Production of Yogurt Powder Using Foam-Mat Drying

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Abstract

Yogurt powder was produced by using foam-mat drying method. Two types of foaming agents as methylcellulose and egg albumin were used at different concentrations as 0.5, 1.0, 1.5 and 2.0% for methylcellulose and 1, 2, 3 and 4% for egg albumin, respectively. The mixture of plain yogurt and foaming agent were blended by using high speed mixer (900 W) for 5, 7, 9 and 12 min. Characteristics of yogurt foam, as foam density, foam stability and foam expansion, were determined. Three percentage of egg albumin with the mixing time of 12 min provided better foam characteristics. The yogurt foam was then dried at 50, 60 and 70°C for 3 h. The dried yogurt was blended and kept in an air tight container. Characteristic of yogurt powder as moisture content, water activity (a_w) and glass transition temperature (T_g) were analyzed. Simultaneously, the food application of yogurt powder in drinking yogurt was studied. Yogurt powder (15%) was dissolved in cold water (85 ml) and then mixed well. Orange flavor (0.1 g) and color (0.1 g) were added into the product. Two physical characteristics of the finished product, viscosity and cohesiveness, were measured. Moreover, sensory evaluation was performed by using 9-point hedonic score and 30 panelists. The highest viscosity product was obtained when 60°C yogurt powder was used. Sensory qualities of drinking yogurt of all treatments were not significant ($p>0.05$) different. The yogurt powder (60°C) had a_w of 0.348, moisture content 8.5%, T_g 25.51 °C and lactic acid bacteria count 5.6 x 10^7 cfu g^{-1}. The preference scores of drinking yogurt made by using yogurt powder were 6.7, 6.8, 6.6 and 6.7 for appearance, flavor, texture and overall, respectively.

***Keywords**: yogurt, foam-mat drying, egg albumin, yogurt powder, methylcellulose*

1. Introduction

The principle intention of yogurt powder manufacture is to store the product in a stable and readily utilizable state. Yogurt powder becomes interesting dairy ingredients for a wide variety of food application for a unique flavor and nutrients. Yogurt powder has been produced by fermentation of non-fat milk using yogurt cultures, *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus salivarius* subsp. *thermophilus*, until reach a desirable pH. Then the yogurt has been dried. There are also other types of blended dairy ingredients that have same flavor and function as yogurt powder. The blended yogurt powder may contain other cultured dairy products such as cultured whey, culture whey protein concentrate and cultured dairy solids, including nonfat dry milk, whey powder, lactic acid and natural/artificial flavors. Silicon dioxide may be added as anti-caking agent. The variation between yogurt powder and blended yogurt powder in flavor and functional properties depends on the used culture and pH of yogurt before drying. The commercial yogurt powder contains 3.0-5.0% moisture, 1.2-2.0% fat, 33.0-36.0% protein, 50.0-51.5% lactose and 7.0-8.0% ash. Yogurt powder can be used to replace fresh yogurt for beverage and dip. It can be also used in confectionary as coating material for coating of fruit, nut and cereal (Childs and Drake 2008).

At present, yogurt powder is commercially produced by using spray drying method, but there are some factors needed to be concerned. First, the concentration of yogurt before drying should be performed at 50-60°C. Second, the drying condition should be moderate to ensure a high viable cell count of yogurt cultures. The count of lactobacilli in commercial yogurt powder was 7 x 10^5 cfu g^{-1} (Rybka and Kailasapathy 1995; Kim *et al.* 1997).

Foam mat drying, originally develop by Morgan, is a process in which the liquid or semi food is converted to form stable foam by cooperation with foaming agents or stabilizing agents. The foam is then spread into a thin sheet and dried by using hot air at lower temperature compared to other drying techniques such as spray drying and steam drying. The dehydrated product can be converted into powder later using grinding process (Chandak and Chivate 1972; Labelle 1984; Srinivasan 1996). The cooperation of air bubbles into the foam is important and affects to drying rate. Usually, drying rate of foam-mat drying is relatively high due to the larger surface area exposed to the drying air, resulting in rapid moisture removal (Brydigyr *et al.* 1977). Although the product may be sticky at drying temperature, it can be carried to cool down and crisped before it is removed from the tray. The dehydrated powder or flakes has better quality than that of drum dried and spray dried products because of its honey comb structure and better reconstitution properties. There are also fruit powders produced by using foam-mat drying such as mango (Srivastava 1998), star fruit (Karim and Wai 1999), papaya (Kandasamy 2001) and banana (Sankat and Castaigne 2004).

