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Comparing the Efficiency of Two Carrier Types on Drum Drying of Tamarind Juice

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Abstract

The main purpose of this work was to study the effect of carrier agents on the drying capability and the qualities of tamarind powder produced by a drum dryer. Two popular carrier agents, namely maltodextrin and modified starch, were applied to tamarind juice at juice-to-carrier-agent ratios of 1:0.3, 1:0.4, 1:0.5, 1:0.6, 1:0.7 and 1:0.8 (w/w). A double drum dryer was employed in this work at a drying temperature of 140°C, drum rotational speed of 0.50 rpm and gap between drums of 0.15 mm. The efficiency of carrier agent was evaluated by the capability of drying and product qualities such as product recovery, bulk density, total solid, moisture content and color difference. The results of the experiment indicated that the ratio of the carrier agent affected the drying capability. The tamarind powder were easily removed from the drums by doctor blades without sticking at the lowest ratios of moltodextrin and modified starch of 1:0.6 and 1:0.4, respectively. Furthermore, when considering the qualities of tamarind powder, as a carrier modified starch led to better tamarind powder qualities than maltodextrin

Keywords: Tamarind, Carrier agents, Drum drier

1 Introduction

Tamarind is one of the most important fruits of Thailand with the total production over 100,000 tons a year. Tamarind juice is an essential ingredient that provides the inimitable sour taste in many kinds of Thai food (Jittanit et al., 2011). However, the use of the fresh pulp still has many disadvantages due to its short shelf-life of about 6-8 months and, high cost of transportation. In addition, preparation for cooking is rather difficult. To overcome the aforementioned problems, a method of transforming tamarind paste into powder by a drum dryer is proposed.

A drum dryer consists of two hollow cylinders rotating in opposite directions. The drums are heated high temperature of saturated steam inside. A thin film of solution is coated on the outside surface of a heated drum and subsequent removal of the film of dry solids by applying the doctor blade. Drum drying is commonly used in production of low moisture baby foods and fruit powder. It is a technique widely used in the food industry to produce food powder particularly for heat sensitive products where short time high temperature drying is permissible (Nastaj, 2000). Additionally, Sunee (2008) stated that production of azuki bean powder using drum drying is advantageous because it can save time in product preparation, save storage space and convenie-nce to the users. Drum drying is a low cost and easy production process (Russamon, 1999).

Fruit juices are very difficult dried with a drum dryer because of the presence of low molecular weight sugars and acids, which have a low glass transition temperature, and high hygroscopicity (Jaya and Das, 2004). While under drum drying temperatures, they tend to stick to the surface of the drum and cannot be removed from the drums by doctor blades (Bhandari and Howes, 2005). Some possible consequences are related to impaired product stability, decreased yields (because of stickiness on the surface of the drum), and even operating problems to the dryer (Bhandari et al., 1997). Such problems can be alleviated by adding carrier agents, which are high molecular weight, such as

maltodextrin (MD), which decrease powder hygroscopicity and increasing the glass transition temperature (Silva et al., 2006). Additionally, Carneiro et al. (2013) reported MD is a relatively low cost and low viscosity at high solids concentrations. However, the biggest problem of this carrier is its low emulsifying capacity. Therefore, it is common to use MD in combination with other carriers, such as gum arabic (Fernandes et al., 2008) or modified starch (Bule et al., 2010) in order to obtain an effective juice powder by drum drying. Oliveira et al. (2009) pointed out that gum arabic has a glass transition temperature higher than MD and is very efficient in flavour retention, which suggests that it is probably reducing powder hygroscopicity more effectively than MD, but gum arabic is expensive. So, this motivated researchers to look for materials to replace it. Modified starch (MS), a carbohydrate that changes the native starch's property in accordance with a certain application. Such as modified starch can be used to replace other substances, like emulsifiers. Nonpolar modified starch can act as an emulsifier, offering stable emulsions.

The purpose of the present study was to evaluate the effects of MD and MS as carrier agents on the capability of drying and the quality of drum dried tamarind powder.

