Research Article

Effect of Spray Drying Air Temperature to the Changes of Properties of Skimmed Coconut Milk Powder

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Abstract
This study investigated different conditions for producing suitable skimmed coconut milk powder using spray drying process. Skimmed coconut milk is a by-product of the virgin coconut oil extraction process. The skimmed coconut milk was composed of 6.4% protein, 0.27% fiber, 6.27% sugar, 3.6% fat and 86.93% moisture content. Spray drying involved an inlet flow rate of 0.27 m^3/s, temperatures between 190 and 210°C and the use of 15 and 20% maltodextrin as drying aid. As inlet and outlet temperatures increased, the product yield, moisture content, bulk density and wettability reduced. The particle size of skimmed coconut milk powder was found to be 250 µm. The average percentage of solubility of the skimmed coconut milk powder in the current study was 39.57%. The amino acid content analysis was carried out using the HPLC method to reveal the glutamic acid and arginine acid as non essential amino acid. The color of skimmed coconut milk powder at high inlet temperatures caused significant changes in L* and b* and high maltodextrin concentrations caused significant changes of a* ($p < 0.05$). The optimum yield of skimmed coconut milk powder was 18.65% when using 20% maltodextrin with an inlet temperature of 190°C and an outlet temperature of 80°C for spray drying.

Keywords: Skimmed coconut milk, Virgin coconut oil, Coconut protein, Maltodextrin, Spray drying

1 Introduction

Coconut is a versatile crop and an essential ingredient in many food products. Coconut milk, an emulsion of milky, oil and water is generally obtained from coconut meat [1]. Because coconut milk can easily lose the stability of the emulsion, many processing methods to preserve and extend the shelf-life particularly canning, spray-drying and freezing, and new ways to use coconut milk in food preparation have been developed [2]. The virgin coconut oil (VCO) can be separated from coconut milk using the cold virgin oil extraction process. The VCO is currently a popular ingredient in skincare, food and health products. The VCO differs from other vegetable oils due to its high content of medium chain fatty acids specifically lauric acid. The traditional VCO preparation is separated by a fermentation method, where the coconut milk is fermented for 24–36 h to separate into two phases with the VCO stays in the top phase [3]. There are some proteins present in the aqueous phase of the coconut milk emulsion that could act as an emulsifier to stabilize the fat globules [4]. The coconut milk emulsion can also be prepared via many processes such as enzymatic treatment, heating and freeze thawing [5].

VCO is obtained by using a batch centrifuge at the speed of 5,500 rpm at room temperature for 30 min [6]. The coconut kernel residues obtained after coconut milk extraction and VCO were analyzed for their potential use as dietary fibers [7].

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The VCO extraction process generates a lot of whey or skimmed coconut milk which is rich in edible proteins that currently is being considered as a waste [8]. Instead of being a waste that can cause water pollution, the skimmed coconut milk can be dried and used as edible powder used in soft drink or food product.

Before the spray-drying process, the feed is mixed with carrier agents such as maltodextrin (MD) or arabic gum (AG). Some drying carriers such as MD and AG are usually used in the feed to overcome the problems of temperature and relative humidity [9]–[11]. MD is the most popular adjunct in spray drying due to its physical properties such as high water solubility; AG is recommended for fruit juice drying due to its emulsification properties and because it dissolves easily in water [12].

Spray drying is a technique commonly used in the food industry to make food powder due to its effectiveness under optimum conditions [10]. The optimum conditions for spray drying of coconut milk with added MD (DE10) at 40–45% of coconut milk content with respect to corresponding studied were inlet temperature of 180°C and the feed rate of 0.9 L/h [13]. Fang and Bhandari [14] reported that high efficiency of the bayberry juice spray drying process was achieved by adding MD (DE 10) or Arabic gum. Due to the short period of heat contact and the high rate of evaporation and high percentage of powder recovery. The objective of this research was to study effect of hot air spray drying temperature and concentration of MD on the properties of skimmed coconut milk powder.

