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Anti-caking Agent Effects on the Properties of Spray-dried 'Cempedak' Fruit Powder

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ABSTRACT

'Cempedak' fruit, an aromatic fruit that has a short shelf life can be converted into powder through spray-drying process. However, the spray-dried powder that was obtained had a high tendency to cake. Hence, three different anti-caking agents (calcium silicate, silicon dioxide, and calcium phosphate) were added separately at a concentration of 1.5% (w/w). It was found that calcium phosphate (1.5% w/w) yielded 'cempedak' fruit powder with lowest moisture content, water activity, hygroscopicity, and caking (change in cake height ratio), with minimal color changes in its reconstituted form and low viscosity. Different calcium phosphate concentration (0-2.00% w/w) was then applied in the production of 'spray-dried' powder. With increase of calcium phosphate addition from 0 to 0.66%, the moisture content, water activity, hygroscopicity, cake height ratio of 'cempedak' powder decreased, with no significant decrease with further addition. Calcium phosphate (0.66 % w/w) yielded powder with the best properties: lowest moisture content (4.65%), water activity

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(0.18), hygroscopicity (22.0), and change in cake height ratio (0.17). In addition, there was a minimal change in color of its reconstituted powder, with a slight change in viscosity.

Keywords: Anti-caking agent, caking properties, 'cempedak' fruit, spray-drying

INTRODUCTION

Caking of food powders results from combined factors, which include composition, particle size, temperature, pressure, and relative humidity (Lipasek et al., 2011). Anti-caking agents are substances that can prevent caking, lumping, and aggregation of hygroscopic powders by improving their flowability (Aguilera et al., 1995; Jaya et al., 2006; Phanindrakumar et al., 2005). The anti-caking agent function acts as moisture-protective barrier, by competing with powders for moisture (Barbosa-Cánovas et al., 2005). The flowability is improved and caking is inhibited by acting as surface physical barriers between particles and on its surface (Aguilera et al., 1995; Phanindrakumar et al., 2005).

Low molecular weight sugars are known to cause caking during storage (Chung et al., 2000). These sugars are very hygroscopic and tend to be sticky. They also create high agglomerates upon exposure to moisture (Cano-Chauca et al., 2005). Due to differences in the powder hygroscopicity between water-soluble amorphous and crystalline solids, re-crystallization of the metastable amorphous form free moisture (Hartmann & Palzer, 2011). The released water later influences the crystallization velocity of the residual amorphous fraction that leads to caking.

Anti-caking agents which are known to absorb excess water, was commonly added into food powder, as with addition, it will help the powder maintain their free-flowness (Lipasek et al., 2011). In addition, anti-caking agents have the capability to absorb oils and nonpolar organic compounds by encapsulating powder particles (Jaya & Das, 2004). The use of anti-caking agents also promotes the reduction in moisture migration dynamics through gradients of water activity (Castro et al., 2006).

Common anti-caking agents include calcium stearate, silicon dioxide, calcium phosphate, calcium silicate, and corn starch (Lipasek et al., 2011). These anti-caking agents are effective at low concentrations and are generally used in concentrations up to 3%, as their legal allowable concentration is restricted to a limited level, which in practice is generally within 1% or less (Hollenbach et al., 1982; Jaya & Das, 2005). The addition of calcium phosphate, calcium silicate or calcium oxide has been found to give a favorable free-flowing characteristic to powder when it is stored (Jaya & Das, 2005; Jaya et al., 2006). Chang et al. (2019) incorporated calcium silicate and tricalcium phosphate in the production of soursop powder. The addition of 0.25% calcium phosphate in the production of *Garcinia indica* powder and pineapple powder produced powders (Nayak & Rastogi, 2010; Phanindrakumar et al., 2005). In addition, the inclusion of calcium phosphate in kiwi fruit powder was found to reduce its moisture content when added together with Arabic gum (Benlloch-Tinoco et al., 2013).