2 Materials and Methods

2.1 Materials

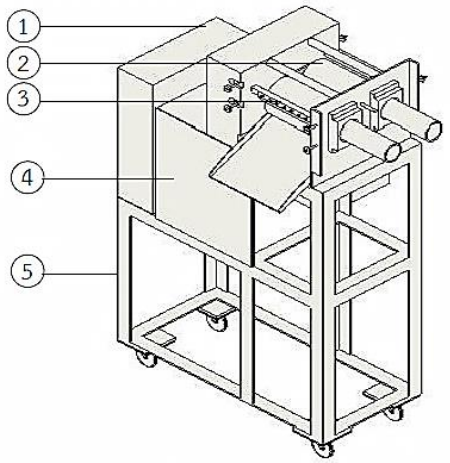
Tamarind flesh (Tamarindus indica L.) was purchased from a local market in Nakhon Ratchasima, Thailand. MD with dextrose equivalent of 10-12, pH of 4.5-6.5 and moisture content of 5.0-6.0% was purchased from Nutrition SC CO., LTD., Nakhonpathom, Thailand. MS with pH of 4.0-6.0 and moisture content of 4.0-8.0% was purchased from Questex CO., LTD., Sumutprakarn, Thailand.

2.2 Tamarind Juice Preparation

Tamarind flesh was deseeded and mixed with hot water at 80°C at a ratio of 1:5 (w/w). The mixture was squeezed into tamarind paste. Then, the juice was screened with the two-layer of cheesecloth to discard the residues. The total soluble solid of juice was determined and adjusted to be 12°Brix. After that, either MD or MS was added as a carrier agent to the juice at juice-to-carrier-agent ratios of 1:0.3, 1:0.4, 1:0.5, 1:0.6, 1:0.7 and 1:0.8 (w/w). The initial ratio of 1:0.3 was used by Kanniga (2006). Each the sample feed 500 ml.

2.3 Drum Dryer Setting

A double drum dryer with nip feed was employed in this work shown in Figure 1. The dryer, which consists of five main parts. The Control box was a box to control the drum outside surface temperature and drum speed of the rollers were 140°C and 0.50 rpm, respectively. Cylindrical hollow rollers made of stainless steel had a diameter of 15 cm, a length of 20 cm and a gap between drums of 0.15 mm. Doctor blades made of stainless steel were used for scraping food through the process of drying out. An electric motor of 1 HP was used to drive the machine. Finally, the structure that supports the weight of the whole machine.



① Control box ② Cylinder hollow rollers
③ Doctor blades ④ Electric motor ⑤ Structure

Figure 1 A drawing of double drum dryer.

2.4 Drying Experiments

The drying experiments were carried out using the randomized complete block design of two carrier agent (MD and MS), and six ratios of tamarind juice and carrier agent (1:0.3, 1:0.4, 1:0.5, 1:0.6, 1:0.7 and 1:0.8 w/w). At the end of drying, the tamarind powder was collected, weighed and kept in the sealed container for determination of the qualities. The procedure for the raw material preparation until the drying of tamarind is shown in Figure 2.

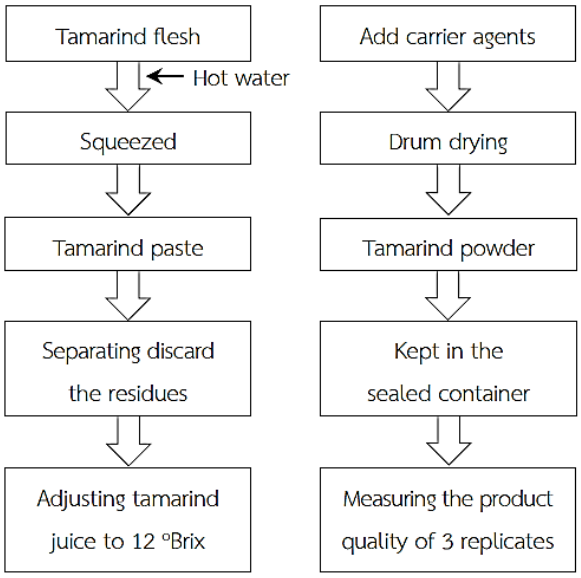


Figure 2 Schematic diagram of the experimental procedure.

