Study the rate of drying and level of osmosis dehydration on physical properties of dried Mango Cengkir

Y Deliana¹, E Wulanardi² and I M Salam³

¹ Socioeconomic Department, Faculty of Agriculture, Universitas Padjadjaran
² Food Industrial Technology Department, Faculty of Agriculture Industrial Technology, Universitas Padjadjaran
³ Jl. Raya Bandung Sumerang KM.21, Hegarmanah, Kec. Jatinangor, Kabupaten Sumber, Jawa Barat 45363

Email: y.deliana@gmail.com;

Abstract. Cengkir mango is an agricultural product of Indonesia, especially in Indramayu which is very abundant. But it is not offset by the high level of fruit consumption in Indonesian society. Further processing is carried out to obtain product diversity and shelf life. This can be overcome by processing the cengkir mango into a dried cengkir mango. In the processing, several things need to be observed the initial treatment of drying is osmosis dehydration, sugar solution concentration, drying time and drying rate. The purpose of this study was to determine the drying rate of dried cengkir mango at various levels of sugar solution concentration to produce the physical properties of good dried cengkir mango. The research method used is descriptive analysis. Descriptive method consisting of 9 treatments of 30 °brix sugar solution at 40 °C, 50 °C and 60 °C; 40 °brix sugar solution at 40 °C, 50 °C and 60 °C; and 50 °brix sugar solution at 40 °C, 50 °C and 60 °C. The treatment of 30 °brix sugar solution at a temperature of 60 °C has a good correlation to the decrease in water content with a value of r = 0.9483 and a low drying rate correlation of 0.2932 produces good physical properties with levels aw0.56, colorsΔH 1.58 and texture 6030 g/cm².

Keyword: dried cengkir mango, drying rate, osmotic dehydration

1. Introduction

1.1. Background

Agricultural processed products in Indonesia has been developed such as processed tubers, cereals, nuts, coffee, tea, cocoa, vegetables, and fruits. Processed fruit does not develop much in several regions in Indonesia. The various types of fruit, mango is a fruit that has a sweet taste, attractive color and quite high vitamin content [1]. Mango is one of the periodical fruits that are very popular both as fresh fruit or in processed form. In addition to good taste, mango is a good source of nutrition for health. Mango fruit pulp contains vitamin A ranged between 1200–16400 SI. In addition to vitamins A, mango fruit also contains vitamin C ranged from 6–30 mg / 100 g fruit [2].

Mango fruit is an indigenous fruit of Indonesia which loved because it tastes sweet, good texture and unique. Mango fruit is widely available in Cirebon, Indramayu, Majalengka and Kuningan. So
many mango products in Indonesia, the total production of mangoes produced in Indramayu district reached 330 tons per year. Mango fruit usually consumed as fresh fruit, there are also processing mango to preserve mango, syrup, fruit pulp, fruit bars and other. The low levels of consumption of fruit in Indonesian society are about (40 kg/capita/year), is not comparable to the amount of mangoes harvest. Meanwhile, mango has high moisture content so can easily be damaged by microbial activity. Therefore it is necessary to do mango postharvest processing so that the mango can be stored longer [2].

Mango can also be processed into refined products that have higher economic value and have a longer shelf life. One of the post-harvest processing that can be implemented is drying method. Drying is a process of water content reduction so that the fruit can be stored longer. There are several methods of drying can be applied for post-harvest processing of mangoes, such as drying or simulated drying using a dryer. These methods can cause quite a high shrinkage. Products also can be contaminated by dirt and become less sterile products. Osmotic dehydration is one of the alternative methods, commonly used as a pretreatment in the drying process. Osmotic dehydration benefit is linked with the quality of the ingredients during storage, such as reducing water activity and the activity of enzymes that cause browning [3]. The application of osmotic dehydration on mango slices meant for nutritional quality, color, aroma, and taste better products of processed semi-wet mangoes. Similar to the drying process in general, osmotic dehydration also using a dryer to reduce the moisture content in the substance. Dryer media used in the osmotic dehydration is a hypertonic solution such as a sugar solution and salt have higher concentrations than the dried substance. Osmotic solution concentration and temperature can cause a decrease in water content in the dried substance. Besides media and temperature dryer, the substance dimension also affects the drying process. The larger dried substance surface, drying rate also becomes higher [4].

