Effects of Maltodextrin and Silicon Dioxide Added as Anticaking Agents on the Properties of Instant Date Palm (*Phoenix dactylifera* L.) Powder Using Spray Drying

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***Abstract*—Date palm (*Phoenix dactylifera* L.) is a highly nutritional fruit containing many health benefiting nutrients. The date fruit at Tarm (fully ripened) ripening stage is rejected by consumers as a result of its dark brown skin and bad appearance. Therefore, it is commonly processed into various products. This study aims improve the properties of instant date palm powder (IDPP) produced by spray drying by optimizing the amounts of the anticaking agents Maltodextrin (MD) and Silicon dioxide (SiO_2). MD (20-40 %w/v of date solution) was used in powder preparation then mixed with SiO_2 (0.5-1.5 %w/w of powder) and analyzed for its physicochemical properties and sensory acceptance. The results show that MD and SiO_2 significantly affected on properties of IDPP. Increasing the amount of MD and SiO_2 increased the yield recovery, tapped density and sensory acceptance score, while decreasing moisture content, bulk density, hygroscopicity (HG) and reducing sugar (RS). The optimized amounts of MD and SiO_2 in IDP production were 35.82 %w/v of date solution and 0.72 %w/w of powder respectively. These amounts provided the highest yield recovery (31.45±0.98%), tapped density (649.67±6.98kg/m^3) and sensory acceptance score (powder distribution was 7.6±0.6 and overall liking was 7.3±1.0), as well as the lowest moisture content (4.25±0.12%), bulk density (478.34±10.56kg/m^3) and HG (17.79±0.45%).**

***Index Terms*—date palm, *Phoenix dactylifera* L., spray drying, anticaking agents, Maltodextrin, Silicon dioxide**

I. Introduction

The date palm (*Phoenix dactylifera* L.) is a tropical and subtropical tree which belongs the family Palmae. Date fruit contains high levels of essential nutrients including carbohydrate, mineral, fiber and vitamins. In recent years, worldwide production, utilization and industrialization of dates has increased continuously [1]. In 2004-2014, the worldwide production of dates increased from 6.6 to 7.6 million tons and Asia was the highest date producer [2]. Date fruit contains a high level of carbohydrates (total sugar about 44-88%), fat (0.2-0.5%), protein (2.3-5.6%) and dietary fiber (6.4-11.5%) [3]. In additions, dates are rich in antioxidants and benefit the brain physically through a neuroprotective effect [4].

Besides direct consumption, dates are used to produce several products such as date-paste, date-juice, date-syrup, date-dip, date-jam, and date-sugar. IDPP is a potentially valuable product which can extend the shelf-life of dates, convenient to consume and can be used for many applications, but the trouble of fruit powder production is the stickiness of powder during drying, handling, and storage [5].

Spray drying is a drying technique for transforming liquid food products into powder form. In spray drying, there is an accelerated change in the physical properties of products during the drying process. For the spray drying of high sugar content products, adding large amounts of carrier agents has been the most widely used method to produce a stable powder form [6].

The stickiness of fruit powder is mainly due to the principle component of low molecular weight sugar and some organic acids which have low glass transition temperature (Tg) and high hygroscopicity (HG) [7]. Thus, anticaking agents are used to reduce the stickiness in fruit powder. Reference [8] shows that anticaking agents added in food can reduce caking and improve powder properties such as flowability, moisture content, and caking of powder. For the crystalline ingredient powder, anticaking agents have several mechanisms: 1) reduce moisture; 2) create moisture-protective barriers on the surface of particles; 3) create smooth surfaces of powder particles to reduce inter-particle friction; and 4) inhibit crystal growth that cause solid bridge formation.

This research aim to investigate the function of two kinds of anticaking agents on the physicochemical properties of spray dried IDPP in order to find the optimal amounts for production

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II. Materials and Method

A. Materials

The Deglet-Nour variety of date palm at the Tarm stage of ripening was received from Daily Green (2507) CO., Ltd. (Chiang Mai, Thailand). MD and SiO_2 were purchased from Union Science Co., Ltd. (Chiang Mai, Thailand).

B. Instant Date Palm Powder Preparation

Date palm fruit was pitted and minced to make date paste, then kept at -18 ℃ until used. The date paste was blended with water in a ratio of 1:3 (17 ºBrix) and filtrated through a bilayer of muslin cloth. The date palm solution was mixed with MD (20, 30 and 40 %w/v) and heated to 60 ℃ before dried using a spray dryer (JCM Engineering Concept Co., Ltd, Bangkok, Thailand) at a feed flow rate 0.04 L/min. Inlet and outlet temperature were 180 ℃ and 95 ℃, respectively. The collected powder was kept in a polypropylene bag and stored in desiccator containing silica gel for 1 hour. After that the IDPP was mixed with SiO_2 (0.5, 1.0 and 1.5 %w/w) before winnowed though a 50 mesh sieve. The IDPP was kept in ac aluminium foil bag and stored in desiccator containing silica gel for further analysis.

