OPTIMIZATION OF TECHNOLOGICAL PARAMETERS IN THE SPRAY DRYING OF COCONUT MILK POWDER WITH HIGH FAT CONTENT

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ABSTRACT: *This research focuses on the spray drying of coconut milk powder with high fat content (50% of dry weight). The spray drying was carried out by Mobile Minor TM-2002 systems (Niro, Denmark). The influence of different technological parameters on the spray drying was examined. The central composite design method was used for operation optimization. Some optimal technological parameters of the spray drying were as follows: feed concentration: 24% weight/ weight (w/w); inlet and outlet temperatures of drying agent: 155±2°C and 75±2°C, respectively; pump rate of feed: 1.6L/h and rotary speed of atomizer: 20.000rpm. In these conditions, the product recovery yield was 82.2%.*

Keywords: *coconut milk powder, fat, maltodextrin, soya protein, spray drying*

1. INTRODUCTION

Coconut milk has been widely used in preparation of different foods in ASEAN countries [5]. Coconut milk powder can be produced by the spray drying of coconut milk. Spray drying has many advantages in comparison with other drying techniques. Short drying time and low temperature of the product during spray drying permit to minimize the loss of heat sensitive and volatile compounds in food. Therefore, the nutritional and sensory characteristics of the final product are improved [3,4].

In the production of coconut milk powder with high fat content (50% of dry weight), spray drying is one of the most important operations. High concentration of fat in the coconut milk makes the realization of spray drying become impossible. The particles of coconut milk powder are lumped and stuck on the drying chamber. In practice, fat microencapsulation before spray drying is essential for preventing particle lumping in the obtained powder [1,5].

Up to present, only a few researches on fat microencapsulation in the production of coconut milk powder with high fat content have been carried out in our country. Different microencapsulating agents such as maltodextrin, lactose, whey, skim-milk... have been tested for fat microencapsulation. The product recovery yield of the spray drying reached approximately 60% [3]. This value is quite low and high loss in the spray drying augments significantly the product price.

In this paper, the spray drying of coconut milk powder with high fat content was examined. The objective of this study was optimizing some technological parameters of the spray drying for improving the product recovery yield.

2. MATERIALS AND METHODS

Materials:

- Coconut: 11 month old coconut (*Cocus nucifera*) was supplied by a farm in Ben tre (Vietnam).

- Additives: maltodextrin with Dextrose Equivalence DE17 (originated from Thailand) and soya protein isolate with protein content: 90% of dry weight (originated from Japan) were used as fat microencapsulating agents. All chemicals used in this study were supplied by Hoa nam Co., Ltd. (Ho Chi Minh city).

Experimental procedure:

Coconut milk powder was prepared by the following procedure: Coconut pulp → Expression → Filtration → Centrifugation → Mixing with additives → Homogenization → Spray drying → Packaging → Coconut milk powder [3].

Centrifugation (880*g) was realized for regulation of fat content in the coconut milk. Then maltodextrin and soya protein isolate were added to the coconut milk. The content of maltodextrin and soya protein isolate used in this procedure was 45% and 15% of fat content in the coconut milk. After that, the mixture was homogenized by a two stage homogenizer (APV, Denmark). The first and second stage pressure was 300bar and 60 bar, respectively. Finally, the mixture was spray-dried by Mobile Minor TM-2002 systems (Niro, Denmark). Air was used as drying agent.

Spray dryer Mobile Minor TM-2002 consists of drying chamber, rotary atomizer, peristaltic pump for feed, air heater, distributor of drying agent, cyclone for product recovery and centrifugal fan. The maximum of water evaporation rate is 7kg water/ hour. The inlet and outlet temperatures of air are continuously and automatically measured by an equipment – Erotherm, Model 5100E (United Kingdom) that is directly connected with spray dryer Mobile Minor TM-2002.

Analytical methods:

- Total solids, moisture and fat content were quantified by the official analytical methods of the Association of Official Analytical Chemists AOAC [2].

- Product recovery yield of spray drying: $Y = TS_2/TS_1$ (%), where: TS_1: total solid content in the coconut milk sample before spray drying (g), TS_2: total solid content in the obtained coconut milk powder after spray drying (g), [3].

- Water evaporation rate during the spray drying was calculated as the content of evaporated water (in kg) per 1 hour, [3].