Osmotic dehydration process using a hypertonic solution such as sugar and salt solution. Dehydration osmosis can remove water from substances without any water phase change so that it takes less energy because it does not require heat for water phase change from liquid to vapor. Osmotic dehydration based on diffusion process, therefore the water out timing from the substance may affect the rate of water loss or acquisition of solids into the material [1].

1.2. Identification of problems
Based on the explanation above, the identification of the problem is: "How the drying rate and the physical characteristics of dried mango Cengkir at different levels of concentration of sugar solution?"

2. Materials and methods

2.1. Time and place of experiment
The main research was performed in April-June 2018. The study was accomplished in Invivo Laboratory, Laboratory of Food Processing Technology, Laboratory of Engineering of Food Processing and Testing Laboratory.

2.2. Materials and equipment experiment
The materials used in the study was mango fruit with medium maturity level (slightly soft texture, skin color dark green, reddish-yellow flesh) from Indramayu. Other materials used were distilled water, and sugar. The tools used in this study was plastic, aluminum foil, clingwrap, jars, spoons, knives, spray bottles, beakers, analytical balance, trays, basins, pots, stoves, desiccator, oven blowers, handheld refractometer N 1, handheld refractometer N 2, refractometer electronics, and refrigeration.

2.3. Research methods
The method used is a descriptive analysis which consisted of 9 treatments and two replications. Independent variable (x) represented the degree of sugar solubility and the drying temperature, while
the dependent variable (y) represented the main observations in the form of characteristic testing. The treatment was different levels of solubility sugar and the drying temperature, which were:
A= 30 °brix sugar solution at 40 °C
B= 40 °brix sugar solution at 40 °C
C= 50 °brix sugar solution at 40 °C
D= 30 °brix sugar solution at 50 °C
E= 40 °brix sugar solution at 50 °C
F= 50 °brix sugar solution at 50 °C
G= 30 °brix sugar solution at 60 °C
H= 40 °brix sugar solution at 60 °C
I= 50 °brix sugar solution at 60 °C

3. Results and discussion

3.1. Water content and drying rate
In the process of making dried mango products, the water content was measured regularly by thermogravimetric method. The initial water content, the final water content in a variety of drying time, and the drying rate can be obtained. Data of water content all treatments were presented in figures 1 to 3.

![Figure 1](image)

**Figure 1.** Decrease of water content in the drying temperature at 40 °C.

Determination of the initial water content of the same treatment is quite challenging because of the mangoes maturity was identified through color, texture and form uniform. The same maturity level also has water content difference.

Based on the data obtained after drying, the final water content in each treatment exceeds the desired limit. This proves that the drying time to dried Cengkir mango were standardized but there were differences in a time required for each treatment. Thus the drying time can be calculated when the desired final water content is 25% (wb) at a variety of treatments.