‘Cempedak’ fruit (*Artocarpus integer* L.) is an aromatic fruit that is popular in Southeast Asia. It can be consumed ripe or unripe, or processed into chips or creamed to make jams and cakes (Chong et al., 2008; Lim, 2012). As ‘cempedak’ is seasonal and has a short shelf-life, it can be converted into powder for better storage and product variability (Pui et al., 2018). The ‘cempedak’ powder has yield of 57.1%, moisture content of 6.11%, water activity of 0.22, hygroscopicity of 30.6g/100g, and carotenoid content of 1.43 mg/g. With water solubility index of 88.45, the ‘cempedak’ fruit powder can be incorporated into different food product such as pastries, cakes, or reconstituted into juice.

The present study was conducted to improve the properties of ‘cempedak’ fruit powder that was obtained through spray-drying. The powder obtained was found to have a high moisture content (more than 5%), which on visual observation led to caking and lumping during storage. Thus, it became necessary to add anti-caking agents and investigate whether the properties of the resulting ‘cempedak’ fruit powder could be improved. Three common anti-caking agents, namely calcium phosphate (CP), silicon dioxide (SIO), and calcium silicate (CS) all at 1.5% (w/w) concentration, were added separately to enzyme-liquefied ‘cempedak’ pulp before spray-drying and their effects on powder properties including moisture content, water activity, hygroscopicity, color of powder, and change in cake height ratio (caking) during storage were investigated. In addition, the spray-dried powder with anti-caking agents was also reconstituted with water (50 mL), whereby the change in color and viscosity were determined.

MATERIALS AND METHODS

Materials

‘Cempedak’ variety CH28 was procured in 3 different batches (n = 3), with ten fruits per batch) from the Department of Agriculture, Serdang, Selangor, Malaysia. The ‘cempedak’ fruit were wrapped with newspaper and ripened fruit were used (with strong aroma when it is ripe). The ‘cempedak’ fruit has total sugar and fiber content of 27-28 g in 100 mL, and 5%, respectively, with total soluble solids of 34-35°Brix (Pui et al., 2018). Celluclast® 1.5 L (for enzyme treatment of ‘cempedak’ pulp) was purchased from Novozymes, Denmark, while Maltodextrin 10 DE (drying aid) was purchased from Bronson and Jacobs, Kuala Lumpur, Malaysia. Food grade anti-caking agents i.e. calcium phosphate (CP), silicon dioxide (SIO), and calcium silicate (CS), were purchased from V.I.S. FoodTech, Malaysia.

Preparation of Spray-Dried ‘Cempedak’ Fruit Powder Containing Anti-Caking Agents

Ripe ‘cempedak’ fruit (weighing 1.5-2 kg each) were slit into half, and the arils removed. After the removal of seeds, the fruit pulp homogenized at low speed for one minute using a commercial blender to obtain a homogenous puree. To prepare 'cempedak' juice, homogenized 'cempedak' puree was mixed with distilled water at 1: 2 puree: water ratio and incubated with 1.2% (v/w) Celluclast® 1.5 L for 1 hour at 45°C and 100 rpm in a shaking water bath (WNB 14, Memmert GmbH + Co. KG., Schwabach, Germany). The end product (liquefied 'cempedak' puree) was then subjected to pasteurization at 90°C for 5 min in a water bath to inactivate the added enzyme and endogenous enzymes, and/or microorganisms that might be present (Pui et al. 2018).

A Büchi B-290 mini spray-dryer (Büchi Labortechnik AG, Flawil, Switzerland) was used to convert the enzyme-treated 'cempedak' pulp obtained above into powder (Pui et al. 2020). Before spray-drying, 15% (w/w) matlodextrin and 1.5% (w/w) of an anti-caking agent (calcium silicate, calcium phosphate, or silicon dioxide) were added, and the mixture mixed thoroughly with a homogenizer (T25, IKA®-Werke Gmbh & Co., Staufen, Germany). The spray-dryer feed was stirred continuously at room temperature, and when inlet air temperature in the spray-dryer reached 160°C, the mixture was pumped into an atomizer to be spray-dried. In all experiments, the spray-dryer aspirator rate and pump rate were kept constant at 100% and 10%, respectively. The outlet spray-dryer temperature ranged from 85-95°C. The spray-dried 'cempedak' fruit powder was collected from product vessel and stored in amber glass bottles at 4°C prior to powder analysis.

