Processing feasibility and qualities of freeze dried mango powder for SME scale

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Abstract. This research studied the processing feasibility and quality of the premium mango powder ‘Mahachanok’ for SME business. Freeze-dried mango powder as an alternative high quality mango powder. The frozen mango puree was thawed at 4°C for 12 hours. The freeze dry processes to freezing and vacuum drying product within a single chamber. The operation cycle included 3 main steps: First step was rapidly frozen with contact plate and air blast freezing at -50°C until core product temperature was -20°C. After that, two steps drying were operated at 40 Pa. The primary drying was operating until core product temperature reached to -10°C, respectively. The secondary drying temperature was controlled at 40°C. The freeze dried mango powder price reached to 1,322.76 baht/kg. In addition, physical properties (total soluble solids, pH and color) of rehydrated freeze dried mango sample were similar to mango puree, which had not significantly different (p<0.05). Thus, freeze drying can be developed and applied to process as premium mango powder at the industrial level.

1. Introduction
Mango (Mangifera indica L.) is a popular and economically important tropical fruit throughout the world, due to its excellent eating quality (bright yellowish, sweet and sour taste) and high nutritional composition [1]. Mahachanok is a new variety of mango. Which is the breeding of ‘Sunset mango’ and ‘Nangklungwan, that has great attention because its excellent flavor and aroma. The ripe mangoes have reddish-purple peel, sweet and sour taste (15-18 °brix) [2]. The mango peels, pulp and seeds are rich in antioxidant and phenolic compounds such as carotenoids, anthocyanins, mangiferin, gallic acid, caffeic acid, tannin and many other biologically active components that have positive influences on health [3, 4].

The amount of mango Thailand exports estimated 59,045 tons and valued at 3,323 million baht in 2017 [5]. However, the fresh mangoes containing up to 80 percent water. Its can be perishable and deteriorate in a short period of time if improperly handled, resulting in physical damage and quality loss. Therefore, the mango processing has a role in adding value to that product such as frozen mango, mango juice, mango jam, mango sauce, dried mango etc.

At present, the development of high quality fruits powder may match the increasing global demand for more natural flavoured. Natural fruit powders were great demanded by the food, pharmaceutical and cosmetic industries [4]. For example, mango powders can be used as ingredients for healthy drinks, baby foods, sauces, yogurt, ice cream, nutrition bars and supplementary food. Moreover, rehydrated mango can be used as juice concentrates or purees. The food powders are easy to preserve, transport, store and weight and process. Most fruit
powders obtained commercially by spray drying because rapid drying, large throughput and continuous operation. However, several drying technologies can be viable commercial options for manufacture of fruit powders, including drum drying, refractance window drying and freeze drying [6].

Freeze drying is a process that can reduce the problem of thermal effects on the product due to the freeze drying using low temperature and pressure, which uses the sublimation principle, the first step of process is freezing the product and then dried under the pressure below the triple point. Freeze dried products have properties similar to the raw materials when compared another drying process [7-8] as same as the research of O.A. Caparino et al. in 2012 [4] found that the mango freeze dried powder was selected to be the best process to maintain the quality and also maintain property as a fresh puree. However, the freeze dry process with freezing and vacuum drying within a single chamber have not been performed to dried mango puree. This research aims to study the feasibility of the premium mango powder production process, including process feasibility analysis, physical properties and total phenolic content of freeze dried mango powder ‘Mahachanok’ for the SME business.

2. Materials and methods

2.1. Raw material

The mangoes (Mangifera indica L. cv. ‘Mahachanok’) were obtained from Chiangmai Fresh Co., Ltd. (Chiang Mai province, Thailand), which has received GAP certification from The Department of Agriculture and focus on intensive care agriculture. The fruits were wrapped with paper manually individually by hand instead of using pesticides. In addition, mangoes are separated and preserved with meticulousness in order to obtain premium ‘Mahachanok’ mango. Mangoes were washed with chlorine solution (200-300 ppm), trimmed and crushed the mango into mango puree. The average total soluble solids of mango puree was 15-19˚brix and pH 3.4-5.0. The puree was packed in 5 kg Linear Low-Density Polyethylene (LLDPE) bags, freezing and storage at -18°C.

