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Comparison of dehydration behaviours between cellulosic and starchy plant materials under dip dehydration and Osmotic dehydration methods

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Dip dehydration is a novel variant of osmotic dehydration, and it is an alternative to overcome high salt/sugar uptake, which is the main problem in osmotic dehydration. However, the information on the effect of raw material properties on the mass transfer during dip dehydration is very limited. Therefore, this study investigates the effects of different raw material structures (starchy e.g. potato and sweet potato; and cellulosic e.g. apple) on the extents of water loss, solid gain and process efficiency index during dip dehydration and osmotic dehydration. Samples were subjected to two different osmotic solutions; sucrose 50% w/v and NaCl 10% w/v with four-time intervals (40, 80, 120 and 160 min for sucrose solution and 10, 20, 30 and 40 min for NaCl solution). It was found that water loss of sweet potato was always much lower than potato and apple due to its low initial moisture content. Dip dehydration resulted in a comparable extent of water loss to osmotic dehydration but significantly lower solid gain and higher process efficiency index in all cases. Therefore, dip dehydration can be used as an alternative to osmotic dehydration to produce an incredibly healthy product option.

Keywords: Dip dehydration, osmotic dehydration, water loss, solid gain

INTRODUCTION

Fruits are known for their flavours, aesthetic appeal and certain essential functional necessities in daily diet. Most fruits are usually soft, fleshy and edible, and because of high moisture content, they are prone to spoil by moulds and yeasts, and thus, preservation is needed to increase their shelf life.

Drying is one of the simplest methods of preservation to reduce the moisture content of fruits and vegetables. Proper drying and storage techniques resulted in the longer shelf life of products. There are numerous dehydration methods available for commercial industry and domestic application and one of them is osmotic dehydration. Osmotic dehydration is a natural process to remove the moisture inside the food samples by immersing the material such as pieces of fruit and vegetables in a hypertonic solution for instance, sugar or salt solution. Due to osmotic pressure gradient, the water diffused out from samples and at the same time, the solutes diffused into the samples (Haj Najafi et al. 2014). Although osmotic dehydration is known for its advantages, several limitations arise. One of them is high solute gain owing to increases of solute diffusion over the time towards tissue cells (Azuara et al. 2009). A product with high solute uptake is not desirable, which can potentially pose major health problems and severely alter the organoleptic and functional properties of the products.

Therefore, Mokhtar et al. (2019) has developed a new variant of osmotic dehydration named dip dehydration to overcome high solid uptake during the process. Dip dehydration involves briefly dipping samples in a concentrated solution for a short time, then it exposed to ambient conditions for dehydration purposes. The study reported that dip dehydration has a good performance in water loss but with lower salt/sugar gain. However, the study was limited to potato slices only as a food sample, and according to Ramya and Jain (2017), fruit and vegetable characteristics such as tissue microstructure is one of the factors that significantly affect the dehydration rate. Moreover, previous studies also reported that the nature of the raw material including the types, species, varieties, maturity level, structure, size and shape affected the mass transfer phenomena during osmotic dehydration (Tortoe and Orchard, 2006; Pereira et al. 2006; Porciuncula et al. 2013; Silva et al. 2014).

To date, there is no study on the effect of different types of fruits or vegetables treated under dip dehydration. Therefore, this study aims to determine how the different tissue structures contribute to the variation in the water loss patterns. Potato and sweet potato are categorized as starchy plant materials while apple is categorized as a cellulosic fruit. Thus, these plant materials were chosen in this study to compare the dehydration behaviours in different textures of the samples.

MATERIALS AND METHODS

Materials

Fresh potato, sweet potato, apple, sucrose and sodium chloride (NaCl) were obtained from a local supermarket in Besut, Terengganu. The potato, sweet potato and apple were selected to obtain samples of uniform shape and size. The initial moisture content (wet basis) was 83.12 ± 2.30% for potato, 71.72 ± 2.90% for sweet potato and 87.89 ± 0.45% for apple.