After selecting the most suitable anti-caking agent, the spray-drying experiment was repeated using different concentrations (0, 0.25, 0.66, 1.50, and 2.50% w/w) of the anti-caking agent. The 'cempedak' fruit powders spray-dried with anti-caking agents were analyzed in terms of moisture content, water activity, hygroscopicity, color, caking and surface morphology. In addition, the powders were reconstituted 50 mL water and the reconstituted powder tested in the aspect of its change in color and viscosity.

Analysis of Spray-Dried 'Cempedak' Fruit Powder

Moisture Content and Water Activity. 'Cempedak' fruit powders were determined following method by Association of Official Analytical Chemists (AOAC) with drying in oven (Memmert, Germany) at 105°C for 5 hours and repeated until the weight is constant, whereas the water activity was measured using water activity meter at 25±1°C (PRE 00207, AquaLab Pre, Decagon Devices, Inc., Pullman, USA) (AOAC, 2000; Chang et al., 2020). Calibration was carried out using potassium sulfate (K_2SO_4) and potassium chloride (KCl) solution, prior to sample measurement.

Hygroscopicity. About 2 g of 'cempedak' fruit powder was placed into a pre-weighed Petri dish (100 mm × 15 mm). The dish was then placed in an airtight desiccator (that contains 500 mL of saturated solution of Na_2SO_4) for one week at room temperature. The difference in the weight after storage was used to calculate the hygroscopicity (Cai & Corke, 2000).

Color. A HunterLab ColorFlez Ultra-Scan® spectrophotometer (Hunter Associates Laboratory Inc., Reston, USA) was employed in the color determination of 'cempedak' fruit powder (Chang et al., in press; Wong et al., 2015). The instrument was first calibrated against a white tile and black tile, respectively. Color analysis was conducted at room temperature and its readings were expressed in *L** (lightness-darkness), *a** (greenness-redness), and *b** value (blueness-yellowness).

Caking Test (Change in Cake Height Ratio). Cake height ratio was determined using the caking test according to Janjatović et al. (2012), using a powder rheometer, TA.HDplus Powder Flow Analyzer (Stable Micro Systems, Godalming, England). The apparatus' powder column was filled with 'cempedak' fruit powder until it reached the 70 mm mark. In the first two conditioning cycles, the blade of the apparatus leveled the top of the powder column and the blade measured the height of the column, followed by moving down of bladed through the height of the column and then moving down again through the column at a tip speed of 20 mms^{-1}. The powder was then compacted to 200 g force before being sliced by blade at 10 mms^{-1}. This movement of compaction was repeated four more times. Cake strength is defined as the work (g.mm) required to cut the cake, while the mean cake strength on the other hand, is the average force to cut the cake expressed in grams. The measurement of settlement and powder column compaction is defined as the change in cake height ratio (current cycle cake height divided by initial column height).

Surface Morphology. The surface morphology of 'cempedak' fruit powder was evaluated using a scanning electron microscope (SEM) (LEO 1455 Variable Pressure SEM, Carl Zeiss, Germany). The 'cempedak' fruit powders were attached using a two-sided carbon-conducting tape, and covered with a thin layer of gold using sputter coater (BAL-TEC SCD 005, Japan) (Tonon et al., 2008). Scanning electron micrographs were obtained at an accelerating voltage of 5 kV and digital images were captured at magnifications of 2000×.

Reconstitution of Spray-Dried 'Cempedak' Fruit Powder. 'Cempedak' fruit powder was reconstituted with water to the same solids content as the spray-drier feed (10%). The powder (2.5 g) was mixed with water (25 mL) and mixed with vortex for 2 min (Grabowski et al., 2008). The color of reconstituted 'cempedak' fruit powder was evaluated using a HunterLab UltraScan ColorFlez colorimeter (Hunter Associates Laboratory Inc., Reston, USA) and its change in color (ΔE) was calculated according to Eq. 1.

$$\Delta E = \sqrt{((L - Lo)2 + (a - ao)2 + (b - bo)2)} \quad (1)$$

HunterLab values *L**, *a**, and *b** represents lightness-darkness, greenness-redness, and blueness-yellowness, respectively.