C. Physicochemical Properties

1) Morphology of IDPP

The microstructures of IDPP were examined using a scanning electron microscope (SEM, JSM5410-LV, JEOL, Japan) with a voltage of 15kV.

2) Yield recovery

Yield recovery was calculated as the ratio of total content of receiving powder to amount of date paste, MD and SiO_2.

3) Moisture content

About 2 g of date powder was spread on an aluminum can and dried using a vacuum oven at 70 ℃ until the weight was constant [9]. Moisture content was expressed as a percentage of moisture per sample weight.

4) Bulk density, tapped density and flowability

3 g of powder was put inside an empty measuring cylinder (10-ml). The bulk density was determined by (1), where "a" is powder mass (kg), "b" is volume of powder (m^3), and "c" is bulk density (kg/m^3).

$$a / b = c \quad (1)$$

After observing the bulk density, the powder containing cylinder was tapped until the volume was stable (the difference of powder volume was less than 0.02 ml). The tapped density was calculated by (2), where "a" is powder mass (kg), "d" is tapped volume (m^3), and "e" is tapped density (kg/m^3).

$$a / d = e \quad (2)$$

Flowability of powder was determined according to [10]. The Hausner ratio (HR) is a value that relates to the flowability of powder or granules. Bulk density and tapped density were used to calculate the HR value following (3). The Carr Index (CI) is relats to the compressibility and flowability and is calculated by (4), where "e" is tapped density, "c" is bulk density, "f" is HR, and "g" is CI. The HR and CI values are described in Table I.

$$e / c = f \quad (3)$$

$$((e - c) / e) * 100 = g \quad (4)$$

TABLE I. Defining the Flowability of HR and CI

HR		**CI (%)**	
1.0-1.1	Free flowing	5-15	Excellent flowability
1.1-1.25	Medium flowing	15-25	Medium flowability
1.25-1.4	Difficult flowing	>25	Poor flowability
>1.4	Very difficult flowing		

5) Hygroscopicity (HG)

Hygroscopicity (HG) was determined using the method of Tze *et al.* [11]. Approximately 1 g of date powder was spread on a glass plate and stored in a desiccator containing saturated solution of Sodium chloride (75.35% RH) for 1 week. After one week, the samples were weighed and HG was calculated as percentages of adsorbed moisture per dry solids.

6) Solubility

Solubility of powder was determined following method of Cano-Chauca *et al.* [12]. 1 g of powder and 100 ml of water were transferred into a blender jar and blended at high velocity for 5 min. The solution was carefully poured in tubes and centrifuged at 3000 rpm for 5 min. About 25 ml of supernatant was removed and the leftover mixture was placed on a weighed glass plate and immediately dried using a hot air oven at 105 ℃ for 5 hours. The solubility (%) was calculated by weight difference.

7) Sugar content

Sugar content as reducing sugar (RS) was determined using a dinitrosalicylic acid (DNS) method according to the method of Miller [13] with some modifications. 1 g samples were extracted with 100 ml of water and shaken for 2 hours after that filtrated through filtrated paper (Whatman No. 1, UK). The clear solution was collected for RS analysis. 0.5 ml of sample solution was mixed with 2 ml of DNS solution, prepared by mixing 1.06 g of dinitrosalicylic acid, 141.6 g of water, 1.98 g of NaOH, 30.6 g of potassium sodium tartrate, 0.83 g of sodium metabisulphite, and 0.76 g of phenol together. The mixture was incubated in a water bath at 95 ℃ then cooled and mixed with 2.5 ml of water before being measured for absorbance at 550 nm. Glucose was used as a standard and RS content was expressed as % dry basis.

D. Sensory Acceptance Test

The IDPP was evaluated by untrained consumers (n=50) using a 9-point hedonic scale [14] with IDPP sensory attributes including powder distribution and overall liking. IDPP was presented in a closed transparent plastic cup coded with a randomized three-digit number. The randomized order of presenting IDPP samples to

consumers was used with 2 groups of samples (5 samples per group). Tests were performed in individual air-conditioned booths (25 ℃) in the Sensory Evaluation and Consumer testing Laboratory (Devision of Product Development Technology, Faculty of Agro-Industry, Chiang Mai University, Chiang Mai, Thailand).