Statistical treatment:

All experiments were carried out in triplicate. The obtained results were subjected to analysis of variance (ANOVA), $p<0.05$ using Statgraphics plus, version 3.2.

3. RESULTS AND DISCUSSION

3.1. Influence of feed concentration

In this experiment, the coconut milk samples with different contents of total solids (18, 22, 26, 30, 34%) were alternatively spray-dried. Other technological parameters of spray drying were as follows: temperature of inlet air: 150°C, rotary speed of atomizer: 20.000rpm and feed rate: 1.73L/h. The results are presented in Table 1.

It can be noted that increase in feed concentration reduced slightly the moisture content of the coconut milk powder. However, moisture content in all samples was lower than the recommended maximum (5%) in powder technology.

When the feed concentration augmented from 18% to 34% w/w, the water evaporation rate decreased from 24.8 to 19.9kg/h. Water evaporation in spray drying is realized by 2 successive stages: water diffusion from the center to the surface of the atomized droplets; and water evaporation from the droplet surface into the environment. The first stage was carried out by water concentration difference between the center and the surface of the droplets; and the second stage – by the pressure difference between the droplet surface and the environment [4]. It is likely that high concentration of dry matters in the feed reduced water diffusion rate in the droplets, so decreased the water evaporation rate.

Table 1. Influence of feed concentration on coconut milk spray drying

Feed concentration (% w/w)	18	22	26	30	34
Moisture of coconut milk powder (%)	3.0[a]	2.8[b]	2.8[b]	2.6[c]	2.6[c]
Water evaporation rate (kg/h)	24.8[a]	23.2[b]	21.2[c]	20.8[d]	19.9[e]
Product recovery yield (%)	71.7[a]	72.5[a]	77.9[b]	71.2[a]	71.6[a]

Each value represents mean and standard deviation of three independent samples. Different letters in each row mean significant difference ($P<0.05$)

The product recovery yield became maximum (77.9%) when the feed concentration was 26% w/w. This concentration was therefore chosen for the following experiment.

3.2. Influence of drying agent temperature

In spray dryer Mobile Minor TM-2002, drying temperature is regulated by inlet air temperature. Outlet air temperature cannot be regulated. In this experiment, the temperature of the inlet air varied from 130 to 170°C. Other parameters of the operation were fixed: total solids in the coconut milk before spray drying: 26%, rotary speed of atomizer: 20.000rpm, feed rate: 1.73L/h. Table 2 shows the obtained results.

Table 2. Influence of drying agent temperature on coconut milk spray drying

Temperature of inlet air (°C)	130±2	140±2	150±2	160±2	170±2
Temperature of outlet air (°C)	54±2	59±2	65±2	71±2	77±2
Moisture of coconut milk powder (%)	3.0[a]	2.8[b]	2.8[b]	2.6[c]	2.6[c]
Water evaporation rate (kg/h)	24.8[a]	23.2[b]	21.2[c]	20.8[d]	19.9[e]
Product recovery yield (%)	71.7[a]	72.5[a]	77.9[b]	71.2[a]	71.6[a]

Each value represents mean and standard deviation of three independent samples. Different letters in each row mean significant difference ($P<0.05$)

The higher the inlet air temperature, the higher the outlet air temperature, the lower the moisture content of coconut milk powder. In addition, increase in inlet temperature of the drying agent augmented the water evaporation rate. Perhaps it was due to the acceleration of water diffusion from the center to the surface of the atomized droplets in the drying chamber.

When the air inlet temperature increased from 130 to 150°C, the product recovery yield augmented from 71.7 to 77.9%. However, increase in air inlet temperature from 150 to 170°C reduced the recovery yield of the coconut milk powder. It was explained that too high temperature of the drying agent made the coconut milk fat transform in liquid phase during the spray drying. So some particles in the coconut milk powder were lumped and the product was easily stuck on the drying chamber. This phenomenon decreased the product recovery yield. Therefore, it can be concluded that 150°C was suitable temperature of the drying agent in the spray drying of coconut milk powder.

3.3. Influence of rotary speed of atomizer

In this experiment, the rotary speed of atomizer varied from 12.500 to 22.500rpm. Other technological parameters of the spray drying were as follows: content of total solids in the coconut milk: 26%, inlet air temperature: 150°C, feed rate: 1.73L/h.