The viscosity of the reconstituted 'cempedak' fruit powder was measured using a Brookfield viscometer (DV-II+Pro, Brookfield Viscometer Ltd., Harlow, England), RheocalcT 3 software programme and small sample adaptor. The viscometer was auto-zeroed prior to analysis. The reconstituted 'cempedak' powder (15 mL) was poured into the sample cup, and analysis was carried out at 20 rpm rotational speed. Viscosity value is expressed in centipoise (cP).

Statistical Analysis

Data obtained from this study was analyzed using one-way ANOVA (Minitab software 17, Minitab Inc., Pennsylvinia, USA) where significant differences in the various treatments were determined using Tukey's test ($p \leq 0.05$). Results were expressed as means ± respective standard deviations of three replicates.

RESULTS AND DISCUSSION

Effects of Different Anticaking Agents on Properties of 'Cempedak' Fruit Powder

In this study, the effect of three different anti-caking agents (calcium phosphate, silicon dioxide, and calcium silicate) were on the properties of the spray-dried 'cempedak' fruit powder was examined. The moisture content, water activity, hygroscopicity, color, change in cake height ratio of 'cempedak' fruit powder after spray-drying are shown in Table 1. Moisture is recognized as a factor that affects caking the most (Chen & Chou, 1993). When powders are stored in a contained packaging, besides the transfer of moisture from environment; if the temperature changes, there may be condensation and evaporation of moisture, which eventually leads to crystallization of powder (Hartmann & Palzer, 2011). Moisture collected on the surfaces of powders causes moisture re-distribution or absorption and contributes to the stickiness of the surfaces. This encourages inter-particle binding, formation of clusters, and inter-particles fusion which eventually leads to caking (Jaya & Das, 2003).

From Table 1, the addition of calcium phosphate caused the biggest reduction of moisture content (17.3 %), followed by silicon dioxide (9.8%), and calcium silicate (3.6%). On the other hand, the 'cempedak' fruit powders had water activities ranging from 0.18-0.21, indicating that all the powders may be considered as stable (Fitzpatrick et al., 2007).

The higher reduction of moisture content in 'cempedak' fruit powder incorporated with calcium phosphate may be due to its ability that can take water up 10% of its weight. Although both silicon dioxide and calcium silicate were reported to have the capability to absorb moisture, the function was not obvious as compared to calcium phosphate in this study (Chung et al., 2001).

The uptake of water by calcium phosphate in kiwi fruit powder, where there was a reduction of moisture content, with slight decrease in water activity (Benlloch-Tinoco et al., 2013). Calcium phosphate was previously added into mango juice to obtain a non-sticky and free-flowing

Table 1
Effects of different anti-caking agents on the properties of ‘cempedak’ fruit powder

Anti-caking agents	No anti-caking agent (control)	Calcium silicate (1.5% w/w)	Silicon dioxide (1.5% w/w)	Calcium phosphate (1.5% w/w)
Moisture content (%)	5.91±0.11[a]	5.70±0.26[ab]	5.33±0.13[b]	4.89±0.07[c]
Water activity	0.22±0.00[a]	0.21±0.01[a]	0.19±0.00[b]	0.18±0.01[b]
Hygroscopicity (g/100 g)	25.00±1.00[a]	26.03±0.55[a]	25.70±0.73[a]	22.67±0.58[a]
$L*_p$	72.63±0.58[a]	70.55±0.61[a]	74.0±1.20[a]	72.83±0.99[a]
$a*_p$	9.17±0.30[a]	7.65±0.95[a]	8.63±1.16[a]	8.03±1.01[a]
$b*_p$	32.11±0.51[a]	28.86±0.50[b]	28.30±0.99[b]	30.38±1.00[b]
Change in cake height ratio	0.31±0.05[a]	0.34±0.05[a]	0.29±0.01[b]	0.20±0.01[b]

Each value represents the mean of triplicate samples ± standard deviation. $L*_p$, $a*_p$, and $b*_p$ = Color of powder. Values within the same row with different superscripts (a-c) are significantly different at $p \leq 0.05$, as measured by Tukey’s HSD test

freeze-dried mango powder (Jaya & Das, 2004). Silicon dioxide (2% w/w) and calcium silicate (2% w/w) were able to improve the physical stability in terms of particle size of powdered sodium ascorbate (Vitamin C) (Lipasek et al., 2011). In the work of Chang et al. (2019), it was reported that calcium phosphate was a more stable anticaking agent as compared to calcium silicate. Calcium phosphate has a higher glass transition temperature that causes better prevention of moisture adsorption as it forms a protection barrier on the dried powder.

