Application Note
No. 218/2016

Spray drying skim milk, concentrated milk, full cream milk

1. Introduction

Spray dryers are used to transform a liquid, i.e. solutions, suspensions or emulsions into dried powders; for example in industrial chemistry, and in the pharmaceutical, biotechnology and food industry. It is a quick, gentle and single step drying process.
A major application is the production of milk powder. In general, liquid milk is easily denaturized and difficult to store for a long time. To prolong its shelf life and to simplify transportation milk is spray dried to milk powder.
In this work, a BUCHI Mini Spray Dryer B-290 in employed to investigate the effects of drying temperature on the yield and sample throughput of different milk products processed to milk powder.

2. Equipment

- BUCHI Mini Spray Dryer B-290
- BUCHI Rotavapor® R-300, Interface I-300 Pro, Vacuum Pump V-300, Recirculating Chiller F-305 and Heating Bath B-300 Base

3. Sample preparation

All the materials were purchased from a local supermarket in Beijing. The composition of milk sample (% solids) is shown in Table 1.

- Natural skim milk was used as purchased in liquid form.
- Concentrated milk from powder was made by mixing 82.4 g milk powder (either skim or full-cream) with 117.6 g distilled water, which was dissolved at 50 °C.
- The concentrated full-cream milk was prepared in a Rotavapor® R-300. 700 mL of liquid milk was concentrated to 200 g by evaporating 500 g of water. The evaporation parameters are listed in Table 2.

Table 1: Composition of milk samples

	Solids concentration (% total weight)	Processed quantity	Fat (% solids)	Protein (% solids)	Carbohydrate (% solids)
Natural skim*	8.2	250 mL	0	36.6	62.2
Skim concentrate (powder)**	41.2	200 g	1.2	32.6	56.2
Full-cream concentrate (powder)**	41.2	200 g	28.5	23.8	41.6
Full-cream Concentrate*	41.2	200 g	30.2	25.9	43.1

*Calculated based on the label, **labelled values

Table 2: Rotavapor® R-300 settings for concentrating full-cream milk

Water bath temperature	50 °C
Vacuum degree	50 mbar
Rotation speed	200 rpm
Condensation temperature	5 °C

4. Spray Drying Parameters

Spray drying experiments were performed at three different inlet temperatures, 120°C, 160 °C and 200 °C, while letting the other parameters unchanged, as listed in Table 3. The outlet temperature cannot be set, it is a function of the inlet temperature, the aspirator performance the feed rate and the spray gas flow rate.

Table 3: Spray drying parameters.

Inlet Temperature		200 °C	160 °C	120 °C
Outlet Temperature	Natural skim	83 °C	50 °C	41 °C
	Skim concentrate (powder)	103 °C	92 °C	71 °C
	Full-cream concentrate （powder）	115 °C	102 °C	66 °C
	Full-cream concentrate	110 °C	85 °C	60 °C
Aspirator		100 %	100 %	100 %
Feed rate		8 mL/min	8 mL/min	8 mL/min
Spray gas flow		40 mm	40 mm	40 mm

Two yields were calculated according to equations (1) and (2). Equation (1) describes the yield calculated from the collected dry mass in the collecting vessel divided by the processed solid matter. The total yield, calculated according to equation (2) takes into account the powder in the collecting vessel and the powder sticking on the glass cylinder of the instrument. Therefore, the total yield is equal or higher than the yield. In an optimized spray drying process, we aim to get a maximum yield.

Figure 2: BUCHI Mini Spray Dryer B-290.

$$\text{Yield} = \frac{M_{\text{powder from collecting vessel}}}{M_{\text{processed solid matter}}} \qquad (1)$$

$$\text{Total Yield} = \frac{M_{\text{powder from collecting vessel and cylinder}}}{M_{\text{Processed solid matter}}} \qquad (2)$$

5. Results and discussions

Table 4: Spray drying results.

Inlet temperature	Recovery	Natural skim	Skim concentrate (powder)	Full-cream concentrate （powder）	Full-cream concentrate
120 °C	Yield	65 %	47 %	37 %	17 %
	Total Yield	94 %	78 %	73 %	51 %
160 °C	Yield	78 %	54 %	43 %	51 %
	Total Yield	96 %	76 %	78 %	92 %
200 °C	Yield	73 %	59 %	40 %	28 %
	Total Yield	88 %	83 %	85 %	78 %