On drying 40 °C with a concentration of the sugar solution, it takes 20 hours of blower drying oven to get dried mango with an average water content of 17% (%wb). On drying 50 °C with a concentration of the sugar solution, it takes 14–16 hours of blower drying oven to get dried mango with an average
water content of 21% (%wb). According to [5], the time required in the drying process is influenced by the structure of the material, the distribution of airflow, temperature, humidity, and air velocity. From figure 1, graph the decline drying the water content of 40 °C showed a high decrease of moisture content in the treatment 30 °brix, 40 °brix, and 50 °brix between 0 to 18 hours. With details on each treatment temperature decrease can be seen in attachment 2 (table 1). At 0 up to 18 hours of treatment temperature decrease high enough to be considered a period of evaporation of free water contained in the surface of the substance. After passing 18 hours of drying, the water content decreases to the texture of dried mango dried reached the limit of dried wrinkles in each treatment. Regression calculation on the data reduction the water content by drying 40 °C. From the results of the regression calculation, 40 °C moisture reduction obtained the correlation value was increased sequentially from 30 °brix, 40 °brix, and 50 °brix with a value of 0.8451, 0.8716 and 0.9395. This shows the correlation of pretreatment Cengkir mango soaked in different concentration of the solution. The higher the concentration of the solution at the same drying has a positive effect. Pretreatment is done to decreased water content of the sample before drying, can be indicated by the value of the water content in the first hour of drying after soaking, the average of water content below 80% (%wb) at treatment 30 °brix, 40 °brix and 50 °brix that when the moisture content of fresh fruit ranges from 80% to 90% (%wb). The initial treatment with sugar solution soaking causes osmosis dehydration in Cengkir mangoes, when this happened, the water contained in the sample was attracted to the solution and the sugar contained in the solution is absorbed into the Cengkir mango.

In figure 4 the rate of drying with a temperature of 40 oC was increased and decreased in every two hours observation. But at 40 oC, there was high an increased drying rate on every treatment after passing through the drying hour to 5. This was due at 40 °C takes time to adjust to the environment temperature. Samples will be placed on the drying trays made of aluminum alloy and stainless pan that has a temperature of 25 °C or room temperature. state that diffusion of water is mainly caused by mass transport mechanisms during the first phase of drying. The humidity of the product migrated and replaced the capillary surface due to evaporation of moisture diffusion and eventually become the dominant mechanism.

Based on the graph in figure 4, soaking treatment 50 °brix reach the highest drying rate at one point of time but not in the overall drying time. The drying rate value obtained correlation values were increased from treatment 50 °brix, 30 °brix, and 40 °brix with a value of 0.5873, 0.5911 and 0.7459. From the measured values, 40 °brix treatment at 40 °C drying has a good correlation between pretreatment soaking with the drying rate. Can expect need compatibility between the osmotic dehydration level with the drying temperature, because of the more concentration of sugar solution, the solids of Cengkir mango can increase too.

![Figure 2. Decrease of water content in the drying temperature 50 °C.](image-url)
The graph showed a high decrease of 50 °C drying temperature enough on 30 °brix soaking treatment, 40 °brix, and 50 °brix between 0 to 8 hours. With details of temperature decrease on each treatment can be found in attachment 2 (table 3). At 0 until 8 drying hours, temperature decrease on a variety of treatment high enough to be considered a period of evaporation of free water contained in the surface of the substance. After passing through 8 hours of drying, the decrease in water content caused the texture of dried mango dried reached the limit of drying wrinkles or also called falling rate.

Based on the graph in figure 5 shows the decline rate of the gray lines (50 °brix) that always has the lowest rate in every hour, followed by 30 °brix and 40 °brix soaking treatment solution. This shows there is a relationship between pretreatment before drying toward moisture reduction. If the solution concentration goes higher, the greater the correlation value obtained on drying with a temperature of 50 °C. The correlation values obtained in the treatment 40 °brix, 30 °brix and consecutive 50 °brix 0.940, 0.9553 and 0958. The correlation values can be classified with a positive correlation because of the value that approaching the value of 1 or can be called perfect.

The initial treatment with soaking sugar solution in high concentration before drying impact on the decline moisture content when drying, either at the start to finish drying. The higher the concentration that is used the greater the water released and the greater solids get into the sample membrane.