In addition, a combination of calcium oxide, calcium silicate and calcium phosphate at the concentration of 0.25% were applied into pineapple powder (Phanindrakumar et al., 2005). It was found that the addition of anti-caking agents caused a decrease of the water uptake (hygroscopicity) when subjected to 43% relative humidity for 12 hours, as compared to control (without anti-caking agents). However, the mechanism and the difference among the effects of each anti-caking agent were not discussed. From Table 1, it is noted that the addition of anti-caking agents did not show significant increase ($p>0.05$) in powder hygroscopicity.

The color of ‘cempedak’ fruit powder incorporated with different anti-caking agents was also recorded in Table 1. The addition of silicon dioxide produced ‘cempedak’ fruit powder with an increase of 2.57 in $L*$value, indicating that the powder was slightly lighter than the ‘cempedak’ fruit powder with no added anti-caking agent and powder incorporated with calcium silicate and calcium phosphate. The addition of all three anti-caking agents did not show any significant effect ($p>0.05$) on powder redness, while decreasing its yellowness (Table 1). However, there were also no significant difference observed in the $b*$ of all powder incorporated with different anti-caking agents. In general, with the addition of anti-caking agents, the total change in color with the incorporation of calcium phosphate (2.22), calcium silicate (4.15), and silicon dioxide (4.63), were of lower range and these small differences were not visible to eye.

Changes in cake height ratio portray the caking characteristics of a powder, where an increase in cake height ratio indicates that a powder has a high tendency to cake (Tze et al., 2012). From Table 1, it can be observed that the addition of calcium phosphate managed to reduce the change in cake height ratio drastically (reduction of 35.4%), while calcium silicate and silicon dioxide did not decrease the change in cake height ratio. This indicates that addition of calcium phosphate reduced the powder's tendency to cake, which is an important criterion for powder storage. The result is in agreement with the addition of calcium phosphate (0.01-0.02 kg/kg) in mango powder, giving the desired free-flowing property to the powder during storage (Tainter & Grenis, 2001).

The SEM morphological images of 'cempedak' fruit powder produced with different anti-caking agents (2000x magnifications) are shown in Figure 1. From the figure, it can be seen that the addition of anti-caking agents improved the surface appearances of 'cempedak' fruit powder. It is also noted that silicon dioxide produced a powder with the smoothest surface, followed by calcium silicate, and lastly, calcium phosphate. From Figure 1, it is found that 'cempedak' fruit powder added with anti-caking agents had lesser holes and dents as compared to the 'cempedak' fruit powder without anti-caking agents. However, the 'cempedak' fruit powder added with silicon dioxide had a smooth surface yet was agglomerated together. Slight wrinkle was found on the surface of 'cempedak' fruit powder incorporated with calcium phosphate.

Dents that are present on the surface of powder, which is attributed to the shrinkage of particles during drying and cooling, have adverse effect on the flow properties of powder particles (Benkovic & Bauman, 2009). The faster degradation rate is often linked with the wrinkled particles, which occurs due to the fast water evaporation, which leads to collapsed hollow spherical structures and thus the formation of microfissures (Ferrari et al., 2013).

The 'cempedak' fruit powder was reconstituted in order to determine its change in color compared to control (without anti-caking agents) as shown in Table 2. From the table, it is found that there was no significant difference (p>0.05) among the color values of 'cempedak' fruit powders (L^*, a^*, b^*) incorporated with different anti-caking agents.

The addition of anti-caking agents increased the viscosity of reconstituted 'cempedak' fruit powder, as shown in Table 2. Although the addition of different anti-caking agents caused a slight increase of viscosity, these viscosities were considered low, indicating that the increase might not be observed. The increase in total solid (with the addition of anti-caking agents), increased the viscosity of reconstituted powder. This accounts for the suspending stabilization of particles in dispersion system (Ferrari et al., 2013).