E. Experimental Design and Statistical Analysis

The experiment was created using 3^2 factorial design with 2 center points, two kinds of anticaking agents, with MD and SiO_2 varied according to Table II. All data analyzed was carried out in triplicate and reported as mean ± standard deviation of mean (SD). The Duncan's Multiple Range test (DMRT) was used to analyze mean separation using the SPSS 17.0 (SPSS Inc., IBM Corp., IL, USA) program with the significant level determined at 95% confidence limit (p<0.05). Response surface methodology (RSM) was used to analyze data results by the design expert program (Design 6.0.2, Stat-Ease, Inc., MN) to optimize a suitable formula for producing IDPP.

TABLE II. THE VARIATION OF ANTICAKING AGENTS IN IDPP PRODUCTION USING 3^2 FACTORIAL DESIGN WITH 2 CENTER POINTS

Treatment	Coded		Actual	
	A	B	MD (%w/v)	SiO_2 (%w/w)
1	-1	-1	20	0.50
2	0	-1	30	0.50
3	1	-1	40	0.50
4	-1	0	20	1.00
5	0	0	30	1.00
6	1	0	40	1.00
7	-1	1	20	1.50
8	0	1	30	1.50
9	1	1	40	1.50
10	0	0	30	1.00

III. RESULTS AND DISCUSSION

A. Physicochemical Properties

IDPP produced according to the experimental design was analyzed for physicochemical properties and sensory acceptance. The morphology of IDPP is shown in Fig. 1. With a low content of MD (20%w/v), which provided low feed solid concentration, there were large spherical particles with an absence of surface cracks. Additionally, the particles were coagulated together with solid bridge formations (Fig. 1a and 1b). On the other hand, the powder with the higher feed solid concentration had smaller spherical shaped particles with less agglomeration and some surface cracks (Fig. 1c and 1d). From the comparison of Fig. 1a and Fig. 1b, it was found that the solid bridge formation of particles was reduced through an increase of SiO_2. Fig. 1e shows the particles of IDPP produced with MD 30%w/v and SiO_2 1.0%w/w. These particles maintained their spherical shape with some agglomeration and surface cracks. The difference in powder characteristics was caused by the difference in feed solid content. This cause agrees with the research of Chegini and Ghobadian [15] who found that low feed solid content (high feed flow) increased the particle size and moisture content of spray dried orange juice powder.

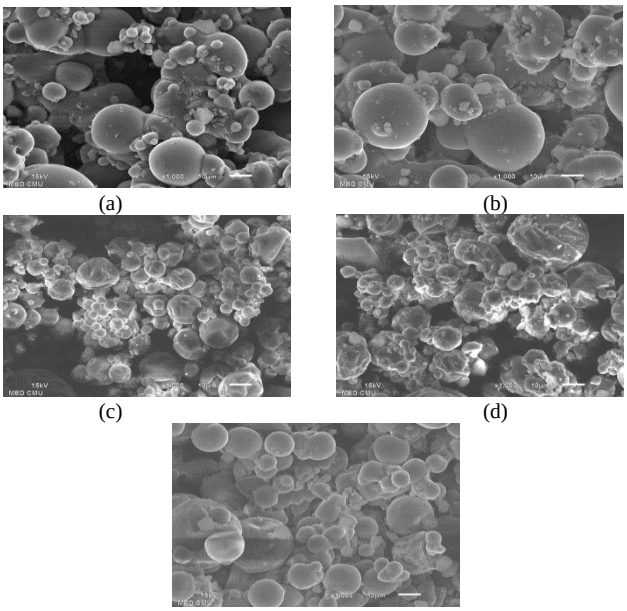

Figure 1. SEM photographs of IDPP at (a) MD 20%w/v and SiO_2 0.5%w/w; (b) MD 20%w/v and SiO_2 1.5%w/w; (c) MD 40%w/v and SiO_2 0.5%w/w; (d) MD 40%w/v and SiO_2 1.5%w/w and (e) MD 30%w/v and SiO_2 1.0%w/w.

The results demonstrate that all physicochemical properties and sensory acceptances were significantly different, as shown in Table III. There were eight responses from physicochemical properties and two responses from consumer acceptance that fit to create the regression model. The relationship between MD and SiO_2 is explained in Table IV.

The yield recovery ranged from 28.65±1.84% to 37.94±1.02% and the highest yield recovery was from MD and SiO_2 at 40%w/v and 1.0%w/w, respectively. The yield recovery was affected by increasing the amount of MD as shown in Fig. 2a. The consequences of the addition of MD was a reduction in sticky point temperature and improved handling properties of fruit powder and is in concurrence with the research of Jaya and Das [7]. Furthermore, the results concur with the finding of Quek *et al.* [16] in that MD was a good encapsulant for low molecular weight sugars such as glucose, fructose, sucrose, and organic acids which Improve the yield recovery of powder by reducing the moisture content and stickiness of the spray-dried product.

