 0.45^b	25.58 ± 0.40^{ab}	81.65 ± 0.85^a	25.86 ± 0.46^{ab}
SD_AG 15	78.05 ± 2.00^a	4.50 ± 0.08^a	24.92 ± 1.31^b	79.78 ± 0.41^b	25.32 ± 1.13^b

Values are means ± SD of triplicate determination. Means with different lowercase superscripts in the same column are significantly different ($p < 0.05$). SD = spray dried, AG = Arabic gum.

Table 5. Particle size, water solubility index, and water absorption index of spray-dried cantaloupe powders produced with different concentrations of Arabic gum (0 - 15% AG).

Sample	Particle size, D[4,3] (µm)	Span	Water solubility index (%)	Water absorption index
SD_AG 5	34.01 ± 0.46[b]	1.44 ± 0.02[a]	90.50 ± 0.35[b]	0.23 ± 0.03[a]
SD_AG 10	38.97 ± 0.39[b]	1.08 ± 0.05[b]	92.38 ± 0.70[a]	0.22 ± 0.01[a]
SD_AG 15	48.50 ± 3.44[a]	1.04 ± 0.08[b]	91.57 ± 0.20[ab]	0.20 ± 0.02[a]

Values are means ± SD of triplicate determination. Means with different lowercase superscripts in the same column are significantly different ($p < 0.05$). SD = spray dried, AG = Arabic gum.

binder. The span value of spray-dried cantaloupe powder ranged from 1.04 to 1.44, thus indicating that there was only a very small difference in the physical characteristics of the spray-dried cantaloupe powder.

Water solubility and water absorption index

The water solubility index (WSI) and water absorption index (WAI) of spray-dried cantaloupe powder are shown in Table 5. The WAI was in the range of 90.50 to 92.38, thus considered high solubility powder. The high solubility spray-dried cantaloupe powder might be due to the good solubility of AG that had been mentioned earlier (Mariod, 2018). Generally, a high WSI is desirable as it affects the physicochemical properties of products in the food and pharmaceutical industry, since it can be easily dissolved and incorporated with other products (Tan *et al.,* 2015).

The WAI of spray-dried cantaloupe powder was in the range of 0.20 to 0.22. The increase in AG concentration decreased the WAI of the powders. However, there was no statistically significant in the WAI of spray-dried cantaloupe powder. Contrary to WSI, a low WAI was found in spray-dried cantaloupe powder which indicated that all the samples had low ability to absorb water and unlikely to be influenced by humidity, and subsequently, the powder will be more stable during storage (Vidović *et al.,* 2014). High WSI and low WAI are favourable for good quality powder. Other than these properties, Phoungchandang and Sertwasana (2010) revealed that an ideal powder should wet rapidly and completely, sink rather than float, and disperse or dissolve without a lump.

Total carotenoid content

Fresh cantaloupe purée (0.71 µg/g) had lower total carotenoid content (TCC) as compared to spray-dried cantaloupe powders (3.53 - 17.86 µg/g). The TCC in spray-dried cantaloupe powder decreased significantly from 17.86 to 3.53 µg/g as AG concentration increased from 5 to 15% (Figure 1a). High carotenoid content was observed at lower AG concentrations (5 and 10%). This result might be due to the addition of a high amount of AG concentration to the feed solution before the spray drying process decreased the fraction of cantaloupe portion in spray-dried powder. Therefore, it caused the dilution in the carotenoid pigment in the mixture, and affected the quality of the fruit powder.

Total phenolic content

Fresh cantaloupe purée (55.28 mg GAE/100 g) had lower total phenolic content (TPC) as compared to spray-dried cantaloupe powders (116.90 - 218.50 mg GAE/100 g). As can be seen in Figure 1b, spray-dried cantaloupe powder produced with 5% AG had significantly higher TPC as compared to spray-dried cantaloupe powders produced with 10 and 15% AG, while spray-dried cantaloupe powder produced with 10% AG had no significant difference with sample produced with 15% AG. Based on the results, the carrier (above 10%) caused a dilution effect on the phenolic compound; higher carrier concentration produced lower total phenolic content in the sample. This agrees with de Souza *et al.* (2014) who reported that the sample with a higher amount of carrier agents would have reduced phenolic compound.