This drying process is comparatively simple and inexpensive; however, the foam stability during drying is very important. If the foam collapses, cellular broken down occurs, resulting in serious impairment of the drying process. The foams are stable when low surface tension and high viscosity occurred at the air/aqueous interface (Cherry and McWatters 1981). There are a lot of factors affecting the foam characteristics or foam properties include chemical composition of food, type and concentration of foaming agent, and mixing time (Hart *et al.* 1967). Therefore, this project aimed to study the production of yogurt power by using foam-mat drying and the qualities of yogurt powder.

2. Materials and Methods

2.1 To study the effect of concentrations of foaming agents and mixing time on some characteristics of yogurt foam

2.1.1 Preparation of yogurt foam: Commercial plain yogurt was used in this experiment. Two types foaming agents as methylcellulose and egg albumin were added into yogurt at different concentrations as 0.5, 1.0, 1.5 and 2.0% for methylcellulose and 1, 2, 3 and 4% for egg albumin, respectively. The mixtures were blended by using high speed mixer (Kenwood, 900 W) for 5, 7, 9 and 12 min.

2.1.2 Analysis of foam characteristics: Characteristics of yogurt foam, as foam density, foam stability and foam expansion, were determined for identifying optimum type and level of foaming agent

2.1.2.1 Foam density: The density of yogurt foam was measured in as mass per volume of foam and expressed as g cm^{-3} (Falade *et al*. 2003):

$$\text{Foam density} = \frac{\text{Mass of foam}}{\text{Volume of foam}}.$$

2.1.2.2. Foam stability: Yogurt foam stability was determined by placing the yogurt foam 100 ml in a beaker and left at room temperature for 3 h. The volume reduction was measured every 30 min. The foam stability was calculated by using the equation developed by Akiokato *et al.* (1983) as the following:

$$\text{Foam stability} = V_0 x \Delta t/\Delta V,$$

where: V_0 is the initial volume of yogurt foam at 0 min.;

$\Delta t/\Delta V$ is the reciprocal of slope from the graph plotted between volume of yogurt foam versus time in min.

2.1.2.3 Foam expansion: Yogurt foam expansion indicating the ability of foam to cooperate air into the structure of foam was determined using method described by Durian (1995) as the followings:

$$\text{Foam expansion} = \frac{[V_1 - V_0]}{V_0} \times 100,$$

where: V_1 = Final volume of yogurt foam, cm^3;
V_0 = Initial volume of yogurt, cm^3.

2.1.3 Statistical analysis: The randomized block and the 4 x 4 factorial designs with three replications were used in this part. The mean comparisons were determined by using Duncan's multiple range test.

2.2 To study the effect of drying temperature on drying behavior, some characteristics of yogurt powder and its food application

2.2.1 Preparation of yogurt foam: Yogurt foam was produced by mixing 3% egg albumin with high speed mixer for 12 min. The yogurt foam was then poured into a Teflon tray with the height of yogurt foam as 0.5 cm. The yogurt foam was then dried in an oven at 50°C, 60°C and 70°C for 3 h. The weight reduction of yogurt foam was measured every 30 min for construction of drying curve. After drying, the yogurt flakes were scrapped from the tray and blended into power. The yogurt powder was kept in the air tight container at room temperature for further analysis.

2.2.2 Characteristic analysis of yogurt powder:

2.2.2.1 Moisture content (AOAC 1997)

2.2.2.2 Water activity (Decagon model)

2.2.2.3 Grass transition temperature (Differential Scanning Calorimetry, µDSC 3 evo)

2.2.3 Food application: Drinking yogurt was made by using yogurt powder for the study of food application. Yogurt powder (15%) was dissolved in cold water (85 ml) and then mixed well. Orange flavor (0.1 g) and color (0.1 g) were added into the product. Two physical characteristics of the finished product, viscosity and cohesiveness, were measured by using Rapid Visco Analyzer (RVA-4, Sweden) and Texture Analyzer model TA-XT2i (Stable Micro Systems Ltd., USA). Moreover, sensory evaluation was performed by using 9-point hedonic scale and 30 panelists for appearance, flavor, texture and overall attributes.

2.2.4 Statistical analysis: The randomized block design with three replications was used in this part. The mean comparisons were determined by using Duncan's multiple range tests.

3. Results and Discussion

3.1 Effect of concentrations of foaming agents and mixing time on some characteristics of yogurt foam

There were two types of foaming agents, methylcellulose and egg albumin, used in this experiment. Methylcellulose as 0.5, 1.0, 1.5 and 2.0% and egg albumin 1, 2, 3 and 4% were added into plain yogurt. The mixtures were then blended by using high speed mixer for 5, 7, 9 and 12 min. The foam properties, as foam density, foam expansion and foam stability, were measured after the yogurt foam was formed. It was recognized that using methylcellulose as foaming for yogurt powder production used longer time for drying up to 6 h. Therefore, only egg albumin was used in this experiment. The properties of yogurt foam using egg albumin as foaming agent was shown in Table 1.