For moisture content, IDPP produced with MD at 40%w/v and SiO_2 at 1.5%w/w provided the lowest moisture content whereas MD at 20%w/v and SiO_2 at 1.0%w/w provided the highest moisture content. Increasing MD and SiO_2 reduced the moisture content of IDPP as shown in Fig. 2b. As reported by Mishra *et al.* [17] who researched the properties of spray-dried amla powder, increasing the MD content reduced the moisture content of the powder by increasing solid content and reducing the total moisture for evaporation.

TABLE III. PHYSICOCHEMICAL AND SENSORY PROPERTIES OF IDPP

T[1]	Yield recovery (%)	Moisture Content (%)	Bulk density (kg/m^3)	Tapped density (kg/m^3)	Hausner Ratio (HR)	Carr Index (CI) (%)	Solubility (%)	Hygrosc-opicity (HG) (%)	Reducing sugar (RS) (g Glucose /100g dry)	Powder Distri-bution	Overall liking
1	29.48 ±1.58^{b}	5.59 ±0.04^{b}	407.98 ±11.31^{e}	544.63 ±5.46^{f}	1.34 ±0.04^{b,c,d}	25.08 ±2.24^{b,c}	97.21 ±1.90^{a,b}	23.92 ±0.24^{a}	50.33 ±0.23^{c}	3.9 ±1.0g	5.2 ±0.6e
2	29.85 ±1.60^{b}	4.29 ±0.03^{e}	459.55 ±10.42^{b}	577.15 ±4.81^{e}	1.26 ±0.03^{e}	20.37 ±2.17^{d}	93.32 ±1.59^{c,d}	21.19 ±0.08^{b}	43.71 ±0.09^{f}	7.0 ±0.6d	7.0 ±0.6a
3	36.09 ±1.05^{a}	4.05 ±0.05^{f}	436.81 ±2.21^{c,d}	675.59 ±18.27^{b,c}	1.55 ±0.04^{a}	35.32 ±1.46^{a}	94.95 ±3.03^{b,c,d}	17.60 ±0.19^{f,g}	41.56 ±0.07^{h}	7.7 ±0.4b	6.8 ±0.6b
4	28.65 ±1.84^{b}	6.24 ±0.04^{a}	417.28 ±10.69^{d,e}	572.15 ±11.67^{e}	1.37 ±0.04^{b,c}	27.05 ±2.27^{b,c}	97.56 ±2.42^{a,b}	23.86 ±0.16^{a}	51.24 ±0.04^{b}	6.4 ±0.6e	5.6 ±0.6d
5	29.34 ±0.91^{b}	4.64 ±0.05^{c}	505.17 ±13.11^{a}	642.56 ±21.06^{d}	1.27 ±0.04^{d,e}	21.34 ±2.78^{d}	95.09 ±2.96^{a,b,c,d}	20.53 ±0.26^{c}	46.64 ±0.16^{e}	7.0 ±0.4c,d	6.6 ±0.5b
6	37.94 ±1.02^{a}	3.77 ±0.02^{g}	461.25 ±17.77^{b}	695.15 ±20.37^{a,b}	1.51 ±0.04^{a}	33.65 ±1.74^{a}	91.82 ±1.03^{d}	17.36 ±0.16^{g}	40.93 ±0.07^{i}	8.2 ±0.6a	7.0 ±0.6a
7	28.53 ±1.53^{b}	5.56 ±0.03^{b}	421.49 ±9.21^{d,e}	585.39 ±9.39^{e}	1.39 ±0.02^{b}	28.00 ±1.19^{b}	96.67 ±0.76^{a,b,c}	24.04 ±0.09^{a}	51.61 ±0.16^{a}	5.2 ±0.7f	5.2 ±0.5e
8	30.63 ±1.25^{b}	4.52 ±0.04^{d}	508.57 ±13.99^{a}	667.97 ±20.16^{c,d}	1.31 ±0.01^{c,d,e}	23.86 ±0.77^{c,d}	95.36 ±0.34^{a,b,c,d}	19.55 ±0.07^{e}	43.24 ±0.05^{g}	6.6 ±0.5e	6.0 ±0.5c
9	36.63 ±0.72^{a}	3.45 ±0.12^{h}	454.22 ±14.52^{b,c}	710.52 ±9.10^{a}	1.57 ±0.06^{a}	36.06 ±2.22^{a}	94.35 ±1.43^{b,c,d}	17.71 ±0.04^{f}	40.46 ±0.06^{j}	7.2 ±0.4	6.7 ±0.5b
10	29.72 ±1.48^{b}	4.67 ±0.04^{c}	509.88 ±11.83^{a}	647.16 ±8.15^{d}	1.27 ±0.04^{d,e}	21.20 ±2.19^{d}	98.68 ±1.75^{a}	20.01 ±0.05^{d}	47.81 ±0.12^{d}	7.2 ±0.7c,d	7.0 ±0.4a
p values	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.009	<0.001	<0.001	<0.001	<0.001

