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Powder Qualities of Foam-Mat Dried Mango

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Abstract

The objectives of this study are to demonstrate powder qualities of foam-mat dried mango using different foaming agents and then compare mango powder qualities of foam-mat drying method to that of the studies in other drying methods. Fresh puree of Mahajanaka mango (*Mangifera indica L.*) grown in the north of Thailand is mixed with glyceryl monostearate (GMS), sugar and soybean isolated (SBI) in different ratios as foaming agents, after that is dried at 70 °C in a tray dryer for 5 h. The color and % foam overrun revealed that GMS with sugar treatments contribute a decent quality more than that with SBI. Therefore, powder qualities of foam-mat dried mango using GMS with sugar are analyzed. Different ratios of GMS and sugar are not affected by their moisture content, solubility, and hygroscopicity values. The best powder quality is found when added 1 % GMS with 5 % sugar during storage at 90 %RH, and 38 ± 2 °C. Comparing the foam-mat dried mango qualities to other drying methods. It was found that foam-mat dried mango indicated a similarity appearance and moisture to spray dried and freeze-dried mango. The disadvantage of foam-mat drying method is a lowest solubility and hygroscopicity, but the more advantage of this method could be a low operation and maintenance cost. Therefore, good qualities of foam-mat dried mango powder with a cost-effective production would be a commercial potential for small-medium enterprise or community enterprise utilization.

Keywords: Foam-mat dried mango, Foaming agent, Drying technology, Mango powder

Introduction

Mango is a tropical fruit which is common in the Asia Pacific region. The biggest mango production is in India, China, and Thailand, respectively [1]. Mango is well known for its exotic flavor, attractive fragrance, beautiful color, and taste and is incredibly famous in the international market [2]. Fresh mango is a valuable exporting fruit of Thailand for many decades. However, mango oversupply problem and poorly post-harvest handling are a major cause for Thai mango production [3]. Processed mango products like puree, juice, concentrate, and powder are applied. Mango powder offers several advantages such as having a much longer shelf life, decreasing transportation costs, and more flexibility for innovative formulations in a new market [4]. Mahajanaka mango (*Mangifera indica L.*), the yellow fruit had identity on color, aroma, and sweet taste. It had the potential to develop into a powdered beverage with an aroma and flavor like fresh fruit juices possible [5].

Several drying technologies can be viable commercial options for mango powder production including drum drying, spray drying, refractance window drying, freeze drying. Each has its own advantages and limitations [4]. Drum drying is a method used for drying out liquids from raw materials with a drying drum. The drum dried particle is larger than the other dried particle and it is a flaky particle. However, this method can dry viscous food, easy to operate and maintenance [6]. Spray drying is a method of producing a dry powder from a liquid or slurry by rapidly drying it with hot gas. The spray dried powder has a uniform particle size within the range of 100 to 300 μm. The advantages of spray drying include its ability to be fully automated and continuous and it is suitable for a variety of feed materials and often used for encapsulation [7]. Refractance window drying uses circulating water at atmospheric pressure to carry heat to the product to be dried. Several foods that are difficult to spray dry without the addition of non-sugar carriers have also been handled successfully in the refractance window dryer. This drying method makes it suitable for processing of high-value foods, nutraceuticals, and food supplements. Moreover, the refractance window drying is simple and inexpensive compared to the freeze drying [8]. Freeze drying is a low temperature dehydration process that involves freezing the product, lowering pressure, then removing the ice by sublimation. The freeze-dried product can maintain its aroma, flavor, and taste nearly to the fresh materials. However, freeze dryer is more expensive batch process and its dried product is not free flowing [9]. Foam-mat drying is an economical alternative to drum, spray and freeze drying to produce food powders. Foam mat drying is a process in which the transformation of products from liquid to stable foam is followed by air drying. Stable gas-liquid foam is the primary condition for successful foam drying [10]. Selection of a suitable drying method is particularly important in terms of cost and final quality of the dried product. Some of these drying methods need high installment, energy expenses make them not suitable [11]. The objective of this study is to evaluating powder qualities of the foam-mat dried mango during processing and accelerated storage condition to see its potential for technology transfer to small-medium enterprise or community enterprise in Thailand.