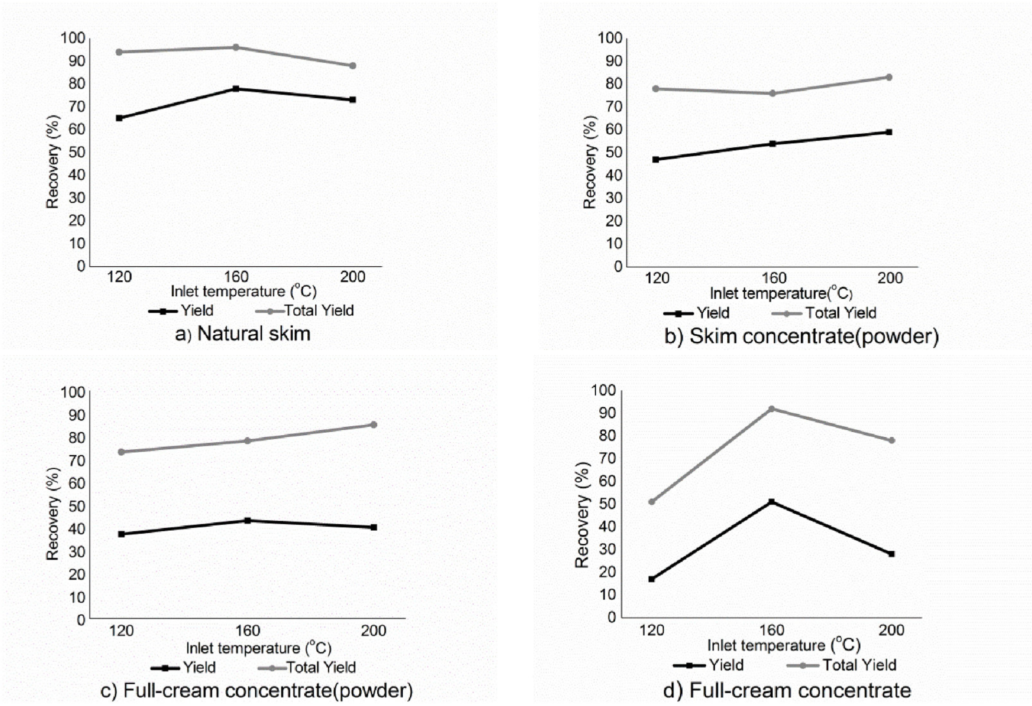

Figure 2: The recoveries of four samples at different temperatures.

a) For natural skim milk, the result shows that yield and total yield were highest at 160 °C inlet temperature with 79 % and 97 %, respectively. Interestingly, the yields were lower at 120 °C and 200 °C. At an inlet, temperature of 120 °C，the yield was 65 % and total yield was 94 %. When the temperature reached 200 °C，the yields were 73 % and 88 %.

   An explanation could be that less water in the final product was weighted with higher dryness at an inlet temperature 200 °C. On the other hand, a higher residual humidity may lead to stickier product which depositing on glass walls at an inlet temperature 120 °C.

b) In the case of skim concentrate (powder), a different correlation could be observed. The yields were 47 %, 54 % and 59 % steadily increasing with the inlet temperature. The highest yield and total yield was observed at an inlet temperature 200 °C.

   We speculate that the moisture of the concentrated skim milk evaporated very quickly and thus the surface of the particles became dryer when increasing the inlet temperature. When the drying temperature was low, the surface of the particle remained moist so that we observed a major amount powder of the powder to stick on the drying cylinder.

c) For full-cream concentrate (powder), we observed a large gap between the total yield and the yield. In general, the highest yield of 43 % was, i.e. powder in the collecting vessel, was obtained at inlet temperature 160 °C. The total yields were 73 %, 78 % and 85 % that the value increased with increasing inlet temperature.

Compared to skim concentrated milk, there were mobile fluid fat globules dispersing in full-cream concentrated milk [1]. We speculate that more particles will stick on the drying cylinder when the drying temperature exceeded the fat melting temperature. It was the reason that it could collect more powder from the cylinder, so the bigger gap than skim milk between the total yield and the yield happened.

d) The yields of full-cream concentrated milk were 17 %, 51 % and 28 % at 120 °C, 160 °C and 200 °C inlet temperatures, respectively. The according total yields were 51 %, 92 % and 78 %.

There were some particles sticking to cylinder that were not dried when the drying temperature was 120 °C. This may be due to the energy was not enough to dry the particles.
However, when the inlet temperature reached 200 °C, the yield and total yield were lower. The system temperature was too high and some of the particles melted and sticked on the cylinder.
It could be observed that the gap between the yield and the total yield was big. The phenomenon was similar with full-cream concentrate (powder), so the reason could be the fat dispersing in the liquid. An explanation for the different behaviour between resuspended milk powder and freshly concentrated milk could be found in the stability of fat micelles.

6. Conclusion

The recoveries of dry powders from different milk products were determined on the BUCHI Mini Spray Dryer B-290. The influence of the inlet temperature on yield and total yield was investigated on four different kind of milk.

1) For natural skim, full-cream concentrate (powder) and full-cream concentrate, the highest yields, i.e. powder in the collection vessel, were observed at an inlet temperature of 160 °C. Most appropriate temperature for spray drying skim concentrate (powder) was 200 °C.
2) For full-cream concentrate (powder) and skim concentrate (powder), the total yields were highest at inlet temperature 200 °C. The total yields for natural skim and full-cream concentrate were highest at inlet temperature 160 °C.
3) The total yields and yields were different between the four kinds of milk at the same inlet temperature. It depends on the compositions of them. The fat content was an important factor for spray drying milk product. The high content of fat will make the gap larger between the total yield and the yield.
4) BUCHI Mini Spray Dryer B-290 is a laboratory spray dryer for investigating the spray-drying process. The advantages are that the drying condition can be repeated, runs are easy to control and optimize for a higher recovery.

The data collected in this study could also serve as a basis for optimizing industrial spray drying processes.

7. Reference

[1] J.J.Nijdam and T.A.G.Langrish. 2005. An Investigation of Milk Powders Produced by a Laboratory-Scale Spray Dryer. Dry Technology.