The different letter in the same column mean significant difference ($p \leq 0.05$)
T[1]=Treatments are in Table I

TABLE IV. REGRESSION EQUATION OF SIGNIFICANT RESPONSES FROM IDPP USING RSM (A = MD AND B = SiO_2)

Attributes	Regression equation (coded)	R^2	*p* values
Yield recovery (%)	29.91 + 4.00A + 0.06B + 3.01A^2 - 0.05B^2 + 0.37AB	0.002	0.9782
Moisture content (%)	4.68 - 1.02A - 0.07B + 0.30A^2 - 0.30B^2 - 0.14AB	0.0054	0.9644
Bulk density (kg/m^3)	503.43 + 17.59A + 13.32B - 60.07A^2 - 15.28B^2 + 0.98AB	0.0073	0.9582
Tapped density (kg/m3)	639.81 + 63.18A + 27.75B - 1.11A^2 - 12.20B^2 - 1.46AB	0.0060	0.9623
Hausner Ratio (HR)	1.27 + 0.09A + 0.02B + 0.17A^2 + 0.02B^2 - 0.01AB	0.0005	0.9897
Carr Index (CI) (%)	21.29 + 4.15A + 1.19B + 9.04A^2 + 0.80*B^2 - 0.54AB	0.0040	0.9903
Hygroscopi-city (HG) (%)	20.24 - 3.19A - 0.24B + 0.40A^2 + 0.16B^2	0.0002	0.9815
RS (g Glucose /100g dry)	46.18 - 5.04A - 0.05B + 0.95A^2 - 1.66B^2 - 0.59AB	0.0103	0.9502
Powder distribution	7.37 + 1.29A + 0.07B - 0.36A^2 - 0.87B^2 - 0.45AB	0.0289	0.9151
Overall liking	6.83 + 0.73A - 0.17B - 0.54A^2 - 0.34B^2 - 0.03AB	0.0237	0.9235

For bulk density, the values ranged from 407.98 ±11.31 to 509.88 ±11.83 kg/m^3. MD at 20%w/v and SiO_2 at 1.0%w/w showed the lowest bulk density, while MD at 30%w/v and SiO_2 at 1.0%w/w showed the highest bulk density. The bulk density increased by adding low amounts MD and SiO_2 and decreased by adding high amounts MD and SiO_2 (Fig. 2c). IDPP with a low amount of MD and SiO_2 showed high moisture content and agglomeration of particles that provided a high powder mass which resulted in the increasing of bulk density. On the other hand, the IDPP produced with high amount of MD and SiO_2 provided low moisture content and smaller particles which were more loosely agglomerated. This IDDP had low powder mass and more porous which resulted in the decreasing of bulk density. The loose agglomeration of IDPP which was produced with a high amount of MD and SiO_2 was caused by hydrogen bonding formed between IDPP particles and SiO_2. Similar results were found in the research of Jonat *et al.* [18], who studied the glidant properties of compacted colloidal silicon dioxide. They stated that a high density hydroxyl group at the surface of excipients was available for conformation of hydrogen bonding with a hydrophilic colloid such as silicon dioxide. Our findings are in agreement with those of Juliano and Barbosa-Cánovas [19] who studied the flowability characterization of food powder. They stated that anticaking agents such as silicon dioxide reduced the caking of food powder by interfering with the liquid bridge and inhibiting the crystal growth of food powder. The tapped density of IDPP showed that the

highest tapped density was achieved with 40%w/v of MD and 1.0%w/w of SiO_2 whereas powder produced at 20%w/v and 0.5%w/w of MD and SiO_2 had the lowest tapped density. While the increasing of MD and SiO_2 increased tapped density of IDPP (Fig. 2d), the high tapped density powder resulted in a low caking-risk powder. In this case low bulk density and high tapped density are considered good characteristics of IDPP.