Preparation of Sample Slices and Osmotic Solutions

Potatoes, sweet potatoes and apples weighing around 150-200 g were carefully chosen for experiments. The potatoes, sweet potatoes and apples were washed and sliced into 1.5 mm of thickness using a domestic slicer (Mandoline slicer, Hebei, China) before samples were cut into round shape (36 mm diameter) using a mould to make all samples were in uniform shape. Then, the sample slices were rinsed under tap water to eliminate the excess starch or any impurities of samples surface, then excess water was blotted with tissue before samples were weighed using an analytical balance. The osmotic solutions were prepared in 50 % w/v for sucrose and 10 % w/v for NaCl with dissolved in distilled water. This concentration was chosen based on the recommendation by Mokhtar et al. (2019).

Dip Dehydration

About 10 g of samples were dipped for 0.5 minute in the concentrated solution (50% w/v of sucrose or 10% w/v of NaCl). Preliminary studies showed that dipping time at 0.5 minute was appropriate time to make the entire surface of slices were occluded with the osmotic solution. After the stipulated time, the samples were taken out from the solution and then, the samples were placed on a stainless-steel mesh and held for dehydration to occur at ambient condition. The total time, which is dipping time and holding time at ambient condition was 40 minutes (in sucrose case) and 10 minutes (in NaCl case), which these total times gave the highest water loss to solid gain ratio as reported by Mokhtar et al. (2019). Then, the slices were dipped again at a same dipping time into the similar concentrated before held at ambient conditions for another 40 minutes (in sucrose case) and 10 minutes (in NaCl case). The process of dipping and holding was repeated four times for both cases as listed in Table 1 to ensure that the water loss rate achieves equilibrium condition (Mokhtar et al. 2019). The treated samples were blotted with a tissue before further analysed.

Table 1: **Osmotic solution concentration and total time employed in dip dehydration.**

Osmotic Solution	Dipping	Dipping time (minutes)	Total time (minutes)
Sucrose solution	Dip 1	0.5	40
	Dip 2	0.5	80
	Dip 3	0.5	120
	Dip 4	0.5	160
NaCl solution	Dip 1	0.5	10
	Dip 2	0.5	20
	Dip 3	0.5	30
	Dip 4	0.5	40

Osmotic Dehydration

For osmotic dehydration technique, potato slices were immersed in sucrose 50% and NaCl 10%. For each experiment, the sample slices were soaked in an osmotic solution and were taken out after 40, 80, 120 and 160 min (in sucrose) and 10, 20, 30 and 40 min (in NaCl). Then, the samples were blotted with tissue to eliminate surface solution. Each slice was then weighed and analysed. The mass ratio of the samples to osmotic solution was kept at 1:20 and at ambient condition.

Determination of Moisture Content and Water Activity

In determination of moisture content, samples were weighed and dried in an oven at 105 ºC until constant weight for approximately 24 hours (AOAC, 2000; Fathullah et al. 2020). The moisture content was calculated from:

$$MC_{wet\ basis}\ (\%) = \frac{M_{wet} - M_{dry}}{M_{wet}} \times 100 \qquad \text{Eqn. 1}$$

where M_{wet} and M_{dry} are mass of the wet sample (g) and mass of the dry solid of the sample (g). Meanwhile, the water activity of osmotic solution and samples were analysed using water activity meter.

Determination of Water Loss (WL) and Solid Gain (SG)

The WL and SG were determined from the following equations (Mokhtar et al. 2019):

$$WL\left(\frac{g}{g}\text{ of fresh sample}\right) = \frac{(M_0 x_0 - M_t x_t)}{M_0} \qquad \text{Eqn. 2}$$

$$SG\ \left(\frac{g}{g}\text{ of fresh sample}\right) = \frac{(M_t s_t - M_0 s_0)}{M_0} \qquad \text{Eqn. 3}$$

where M_o, x_o and s_o are initial mass of sample, initial moisture fractions (g/g wet basis) and initial dry fractions (g/g), respectively. Meanwhile, M, x_t and s_t are mass of sample, moisture fractions (g/g wet basis) and dry fractions (g/g) at time, t, respectively.