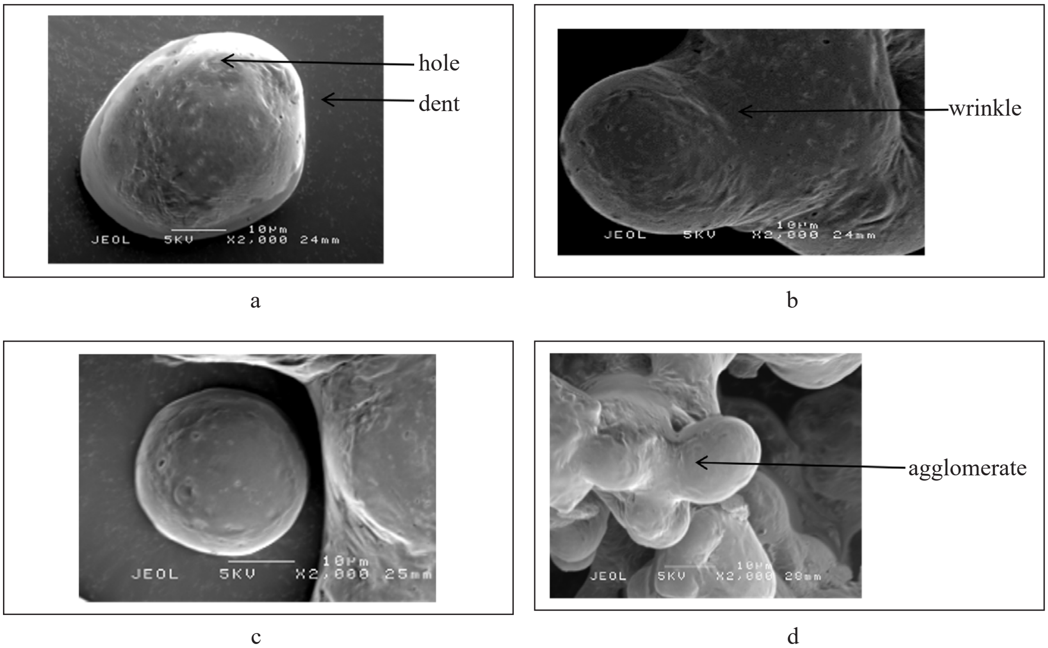

Figure 1. Morphological images of ‘cempedak’ fruit powder produced with different anti-caking agents (2000× magnifications)

Table 2
Effects of different anti-caking agents on the properties of reconstituted ‘cempedak’ fruit powder

Anti-caking agents	No anti-caking agent (control)	Calcium silicate (1.5% w/w)	Silicon dioxide (1.5% w/w)	Calcium phosphate (1.5% w/w)
L^*_{RP}	53.20±1.17[a]	54.11±1.10[a]	55.16±1.03[b]	55.16±0.99[ab]
a^*_{RP}	11.48±0.58[a]	11.78±0.55[a]	10.82±0.05[a]	10.78±0.34[a]
b^*_{RP}	37.74±1.09[a]	34.20±0.61[b]	31.93±0.06[c]	34.60±0.63[b]
ΔE_{RP}	0.00±0.00[a]	3.71±0.60[b]	6.97±0.63[c]	3.85±0.30[b]
Viscosity of reconstituted powder (cP)	3.1±0.0[a]	4.4±0.1[d]	3.8±0.1[c]	3.6±0.1[b]

Each value represents the mean of triplicate samples ± standard deviation. L^*_{RP}, a^*_{RP}, and b^*_{RP} = Color of reconstituted powder, ΔE_{RP} = Change in the color of reconstituted powder. Values within the same row with different superscripts (a-c) are significantly different at $p \leq 0.05$, as measured by Tukey’s HSD test

In general, from the results in Table 2, it is indicated that calcium phosphate was most suitable anti-caking agents as compared to silicon dioxide and calcium silicate in improving the moisture content, water activity, and reduction of caking tendency (low change in cake height ratio).