HR and CI are values which describe the flowability of powder. HR ranged from 1.26±0.03 to 1.57±0.06. It described the flowability of IDPP from difficult flowing to very difficult flowing. HR was affected by the increasing of MD and SiO_2 which increased HR as shown in Fig. 2e. In addition, CI expressed the same trend of powder flowing as medium flowability to poor flowability (20.37±2.17% to 36.06±2.22%). The increasing of MD and SiO_2 increased the CI of IDPP (Fig. 2f). Flowability was affected by SiO_2 properties and lower particle size powder [19]. Reducing sugar content is the main cause of stickiness and high HG of IDPP. The results showed that increasing MD and SiO_2 reduced the RS content and HG of IDPP (Fig. 2g and 2h). The lowest RS content (40.46±0.06 glucose/ 100g dry weight) was from 40%w/v of MD and 1.5%w/w of SiO_2, while the lowest HG (17.36±0.16%) was achieved from 40%w/v and 1.0%w/w of MD and SiO_2. It was confirmed that the HG of food powder depends on RS content as described in the research of Jaya and Das [7]. MD was a good carrier agent which modified the balance of hydrophilic/hydrophobic particles in date powder, and provided less water adsorption as stated in the research of Farahnaky *et al.* [20]. Moreover, IDPP produced with a low amount of MD and SiO_2 provided high solubility in relation to the RS content. The finding is in agreement with the research of Ferrari *et al.* [21] who studied the physicochemical properties of spray-dried blackberry powder (BP). They found that MD was an effective carrier agent for spray-dried BP as it produced less hygroscopic activity, low bulk density, low moisture and high antioxidant activity in BP.

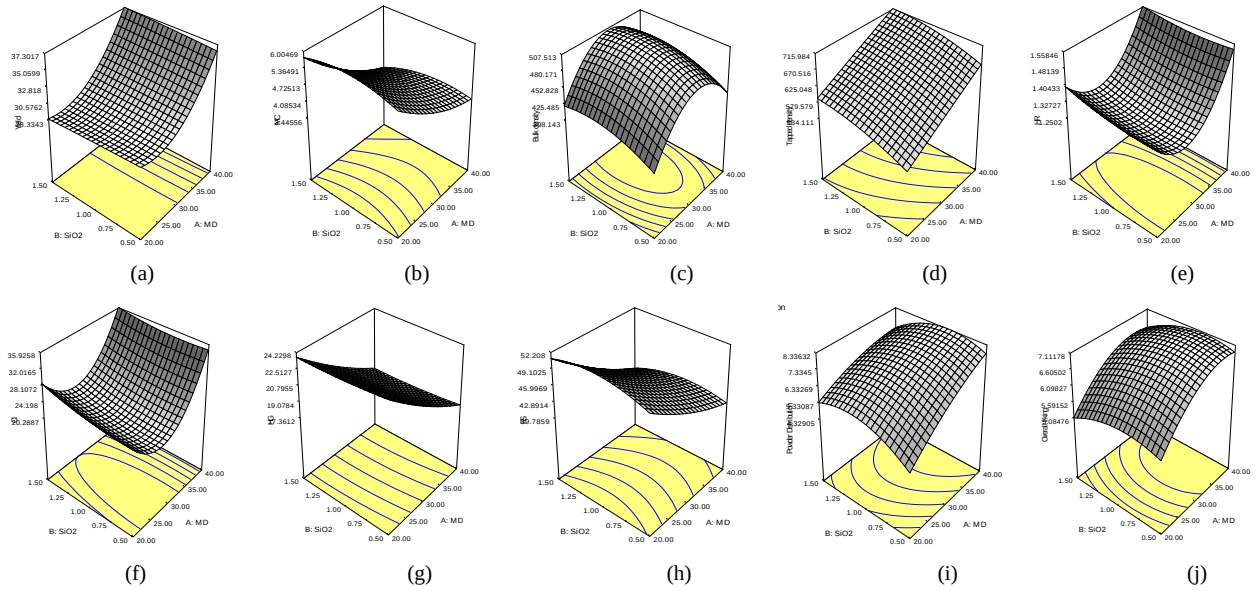

Figure 2. The response surface demonstrate the influence of MD and SiO_2: (a) Yield recovery, (b) Moisture content, (c) Bulk density, (d) Tapped density, (e) Hausner ratio, (f) Carr index, (g) Hygroscopicity, (h) Reducing sugar, (i) Powder distribution and (j) Overall liking.

B. *Sensory Acceptance*

Sensory acceptance was determined by untrained consumers (50 persons) with a 9-point hedonic scale. The liking scores of powder distribution and overall liking ranged from 3.9±1.0 to 8.2±0.6 and 5.2±0.5 to 7.0±0.6, respectively (Table III). The lowest score of powder distribution was IDPP at 20%w/v and 0.5%w/w of MD and SiO_2 respectively, whereas IDPP with 40%w/v of MD and 1.0%w/w of SiO_2 provided the highest score.

Overall liking was found to have the same score trend. Contour plots and regression equations of both attributes showed that the increasing of MD increased the liking score for both attributes but the increasing of SiO_2 decreased the liking scores for both attributes (Fig. 2i and 2j).