2.5 Quality Determination

The qualities of tamarind samples, which included tamarind juice, in terms of total solid, moisture content, total acidity and color, were measured. For the tamarind powder, product recovery, bulk density, total solid, moisture content and color were measured. Apart from that, for the reconstituted tamarind powder were subjected to the determination of solubility, total acidity and color. Then all of qualities will be measured in 3 replicates.

Product recovery was determined using the ratio in the weights of dry solid of tamarind juice and powder (Kanniga, 2006). The product recovery was calculated as:

$$Product\ recovery = \frac{M_a}{M_b}\ x\ 100 \qquad (1)$$

where Ma and Mb are the weights (g) of dry solid of tamarind powder leaving the dryer and tamarind juice being fed into the dryer, respectively.

Bulk density of tamarind powder was determined using tamarind powder into the cylinder of known volume, then placing a cylinder with a tamarind powder and dropped by gravity at a distance of 0.1 m from the cylinder. After that, dropped tamarind powder until overflowing cylinder and then swept to the mouth of the cylinder smooth cylinder surface (Pao., 2005). The bulk density was calculated by using the equation as follows:

$$Bulk\ density = \frac{m}{v} \qquad (2)$$

where m is the mass of tamarind powder (kg) and v is the volume of the cylinder (m^3).

Total acidity of the tamarind was determined using the tamarind 50 ml into a 250 ml erlenmeyer flask and add 200 ml of distilled water, then 3-5 drop of 1% phenolpthalein were added as an indicator. After that, the mixture was titrated with a standard solution 0.1 N of NaOH until at the endpoint. The solution was indicated by color change to light pink (Pao., 2005). The total acidity was calculated as:

$$Total\ acidity = \frac{V\ x\ N\ x\ M_w\ x\ 100}{U \times 1000} \qquad (3)$$

where V is the volume of NaOH which was used in the titration until at endpoint (ml), N is the normality of NaOH, M_w is the molecular weight of tartaric acid = 150, U is the weight of the sample used in the titration (g).

Total solid and moisture content of tamarind was determined using the convection oven method (AOAC, 1984). Samples were dried in an oven at 105°C for 24 h. The total solid content and moisture content of tamarind in wet basis were calculated by using the equation as follows: Samples were dried in an oven at 105°C for 24 h. The total solid content and moisture content of tamarind in wet basis were calculated by using the equation as follows:

$$Total\ solid = \left(1 - \frac{W_2 - W_3}{W_2 - W_1}\right) x\ 100 \qquad (4)$$

$$Moisture\ content = \left(\frac{W_2 - W_3}{W_2 - W_1}\right) x\ 100 \qquad (5)$$

where W_1 is the initial weight of moisture can (g), W_2 is the weight of moisture can and tamarind before drying (g), and W_3 is the weight of moisture can and tamarind after drying (g).

The color of the tamarind juice was determined using Hunter Lab colorimeter in terms of the total color

change between the juice and the reconstituted powder. The color was expressed in terms of L (lightness), a (redness) and b (yellowness) (Shittu and Lawal, 2007). The change in the color was calculated by using the following equation:

$$\Delta E_c = \sqrt{(L_0 - L_p)^2 + (a_0 - a_p)^2 + (b_0 - b_p)^2} \qquad (6)$$

where L0, a0 and b0 are the color values of the tamarind juice, and Lp, ap and bp are the color values of the reconstituted powder.

Solubility of tamarind powder was determined by using about 1 g of each sample which were suspended in 10 ml of water at 30°C in a centrifuge tube. The suspension was stirred intermittently for 30 min before it was centrifuged at 3,000 rpm for 10 min. After that, the supernatant was poured into a moisture can and dried in an oven at 105°C for 24 h (Jaya and Das, 2004). The dry basis solubility of tamarind powder was calculated by using the following equation:

$$Solubility = \frac{M_s}{M_p} \, x \, 100 \qquad (7)$$

where Ms is the weight of dry solid of supernatant (g), and Mp is the weight of tamarind powder (g).

2.6 Statistical Analysis

Each tamarind powder quality parameter reflected the mean of three replicates. Statistical analyses were performed using SPSS. The statistical significance was determined by analysis of variance (ANOVA). The least significant difference of $p<0.05$ was calculated using the Duncan Multiple Range Test (DMRT). The data were expressed as average ± standard deviations.