Effects of Different Concentration of Calcium Phosphate on Properties of ‘Cempedak’ Fruit Powder and Reconstituted Powder

It was found that the mulberry leaf extract (50 mg/mL) had free radical scavenging activity of 49.88±1.23%. A different range of calcium phosphate was applied to analyze its effect in the spray-dried 'cempedak' fruit powder. Results obtained are shown in Table 3. From Table 3, it can be seen that the moisture content of spray-dried 'cempedak' fruit powder was reduced with the addition of 0.66-2.00% calcium phosphate, with a reduction of 17.3-21.3%. Higher solid concentrations produced powders with lower moisture contents (Genovese & Lozano, 2000). The moisture content of less than 5% indicates the acceptable range of fruit powder moisture content (Gallo et al., 2011). Calcium phosphate has been applied in different fruit powders such as kiwi, mango, and pineapple (Benlloch-Tinoco et al., 2013; Jaya et al., 2006; Phanindrakumar et al., 2005).

The water activity with the addition of calcium phosphate (0.18-0.22) indicates the powder is safe microbiologically with water activity values that are in close approximation to 0.2 (Fitzpatrick et al., 2007). The increase in calcium phosphate concentrations led to a reduction in the hygroscopicity of spray-dried 'cempedak' fruit powder (Table 3).

The hygroscopicity of 'cempedak' fruit powder did not reduce further ($p>0.05$) with a further increase in calcium phosphate concentration after 0.66% (w/w), with the total reduction of 9.3-12% in the hygrocsopicity values. This is due to the increase anti-caking agent concentration that acts to create moisture protection barrier for the powder (Phanindrakumar et al., 2005). Thus, the best concentration of calcium phosphate to be incorporated for spray-drying of 'cempedak' fruit powder is 0.66% (w/w).

Table 3
Effects of different calcium phosphate concentrations on properties of 'cempedak' fruit powder

Calcium phosphate concentration (% w/w)	0.00	0.25	0.66	1.50	2.00
Moisture content (%)	5.91 ±0.11[a]	5.44 ±0.14[b]	4.65 ±0.13[c]	4.89 ±0.07[c]	4.85 ±0.30[c]
Water activity	0.22 ±0.00[a]	0.20 ±0.05[b]	0.18 ±0.00[bc]	0.18 ±0.01[b]	0.18 ±0.00[c]
Hygroscopicity (g/100 g)	25.00 ±1.00[a]	23.67 ±0.6[ab]	22.0 ±0.03[b]	22.67 ±0.58[b]	22.00± 0.00[b]
L^*_p	72.63 ±0.58[a]	71.11 ±0.58[a]	71.54 ±0.60[a]	72.83 ±0.99[a]	73.75 ±1.00[a]
a^*_p	9.17 ±0.30[a]	8.77 ±0.85[a]	8.39 ±1.02[a]	8.03 ±1.01[a]	7.64 ±0.95[a]
b^*_p	32.11 ±0.51[a]	31.72 ±1.03[ab]	31.64 ±1.00[ab]	30.38 ±1.00[ab]	30.05 ±0.4[b]
Cake height ratio change	0.31 ±0.05[a]	0.26 ±0.02[b]	0.17 ±0.02[c]	0.20 ±0.01[c]	0.18 ±0.01[c]

Each value represents the mean of triplicate samples ± standard deviation. L^*p, a^*p, and b^*p = Color of powder. Values within the same row with different superscripts (a-c) are significantly different at $p \leq 0.05$, as measured by Tukey's HSD test. P = powder

Microencapsulation of anthocyanin pigment present in *Garcinia indica* Choisy containing 0.25% calcium phosphate was found to have the lowest hygroscopic moisture content of 4.38% (Nayak & Rastogi, 2010). Calcium phosphate (0.01 to 0.02 kg per kg solid) were added on mango in vacuum drying of mango powder, and that optimum amount of calcium phosphate in their study was found to be 0.015kg per kg solid that had low hygroscopicity of 8.33-10.27, however, these values were measured using hygroscopicity measurement apparatus, which is different from this study (Tainter & Grenis, 2001).