Materials and methods

Materials

Fully ripened mangoes (95 - 100 % ripeness) of Mahachanok or Rainbow mango variety were collected from Pa Phai subdistrict, Lee district, Lamphun province, Thailand. Foaming agents and chemicals used in this study were of Food grade and AR grade, respectively. Food grade blender (Tefal Blender, Model BL42S166), Food grade stainless mixer (KitchenAid Mixer, Model 5KSM175PSECA), and Tray dryer (Owner Foods Machinery Co., Ltd, Model 8O6A) were used for the foam-mat operation.

Preparation of mango puree and foam-mat mango samples

Fully ripened mangoes were washed with water to remove dirt and waste. Mango pulp was homogenized using the food grade blender after peeling of skin and stone removal. Mango puree was pasteurized, packed in 2 kg polyethylene (PE) bags, sealed, and then placed in to cartoon boxes and stored at 0 - 4 °C. Cool mango puree was kept in room temperature before adding glyceryl monostearate (GMS), sugar and soybean isolated (SBI) in different ratios (1 % of GMS adding 5 % sugar, 1 % of GMS adding 10 % sugar, 2 % of GMS adding 5 % sugar, 2 % of GMS adding 10 % sugar, 1 % of GMS adding 5 % sugar and 1 % SBI, 1 % of GMS adding 5 % sugar and 2 % SBI, and 1 % of GMS adding 5 % sugar and 3 % SBI). Each treatment was placed in the food grade mixer (8 speeds for 10 min in 3 times) to develop the foam. Foamed pulp was spread in food grade stainless steel trays and dried in tray dried at 70 °C for 5 h.

Physical analyses

Mango puree and foam-mat dried mangos were poured into a glass plate before measuring color. The International Commission on Illumination (CIE) parameters L*, C*, and H* were measured with a Minolta Chroma CR-200 color meter (Minolta Co., Osaka, Japan). The colorimeter was calibrated with a standard white ceramic plate (Y = 85.5, x = 0.3148, y = 0.3218) prior to reading. Three readings were taken from each of 3 locations to calculate an average of L*, C*, and H*. The density of mango puree mixture of each treatment was determined by weighing 100 mL of puree mixture in 100 mL measuring cylinder. For the foam, 200 mL of the foam was transferred into a 250 mL measuring cylinder and weighted. The foam transferring was carried out very carefully to avoid destroying the foam structure or trapping the air voids while filling the cylinder [12]. Triplicate of each treatment were applied and then calculated following this equation below.

$$\%\text{Foam overrun} = \frac{\text{volume of foam} - volume\ of\ mixtue}{volume\ of\ mixture} \text{ x } 100$$

Powder analyses

The water content of foam-mat mango powder was determined using the standard oven method at 70 °C for 24 h (AOAC, 1998). The foam-mat mango powder was weight before placed in a weigh moisture can and after oven-dried until its weight constantly. The moisture content (%) of each foam-mat mango powder was calculated following as this equation.

$$\%\text{Moisture content} = \frac{weight\ of\ can\ before\ oven\ dried - weight\ of\ can\ after\ oven\ dried}{weight\ of\ sample} \text{ x } 100$$

Water activity of foam-mat mango powder was measured using water activity meter (Aqualab 4TE series, Meter Group, Inc. USA). Duplicate samples were measured at 24.7 ± 1 °C.

Foam-mat dried mango powder was sieved and then the powder at 180 - 250 μm particle size were chosen for solubility and hygroscopicity analysis. One gram of foam-mat mango powder was dispersed in 100 mL distilled water by blending at high speed (approximately 13,000 rpm) for 5 min. The dispersed mango powder was then centrifuged at 3,000 g for 5 min. A 5 mL aliquot of the supernatant was carefully pipetted and transferred to a pre-weighed moisture can and then oven-dried at 105 °C for 5 h. Drying was continued and weighed every hour for 2 h. The solubility of powder (%) was determined by taking the weight difference.