Statistical Analysis

Data reported in all figures and tables were expressed in the form of mean and standard deviation values. The means values were subjected to one-way analysis of variance (ANOVA) with Tukey's test to determine the significant difference at 95% confidence level. All the analysis was evaluated using MINITAB 19.1 2019 statistical software.

RESULTS AND DISCUSSION

Water Loss (WL) Behaviour

Figure 1 shows the WL of potato, sweet potato and apple as a function of time under both dehydration treatments. It is clear that WL increases significantly over the time for both treatments in sucrose and NaCl cases. The similar trends also reported by other previous studies on the other fruits and vegetables (Mayor et al. 2007; Silva et al. 2014; Sareban & Souraki, 2016).

In general, the pattern of WL increased at the initial time and WL become slower rate at the end of the process in all cases. It can be explained that WL is more pronounced at initial process due to higher osmotic pressure between the fresh sample and concentrated solution. Subsequently, WL rate becomes slower due to the diffusion of salt or sugar which leads to the formation of a boundary layer on the sample surface.

It is interesting to note that the WL value in sucrose is higher than NaCl solution for all samples. For instance, the maximum WL value of potato treated under dip dehydration in sucrose is 0.53 ± 0.01 g/g, whereas it is only 0.34 ± 0.01 g/g in NaCl solution. Likewise, in the osmotic dehydration, the maximum value of WL for sucrose is 0.52 ± 0.02 g/g, whereas for NaCl is 0.30 ± 0.02 g/g. In the previous studies, it was reported that samples dehydrated in sucrose had higher WL than that other osmotic agents (El-Aour, 2006; Ispir and Togrul, 2009). This is probably due to sucrose has a larger molecule and higher concentration than NaCl, resulting in a faster rate of diffusion.

In Figure 1, it can be observed that sweet potato exhibits the lowest value of WL compared to potato and apple in all cases and this trend mainly due to the different structure and tissue properties of samples. According to Tortoe and Orchard (2006), the food sample such as an apple with porous structure tends to promote the diffusion of water out of the tissue, whereas sweet potato with compact tissue may retard the water diffusion. Moreover, the low moisture content of fresh sweet potato also plays a role in smaller WL value due to less osmotic pressure gradient between samples and osmotic solution (Panda, 2013; Sugumaran et al. 2019). It is also interesting to note that the WL values for dip dehydration are comparable to the osmotic dehydration for all samples. It can be proved that regardless of the structural differences between the samples, a comparable WL value to conventional osmotic dehydration can be achieved through dip dehydration.