2 Materials and Methods

2.1 *Sample preparation*

Fresh mature coconut (10–12 months) from Prachuap Khiri Khan province, Thailand was used. The coconut husk and water were first removed and the coconut meat was finely grated using coconut grater machine. The finely ground coconut meat was squeezed using a screw press machine to obtain coconut milk and residue. Then coconut milk was extracted to obtain VCO and skimmed coconut milk by using a continuous centrifugal cream separator (Elecream Cream Separators, Model N° 80, Los Angeles, USA) operated at 12,000 rpm with a flow rate of 10 L/h. Then skimmed coconut milk was spray dried to get skimmed

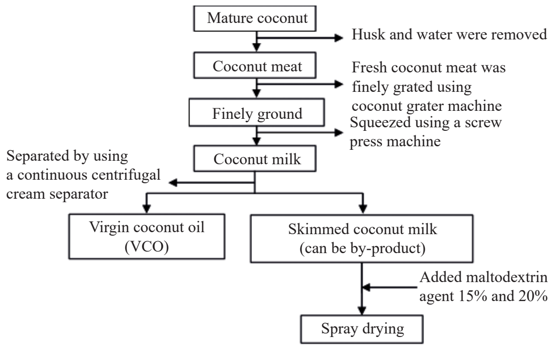

Figure 1: VCO extraction process and preparation of skimmed coconut milk for spray-drying experiment.

coconut milk powder. The samples were prepared by blending the skimmed coconut milk (approximately 7°Brix of total solids) with MD to obtain 15% and 20% final MD concentrations (Figure 1).

2.2 *Analytical methods of raw material*

Skimmed coconut milk was analyzed for chemical compositions including protein, carbohydrate, dietary fiber, sugar, fat and moisture content by using in – house method based on the AOAC official method given in [15]. This part was carried out at Animal Feed Analysis Laboratory, Department of Animal Science, Kasetsart University, Kamphaeng Saen Campus (Thailand).

2.3 *Spray-drying process*

The sample was processed using a small-scale spray dryer (SD – 01, HVAC Engineering Co., Ltd, Pathum Thani, Thailand), which operated at constant 0.27 m^3/s air flow and 47.26 mL/min raw material feed rates. The spray – drying conditions were inlet air temperatures of 190, 200 and 210°C and outlet air temperatures of 80, 85 and 90°C at MD 15 and 20%. Dried product powder was collected in a glass bottle at the base of the cyclone and stored in airtight containers (Figure 2). In this study, a counter-current flow direction was used such that the liquid feed was subjected to the counter current of the heated air from the inlet of the chamber resulting in a uniform heated-air temperature with low humidity which further increased the driving force for mass transfer. The skimmed coconut milk powder was collected immediately in the foil bag attached to the vacuum seal and stored at room temperature.

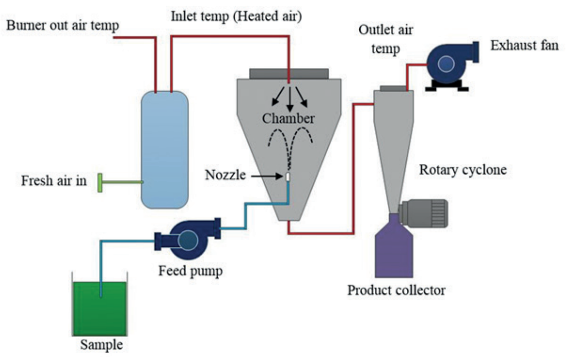

Figure 2: Diagram of the modified spray dryer used in this study.

2.4 *Analytical methods of skimmed coconut milk powder properties*

The skimmed coconut milk powder was analyzed to determine product yield, moisture content, bulk density, wettability, particle size, solubility and amino acid profile.

2.4.1 Product yield

The product yield of samples after spray drying was calculated according to reported equation given in [16]. [Equation (1)]:

$$\text{Product yield (\%)} = \frac{\text{Obtained spray dried power (g)}}{\text{Skimmed coconut milk (g)} + \text{Maltodextrin(g)}} \times 100 \quad (1)$$

2.4.2 Moisture content

The moisture content was determined by holding 5 g of samples for 1 min in a moisture analyzer (model MX-50, A&D Co., Ltd Tokyo, Japan) [17].