One gram of each foam-mat mango powder was set in open containers and then samples were placed in a desiccator containing a saturated solution of NaCl (75.29 % RH). The desiccator was stored for 7 days in an oven at 25 °C. After 1 week, samples were weighted by triplicate. This method was modified and followed as [13]. Hygroscopicity data was calculated according to this equation.

$$\text{Hygroscopicity} = \frac{\Delta m/(m + m1)}{1 + (\Delta m/m)}$$

where Δm is the increasing of powder's weight after reaching equilibrium (g), m is the powder's initial mass (g) and m1 is the initial free water content of the foam-mat mango powder before being exposed to air's humidity (g/100 g).

Accelerated storage of foam-mat dried mango

Twenty grams of foam-mat dried mango powder with an initial moisture content (less than 5 %) was packed in aluminum laminate pouch (6 cm in width and 10 cm in height) and placed in an environment maintained at 90 %RH, and 38 ± 2 °C. Four of these pouches were prepared, and after 30 days within intervals of 15 days modified from [14], one of the pouches was remove from the control condition and then its content analyzed for 1) color measurement, 2) moisture content, 3) water activity, and 4) solubility.

Statistical analysis

The statistical analysis of results was performed using SPSS version 11.0 software based on one-way analysis of variance at a significance level of $p = 0.05$ to determined accordingly the percentage of foam overrun, moisture content, solubility, and hygroscopicity of all control and foam-mat dried samples. Significant differences between means were determined using Duncan's test with 3 replicate data of all analysis items.

Results and discussion

Powder quality of foam-mat dried mango

Fresh mango puree as a control treatment was compared to other treatments which added in different concentrations of foaming agents in term of color changing and %foam overrun (**Figure 1**).

Color of a control sample was not significantly different between before drying and after drying while the L* values of mango puree added by GMS and sugar were increased after drying especially GS1 (1 % of GMS adding 5 % sugar). However, the GMS used with maltodextrin and tricalcium phosphate in vacuum dried mango did not show any significantly different in color values [15,16]. Lighten of adding soybean isolate in different ratios with 1 % of GMS and 5 % sugar was not changed after drying. The c* values and h* value of dried foam-mat mango in each adding foaming agents were decreased. Higher percentage of foam overrun was exhibited a decent quality of foaming. Therefore, adding GMS with sugar in mango puree provided a superior quality of dried foam-mat more than that with soybean isolate. According to the color measurement data and % foam overrun; 4 treatments were chosen for the next powder quality analysis (**Table 1**). Increasing percentage of sugar from 5 to 10 % was rise the moisture content of both 2 different glyceryl monostearate. The lowest percentage of moisture content of dried foam-mat mango was using 1 % of GMS adding 5 % sugar as foaming agents. Moreover, that treatment demonstrated a higher percentage of solubility and hygroscopicity. Therefore, the suitable foaming agent ratio was 1 % GMS and 5 % sugar. It was revealed that the glycerol monostearate was being a good foaming agent with a lower price than egg whites [14].

Accelerated storage of dried foam-mat mango

Accelerated storage was applied for evaluating the quality of each dried foam-mat mango treatments compared to a commercial dried mango (control). The change of dried foam-mat mango color was shown in **Figure 2**. The commercial dried mango provided a higher L*, c* and h* values than the foam-mat 1. The foam-mat dried mango trend to be darker than the commercial one. However, the color of all foam-mat dried mango treatments did not change much under the accelerated storage condition except the beginning period for adding 1 % of GMS with 10 % sugar (GS2) was bring out the lowest h* value. In the same accelerated storage condition, the color changing of dried foam-mat mango using GMS and sugar as foaming agent was contributed a similar changing in vacuum dried mango using GMS with maltodextrin and tricalcium phosphate with an acceptable range [14]. Therefore, the quality of mango powder using GMS and sugar as foaming agents was not differ from that of using the other foaming agents. Price of GMS and sugar were lower than the other foaming agents such as egg white, carboxymethylcellulose, soy protein, egg albumin etc. However, the GMS and sugar were not familiar to be foaming agents because of a water sorption isotherm of sugar. Water activity, moisture content and solubility properties of foam-mat dried mango were studied to demonstrate an excellent quality of GMS and sugar as foaming agents.