Total flavonoid content

Fresh cantaloupe purée (5.74 mg GAE/100 g) had lower total flavonoid content (TFC) as compared to spray-dried cantaloupe powders (15.25 - 25.94 mg GAE/100 g). As shown in Figure 1c, the

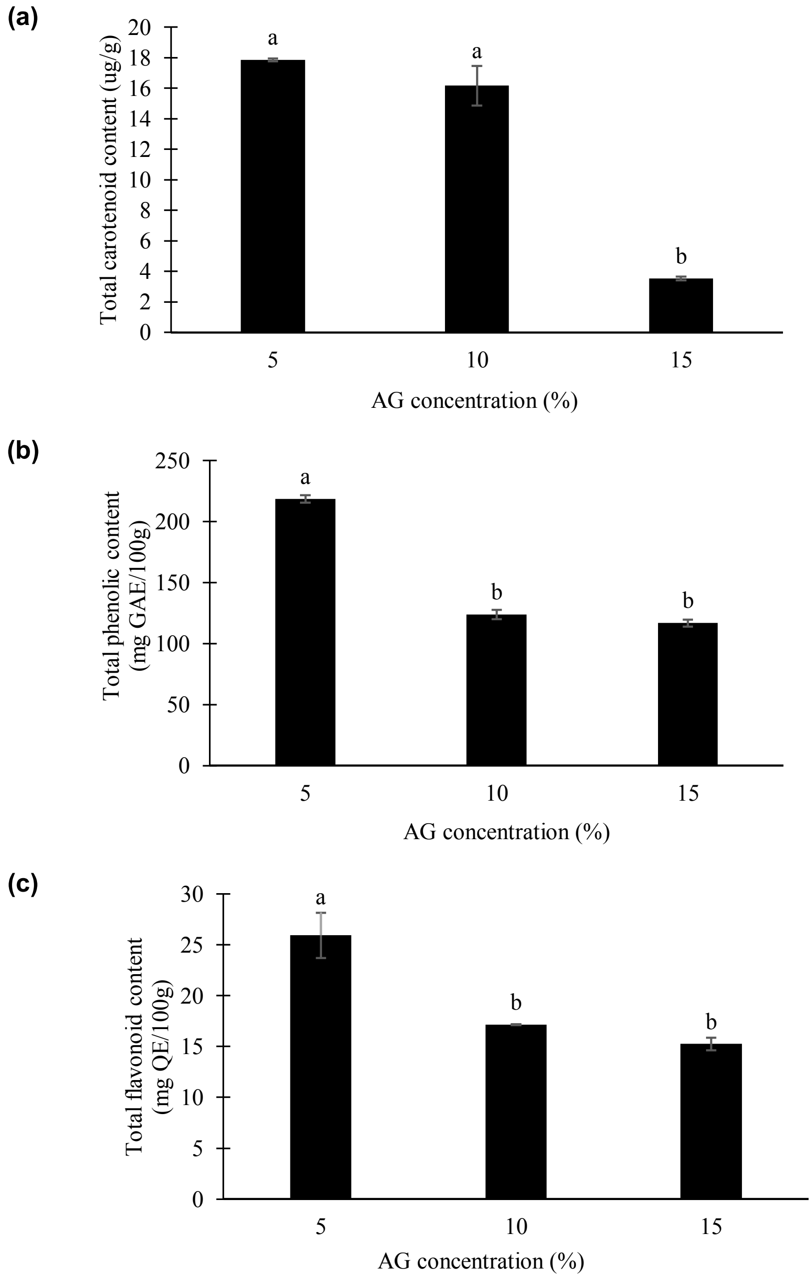

Figure 1. (a) Total carotenoid, (b) total phenolic, and (c) total flavonoid contents of spray-dried cantaloupe powders produced with different concentrations of Arabic gum (0 - 15% AG). Different lowercase letters indicate significant difference ($p < 0.05$).

sample with 5% AG had significantly higher TFC as compared to sample with 10 and 15% AG, while there was no significant difference of TFC between sample with 10 and 15%. This might be due to the fact that the addition of carrier agents would decrease the portion of cantaloupe purée in spray-dried cantaloupe powder, thus the flavonoid content would also be reduced (Peng *et al.,* 2013). A similar result was also reported by Benelli *et al.* (2013) who found that the decrease in TFC with an increase in the carriers was caused by the dilution effect from the addition of carrier to the feed solution.

Cake icing

Colour of cake icing

The control (cake icing without spray-dried cantaloupe powder) showed slightly higher *L** value as compared to cake icing incorporated with spray-dried cantaloupe powder, but there was no statistically significant difference (Table 6). Cake icing incorporated with spray-dried powder showed significantly higher *a** and *b** value as compared to control due to the presence of orange yellowish spray-dried cantaloupe powder (Figure 2).

Table 6. Colour coordinates of cake icings incorporated with and without spray-dried cantaloupe powder.

Sample	*L**	*a**	*b**
CI_C	83.51 ± 0.77[a]	-0.40 ± 0.15[b]	6.83 ± 0.23[b]
CI_SD	80.70 ± 1.77[a]	1.28 ± 0.03[a]	14.78 ± 0.06[a]

Values are means ± SD of triplicate determination. Different lowercase superscripts in the same column indicate significant difference ($p < 0.05$). CI_C = cake icing without spray-dried cantaloupe powder; CI_SD = cake icing with spray-dried cantaloupe powder.