2.4.3 Bulk density

The bulk density was determined according to Shittu and Lawal [18]. A 20 g of skimmed coconut milk powder was put into a 100 mL graduated cylinder and tapped by hand 10 times on a soft surface. The bulk density was calculated by dividing the weight of the skimmed coconut milk powder by the volume.

2.4.4 Wettability

Wettability was evaluated using the skimmed coconut milk powder solubility in water. This method quantifies the wettability of powders by the length of time needed to achieve complete wetting of a given quantity of tested powder starting measuring when it was gently dropped on the surface of water until it immersed in the water without agitation [19]. This experiment was modified from Fatimah, Gugule and Tallei [20] as followed: The 10 g of skimmed coconut milk was poured into 250 mL beaker glass containing 150 mL of distilled water at 25°C. The total time in minute for the powder to completely immerse was measured.

2.4.5 Particle size

The method used to determine the particle size was modified from Shittu and Lawal [18] and Vissotto *et al.* [21]. A total of 100 g of skimmed coconut milk powder was sieved through a set of standard sieves with pore size of 38, 53, 150 and 250 µm, respectively, for 5 min using a mechanical sieve shaker (Retsch Co. Ltd., Haan, Germany). The weight of the sample retained on each sieve was recorded and used to calculate the mass fraction which was defined as the sample weight retained on the sieve divided by the total sample weight.

2.4.6 Solubility

The solubility was determined according to Shittu and Lawal [18]. About 5 g of the skimmed coconut milk powder was suspended in 50 mL of water at 30°C in a centrifuge tube. The suspension was stirred continuously for 30 min before centrifugation at 9,500 rpm for 10 min and drying at 105°C until the weight was constant. The weight of solids recovered after drying was used to calculate the water solubility (%).

2.4.7 Amino acid analysis

Amino acid analysis was performed using Accq-tag analysis of the hydrolysate (AccQ – Fluor™ Reagent Kit, Milford, MA, USA) for 17 amino acid standards using an amino acid analyzer (Waters, 717 plus, HPLC Autosampler, AlphaCom AG, Quellen strasse, Switzerland). The samples were hydrolyzed with 6N HCl under vacuum in a sealed tube at 120°C for 18 h and analyzed using HPLC with a UV detector.

2.5 *Color*

Color was assayed using a color meter. About 0.2 g of skimmed coconut milk powder sample was dissolved in 20 mL of distilled water. The color of samples was measured and expressed as L*, a* and b* values in the CIE system [22] using a MiniScan EZ Color instrument (Global Co., Ltd., Virginia, USA). Triplicate samples were taken and the different energies were calculated using Equation (2) from the L*, a* and b* values obtained by scanning the sample and the reference:

$$\Delta E = \sqrt{(\Delta L^*_{sample} - \Delta L^*_{ref})^2 + (\Delta a^*_{sample} - \Delta a^*_{ref})^2 + (\Delta b^*_{sample} - \Delta b^*_{ref})^2} \quad (2)$$

ΔE is the total color difference
L* defines the lightness value, where L* = 0 is dark color and L* = 100 is white color
a* defines the redness and greenness values, where a*+ indicates redness and a* – indicates greenness
b* defines the yellowness and blueness, where b*+ indicates yellowness and b* – indicates blueness

2.6 *Statistical analysis*

All the analytical methods and color measurements were carried out in triplicate. Results were expressed as mean ± standard deviations. The analysis of variance (ANOVA) was analyzed using the statistical package for social science (SPSS) 16.0. The differences between mean values were compared using Duncan's multiple rang test with the significance level of $p < 0.05$.

3 Results and Discussion

3.1 *Skimmed coconut milk compositions*

The skimmed coconut milk compositions are given in the Table 1.