The foam stability of yogurt foam was not measured because volume of foam did not change when it was stand for more than 3 h, indicating very high stability of yogurt foam (100%), which appeared in all treatments.

There were significantly ($p<0.05$) differences for the foam density. It was noticed that the lowest foam density (0.69 g cm^{-3}) was obtained when 3%/12 min and 4%/5 min were used. These foam densities were slightly higher than that of Hart *et al*. (1967), who stated that the foam density in the range of 0.2-0.6 g cm^{-3} was highly suitable for foam mat drying. Moreover, it was recognized that as the concentration of egg albumin increased, the foam density increased, indicating higher air bubble cooperation. In addition, as the mixing time increased, the foam density decreased; but if it was beyond the ability of foam to hold the air bubbles, the foam collapsed, resulting in lower foam density. This phenomenon occurred when the mixing time of 12 min was used.

Table 1. Characteristics of yogurt foam produced by using egg albumin.

Concentration (%)	Time (min)	Foam density (g cm^{-3})	Foam expansion (%)
1	5	0.82^{cdef}	42.5^{cdef}
	7	0.70^{ab}	66.8^{ab}
	9	0.80^{bcdef}	44.5^{bcdef}
	12	0.75^{abcd}	55.7^{abcd}
2	5	0.76^{abcde}	52.6^{abcde}
	7	0.82^{cdef}	55.9^{cdef}
	9	0.82^{cdef}	42.1^{cdef}
	12	0.88^{f}	31.8^{f}
3	5	0.72^{abc}	66.8^{abc}
	7	0.75^{abcd}	54.5^{abcd}
	9	0.74^{abcd}	56.7^{abcd}
	12	0.69^{a}	67.6^{a}
4	5	0.69^{a}	70.0^{a}
	7	0.87^{ef}	33.7^{ef}
	9	0.85^{def}	37.1^{def}
	12	0.72^{abc}	62.3^{abc}

* The same letters indicate there were no significant different at 95% confidential level.

The lower foam density also indicated the higher volume expansion. This result was parallel to the foam expansion measured. The highest foam expansion was also obtained from 3%/12 min and 4%/5 min, which were 67.6 and 70.0%, respectively. The lower foam density and higher foam expansion increased the drying rate of product (Sankat and Castaigne 2004).

Although the foam properties of yogurt foam made by using 3%/12 min and 4%/5 min were not significant different ($p<0.05$), 3%/12 min was chosen for the further experiment due to the economical reason.

3.2 Effect of drying temperature on drying behavior and some characteristics of yogurt powder produced by using drying temperatures

Yogurt foam was produced by using 3% egg albumin and 12 min mixing time. The foams were then dried in an oven at 50, 60 and 70°C. The weight reduction was measured every 30 min for 3 h. The drying curves were constructed and shown in Figure 1.

There was a similarity of drying behavior of yogurt foam dried at 50 and 60°C. In addition, when the 70°C was used, the rate of drying was faster than those of 50 and 60°C. On the other hand, more heat damage such as brown color occurred due to exposure of product to high temperature.

Some physical properties of yogurt powder were measured. These were water activity, moisture content and glass transition temperature. The results were shown in Table 2.

Although the water activity and moisture content of yogurt powders were not significant different ($p>0.05$) for all temperatures, the higher drying temperature tended to have lower water activity and moisture content. The water activity and moisture content of 50, 60 and 70°C were 0.355, 0.348 and 0.323; and 8.6, 8.5 and 8.5%, respectively.

Table 2. Some characteristics of yogurt powders produced by using different drying temperatures.

Temperature (°C)	Water activity a_w	Moisture content (%)	Glass transition temperature, T_g (°C)
50	0.355^{a*}	8.6^{a}	38.03^{b}
60	0.348^{a}	8.5^{a}	25.51^{a}
70	0.323^{a}	8.5^{a}	25.46^{a}

* The same letters indicate there were no significant differences at 95% confidential level.