The graph showed that the drying rate at 50 °C in solution 40 ob concentration can reach the highest speed. However, the speed average in each hour is not greater than 50 °brix treatment. For the solution treatment of 30 obrix concentration has increased and decreased drastically. 30 °brix 40 °brix and 50 °brix drying rate in treatment increased to a peak at the 8th hour after hour passed its peak and subsequent decline until the end of drying. This happened because the diffusion rate of water vapor from the substance to the surface gets smaller as it becomes more difficult and the bigger the distance to go to get to the surface of the substance. Besides the rate of diffusion of water vapor from the surface of the material to be barred because of the sugar contained in dried mango.

![Figure 3](image)

**Figure 3.** Decrease of water content in the drying temperature at 60 °C.

Based on the graph the drying rate 60 °C every stage of time, for the soaking treatment solution 50 °brix concentration can reach the highest speed of any other treatment at 60 °C. And for the 30 °brix soaking treatment solution, the intensity increase slowly with a longer time. When the value of the drying rate increased to peak at 50 °brix treatment at 60 °C for 3 hours after passing its peak and decrease until the final drying hour.

After calculation of the value of drying water content at 60 °C, obtained correlation values. Correlation value at 60 °C temperature drying treatment increased from treatment 30 °brix to 40 °brix and 50 °brix. However, the increase not balanced by good results on the correlation value and 40 °brix 30 °brix treatment. Only on 50 °brix soaking treatment with a solution that has a good correlation
value, and on 50 °brix treatment anyway, which reached the highest value in the drying rate of drying hours to three. 50 °brix sugar solution soaking treatment has decreased the water content before drying, the water contained in the material is hardbound water is evaporated into the environment. However, drying at 60 °C can suppress the evaporation of the samples occurs effectively.

Water content data and drying rate can be used as a basis for determining the sufficiency of Cengkir dried mango drying. By determining the moisture content of dried mango in SNI 25% (wb), it can be calculated using the equation to determine the drying time at the desired temperature and the desired concentration.

Judging from the graph and the drying rate table in attachment 2 can be seen the range of numbers obtained in all treatments drying 40 °C range between 0% wb/h to 3.28% wb/hour. For drying 50 °C have approximately value drying rate ranging from 1.04% out wb/hr to 5.99% wb/hour. Then to drying at 60 oC have approximately drying rate value ranging from 4.06% wb/hr to 17.93% wb/hour. From the following data, the drying temperature affects the drying rate value. The greater the temperature is, the greater the value of the average drying rate obtained. Evaporation occurs faster at a higher temperature caused higher diffusivity.

50 °brix sugar concentration soaking treatment has the best correlation to the drying 40 °C and 50 °C. While the drying temperature of 60 °C with 40 °brix solution has the best correlation value even if only slightly with 50 °brix treatment. When food was soaked in a highly concentrated osmotic solution, multicomponent transfer process happens, in which the solution is flowing along with the combination of drying, washing, and impregnation in biological membrane matrix [6]

3.2. Water activity (aw)

Measuring of water activity on this Cengkir dried mango with the aw meter. The average value was calculated based on the results of the test multiple samples in a single treatment. The average data from the calculation in each heat treatment temperature and the concentration of the soaking solution can be seen in table 1.

Table 1. The aw Average value in each treatment.

| Treatment  | Solution (°brix) | aw(Average) |
|------------|------------------|-------------|
| 40°C       | 30               | 0.6325      |
| 40°C       | 40               | 0.6365      |
| 40°C       | 50               | 0.6455      |
| 50°C       | 30               | 0.6935      |
| 50°C       | 40               | 0.7455      |
| 50°C       | 50               | 0.7235      |
| 60°C       | 30               | 0.5860      |
| 60°C       | 40               | 0.6545      |
| 60°C       | 50               | 0.6755      |
| Fresh mango|                  | 0.9560      |

The principle of Cengkir dried mango processing is the preservation using high sugar levels so that the water activity (aw) reduced and no water for the growth of microorganisms because sugar can attract water contained in the substance membrane cells [7].

The aw decline is related to the time soaking in a solution of substances such as glucose, fructose, sucrose, and some organic acids. The results can be connected to the appearance of the solid during osmosis pretreatment which produces a strong blocking effect on the migration and evaporation of water during the drying [8].