Table 1: Chemical compositions of coconut milk and skimmed coconut milk

Physicochemical Property	Content (%)	
	Coconut Milk [23]	Skimmed Coconut Milk
Protein	3.5–4	6.40
Carbohydrate	-	7.20
Dietary fiber	-	0.27
Sugar	-	6.27
Fat	31–35	3.60
Moisture content	50–56	86.93

3.2 *Physical properties analysis of skimmed coconut milk powder*

3.2.1 Product yield

The skimmed coconut milk was unable to dry alone because of the sticky texture that would adhere to the drying chamber so carrier agent (MD) had to be added to the raw material. From Table 2, the average product yield values at the concentration of MD content at 15 and 20% were 12.58 and 14.21% respectively, which were significantly different. The result showed that the increase in MD can lead to increased yield. The different average yield values at the inlet air temperatures of 190, 200 and 210°C were 15.02, 13.36 and 11.80% respectively, while the different yield values at outlet air temperature of 80, 85 and 90°C were 15.49, 13.51 and 11.82% respectively. It was found that the product yield decreased as the temperature increased that could be explained by high temperature of inlet and outlet would cause more water to evaporate from the samples than low temperature.From the statistical analysis comparing the interaction of inlet air temperature, MD concentration and the outlet air temperature on the yield product was significantly different. Therefore, the suitable condition for spray drying was 20% MD at the inlet air temperature of 190°C and the outlet air temperature of 80°C because it gave the highest product yield.

3.2.2 Moisture content

Moisture is an important factor for drying various powder products. The moisture is an indicator of the quality of the powder products. From the test, the moisture contents of skimmed coconut milk powder were in the range of 2.22–4.11% (Table 2), where every sample was less than 5%wb. These values were similar to the reported moisture content of dry tea powder (3–5%) and pineapple juice powder (5.1%) [24]. The average moisture content of product with 15 and 20% added MD were 3.13 and 2.60% respectively. It was

Table 2: Yield and moisture content of Skimmed coconut milk powder

Maltodextrin (%)	T Inlet (ºC)	T Outlet (ºC)	Skimmed Coconut Milk Powder Yield (%)	Moisture Content (%)
		80	17.75±2.16	4.11±0.20
	190	85	13.40±3.39	3.13±0.75
		90	12.06±1.09	2.92±0.73
		80	14.08±1.91	3.98±0.28
15	200	85	13.92±0.55	2.99±0.20
		90	7.52±0.35	2.62±0.05
		80	12.63±0.56	2.82±0.27
	210	85	12.06±1.60	2.87±0.75
		90	9.79±0.40	2.69±0.61
Average			12.579±3.07b	3.13±0.67b
		80	18.65±1.82	3.23±0.06
	190	85	15.09±1.70	2.76±0.20
		90	13.15±0.88	2.63±0.71
		80	15.66±6.15	2.46±0.67
20	200	85	14.85±1.44	2.39±0.23
		90	14.11±2.94	2.57±0.37
		80	14.16±0.83	2.48±0.25
	210	85	11.71±3.59	2.63±0.35
		90	10.47±4.40	2.22±0.27
Average			14.21±3.45a	2.60±0.43a
Average	190		15.02±3.02b	3.13±0.67b
	200		13.36±3.71ab	2.84±0.64ab
	210		11.80±2.53a	2.62±0.45a
	Average	80	15.49±3.27c	3.18±0.74b
		85	13.51±2.35b	2.80±0.47a
		90	11.82±2.95a	2.61±0.49a

Note: Different superscript within a column showed significant different at $p < 0.05$

found that using less MD would yield products with higher moisture content. At the inlet air temperatures of 190, 200 and 210°C, the average moisture content were 3.13, 2.84 and 2.62%, respective. The outlet air temperature at 80, 85 and 90°C gave the average moisture content of 3.18, 2.80 and 2.61%, respectively. It was found that as the temperature increased, the product moisture content also decreased. The presence of additional heat in samples at higher temperatures with low relative humidity might have caused the samples to dry better than at lower temperatures. Statistical analysis revealed no significant difference of the interaction among of inlet air temperature, MD, the outlet air temperature and the moisture content. Therefore, MD content at 20% at the inlet air temperature of 210°C and the outlet air temperature at 90°C caused less moisture content.