C. *Optimization and Validation of IDPP*

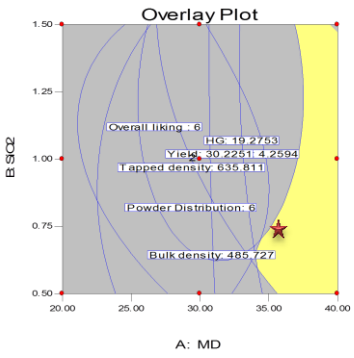

Figure 3. The overlay plot of the response surface demonstrates the optimum formula of IDPP produced with MD (%w/v) and SiO_2 (%w/w)

RSM was used to optimize a suitable formula for IDPP production. As the criteria for responses, yield recovery, tapped density powder distribution and overall liking were defined to the maximum value while moisture content, bulk density and HG were defined to the minimum value. Fig. 3 shows the overlay plot of MD and SiO_2 with the optimized point of MD and SiO_2 at 35.82%w/v and 0.72%w/w respectively. The prediction value of IDPP attributes of yield recovery, moisture content, bulk density, tapped density, HR, CI, HG, RS content, powder distribution and overall liking were 33.09%, 4.18%, 481.23 kg/m^3, 657.96 kg/m^3 1.37, 26.52%, 18.69%, 43.29 g Glucose/ 100g dry weight, 7.84 and 7.08 respectively. Optimized IDPP was produced and analyzed for all responses as the validation value. The prediction value and validation value were expressed in Table V with approximated errors below 10%.

TABLE V. COMPARISON OF PREDICTION VALUE AND VALIDATION VALUE (N=3) OF IDPP

Responses	Prediction value	Validation value	Approximated error (%)
Yield recovery (%)	33.09	31.45±0.98	4.96
Moisture content (%)	4.18	4.25±0.12	1.67
Bulk density (kg/m^3)	481.23	478.34±10.56	4.96
Tapped density (kg/m^3)	657.96	649.67±6.98	1.67
Hausner ratio (HR)	1.37	1.36±0.04	0.60
Carr index (CI)	26.52	26.37±0.04	1.26
Hygroscopicity (HG)	18.16	17.79±0.45	0.86
Reducing sugar (RS)	43.29	42.57±0.12	0.56
Powder distribution	7.8	7.5±0.6	2.0
Overall liking	7.1	7.3±1.0	1.7

IV. CONCLUSIONS

The addition of MD and SiO_2 in spray dried IDPP improve the properties of the powder. The physicochemical properties and sensory acceptance score indicated the most suitable formula of IDPP production using a spray drying technique was with MD at 35.82%w/v and SiO_2 at 0.73%w/w. These values provided the highest yield recovery, tapped density and sensory acceptance along with the lowest moisture content, bulk density and HG. Thus, the researchers conclude that the aforementioned values of MD and SiO_2 will produce the best IDPP for commercial production and consumer consumption.