The highest water activity on the data in table 1 is proved by the drying treatment 50 °C with a concentration 40 °brix and 50 °brix which has a value of 0.7455 and 0.7235. With the lowest aw average value contained in the treatment solution concentration 30 °brix at 60 °C drying
temperature. The average total on all treatments is 0.6661 then it is possible microorganisms grown on Cengkir dried mango products. Bacteria microorganisms will not grow on $a_w$ below 0.91, the fungus can not grow on $a_w$ below 0.81 $a_w$ values from 0.70 to 0.75 represented as the lowest limit for fungal growth. Osmophilic yeast can grow on a minimum $a_w$ of 0.62. Osmotic dehydration treatment removes some of the water, produces moderate moisture, lowering water activity, and stopping most chemical, physical and biological activity content [9].

3.3. Color intensity
The effect of soaking Cengkir mango with various solutions and drying temperatures to mango color was measured by test equipment chromameter color data $L^*$, $a^*$, $b^*$, $\Delta H$, and Descriptive color.

Table 2. Colour testing result.

| Treatment   | L   | a   | $b$ | $\Delta H$ | Descriptive color |
|-------------|-----|-----|-----|------------|-------------------|
| S. Fresh    | 67.50 | 19.71 | 57.93 | -          | Yellowish red     |
| 30 b 40 c   | 62.64 | 11:28 | 46.00 | 4.71       | Yellowish-brown   |
| 40 b 40 c   | 55.77 | 15:36 | 49.50 | 1.53       | Light brown       |
| 50 b 40 c   | 57.86 | 16.67 | 48.23 | 0.31       | Little Red Brown  |
| 30 b 50 c   | 52.06 | 24.76 | 48.78 | 8.20       | Dark Brown Reddish|
| 40 b 50 c   | 54.70 | 21:00 | 47.94 | 4.81       | Young Reddish Brown|
| 50 b 50 c   | 51.02 | 16.95 | 39.00 | 4.19       | Chocolate         |
| 30 b 60 c   | 57.95 | 16.78 | 54.03 | 1.58       | Dark Red Yellowish|
| 40 b 60 c   | 64.67 | 18:32 | 57.94 | 1.32       | Yellowish red     |
| 50 b 60 c   | 51.06 | 20:46 | 44.11 | 5.80       | Reddish brown     |

Table 2 shows the level of luminance (brightness) in each mango with drying and soaking treatment sugar solution has no big difference with fresh mango fruit. And in all treatments have a positive value of $\Delta L^*$. Sample with sugar solution 30 °brix at any temperature has the average brightness level low enough compared to the soaking solution 50 °brix. While mango with 50 °brix treatment at 50 °C has the highest $\Delta L^*$ value.

Initial treatment with sugar solution soaking occurs osmotic forces to the dried mango. Osmosis has a protective effect to the overall color, which can be explained by the fact that there is a monosaccharide in mango system, which is a reactive substance for browning reaction, but leached with simultaneous absorption of sucrose during osmotic dehydration [3].

Table 2 shows the average level of Redness in each treatment not differ much with fresh mango in treatment SF 1. For treatment 30 °brix 40 °C and 60 °C 30 °brix both have the low value of $a^*$, which can be influenced by the used of sugar solution only 30 °brix. Low temperature 40 °C with long heating and short heating at 60 °C. All soaking treatment with drying at 50 °C has $a^*$ average value higher than the drying in 60 °brix 40 °brix. The highest value of $a^*$ at 50 °C 40 °brix has the most reddish color than the other.

Heating with lower temperatures will reduce the oxidation of carotenoid pigments so that the yellow color of the fruit will be more vigilant [9] mentions that drying air temperature for drying apple slices in the range of 40–50 °C. Higher temperatures drying will produce a darker slice. Browning is increased along with increasing drying.