Figure 2. Cake icing without spray-dried cantaloupe powder (control), and cake icing with spray-dried cantaloupe powder (SD).

Power law model

The Power law model coefficient and apparent viscosity at 100 s^{-1} are summarised in Table 7. Rheological results showed that the cake icing exhibited a shear stress rate data that were best fit to the Power Law model with a high correlation of coefficient ($R^2 > 0.98$) at the given temperatures.

The consistency coefficient of cake icings incorporated with and without spray-dried cantaloupe powder decreased with increasing temperature. It was observed that the shear thinning effect for the cake icing increased within the temperature of 15, 25, and 35°C. Moreover, the cake icings with and without spray-dried cantaloupe powder at higher temperatures were shown to be less viscous with K values of 469.00 and 527.71 Pas^n, respectively. Chuah *et al.* (2008) reported that dragon fruit juice decreased in the consistency coefficient with increasing temperature.

Table 7 shows the flow behaviour index (n) of the sample which ranged from 0.112 to 0.156. The cake icing behaved as pseudoplastic (shear thinning) material as the flow behaviour index values were less than 1. No significant difference ($p > 0.05$) on the flow behaviour index of icing for control sample and icing with added spray-dried cantaloupe powder. This meant that icing incorporated with spray-dried cantaloupe powder could easily be squeezed and applied as cake icing similar to control icing.

Table 7. Power law model coefficients for cake icings incorporated with and without spray-dried cantaloupe powder at different temperatures (15 -35°C).

Sample	Temperature (°C)	Consistency coefficient, K ($Pa.s^n$)	Flow behaviour index, n (dimensionless)	n_{100} (Pa.s)	R^2
CI_C	15	531.63	0.132	9.764	0.994
	25	508.39	0.139	9.642	0.978
	35	469.00	0.156	9.620	0.993
CI_SD	15	792.73	0.112	13.278	0.985
	25	607.27	0.147	11.950	0.984
	35	527.71	0.142	10.148	0.995

CI_C = cake icing without spray-dried cantaloupe powder; CI_SD = cake icing with spray-dried cantaloupe powder.

Table 8. Arrhenius model parameter for consistency coefficient (*K*) of cake icings incorporated with and without spray-dried cantaloupe powder.

Samples	E_a (kJ/mol)	A (Pa.s^n)	R^2
CI_C	4.61	78.11	0.97
CI_SD	15.07	1.45	0.98

CI_C = cake icing without spray-dried cantaloupe powder; CI_SD = cake icing with spray-dried cantaloupe powder.

As shown in Table 7, the temperature was able to affect the apparent viscosity. The apparent viscosity of both cake icings, with and without spray-dried cantaloupe powder, decreased with increasing temperature. At all temperatures, the viscosity of cake icings incorporated with spray-dried cantaloupe powder was higher than all the cake icings without spray-dried cantaloupe powder.

Effect of temperature on consistency coefficient

Table 8 depicts the Arrhenius model of the consistency coefficient of cake icings incorporated with and without spray-dried cantaloupe powder. The model showed a satisfactory explanation of the temperature dependence of apparent viscosity in the cake icing at a constant shear rate of 100 s^{-1}. The activation energy (E_a) value calculated for cake icings incorporated with and without spray-dried cantaloupe powder were 15.07 and 4.61 kJ/mol, with R^2 value of 0.98 and 0.97, respectively. Higher activation energy relating to the consistency coefficient indicated that the consistency coefficient was relatively more sensitive to temperature change (Ramzi *et al.,* 2017). From the result, it showed that cake icing incorporated with spray-dried cantaloupe powder was more sensitive to temperature change as compared to cake icing without spray-dried cantaloupe powder.

Conclusion

The present work demonstrated the production of spray-dried cantaloupe powder with 5 to 15% of Arabic gum (AG) concentrations, and results showed that spray drying increased the total phenolic, total flavonoid, and total carotenoid contents up to 4.0-, 4.52-, and 25.15-fold, respectively. As AG increased, the moisture content, hygroscopicity, total carotenoid, and total phenolic, and total flavonoid contents decreased. However, there was no significant difference in the water activities of the spray-dried cantaloupe powder for all the AG concentrations investigated. Spray-dried cantaloupe powder produced with 10% AG exhibited the best quality in terms of moisture content, hygroscopicity, hue, water solubility index, and total carotenoid content. Spray-dried cantaloupe powders with AG could be used as a natural colourant for confectionery products such as cake icing, which promotes food products rich in nutrients.

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