3.2.3 Bulk density

Bulk density is an important factor for package design, transportation and volume calculations. The bulk densities of skimmed coconut milk powder were in the range of 0.43–0.49 g/mL (Table 3). The amount of MD added concentration did not affect the bulk density. For the effect of temperature to bulk density, the higher inlet air temperature caused lower bulk density. When the temperature was high, the rate of moisture evaporation increased causing higher porosity and subsequent reduction of the bulk density. Our results were similar to the report on production of tamarind powder by spray drying process [25]. Chegini and Ghobadian [26] reported that dry, spray-dried powders showed higher bulking weights because water has higher density than dry solids. High bulk density powder means presence of little air inside the powder, and thus requires less storage space. On the other hand, low bulk density powder requires more storage space [27]. The bulk density of skimmed coconut milk powder was similar to the blackberry powder which was in the range of 0.409–0.443 g/mL [28] and also similar to the orange powder with bulk density between 0.34 g/mL and 0.95 g/mL reported by Chegini and Ghobadian [26].

Table 3: The bulk density, wettability and color analysis of skimmed coconut milk powder

Maltodextrin	T_{inlet} (ºC)	Bulk Density (g/mL)	Wettability (min)	L*	a*	b*
15%	190	0.49 ± 0.09a	20.01 ± 5.27b	32.56 ± 0.96a	–0.38 ± 0.05ab	–0.37 ± 0.21a
	200	0.49 ± 0.09a	14.44 ± 6.36ab	32.27 ± 0.68a	–0.36 ± 0.07ab	0.55 ± 0.37bc
	210	0.43 ± 0.06a	10.69 ± 2.73ab	33.15 ± 1.17ab	–0.49 ± 0.19a	0.25 ± 0.78ab
20%	190	0.47 ± 0.58a	19.57 ± 3.59b	31.85 ± 0.08a	–0.33 ± 0.06ab	0.50 ± 0.29ab
	200	0.43 ± 0.58a	14.61 ± 4.96ab	32.57 ± 0.74a	–0.19 ± 0.11b	1.41 ± 0.56c
	210	0.43 ± 0.06a	7.69 ± 4.03a	34.49 ± 1.27b	–0.20 ± 0.05b	1.08 ± 0.17bc

Note: Different superscript within a column showed significant different at $p < 0.05$

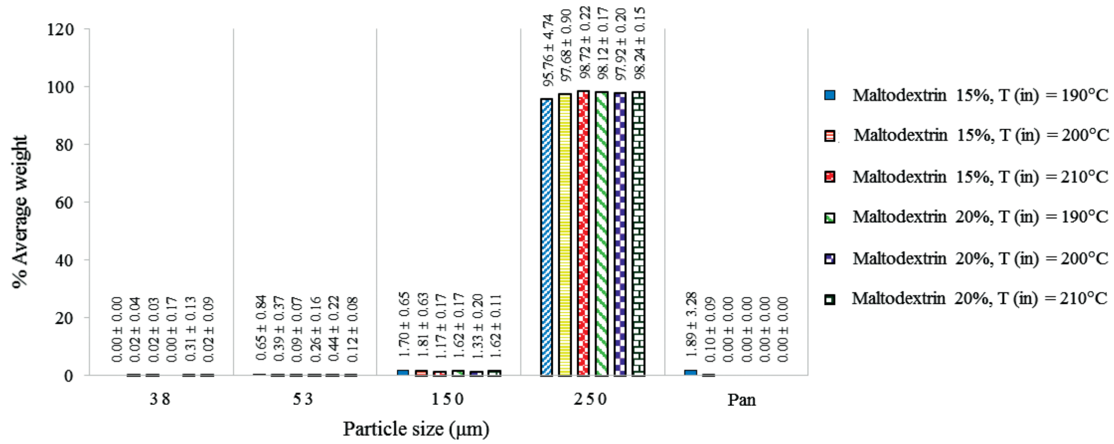

Figure 3: Particle size distribution of the skimmed coconut milk powder produced.