Table 2 shows the average level Yellowness in each treatment did not differ much with fresh mango in treatment Fresh samples, according to [6] that there is no significant difference to the value of $b^*$ on mango fruit fresh mango and mango chips, but there was a slight increase in the value of $b^*$ on mango chips compared to fresh samples air temperature.

Mango fruit used in the manufacture of dry Cengkir mango has a half-matured level of maturity, the texture is quite soft and flesh color yellow-orange. There is a decrease in $b^*$ value is the same in each treatment drying at 40 °C. This drying process occurs too long which leads to brownish color changes connected with the Maillard reaction.
3.4. Texture
Cengkir dried mango products texture that has been observed. Texture Analyzer used to compare hardness values. Hardness is the maximum peak in the first or the pressure at the first bite. The unit used is the kg, g or N. Based on the data, the average value of texture ranging between 4.268 g/cm² to 6.522 g/cm². The highest texture value was in the treatment of 40 °brix 60 °C and the lowest at 60 °C 50 °brix treatment. Soaking treatment with 50 °brix at 40 °C, 50 °C and 60 °C have a slightly different texture value (317 g/cm²).
This treatment has a lower average texture value than other treatments. It can be concluded that the use of a 50 °brix solution gives softness at Cengkir dried mango. Highest texture value shows that the mango has a hard texture, while the lowest texture value indicates that the material has a soft texture. According [9], the higher fruit softness value, the harder the fruit is.

Based on the graph, the level of hardness in the dried fruit decreased with osmosis dehydration and shrinkage treatment. Besides, the sugar component that goes into the fruit when the osmotic dehydration causes texture softening along with changes in moisture content and concentration of solutes such as sugars [3].

Internal structure strength of the fruit cells fruit will decrease at the time of sugar molecules get into the cells. This happens because the cell wall that originally can hold a strong form becomes softer due to the penetration of sugar. Penetration happens by destroying the cell walls of the fruit, so the sugar can get inside and the water content in the fruit can come out [8]. There is also data that strange at 50 °C 30 °brix treatment because the average value is 406 g/cm². This difference could be due to the thickness of the sample are not uniform so that the texture measured a small part of the sample, not the entire surface of the sample.

Soaking with a certain level of sugar solution and drying time at a certain temperature affects the texture of the product. [4] states heating on fruit products can increase the hardness because reduced bond on the pectin molecule and make it stronger, especially in the crosslinks. The higher sugar solution concentration in candied fruit will increase shrinkage levels. This shrinkage is due to the pressure outside of the fruit is high so that water coming out faster than the rate of sugar injection inside the fruit.

Texture measurements showed that soaking with 50 °brix sugar solution in various temperature has the best effect on the texture of the product. Based on table 3, various treatment to mango has positive and negatives affect for the test result. But to get a good Cengkir dried mango, color, texture, and $a_w$ according to standards is needed. In the treatment of 30 °brix at 60 °C have low $a_w$ value. Soaking with 50 °brix sugar solution treatment at various temperature has the best effect on the texture of the mango.
product. There are no significant color differences on mango at each treatment. 30 °brix at 60 °C is the best treatment to produce dried Cengkir mango with good $a_w$ value, a slight color change, and not hard texture compared to other treatments. The decrease in water levels at treatment have a good correlation but a poor drying rate correlation. The higher water content release of osmotic dehydration in the food material before drying will dry faster. But there are certain limitations to obtain optimum drying rate and a decrease in water content.