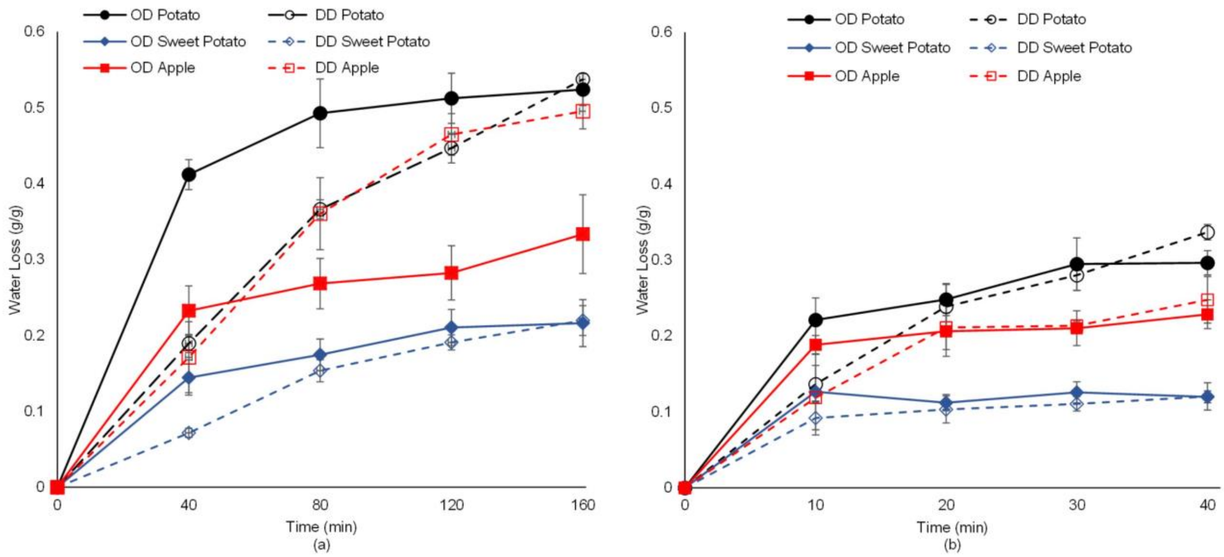

Figure 1: Water loss (WL) of potato, sweet potato and apple during dip dehydration (DD) and osmotic dehydration (OD) in (a) sucrose and (b) NaCl solutions

Moisture Content and Water Activity

Tables 2 and 3 illustrate the comparison of actual moisture content and water activity of the samples throughout the time. It shows that the moisture content of each sample decreased with time for all cases. For example, the initial moisture content of fresh potatoes was 83.12 ± 2.30% and after 160 min, it reduced to 53.31 ± 4.43% in OD, while 57.49 ± 2.57% in dip dehydration (DD) at the same sucrose concentration solution. Likewise, the moisture content only decreased to 72.40 ± 2.40% and 69.18 ± 4.77% after 40 min in NaCl solution under osmotic dehydration and dip dehydration, respectively.

It was obvious that dip dehydration method is closer to conventional osmotic dehydration in terms of reducing moisture content of the samples. This result is in agreement with the study by Mokhtar et al. (2019) on moisture loss of potato in osmotic dehydration, dip dehydration and ambient air drying. Muhamad and Basri (2019) also reported similar trend on the immature Manis Melon treated under osmotic dehydration. The study revealed that decreasing moisture content over time is due to the sample lose water continuously during the process.

Ahmed et al. (2016) reported that water activity is an indicator of food product stability over time under various storage conditions. Besides, water activity influences multiple aspects of food product design, processing, distribution, and consumption. Table 3 lists the water activity of all cases. From the values, it can be observed that the water activity of each sample decreased over time for dip dehydrated and osmo-dehydrated probably due to an increase in water loss. Lowering water activity increases the duration of the lag phase of microbial growth, thereby reducing the growth rate and, finally, the population becomes stable. Certain processes like further drying are usually carried out to reduce the water activity of pre-treated samples to avoid any microbial activity.

Solid Gain (SG) Behaviour

Solid gain is considered to be an adverse phenomenon in osmotic dehydration. The SG was estimated using Eq. 3 and was expressed in g solid per g of fresh sample in Table 4. As expected, SG increased with the time for both sucrose and NaCl solutions for all samples. This behaviour can be explained due to accumulation of solute from osmotic solution at an outer surface of the material increases over the treatment time, and consequently causes to the decreasing of water loss rate at the end of the process as clearly shown in Figure 1.

Table 2: Moisture content of sample slices after treated under dip dehydration (DD) and osmotic dehydration (OD) in sucrose and NaCl solutions.