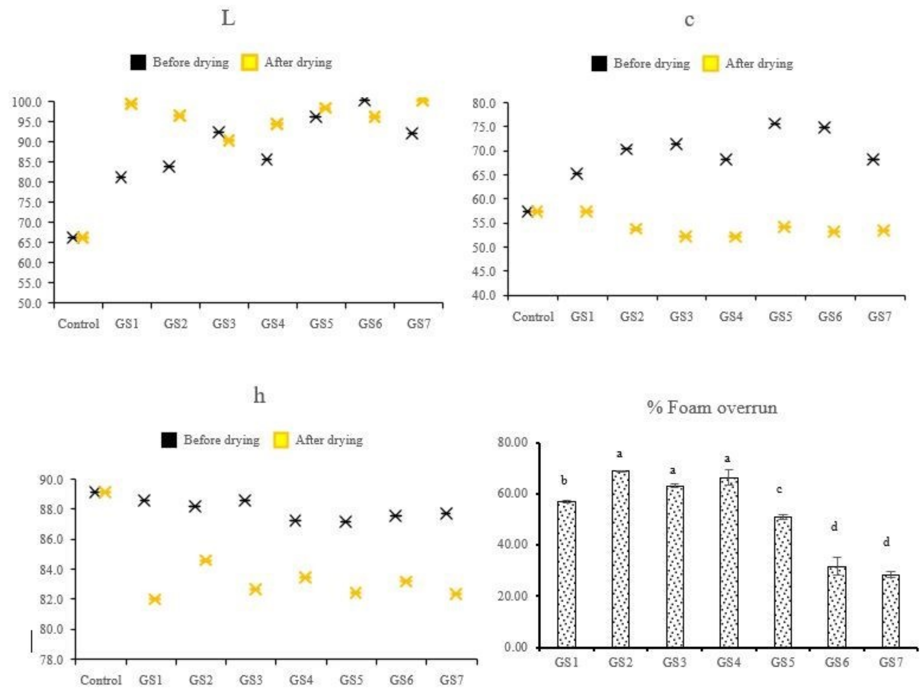

Figure 1 Comparing L*, c* and h* value (color parameter) and % Foam overrun of Control sample to GS1 (1 % of GMS adding 5 % sugar), GS2 (1 % of GMS adding 10 % sugar), GS3 (2 % of GMS adding 5 % sugar), GS4 2 % of GMS adding 10 % sugar), GS5 (1 % of GMS adding 5 % sugar and 1 % SBI), GS6 (1 % of GMS adding 5 % sugar and 2 % SBI), and GS7 (1 % of GMS adding 5 % sugar and 3 % SBI).

Table 1 Comparing the percentage of moisture content, solubility, hygroscopicity of foam-mat dried mango in different concentration of foaming agents.

Powder analysis	GS1	GS2	GS3	GS4
Moisture content (%)	2.58 ± 0.36^{d}	4.56 ± 0.02^{a}	3.80 ± 0.05^{c}	4.17 ± 0.04^{b}
Solubility (%)	1.554 ± 0.001^{a}	0.779 ± 0.001^{ab}	0.728 ± 0.003^{b}	0.776 ± 0.014^{ab}
Hygroscopicity (%)	0.045 ± 0.005^{a}	0.026 ± 0.001^{b}	0.026 ± 0.001^{b}	0.025 ± 0.001^{b}

Remark: Various letters in the rows show statistical difference among the results ($p < 0.05$) of those foam-mat dried mango treatments; GS1 (1 % of GMS adding 5 % sugar), GS2 (1 % of GMS adding 10 % sugar), GS3 (2 % of GMS adding 5 % sugar), GS4 2 % of GMS adding 10 % sugar).