2.2. Raw material preparation

The frozen mango puree was thawed at 4°C for 12 hours until the final temperature was 4°C, stirred at 25 ℃ until well combined. The mango puree was put in a 34x48 cm aluminium tray 1.5 kg.

2.3. Freeze drying

The Kryo “D” Freezer was designed for freezing and vacuum drying within a single chamber. In addition, the refrigeration system is designed for combines between the air blast freezer (-50°C) and the semi-contact plate freezer (R-507: non-CFC). This can quickly freeze the product. The schematic diagram of the equipment was shown in Fig. 1.

Figure 1. Schematic diagram of designed freeze dryer
In figure 2 shows the setting temperature and pressure operation of freeze dry machine. Sample was frozen in the chamber until the sample temperature was -20°C (B). The product core temperature was detected by the RTD probe. The system was primary dried, by operating the pressure lower than 40 Pa and then the shelf temperature was heated to -10°C, respectively (E, F, G). The secondary drying, shelf temperature increases to 40°C. The freeze drying was completed when the difference of core temperature of 1°C.

![Figure 2. Changes of temperature and pressure during freeze drying process](image)

2.4. Handling and packaging of samples.
Mango freeze dried products (fig 3) were grind using blender (Hr2115, Philips, Netherlands) at level 5 for 20 seconds, then sieved to get particle size of 500 μm and sealed in aluminium foil. During storage, samples were kept in a controlled room at a temperature of 25 °C and relative humidity of 30-40% RH.

![Figure 3. Steps for freeze dried mango powder processing](image)

2.5. Mango powder characterization
2.5.1. Powder yield (%Yield). The powder yield was estimated at the relationship between the weight of the freeze dried product and the weight of the mango puree were calculated as follows:

\[ Y = \frac{W_2}{W_1} \times 100 \]  

(1)

Where \( Y \) is powder yield (%), \( W_1 \) is the weight of the mango puree sample (g) and \( W_2 \) is the weight of the mango freeze dried sample (g).

2.5.2. Total soluble solid (TSS) and pH. The pH and total soluble solids (TSS) contents were evaluated in a 10 mL sample, which mango powder was reconstitution with distilled water according to the weight loss and that were taken to quantify pH, using a pH meter (Lab855,Sl Analytics, Germany) and total soluble solid was determined by refractometer (HI96800, Hanna, Romania) with three replication.
2.5.3. **Moisture content.** Moisture content was determined using hot air oven method [9]. Powder sample was dried in the oven at 105°C until a constant weight was achieved. Then, the following relation was used:

$$\text{Moisture content} = \frac{(W_1 - W_2)}{W_1} \times 100$$

Where \(W_1\) is weight of powder before drying (g) and \(W_2\) is weight of powder after drying (g). Moisture content was expressed as percentage (wet basis). The analysis was triplicated.

2.5.4. **Water activity (aw).** Mango freeze dried powder samples were taken about 2.00 grams to determine water activity using electronic water activity meter (Decagon Model, AquaLab, USA). Three replications of water activity were performed for each sample.

2.5.5. **Color.** The fresh or rehydrated mango puree samples were measured using spectrophotometer (ColorFlex, Hunter Lab, UK) in terms of CIE \(L^*\), \(a^*\) and \(b^*\) values. The Color values were expressed as:

\[L^* = \text{lightness} (100) / \text{darkness} (0)\]
\[a^* = \text{red} (+) / \text{green} (-)\]
\[b^* = \text{yellow} (+) / \text{blue} (-)\]

The total color difference (\(\Delta E\)) was calculated as in equation (3). [10]

$$\Delta E = [(L^*_{\text{fresh}} - L^*)^2 + (a^*_{\text{fresh}} - a^*)^2 + (b^*_{\text{fresh}} - b^*)^2]^{1/2}$$