The obtained results showed that change in rotary speed of atomizer did not influence significantly on the product moisture and water evaporation rate during the spray drying. The moisture content of the coconut milk and water evaporation rate varied from 2.8 to 3.0% and from 23.1 to 23.9kg/h, respectively. Nevertheless, the product recovery yield was influenced by the rotary speed of atomizer.

Figure 1 indicates that increase in rotary speed of atomizer augmented the recovery yield of coconut milk powder. However, too high rotary speed of atomizer decreased the diameter of atomized droplets in the drying chamber. Therefore, the product particle size became smaller and the recovery of coconut milk powder by a cyclone became difficult. This phenomenon reduced the product recovery yield.

When the rotary speed of atomizer was 20.000rpm, the recovery yield of coconut milk powder was the highest (78.8%). This rotary speed of atomizer was therefore chosen for the next experiments.

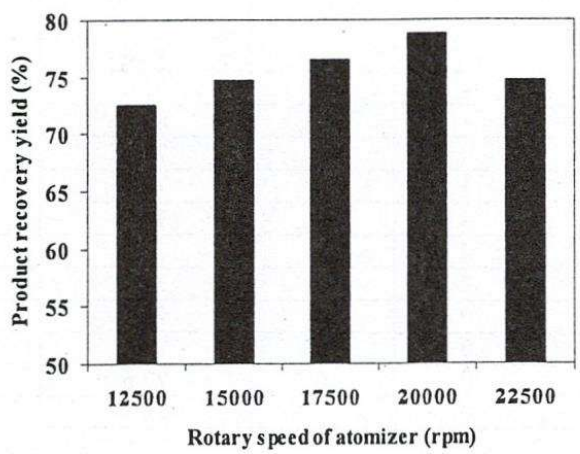

Figure 1. Influence of rotary speed of atomizer on the recovery yield of coconut milk powder

3.4. Influence of pump rate of feed

The coconut milk was pumped to the drying chamber with different rates (1.47-2.00L/h). The content of total solids in the coconut milk was 26%, the inlet air temperature – 150°C, the rotary speed of atomizer – 20.000rpm. Table 4 presents the results.

Table 4. Influence of pump rate of feed on coconut milk spray drying

Pump rate of feed (L/h)	1.47	1.60	1.73	1.87	2.00
Moisture of coconut milk powder (%)	2.7^a	2.8^a	3.0^b	3.1^b	3.2^b
Water evaporation rate (kg/h)	18.3^a	21.0^b	23.4^c	25.1^d	27.4^e
Product recovery yield (%)	78.7^a	80.7^b	78.8^a	78.2^a	77.6^a

Each value represents mean and standard deviation of three independent samples. Different letters in each row mean significant difference (P<0.05)

Increase in pump rate of feed augmented slightly the moisture of the coconut milk powder, but augmented significantly the water evaporation rate. It can be explained that high pump rate of feed increased the number of atomized droplets in the drying chamber. So the contact surface between the droplets and the drying agent augmented. The water evaporation rate was notably improved. The higher the pump rate of feed, the higher the water evaporation rate.

The maximum of product recovery yield was 80.7% when the pump rate of feed was 1.60L/h.

3.5. Optimization of spray drying in the production of coconut milk powder

A central composite design method was used in optimization of coconut milk spray drying. Two factors were chosen:

- X: Feed concentration (%w/w), with: X=[-1,+1], X(0)=26%, X(-)=24%, X(+)=28%
- Y: Inlet air temperature (°C), with: Y=[-1,+1], Y(0)=150°C, Y(-)=145°C, Y(+)=155°C.

Z_1 and Z_2 were product recovery yield (%) and water evaporation rate (kg/h), respectively. Table 5 presents the experimental plan. The obtained results are showed in Table 5, Figure 2 and 3.