	Sucrose 50%			NaCl 10%		
Sample	**Time (min)**	**DD**	**OD**	**Time (min)**	**DD**	**OD**
Potato	0	83.12 ± 2.30^{aA}	83.12 ± 2.30^{aA}	0	83.12 ± 2.30^{aA}	83.12 ± 2.30^{aA}
	40	76.99 ± 1.75^{bA}	62.20 ± 3.27^{bB}	10	77.83 ± 2.45^{bA}	71.84 ± 3.32^{bB}
	80	70.34 ± 1.44^{cA}	56.05 ± 6.52^{bcB}	20	73.58 ± 3.36^{bcA}	72.23 ± 3.22^{bA}
	120	62.95 ± 3.37^{dA}	56.96 ± 6.28^{bcA}	30	72.40 ± 2.93^{bcA}	71.09 ± 2.72^{bA}
	160	57.49 ± 2.57^{eA}	53.31 ± 4.43^{cA}	40	69.18 ± 4.77^{cA}	72.40 ± 2.40^{bA}
Sweet potato	0	71.72 ± 2.90^{aA}	71.72 ± 2.90^{aA}	0	71.72 ± 2.90^{aA}	71.72 ± 2.90^{aA}
	40	70.45 ± 2.10^{aA}	55.15 ± 3.64^{bB}	10	65.60 ± 3.14^{bA}	66.62 ± 2.83^{bA}
	80	66.30 ± 2.12^{aA}	51.09 ± 6.60^{bB}	20	64.76 ± 4.47^{bA}	65.17 ± 1.94^{bA}
	120	65.23 ± 3.19^{abA}	51.43 ± 1.90^{bB}	30	64.36 ± 1.89^{bB}	67.35 ± 1.46^{bA}
	160	60.79 ± 4.96^{bA}	53.05 ± 4.61^{bB}	40	64.94 ± 2.99^{bA}	65.94 ± 2.14^{bA}
Apple	0	87.89 ± 0.45^{aA}	87.89 ± 0.45^{aA}	0	87.89 ± 0.45^{aA}	87.89 ± 0.45^{aA}
	40	79.37 ± 2.51^{bA}	72.93 ± 1.67^{aB}	10	85.21 ± 0.47^{aA}	84.83 ± 2.82^{aA}
	80	74.20 ± 1.82^{bA}	71.73 ± 2.91^{abA}	20	82.76 ± 1.03^{aA}	84.01 ± 2.20^{aA}
	120	67.14 ± 3.35^{cA}	66.89 ± 3.61^{abA}	30	82.85 ± 0.15^{aA}	83.22 ± 0.94^{aA}
	160	61.04 ± 5.23^{cA}	65.38 ± 2.55^{bA}	40	82.08 ± 2.94^{aA}	83.30 ± 1.96^{aA}

Same lowercase letters are insignificant at p<0.5 for mean values in order to column.
Same uppercase letters are insignificant at p<0.5 for mean values in order to row.

Table 3: Water activity, a_w of sample slices after treated under dip dehydration (DD) and osmotic dehydration (OD) in sucrose and NaCl solutions.

	Sucrose 50%			NaCl 10%		
Sample	**Time (min)**	**DD**	**OD**	**Time (min)**	**DD**	**OD**
Potato	0	0.982 ± 0.004^{aA}	0.982 ± 0.004^{aA}	0	0.982 ± 0.004^{aA}	0.982 ± 0.004^{aA}
	40	0.981 ± 0.003^{aA}	0.967 ± 0.111^{aA}	10	0.973 ± 0.001^{aA}	0.961 ± 0.009^{aA}
	80	0.976 ± 0.004^{aA}	0.961 ± 0.004^{bB}	20	0.964 ± 0.030^{bA}	0.935 ± 0.033^{bA}
	120	0.970 ± 0.008^{aA}	0.959 ± 0.005^{bA}	30	0.952 ± 0.030^{bA}	0.937 ± 0.027^{bA}
	160	0.966 ± 0.008^{bA}	0.961 ± 0.007^{bA}	40	0.944 ± 0.020^{cA}	0.939 ± 0.024^{bA}
Sweet potato	0	0.984 ± 0.002 ^{aA}	0.984 ± 0.002 ^{aA}	0	0.984 ± 0.002 ^{aA}	0.984 ± 0.002 ^{aA}
	40	0.982 ± 0.002^{aA}	0.958 ± 0.005^{aB}	10	0.967 ± 0.001^{aA}	0.946 ± 0.001^{bB}
	80	0.975 ± 0.002^{bA}	0.955 ± 0.010^{aB}	20	0.960 ± 0.008^{aA}	0.940 ± 0.006^{bA}
	120	0.970 ± 0.003^{cA}	0.957 ± 0.006^{aA}	30	0.951 ± 0.050^{bA}	0.938 ± 0.004^{bA}
	160	0.962 ± 0.001^{dA}	0.954 ± 0.001^{aB}	40	0.954 ± 0.003^{bA}	0.941 ± 0.005^{bA}
Apple	0	0.981 ± 0.004 ^{aA}	0.981 ± 0.004 ^{aA}	0	0.981 ± 0.004 ^{aA}	0.981 ± 0.004 ^{aA}
	40	0.972 ± 0.004^{aA}	0.964 ± 0.001^{bA}	10	0.972 ± 0.001^{aA}	0.958 ± 0.001^{bB}
	80	0.964 ± 0.002^{abA}	0.968 ± 0.001^{bA}	20	0.963 ± 0.002^{bA}	0.954 ± 0.003^{bA}
	120	0.952 ± 0.004^{bcB}	0.978 ± 0.001^{aA}	30	0.963 ± 0.004^{bA}	0.957 ± 0.006^{bA}
	160	0.946 ± 0.012^{cA}	0.971 ± 0.001^{abA}	40	0.963 ± 0.004^{bA}	0.943 ± 0.009^{bA}