3 Results and Discussions

3.1 Properties of Tamarind Juice

The fresh tamarind juice, after squeezing and screened with the use of two-layer cheesecloth had the total soluble solid of 12°Brix, the total solid of 11.72% and the moisture content of 88.28%. The mean and standard deviation of color in terms of L (lightness), a (redness) and b (yellowness) were 32.82±0.81, 7.85±0.19 and 18.77±0.39, respectively, while the total acidity and pH was 24.50%±0.09, 3.36±0.01, respectively.

3.2 Capability of Drying

When applying the MD at ratios of 1:0.3, 1:0.4 and 1:0.5, the feed was sticky and could not be scraped off the drums, as well as the cases of using MS at the ratio of 1:0.3. While, in the cases of using MD at the ratio of 1:0.6, 1:0.7 and 1:0.8, the feed was dried as flakes and cloud be removed from the drums by doctor blades, as well as the cases of using MS at the ratio of 1:0.4, 1:0.5, 1:0.6, 1:0.7 and 1:0.8. So, the lowest amount of MD to add in the tamarind juice was 60%, while MS used only 40%.

3.3 Qualities of Product

The results of experiments indicated that the product recovery were increased when the ratio of the carriers were increased (Figure 3) because the carriers are helping to increase molecular weight compounds, so it have a high glass transition temperature as a result drying up and the output of the drying process increases. They also found that, the MS had better product recoveries of tamarind powder than the MD did at ratios of 1:0.3, 1:0.4, 1:0.5 and 1:0.6, although without the problem of sticky of the MD at a ratio of 1:0.6.

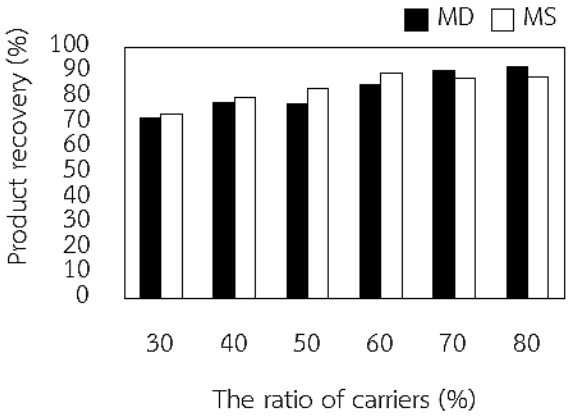


Figure 3 The product recovery of tamarind powder.

The effect of the different carriers used to produce the tamarind powder on bulk density is shown in Figure 4. The results showed that, the bulk density of tamarind powder decreased when the ratio of carrier increased. Similar results were observed, when tomato juice was dried using carrier in a spray dryer (Goula and Adamopoulos, 2004).

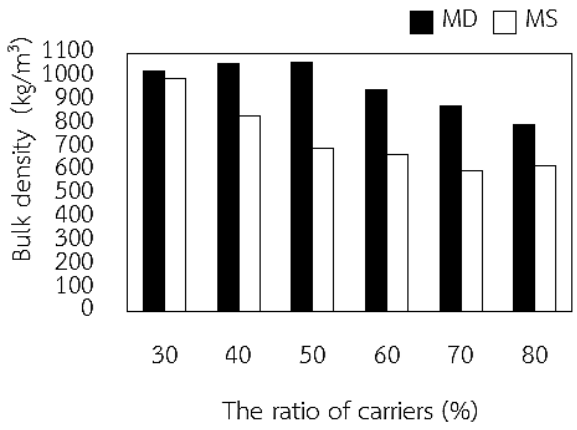


Figure 4 The bulk density of tamarind powder.

The effect of the different carriers used to produce the tamarind powder on total acidity is shown in Figure 5. The result showed that, after reconstitution tamarind powder to achieve the total acidity of the tamarind juice between 9.20% to 16.80% because the tamarind juice was diluted by the carrier prior to drying. Apart from that, MD is a carrier with had lower of total acidity than MS.