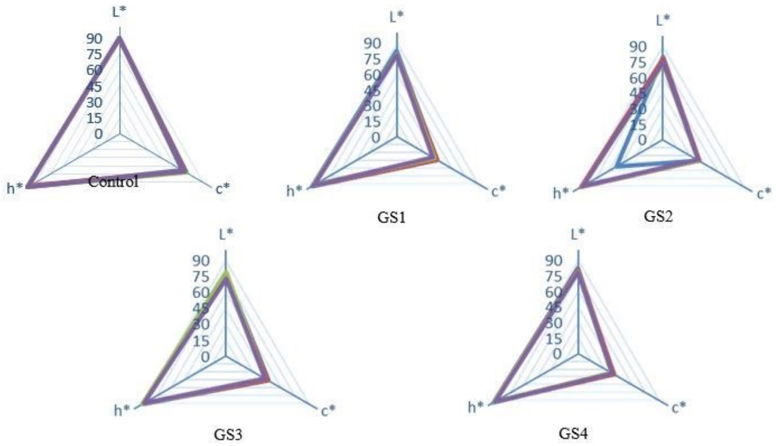

Figure 2 Color changing during the accelerated storage condition of commercial dried mango (control) and those foam-mat dried mango treatments; GS1 (1 % of GMS adding 5 % sugar), GS2 (1 % of GMS adding 10 % sugar), GS3 (2 % of GMS adding 5% sugar), GS4 2 % of GMS adding 10 % sugar).

Comparing the powder quality of commercial dried mango to foam-mat dried mango demonstrated in **Figure 3**. The commercial dried mango had the lowest water activity even though at 90 days it was still lower than 0.4. The water activity of the foam-mat dried mango adding 1 % of GMS and 5 % sugar was increasing and reached 0.4 at 70 days but was still lower than 0.6 at 90 days. The other 3 treatments contributed to a higher water activity more than 0.4 at 40 days and those would be 0.6 at 90 days. The moisture content of the commercial dried mango was less than 5 % during storage time with a consistency of % solubility of more than 1 %. On the other hand, all the foam-mat dried mango treatments showed a moisture content 4 to 6 % with a lower % solubility than the commercial one. These qualities changing revealed that the commercial dried mango would be processed by spray dryer as their powder quality was constantly more than the others. The best powder quality during this accelerated storage condition was the foam-mat dried mango applying 1 % of GMS adding 5 % sugar as foaming agent.

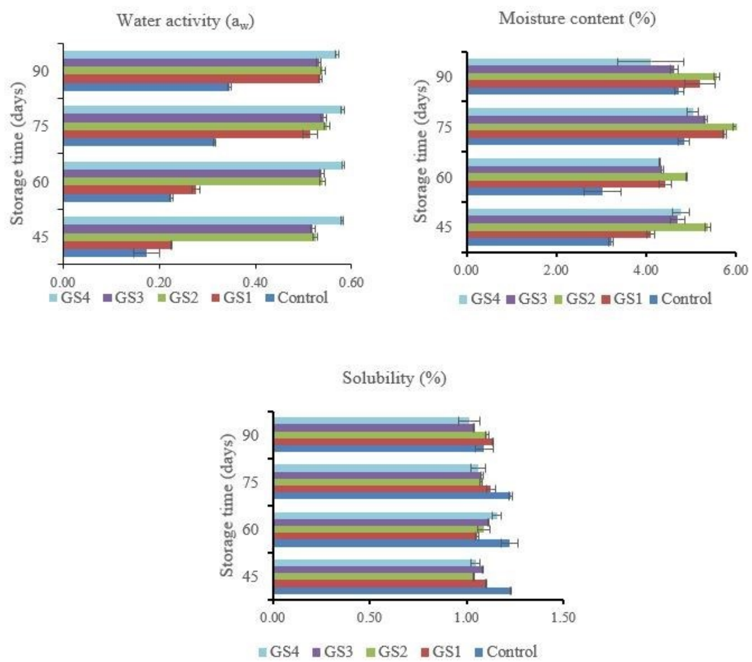

Figure 3 Comparing water activity, percentage of moisture content, and solubility during the accelerated storage condition of commercial dried mango (control) and those foam-mat dried mango treatments; GS1 (1 % of GMS adding 5 % sugar), GS2 (1 % of GMS adding 10 % sugar), GS3 (2 % of GMS adding 5 % sugar), GS4 2 % of GMS adding 10 % sugar).