3.2.4 Wettability

Wettability is the ability of the powder to overcome the surface tension between dry powder and water. High porosity particles or large gap pores for large particles show high wettability [29]. The wettability of skimmed coconut milk powder were between 7.69 and 20.01 min (Table 3). It was observed that the wettability decreased as the air temperature increased and that the wettability was inversely related to particle size. Large particles possess large spaces between the powder particles and allow more interactions with surrounding water molecules [16]. The wettability decreased as the amount of MD increased because MD acts as a bulking agent that affects the pore structure; by making the powder less porous, the density would increase [30]. Our results indicated that the inlet air temperature had significant effect on the wettability of skimmed coconut milk powder ($p < 0.05$).

3.2.5 Particle size

Particle size is the most important property of food powder and it affects most product properties. From Figure 3, various particle sizes gave similar yields of skimmed coconut powder passing through the sieves. The range of %average weight at particle size 38, 53, 150, 250 μm and pan were 0–0.31, 0.12–0.65, 1.17–1.81, 95.76–98.72 and 0–1.89%, respectively. All treatments yielded the majority particle size 250 μm. In general, the density decreases as the particle increases in size; the higher the average diameter of the particle, the higher the interstitial air content is between the particles and therefore the larger the volume leads to lower density [31].

3.2.6 Solubility

Solubility affects sensory attributes such as taste perception [28]. It should be noted that particle dispersion in the aqueous phase is not the same as dissolution. The percentage average solubility of the skimmed coconut milk powder in the current study was 39.57% which was optimal for solubility in water. Pathare *et al*. [32] reported that the high drying temperatures applied in the spray dryer had a positive effect on solubility because these temperatures resulted in high porosity of the powders and subsequently a greater specific surface area of the powder. The specific surface area is directly related to the contact surface area between the powder and water during dissolution.

3.2.7 Amino acid analysis

Detailed analysis of the amino acids using HPLC showed in Figure 4. The abundance of amino acids (in decreasing order) were glutamic acid (1.11 g/100 g sample), arginine acid (0.37 g/100 g sample) and aspartic acid (0.34 g/100 g sample). The least abundant amino acid was cysteine (0.07 g/100 g sample) (Table 4).

3.3 *Color analysis*

The skimmed coconut powder was made from skimmed coconut milk by applying MD as the carrier