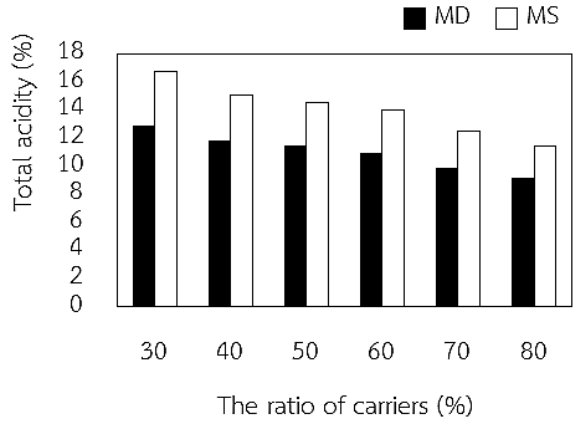


Figure 5 The total acidity of reconstituted tamarind powder.

The effect of the different carriers used to produce the tamarind powder on moisture content is shown in Figure 6. Moisture content is an important powder property, which is related to the drying efficiency. The moisture content of tamarind powder varied from 2.50% to 4.31%, which was close to the moisture content of spray dried blackberry (Ferrari et al., 2012). Increasing the ratio of the carrier resulted in a decrease in the moisture content due to high solid ratio. However, the moisture content of MD was more than MS. This behavior was probably due to the differences between the chemical structures of the carriers (Yousefi et al., 2011).

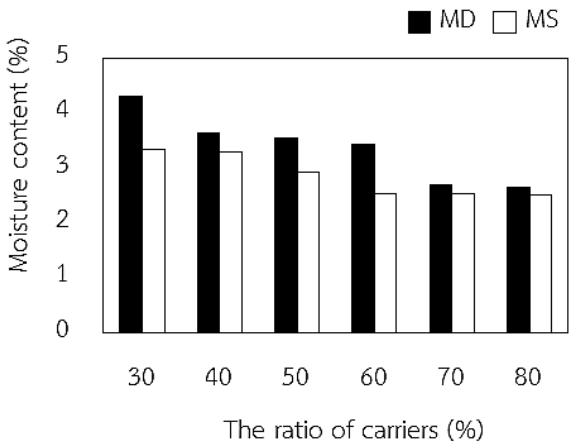


Figure 6 The moisture content of tamarind powder.

The total color change of reconstituted tamarind powder increased as the ratio of MD increased from 30% to 50%, then the total color change are not different (Figure 7). Similarly, the ratio of MS from 40% to 80%, because the dried product could be removed from the drums by doctor blades.

The effect of the different carriers used to produce the tamarind powder on solubility is shown in Figure 8. No significant differences was found in powder solubility for MD and MS. All of the powder samples, except the one produced from MD at the 1:0.3 ratio, had a high degree of solubility, reaching values above 80% (Table 1).

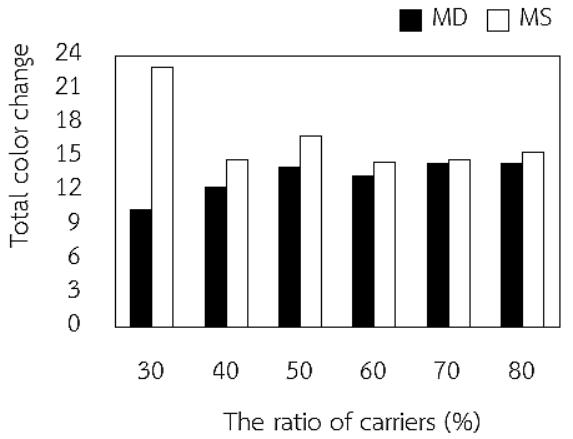


Figure 7 The total color change of tamarind between the fresh juice and the reconstituted powder.