There is no significant increase (p>0.05) in the aspect of 'cempedak' fruit powder lightness and redness (Table 3). The addition of 2% calcium phosphate decreased powder yellowness by 4%. In general, the total color difference in powder that ranges from 1.47 to 2.8, indicating that the color difference cannot be detected visually (Obón et al., 2009). It is also found that increase in calcium phosphate concentration leads to the increase in overall color difference (Tainter & Grenis, 2001). The reduction of change in cake height ratio with the addition of 0.66-2.00% (w/w) calcium phosphate is noted in Table 3. The powder flow and degree of caking of mango powder are found to exhibit decreasing trend with the increase of calcium phosphate concentration (0.1 to 0.2 kg/kg) (Jaya & Das, 2004).

Figure 2 shows the SEM morphological images of 'cempedak' fruit powder produced with 0.66% (w/w) calcium phosphate (2000× magnifications). From the figure, it is shown that the surface appearances of 'cempedak' fruit powder with 0.66% (w/w) calcium phosphate were with lesser dent. Table 4 shows the effects of calcium phosphate concentration on total color change and viscosity of reconstituted 'cempedak' fruit powder. It is observed that the total color change of reconstituted 'cempedak' fruit

Table 4
Effects of different calcium phosphate concentrations on properties of reconstituted 'cempedak' fruit powder

Calcium phosphate concentration (% w/w)	0.00	0.25	0.66	1.50	2.00
L^*_{RP}	53.20 ±1.17^{a}	54.97 ±0.04^{ab}	55.16 ±0.61^{ab}	555.16 ±0.99^{ab}	56.88 ±1.03^{b}
a^*_{RP}	11.48 ±0.58^{a}	11.09 ±0.63^{a}	11.00 ±0.71^{a}	10.68 ±0.43^{a}	10.63 ±0.87^{a}
b^*_{RP}	37.74 ±1.09^{a}	36.65 ±0.69^{ab}	36.49 ±0.62^{ab}	34.60 ±0.63^{b}	32.93 ±1.06^{b}
ΔE_{RP}	0.00 ±0.00^{a}	2.01 ±0.10^{b}	2.52 ±0.64^{b}	3.85 ±0.30^{c}	4.1 3±0.32^{c}
Viscosity (cP)	3.1 ±0.0^{a}	3.3 ±0.1^{b}	3.5 ±0.1^{bc}	3.6 ±0.1^{bc}	3.8 ±0.1^{c}

Each value represents the mean of triplicate samples ± standard deviation. L^*_{RP}, $a^*_{RP,}$ and b^*_{RP} = Color of reconstituted powder, ΔE_{RP} = Change in the color of reconstituted powder. Values within the same row with different superscripts (a-c) are significantly different at p≤0.05, as measured by Tukey's HSD test. RP = reconstituted powder

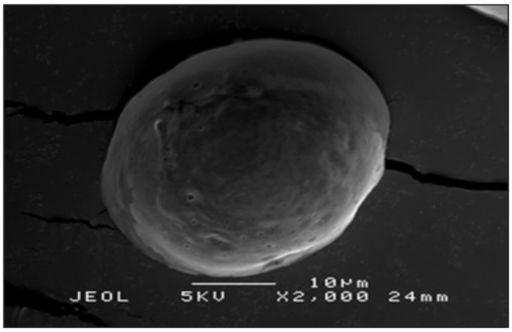

Figure 2. Morphological images of 'cempedak' fruit powder produced with 0.66% (w/w) calcium phosphate (2000× magnifications)

powder increased with the increase of calcium phosphate concentration. The total color changes values that is lesser than 5, obtained from all reconstituted powder, indicates that the color changes were not obvious (Obón et al., 2009). On the other hand, the addition of different concentration of maltodextrin causes a slight increase of viscosity. However, the increase may not be observed as the viscosity values are low.

CONCLUSIONS

This study demonstrated the effects of three anti-caking agents: calcium silicate, silicon dioxide, and calcium phosphate on the characteristic of spray-dried 'cempedak' fruit powder, with the aim of improving powder properties to reduce clumping and caking. Addition of calcium phosphate significantly decreased the moisture content, water activity, and degree of caking of the 'cempedak' fruit powder. The optimal amount of calcium phosphate was calculated as 0.66% (w/w), with a significant reduction of hygroscopicity of 'cempedak' powder. Therefore, 0.66% (w/w) calcium phosphate can successfully be used to improve the 'cempedak' fruit powder properties. However, the packaging material to better protect the powder from caking and absorption of water has to be further examined.

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