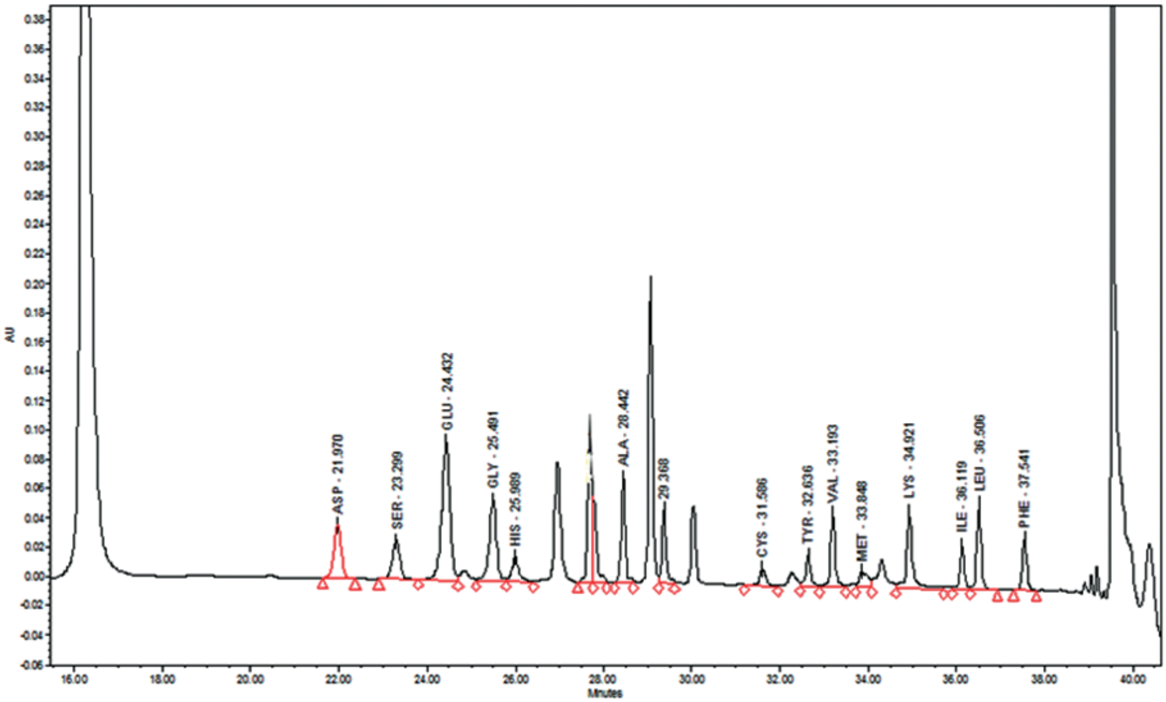

Figure 4: HPLC analyses of skimmed coconut milk powder samples (see Table 4 for definitions of abbreviations for amino acids shown here).

Table 4: Amino acid content analysis

Amino Acid	Content (g/100 g)
Asp (Aspartic acid)	0.34
Ser (Serine)	0.16
Glu (Glutamic acid)	1.11
Gly (Glycine)	0.16
His (Histidine)	0.1
Arg (Arginin)	0.37
Thre (Threonine)	0.26
Alanine (Ala)	0.18
Pro (Proline)	0.16
Cys (Cysteine)	0.07
Tyr (Threonine)	0.11
Val (Valine)	0.21
Met (Methionine)	0.09
Lys (Lysine)	0.25
Ile (Isoleucine)	0.12
Leu (Leucine)	0.23
Phe (Phenylalanine)	0.16

aid. The color parameters of skimmed coconut milk powder are given in Table 3. Lightness (L*) values were significantly higher in the skimmed coconut powder obtained at higher inlet temperature. This was similar to that reported by Santhalakshmy *et al*. [16] for spray-dried jamun fruit juice powder. The amount of MD had no effect on brightness. The a* values of skimmed coconut milk powder were between –0.49 and –0.19 which had color in the green tone, and the b* values of skimmed coconut milk powder were between –0.37 and 1.41 which had color along the yellow tone. It was also found that high inlet temperature caused a significant change of L* and b* and high MD concentrations caused a significant change of a*.

4 Conclusions

The results of this study showed that skimmed coconut milk powder could be produced using the spray drying technique. The skimmed coconut milk should be concentrated by adding MD so that the product has small particle size and thus would be suitable for drinking. The drying conditions depended on the total solid content of the raw material and the inlet temperature before the spray-drying process and these parameters influenced the yield recovery and moisture content. The highest yield of 18.65% was produced with the application of 20% MD with an inlet temperature of 190°C and an outlet temperature of 80°C for spray drying; while the lowest moisture content of 2.22% was produced with the application of 20% MD with the inlet temperature of 210°C and the outlet temperature at 90°C. The bulk density of the skimmed coconut milk powder was in the range of 0.43–0.49 g mL^{-1}. The wettability of the skimmed coconut milk varied from 7.69–20.01 min. The particle size of the skimmed coconut milk powder was 250 µm. The average percentage solubility of the skimmed coconut milk powder in the current study was 39.57%. Amino acid analysis identified the most abundant amino acid as glutamic acid, followed by arginine acid and aspartic acid which are beneficial because they regulate growth hormones, help burn fat in the body and reduce the level of cholesterol in human body, respectively [33]. The color of skimmed coconut milk powder at high inlet temperatures caused significant changes of L* and b* and high MD concentrations caused significant changes of a*. Therefore, the skimmed coconut milk powder produced from spray drying process could be a valuable, marketable health supplement and an added value by – product of the VCO extraction process.

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