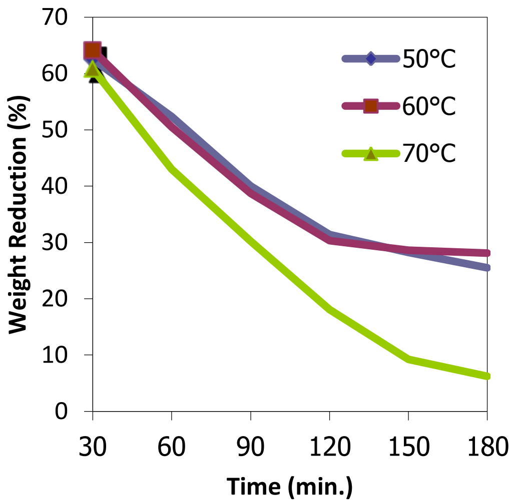

Fig. 1. Drying curve of yogurt powder made by using foam mat drying.

Glass transition temperature (*Tg*) is the temperature that the amorphous solid transform to rubbery state (Slade and Levine 1991). During drying of yogurt foam, the water was removed from the three dimension structure of yogurt, resulting in amorphous structure of yogurt powder. The glass transition temperature of yogurt powder dried at 50°C was significantly ($p<0.05$) higher (38.03 °C) than the others (25.51 and 25.46°C). Although the higher glass transition temperature of 50°C implied that this yogurt powder can be kept at room temperature (30°C) without changing to rubbery state, the spoilage of yogurt powder and loss of lactic acid bacteria might be occurred due to higher storage temperature. For yogurt powder dried at 60 and 70°C, they were required to be kept at temperature lower than 25°C for the tropical country like Thailand or room temperature for the climate country.

For the food application, these yogurt powders were used to produce drinking yogurt by dissolving 15 g of yogurt powder to 85 g of water. Some physical and sensory properties of the products were evaluated. The results were shown in Tables 3 and 4. It was noticed that there were no significant differences ($p>0.05$) in cohesiveness of drinking yogurt made by using yogurt powder dried at 50, 60 and 70°C. Conversely, yogurt power dried at 50 and 60°C provided higher viscosity (6.82 and 7.06 RVA unit, respectively) than that of 70°C (3.18 RVA unit), which might be caused by less protein damage. Furthermore, there were no significant difference ($p>0.05$) in all attributes of the products when the sensory analysis was performed by using 9-point hedonic scale and 30 panelists. The result indicated that the panelists "Moderately Like" the products. For the keeping quality reason, the drying temperature of 60°C was chosen.

Table 3. Some physical characteristics of drinking yogurt made by using yogurt powder.

Temperature (°C)	Viscosity (RVA unit)	Cohesiveness (g)
50	6.82[a]	-11.13
60	7.06[a]	-12.12
70	3.18[b]	-10.13

* There were no significant differences at 95% confidential level.

Table 4. Sensory properties of yogurt powder produced by using foam mat drying at different temperatures.

Tempe-rature	Appea-rance	Flavor	Texture	Overall
50°C	6.6*	6.6	6.5	6.5
60°C	6.7	6.8	6.6	6.7
70°C	7.2	6.9	6.8	6.9

* There were no significant differences at 95% confidential level for all attributes.

Table 5. Number of lactic acid bacteria in yogurt powder (60°C) and fresh yogurt (dry basis).

Yogurt type	Number of lactic acid bacteria (cfu g^{-1})
Fresh	9.8×10^7
Powder	5.6×10^7

* There were no significant differences at 95% confidential level.

The number of lactic acid bacteria was enumerated compared with fresh yogurt (dry basis) as shown in Table 5. It was observed that the number of lactic acid of these products were similar to each other, which was approximately 10^7 cfu g^{-1} of sample. The number of lactic acid bacteria in yogurt powder was less 0.5 log than that of fresh yogurt, indicating less effect of foam-mat drying on the survival of these bacteria due to lower temperature and shorter period of drying. The number of lactic acid bacteria in yogurt powder of this experiment was higher than that of commercial yogurt powder (7 x 10^5 cfu g^{-1}), which was reported by many scientists (Pan *et al.* 1995; Rybka and Kailasapathy 1995; Kim *et al.* 1997).

4. Conclusion

The appropriate condition for producing yogurt powder was the use of 3% egg albumin as foaming agent with the mixing time of 12 min and drying temperature as 60°C for 3 h. The yogurt foam had a very high foam stability, low foam density and high foam expansion. The preference scores of drinking yogurt made by using yogurt powder were 6.7, 6.8, 6.6 and 6.7 for appearance, flavor, texture and overall, respectively. The yogurt powder had a_w of 0.348, moisture content 8.5% and Tg of 25.51°C. The yogurt powder contained lactic acid bacteria as high as 5.6 x 10^7 cfu g^{-1} (dry basis), which was similar to that of fresh yogurt (dry basis).

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