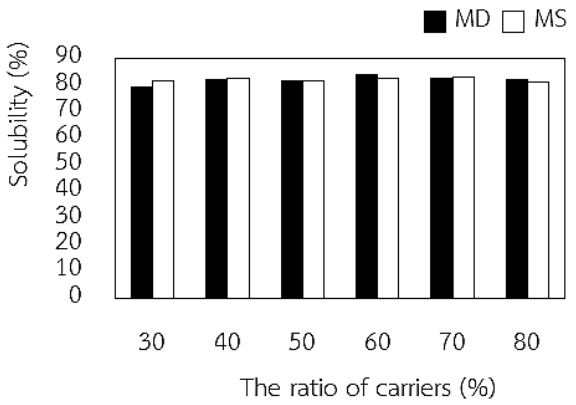


Figure 8 The solubility of tamarind powder.

3.4 Statistical Analysis

Base on the statistic analysis (Table 1), while all other quality parameters of different samples were significantly different ($p<0.05$), the solubilities were not. The highest yield of product recovery was obtained with 80% MD. And the least bulk density was obtained using 70% MS. The highest acid of total acidity was obtained when 30% MS was used as the carrier. And the lowest moisture content was obtained using 80% MS. While the lowest total color change was obtained using 30% MD. Furthermore, the powder solubility was not affected by the types and concentration of the carrier.

4 Conclusions

The effect of the ratio of carriers on the drying behavior and quality were different for different parameters. The substance takes to make tamarind powder can be removed from the drums by doctor blades and has product recovery of more than 80% when 60% MD and 40% MS was used as carrier. And it can be concluded that using MS as carrier leads to better quality of tamarind powder (such as bulk density, total acidity and moisture content) than using MD as the carrier. However, with the high cost of MS, using these carriers in combination would be preferred.

Table 1 Average ±standard deviation for the quality of tamarind powder.

No.	Carrier (%)	PR (%)	BD (kg/m^3)	TA (%)	MC (%)	ΔE_c	SO (%)
1	MD = 30	71.98±0.24^{a}	1024.49±9.79^{a}	12.90±0.15^{a}	4.31±0.22^{a}	10.40±1.51^{a}	79.25±1.36
2	MD = 40	78.12±0.09^{b}	1057.23±11.44^{b}	11.80±0.08^{b}	3.62±0.02^{b}	12.31±0.64^{ab}	82.31±0.38
3	MD = 50	77.20±0.23^{c}	1062.94±12.75^{b}	11.45±0.08^{c}	3.54±0.33^{b}	14.10±1.22^{bc}	81.41±5.06
4	MD = 60	85.00±0.22^{d}	943.68±8.89^{c}	10.90±0.08^{d}	3.43±0.14^{b}	13.38±0.52^{bc}	84.15±0.93
5	MD = 70	90.59±0.02^{e}	879.11±5.28^{d}	9.90±0.15^{e}	2.70±0.08^{cd}	14.48±0.23^{c}	82.56±2.08
6	MD = 80	92.28±0.37^{f}	796.23±2.55^{e}	9.20±0.08^{f}	2.63±0.15^{cd}	14.44±0.58^{c}	81.95±2.37
7	MS = 30	73.29±0.40^{g}	995.29±7.80^{f}	16.80±0.15^{g}	3.33±0.22^{b}	22.94±1.05^{e}	81.41±0.45
8	MS = 40	80.03±0.15^{h}	832.66±22.48^{g}	15.10±0.08^{h}	3.29±0.11^{b}	14.80±1.74^{c}	82.50±2.06
9	MS = 50	83.29±0.12^{i}	694.27±9.91^{h}	14.60±0.08^{i}	2.91±0.07^{c}	16.91±1.22^{d}	81.64±2.43
10	MS = 60	89.74±0.43^{j}	669.85±3.82^{i}	14.05±0.08^{j}	2.53±0.06^{cd}	14.61±0.12^{c}	82.64±1.12
11	MS = 70	87.55±0.16^{k}	600.65±6.54^{j}	12.55±0.08^{k}	2.53±0.02^{cd}	14.79±0.27^{c}	82.92±2.64
12	MS = 80	88.20±0.16^{l}	623.97±2.56^{k}	11.50±0.08^{c}	2.50±0.05^{d}	15.45±1.13^{cd}	81.37±0.45

PR=Product recovery, BD=Bulk density, TA=Total acidity, MC=Moisture content, =Total color change, SO=Solubility

$^{a-l}$Different letters in the same column indicate significant differences ($p<0.05$).

5 Acknowledgement

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