Table 5. Optimization of coconut milk spray drying - Experimental plan and results

Experiment number	X	Y	Z_1 (%)	Z_2 (kg/h)
1	+	+	78.0	17.4
2	-	+	81.4	19.2
3	+	-	83.0	17.9
4	-	-	79.0	22.1
5	+	0	78.8	17.2
6	-	0	78.8	19.5
7	0	+	81.8	18.9
8	0	-	79.2	19.1
9	0	0	78.1	19.4
10	0	0	78.6	19.9
11	0	0	77.6	19.5
12	0	0	78.1	19.3

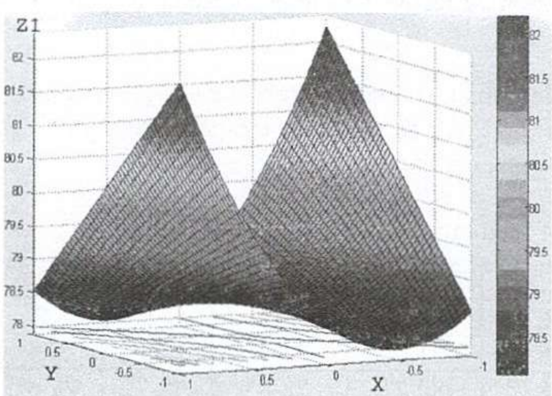

Fig 2. Influence of feed concentration (X) and inlet air temperature (Y) on product recovery yield Z_1

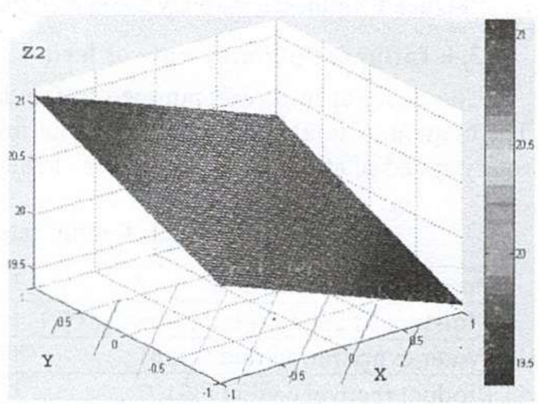

Fig 3. Influence of feed concentration (X) and inlet air temperature (Y) on water evaporation rate Z_2

The regression equations were as follows:

$$Z_1=78.49-1.84XY+1.89Y^2$$

$$Z_2=20.24-0.41X+0.44Y$$

From the obtained regression equations, both values Z_1 and Z_2 reached maximum (Z_1=82.2%, Z_2=21.09kg/h) when X=-1 and Y=1. In this case, the content of total solids in the coconut milk before spray drying was 24%, the inlet and outlet temperatures of drying agent were 155±2°C and 75±2°C, respectively. The moisture and fat contents in the obtained product were 2.7% and 52.2%, respectively. In comparison with the results in part 3.1 and 3.4., the product recovery yield in part 3.5. increased 4.3% and 1.5%, respectively.

4. CONCLUSION

Spray drying was the important operation in the production of coconut milk powder with high fat content. Optimization of spray drying by the central composite design method augmented the product recovery yield. The optimal parameters found in this study were fundamental references for the application of spray drying in the production of coconut milk powder with high fat content on industrial scale.

TỐI ƯU HÓA CÁC THÔNG SỐ CÔNG NGHỆ TRONG QUÁ TRÌNH SẤY PHUN BỘT SỮA DỪA CÓ HÀM LƯỢNG BÉO CAO

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TÓM TẮT: *Bài báo này nghiên cứu quá trình sấy phun bột sữa dừa có hàm lượng béo cao (chiếm 50% khối lượng chất khô). Quá trình sấy phun được thực hiện trên hệ thống thiết bị Mobile Minor TM-2002 (Niro, Đan mạch). Sự ảnh hưởng của các thông số công nghệ đến quá trình sấy phun được khảo sát. Phương pháp quy hoạch thực nghiệm bậc hai - cấu trúc có tâm -được sử dụng để tối ưu hóa quá trình. Một vài thông số công nghệ tối ưu của quá trình sấy phun bột sữa dừa như sau: Nồng độ chất khô trong dịch sữa dừa trước khi sấy phun là 24% (w/w), nhiệt độ tác nhân sấy tại cửa vào và cửa ra của buồng sấy lần lượt là 155±2°C và 75±2°C, lưu lượng bơm mẫu nguyên liệu vào thiết bị sấy là 1.6L/h và tốc độ quay của đầu phun ly tâm là 20.000 vòng/phút. Trong những điều kiện trên, hiệu suất thu hồi sản phẩm bột sữa dừa trong quá trình sấy phun là 82.2%.*

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