2.5.6. **Bulk density.** Bulk density was determined according to Shishir et al [11]. The cylinder container was set up distance between bottom of loading funnel and top of the cylinder container as 15 cm, using 60 cm³ cylinder container. The powder was loaded to flow through the funnel into the cup until it overflows and scraped excess powder from the top of the cup by smoothly moving spatula. The cylinder container with mango powder samples was then weighed. The experiment was replicated five times. The bulk density was expressed by the equation (4):

$$\rho = \frac{m}{V}$$

Where \(\rho\) (g/cm³) is bulk density, \(m\) (g) is the mass of powder samples and \(V\) (cm³) is the volume of receiving cup. The bulk density measurements were performed in five repetitions.

2.6. **Total phenolic content.** Mango powder (25 g) was rehydrated with 107 mL of distilled water and centrifuged (MIKRO 220R, Hettich, German) at 6,000 rpm, 4°C for 20 min, then store the supernatant in opaque bottles at -18°C for further analysis.

Total phenolic content (TPC) in the mango puree extracts was determined using the Folin-Ciocalteu method described by Chan et al. [12]. The diluted extract (2.25 mL) was added 4.75 mL distilled water and mixed with 0.25 mL of Folin–Ciocalteau's reagent by vortex. After 5 min, 1.00 mL of 10% w/v Na2CO3 was added to the mixture. The absorbance was measured at 730 nm using a spectrophotometer after 10 min reaction.

2.7. **Statistical analysis.** Data were processed using SPSS 20 while analyses of variance were conducted by the SPSS Paired Sample T-test procedure. Mean values were considered significantly different when \(p < 0.05\).
3. Results and discussion

3.1. Feasibility analysis of freeze dried mango powder.
In this research shows the method of adding value to mango products with the mango processing as shown in Figure 4. Although the processing makes the percentage of yield decrease, which reverses the value of the product increases. Fresh mango could be sold in the market as 15 baht/kg. However, the fresh mango have a short shelf life. Therefore, some entrepreneurs increased value added and extended shelf life of mango using processes such as freezing or dehydration. Figure 4 shows yield percentage of frozen mango puree was 60% but the price of frozen mango puree was 6 times as higher as the fresh mango price, in addition, frozen puree could be stored more than 1 year at temperature of -18°C. Moreover, freeze dry process was applied to create premium mango powder from mango puree which was maintained nutritional value and could be stored more than 1 year at room temperature. Freeze dried mango powder reached up to 1,300 baht/kg that was 80-90 times as higher as the fresh price.

![Figure 4. Processing flow diagram of mango products](image)

Mango powder has 4 basic cost components (Figure 5): raw material cost 10%, freeze drying process cost 84% due to the small amount of production, so the average cost per piece is high value. Which the production cost will be lower when there is more production or manufactured at the industrial level. The packaging cost is 4% and the last part is the production labor cost of 2%.

The price of the freeze dried mango powder has been in a high position for price and quality. The marketing plan will put the mango powders may also offer the flexibility for innovative formulations. For example, mango powder can be used as a replacement for concentrated fruit juices or purees, ingredient in baby food, sauces, fermentation, yogurt, ice cream, nutrition bars, cereals and cosmetics product for increase nutrition.
3.2. Drying time characteristics of mango powder in the freeze-drying process.
The moisture content decreased with drying time for mango puree (Figure 6). It was found that the duration time of freeze drying approximately 76.30 hours. The primary and secondary drying time were 65 and 10 hours, respectively. The primary drying time were take longer than secondary drying because its used low temperature for drying.