**Table 3.** Results of experiment at all treatment.

| Treatment        | Moisture Content Decline $r$ | The drying rate (wb% / hour) $r$ | $a_w$ | Colors ($\Delta H$) | Texture (gf/cm$^2$) |
|------------------|------------------------------|----------------------------------|-------|---------------------|---------------------|
| S. Fresh         |                              |                                  | 0.9560| 4.71                | 6480                |
| 30 °brix 40 °C   | 0.8451 0714                  | 0.6511 0.4239                    | 0.6325| 4.71                | 6480                |
| 40 °brix 40 °C   | 0.8716 0760                  | 0.8246 0.6799                    | 0.6365| 1.53                | 6202                |
| 50 °brix 40 °C   | 0.9395 0883                  | 0.6598 0.4354                    | 0.6455| 0.31                | 4585                |
| 30 °brix 50 °C   | 0.9553 0926                  | 0.0823 0.2868                    | 0.6935| 8:20                | 409                 |
| 40 °brix 50 °C   | 0.9408 0885                  | 0.0480 0.2304                    | 0.7455| 4.81                | 5428                |
| 50 °brix 50 °C   | 0.9589 0.920                 | 0.0692 0.2304                    | 0.7235| 4:19                | 4538                |
| 30 °brix 60 °C   | 0.9483 0899                  | 0.2932 0.0862                    | 0.5860| 1:58                | 6030                |
| 40 °brix 60 °C   | 0.9307 0866                  | 0.3527 0.1244                    | 0.6545| 1:32                | 6522                |
| 50 °brix 60 °C   | 0.8820 0778                  | 0.8848 0.7829                    | 0.6755| 5.80                | 4268                |

4. Conclusions and recommendations

Soaking treatment in sugar solution and temperature correlates with the decrease in water content and drying rate of dried mango. Decreased water moisture at 50 °C with 50 °brix treatment has the best correlation. 50 °brix treatment at 60 °C has the best correlation drying rate. 30 °brix at 40 °C and 40 °brix at 40 °C have the smallest $a_w$ value. Soaking with 50 °brix sugar solution treatment at various temperatures has the best effect on the texture of the product. There are no significant colors different on mango at each treatment. 30 °brix at 60 °C is the best treatment to produce dried Cengkir mango with good $a_w$ value, the intensity of color and texture.

References

[1] Lobo F A, Nascimento M A, Domingues J R, Falcão D Q, Hernandez D, Heredia F J and de Lima Araujo K G 2017 Foam mat drying of Tommy Atkins mango: Effects of air temperature and concentrations of soy lecithin and carboxymethylcellulose on phenolic composition, mangiferin, and antioxidant capacity *Food Chem.* **221** 258–66

[2] Rozana 2016 Pengeringan dan mutu manisan mangga (mangifera indica l)

[3] Allahdad Z, Nasiri M, Varidi M and Varidi M J 2019 Effect of sonication on osmotic dehydration and subsequent air-drying of pomegranate arils *J. Food Eng.* **244** 202–11

[4] Rahaman A, Zeng X A, Kumari A, Rafiq M, Siddeeg A, Manzoor M F, Baloch Z and Ahmed Z 2019 Influence of ultrasound-assisted osmotic dehydration on texture, bioactive compounds and metabolites analysis of plum, *Ultrason. Sonochem* **58**
[5] Zotarelli M F, da Silva V M, Durigon A, Hubinger M D and Laurindo J B 2017 Production of mango powder by spray drying and cast-tape drying, Powder Technol. 305 447–54

[6] Link J V, Tribuzi G, Oliveira de Moraes J and Laurindo J B 2018 Assessment of texture and storage conditions of mangoes slices dried by a conductive multi-flash process J. Food Eng. 239 8–14

[7] Dissa A O, Desmorieux H, Bathiebo J and Kouledia J 2008 Convective drying characteristics of Amelie mango (Mangifera Indica L. cv. 'Amelie') with correction for shrinkage J. Food Eng. 88(4) 429–37

[8] L M Raghavi J A Moses and C Anandharamakrishnan 2018 Refractance window drying of foods: A review J. Food Eng. 222 267–75

[9] Ahmed I, Qazi I M and Jamal S 2016 Developments in osmotic dehydration technique for the preservation of fruits and vegetables Innov. Food Sci. Emerg. Technol. 34 29–43