Comparing drying method on quality of dried mango

There were many types of drying methods for food processing which had advantages and limitations on agriculture raw materials. This study would like to compare the foam-mat drying results to the other drying method for dried mango production to see how potential commercialization of the foam-mat drying for small and medium enterprise. Physical properties of dried mango produced from reflectance window drying, freeze drying, drum drying, and spray drying were studied by Caparino *et al.* [4]. The water content of foam-mat dried mango was 2.58, 4.56, 3.80, 4.17 % applying different concentration of foaming agent (**Figure 3**) compare to Caparino *et al.* [4] results that each drying method had a different percentage of moisture content such as reflectance window dried mango obtained 1.70 %, the freeze dried mango was 2.30 % , the drum dried mango presented 1.30 % and the spray dried mango exhibited 4.30 %. Surprisingly, the moisture content of foam-mat dried mango adding 1 % of GMS with 5 % sugar was not differ from that of freeze-dried mango as well as the foam-mat dried mango within the other foaming agent ratios were obtained the moisture content were quite like that of spray drying method. It was shown that the foam-mat drying method exhibited an excellent quality in terms of moisture content of dried mango as same as freeze drying and spray drying. Comparing temperature and time for drying of each method shown that reflectance window drying using 74 ± 2 °C for 3 min, freeze drying required 20 ± 0.5 °C for 1,860 min, drum drying applying 105 ± 5 °C for 0.9 min, and spray drying using 90 ± 2 °C for 0.05 min [4] while foam-mat drying using 70 ± 5 °C for 420 min. The color of reflectance window dried mango powder was not difference from freeze dried mango powder but were significant different from drum dried mango power (darker), and spray dried mango power (lighter) [4] however, the L*, c* and h* value of foam-mat dried mango powder was higher than the above drying method. Therefore, the foam-mat dried mango powder would be the lightest. The other physical properties of dried mango such as percentage of solubility and hygroscopicity of the foam-mat dried mango powder was the lowest (less than 1 %) while the other drying methods shown the higher value of both 2 parameters around 90 % solubility and 16 - 20 % hygroscopicity.

According to the comparing mango powder qualities results of foam-mat drying to others drying method studied by Caparino *et al.* [4], it could be concluded that the moisture content of foam-mat dried mango was not higher than that of others drying method. Furthermore, the color of foam-mat dried mango was in an acceptable range so that the foam-mat drying was suitable for mango powder production. Comparing the major fixed cost of those drying method, the freeze dryer was the highest price (more than 100,000 US dollars) and requires at least 1,860 min for 1 operation. The spray dryer was the second highest price (around 80,000 - 100,000 Us dollars) followed by the drum dryer that was approximately 10,000 Us dollars and both of 2 drying methods require less than 1 min for 1 operation. The foam-mat drying was operated using hot air oven with the lowest price (1,000 US dollars) while the operation time was 420 min which was higher than the spray dryer and drum dryer but still lower than the freeze dryer. Therefore, the foam-mat dried mango seems to be a better choice for a small-medium enterprise or community enterprise in terms of the lowest machine cost and convenience to operate. The Mango market has witnessed growth from Million USD to Multimillion USD from 2017 to 2022. With the magnificent CAGR, this market is estimated to reach Multimillion USD in 2029 and basis of product types have been mango butter, a dried mango, a fresh mango, and others [17,18]. The mango puree market was valued at 760 US dollars in 2021 and will grow at 7.3 % CAGR through 2027. The beverages segment would reach 750 US dollars in 2021, growing at a CAGR of 7.2 %. The beverages segment of the global mango puree market is expected to reach a market value of over 1,100 US dollars in 2027, growing at a CAGR of 7.2 % and the ice cream and yogurt segment have been ahead in terms of CAGR, with the highest CAGR of 7.8 % during the forecast period [19]. Obviously, mango has been a one of major agricultural material with a higher economic value and mango powder would be a proper utilization in terms of extending shelf life, convenience for transportation, and being a good ingredient for the other food manufacturers.

Conclusions

The foam-mat dried mango using a glyceryl monostearate and sugar as foaming agents expressed an acceptable quality in terms of the moisture content, color, water activity, and solubility during the accelerated storage conditions as same as to the commercial one. Moreover, the foam-mat dried mango contributes good powder qualities and demonstrates the lowest fix costs such as a machine price, a convenience to operate comparing to the other drying methods. It could be concluded that the foam-mat drying method is cost-effective for mango production especially in small-medium enterprises or community enterprises.

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