![Figure 5](image1.png)

**Figure 5.** Cost structure of freeze dried mango powder in pilot scale production

![Figure 6](image2.png)

**Figure 6.** Freeze drying temperature profile of mango puree

3.3. Physical properties of mango powder.
The result properties of mango after the freeze drying process shown in table 1. “Total soluble solid and pH” of fruit juice is commonly used as the index for sensory acceptability of product [13]. TTS and pH of rehydrated sample were similar to mango puree. The moisture content and water activity of after drying was noticeably decreased. Generally, dry foods have a water activity of approximately 0.2 or less [14]. In addition, the bulk density is a factor that direct relationship with the powder products and including packaging design, transportation and marketing of these products [15]. The bulk density was 0.4940 g/cm³. Powder food have a bulk density of around 0.4 - 1.5 g/cm³ [14]

Mango powder was reconstituted before analyzed for the color values in a term of CIE L*, a* and b* system of products and total colour difference (ΔE) are presented in table 2. There were not significant differences of L*, a* and b* at the 95% confidence level between before freeze drying and rehydration. Therefore, freeze drying did not affect the color value of product. Drying at low temperature like freeze drying was selected to be the best process to maintain the quality of food and also maintain food property as a fresh food, especially in the color.
3.4. Effect of freeze drying on total phenolic content of mango powder.
TPC is one of the most important properties that indicates health benefit of the premium mango powder. Figure 7 show TPC of mango powder product. It has been found that there were a significant difference at the 95% confidence level between mango puree and rehydration powder. The freeze dried mango powder in this research had greater amount of TPC when compared to the research of Siddiq et al. (2013)[16], it was found that the total phenolic compounds in fresh mangoes only 25.98 mg gallic acid equivalent/100 g puree sample.

Furthermore, there are many encapsulating agents used to encapsulate to maintain antioxidant and phenolic compounds in the product, such as gum arabic, dextrose and modified starch Manuela et al., 2016 [17].

Table 1. Physical properties of mango powder.

| Product       | Total soluble solid | pH      | Moisture content (%w.b) | Water activity | Bulk density (g/cm³) |
|---------------|---------------------|---------|-------------------------|----------------|----------------------|
| Fresh         | 18.6±0.4             | 4.77±0.01 | 79.05±0.03              | 0.892±0.045    | -                    |
| After freeze dry | 18.4±0.2             | 4.79±0.01 | 4.88±0.27              | 0.287±0.010    | 0.4940 ±0.0008       |

ns, a b Different letters in the same column within the same section indicate a significant difference (p<0.05). The values shown in the table are mean ± standard deviation.

Table 2. The color of mango powder, fresh mango puree and rehydration.

| Color value | Powder | Mango puree | Rehydration |
|------------|--------|-------------|-------------|
| L*         | 77.41±0.54 | 48.72±0.01mn | 50.44±0.58mn |
| a*         | -2.15±0.15 | 16.58±0.00mn | 15.42±0.14mn |
| b*         | 24.08±0.37 | 51.89±0.03mn | 51.22±0.37mn |
| Photo      | -      | -           | 2.54 ± 1.14  |

mn letters in the same row indicate not statistically significant (p<0.05). The values shown in the table are mean ± standard deviation

Figure 7. The total phenolic content of fresh and freeze-dried mango powder products. a b Different letters in the picture within the same section indicate a significant difference (p<0.05).
4. Conclusions
The product feasibility analysis is important for entrepreneurs and should be considered as well. In this research shows the method of adding value to mango products. Freeze dry process was applied to create premium mango powder from mango puree which was maintained nutritional value. Freeze dried mango powder value up to 1,300 baht/kg (approximately 80 times as the fresh). In production techniques term found that the drying time for mango puree approximately 76.30 hours. TTS and pH of dried rehydrate sample were similar to mango puree. For moisture content and water activity of after drying was noticeably decreased. The color values were not significant differences of $L^*$, $a^*$ and $b^*$ at the 95% confidence level between before freeze drying and rehydration. Therefore, freeze drying did not affect the color value of product. The results of TPC showed that there were a significant difference at the 95% confidence level between mango puree and rehydration powder. However, freeze drying is considered a process that helps to maintain TPC or antioxidant compounds when compared to other processing. Consequently, freeze drying can be developed and applied to process as premium mango powder at the industrial level.

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