Same lowercase letters are insignificant at p<0.5 for mean values in order to column.
Same uppercase letters are insignificant at p<0.5 for mean values in order to row.

Table 4: Solid gain (SG) of potato, sweet potato and apple during dip dehydration (DD) and osmotic dehydration (OD) in sucrose and NaCl solutions

Sample	Sucrose 50%			NaCl 10%		
	Time (min)	DD	OD	Time (min)	DD	OD
Potato	40	4.19 ± 0.28^{aA}	7.57 ± 1.96^{aA}	10	5.28 ± 0.25^{aA}	4.03 ± 0.51^{aB}
	80	6.10 ± 1.26^{aA}	4.74 ± 0.86^{aA}	20	7.01 ± 1.37^{aA}	5.55 ± 0.38^{aA}
	120	5.34 ± 1. 83^{aA}	5.28 ± 0.88^{aA}	30	6.70 ± 1.10^{aA}	4.69 ± 0.42^{aB}
	160	6.40 ± 1.23^{aA}	4.55 ± 0.66^{aA}	40	4.99 ± 0.54^{aA}	3.89 ± 0.60^{aA}
Sweet potato	40	2.83 ± 0.09^{bA}	1.32 ± 0.09^{aB}	10	3.48 ± 0.41^{aA}	2.64 ± 0.29^{aA}
	80	5.41 ± 0.09^{aA}	1.21 ± 0.10^{aB}	20	3.58 ± 0.81^{aA}	1.54 ± 0.13^{bB}
	120	3.12 ± 0.01^{bA}	1.23 ± 0.17^{aB}	30	2.30 ± 0.23^{aA}	1.62 ± 0.05^{bA}
	160	2.37 ± 0.10^{bA}	1.28 ± 0.20^{aB}	40	3.07 ± 0.74^{aA}	1.55 ± 0.25^{bB}
Apple	40	2.81 ± 1.25^{bA}	2.08 ± 0.04^{aA}	10	12.24 ± 0.33^{bA}	12.76 ± 0.81^{aA}
	80	5.66 ± 0.37^{aA}	2.04 ± 0.28^{aB}	20	17.41 ± 0.84^{aA}	14.26 ± 0.34^{aB}
	120	6.22 ± 0.77^{aA}	1.62 ± 0.54^{aB}	30	17.30 ± 1.61^{aA}	14.03 ± 0.51^{aB}
	160	7.02 ± 1.72^{aA}	1.99 ± 0.33^{aB}	40	12.36 ± 2.16^{bA}	10.59 ± 1.19^{aA}

Same lowercase letters are insignificant at $p<0.5$ for mean values in order to column.
Same uppercase letters are insignificant at $p<0.5$ for mean values in order to row.