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REFERENCES

[1] M. Chandrasekaran and A. H. Bahkali, "Valorization of date palm (*Phoenyx dactylifera*) fruit processing by-products and wastes using bioprocess technology – Review," *Saudi J. Biolog. Sci.*, vol. 20, pp. 105-120, 2013.
[2] FAO. (May 2017). Food and Agriculture Organization of the United Nations. [Online]. Available: http://www.fao.org/faostat/en/#data/QC/visualize
[3] W. Al-shahib and R. J. Marshall, "The fruit of the date palm: Its possible use as the best food for the future?" *Int. J. Food Sci. Nutr.*, vol. 54, no. 4, pp. 247-259, 2003.
[4] W. I. W. Ismail and M. N. F. M. Radzi, "Evaluation on the benefits of date palm (*Phoenyx dactylifera*) to the brain," *Altern. Integ. Med.*, vol. 2, no. 4, pp. 2327-5162, 2013.
[5] S. Jaya, H. Das, and S. Mani, "Optimization of maltodextrin and tricalcium phosphate for producing vacuum dried mango powder," *Int. J. Food Prop.*, vol. 9, pp. 13-24, 2006.
[6] B. R. Bhandari, N. Datta, and T. Howes, "Problems associated with spray drying pf sugar-rich foods," *Dry. Technol.*, vol. 15, no. 2, pp. 671-684, 1997.
[7] S. Jaya and H. Das, "Glass transition and sticky point temperatures and stability/molibility diagram of fruit powder," *Food Bioprocess. Technol.*, vol. 2, no. 1, pp. 89-95, 2009.
[8] R. A. Lipasek, J. C. Ortiz, L. S. Taylor, and L. J. Mauer, "Effects of anticaking agents and storage conditions on the moisture sorption, caking, and flowability of deliquescent ingredients," *Food Res. Int*., vol. 45, pp. 369-380, 2012.
[9] AOAC (Associztion of Official Analytical Chemists International), *Official Methods of Analysis*, 16th ed., Maryland, USA, 1998.
[10] N. L. Tze, C. P. Han, Y. A. Yusof, C. N. Ling, R. A. Talib, F. S. Taip, and M. G. Aziz, "Physicochemical and nutritional properties of spray-dried pitaya fruit powder as natural colorant," *Food Sci. Biotechnol.*, vol. 21, no. 3, pp. 675-682, 2012.
[11] K. Muzafar and P. Kumar, "Parameter optimization for spray drying of tamarind pulp using response surface methodology," *Powder Technol.*, vol. 279, pp. 179-184, 2015.
[12] M. Cano-Chauca, P. C. Stringheta, A. M. Ramos, and J. Cal-Vidal, "Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization," *Innov. Food Sci. Emerg.*, vol. 6, pp. 420-428, 2005.
[13] G. L. Miller, "Use of dinitrosalicylic acid reagent for determination of reducing sugar," *Anal. Chem.*, vol. 31, no. 3, pp. 426-428, 1959.
[14] A. V. A. Resurreccion, "Consumer sensory testing for product development," An Aspen Publication, Maryland, 1998.
[15] G. R. Chegini and B. Ghobadian, "Effect of spray-drying conditions on physical properties of orange juice powder," *Dry. Technol.*, vol. 23, pp. 657-668, 2005.
[16] S. Y. Quek, N. K. Chok, and P. Swedlund, "The physicochemical properties of spray-dried watermelon powders," *Chem. Eng. Process.*, vol. 46, pp. 386-392, 2007.
[17] P. Mishra, S. Mishra, and C. L. Mahanta, "Effect of maltodextrin concentration and inlet temperature during spray drying on physicochemical and antioxidant properties of amla (*Emblica officinalis*) juice powder," *Food Bioprod. Process.*, vol. 92, pp. 252-258, 2014.
[18] S. Jonat, P. Albers, A. Gray, and P. C. Schmidt, "Investigation of the glidant properties of compacted colloidal silicon dioxide by angle of repose and x-ray photoelectron spectroscopy," *EUR. J. Pharm. Biopharm.*, vol. 63, pp. 356-359, 2006.
[19] P. Juliano and G. V. Barbosa-Cánovas, "Food powders flowability characterization: Theory, methods, and applications," *Annu. Rev. Food Sci. Technol*., vol. 1, pp. 211-239, 2010.
[20] A. Farahnaky, N. Mansoori, M. Majzoobi, and F. Badii, "Physicochemical and sorption isotherm properties of date syrup powder: Antiplasticizing effect of maltodextrin," *Food Bioprod. Process.*, vol. 98, pp. 133-141, 2016.

[21] C. C. Ferrari, S. P. M. Germer, I. D. Alvim, F. Z. Vissotto, and J. M. D. Aguirre, "Influence of carrier agents on the physicochemical properties of blackberry powder produced by spray drying," *Int. J. Food Sci. Tech.*, vol. 47, pp. 1237-1245, 2012.

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K. Suthapakti, R. Molloy, W. Punyodom, K. Nalampang, T. Leejarkpai, P. D. Topham, and B. J. Tighe, "Biodegradable compatibilized blends of poly(L-lactide) and thermoplastic polyurethane: design, preparation and property testing," *Journal of Polymers and the Environment (Published online)*, 2017.

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R. Samakradhamrongthai, P. Thakeow, P. Kopermsub, and N. Utama-ang, "Application of multi-core encapsulated *Michelia alba* D.C. flavor powder in Thai steamed dessert (*Nam Dok Mai*)," *Chiang Mai Journal of Science*, vol. 44, no. 2, pp. 557-572, 2017.

N. Laokuldilok, P. Thakeow, P. Kopermsub, and N. Utama-Ang, "Optimization of microencapsulation of turmeric extract for masking volatile flavors," *Food Chemistry*, vol. 194, pp. 695-704, 2016.

T. Boonchu and N. Utama-Ang, "Optimization of extraction and microencapsulation of bioactive compounds from red grape (*Vitisvinifera* L.) pomace," *Journal of Food Science Technology*, vol. 52, no. 2, pp. 783-792, 2015.

Hirun, N. Utama-Ang, Q. V. Vuong, and C. J. Scarlett, "Investigating the commercial microwave vacuum drying conditions on the physicochemical properties and radical scavenging ability of Thai green tea," *Drying Technology*, vol. 32, no. 1, pp. 47-54, 2014.