Table 5: Process efficiency index (WL/SG) of potato, sweet potato and apple under dip dehydration and conventional osmotic dehydration

Sample	Sucrose 50%			NaCl 10%		
	Time (min)	DD	OD	Time (min)	DD	OD
Potato	40	4.19 ± 0.28^{aA}	7.57 ± 1.96^{aA}	10	5.28 ± 0.25^{aA}	4.03 ± 0.51^{aB}
	80	6.10 ± 1.26^{aA}	4.74 ± 0.86^{aA}	20	7.01 ± 1.37^{aA}	5.55 ± 0.38^{aA}
	120	5.34 ± 1. 83^{aA}	5.28 ± 0.88^{aA}	30	6.70 ± 1.10^{aA}	4.69 ± 0.42^{aB}
	160	6.40 ± 1.23^{aA}	4.55 ± 0.66^{aA}	40	4.99 ± 0.54^{aA}	3.89 ± 0.60^{aA}
Sweet potato	40	2.83 ± 0.09^{bA}	1.32 ± 0.09^{aB}	10	3.48 ± 0.41^{aA}	2.64 ± 0.29^{aA}
	80	5.41 ± 0.09^{aA}	1.21 ± 0.10^{aB}	20	3.58 ± 0.81^{aA}	1.54 ± 0.13^{bB}
	120	3.12 ± 0.01^{bA}	1.23 ± 0.17^{aB}	30	2.30 ± 0.23^{aA}	1.62 ± 0.05^{bA}
	160	2.37 ± 0.10^{bA}	1.28 ± 0.20^{aB}	40	3.07 ± 0.74^{aA}	1.55 ± 0.25^{bB}
Apple	40	2.81 ± 1.25^{bA}	2.08 ± 0.04^{aA}	10	12.24 ± 0.33^{bA}	12.76 ± 0.81^{aA}
	80	5.66 ± 0.37^{aA}	2.04 ± 0.28^{aB}	20	17.41 ± 0.84^{aA}	14.26 ± 0.34^{aB}
	120	6.22 ± 0.77^{aA}	1.62 ± 0.54^{aB}	30	17.30 ± 1.61^{aA}	14.03 ± 0.51^{aB}
	160	7.02 ± 1.72^{aA}	1.99 ± 0.33^{aB}	40	12.36 ± 2.16^{bA}	10.59 ± 1.19^{aA}

Same lowercase letters are insignificant at $p<0.5$ for mean values in order to column.
Same uppercase letters are insignificant at $p<0.5$ for mean values in order to row.

It can be clearly seen from Table 4 that SG for osmotic dehydration was always significantly higher than dip dehydration samples. For example, SG in the case of osmotic dehydration of apple was 0.168 ± 0.012 for sucrose after 160 min and 0.021 ± 0.003 for NaCl after 40 min. Similar results also reported in the previous study for dip dehydration of potato (Mokhtar et al. 2019). Thus, these results confirm that by employing dip dehydration, the SG of the samples can be significantly reduced, which is potentially health beneficial. Table 4 also shows that SG value of samples treated with sucrose solution was significantly higher ($p<0.05$) than samples treated with NaCl for both dip dehydration and osmotic dehydration. There have been numerous studies reported that solid gain behaviour is affected by types of osmotic agents depending on their molecular weight and concentration. An osmotic agent with smaller molecular weight and higher concentration tend to give higher SG (Mirzayi, 2018; Ispir and Togrul, 2009; El-Aouar, 2006). Therefore, in this study, it is obvious that higher concentration of sucrose attributes to the higher SG value as compared to NaCl solution for all cases.

Process Efficiency Index

Table 5 shows the process efficiency index values, which is a ratio of WL to SG for both dip and osmotic dehydration of potato, sweet potato and apple slices. García (2010) reported that the process efficiency index values are used to evaluate the efficiency of the osmotic dehydration method and it is desirable to maximize WL and minimize SG. Table 5 shows that the highest process efficiency index was obtained for apple treated under dip dehydration (NaCl 10 %), while sweet potato treated under osmotic dehydration (sucrose 50%) resulted in the lowest process efficiency index. It was observed, in general, the samples treated under dip dehydration presented a higher value of efficiency index than osmotic dehydration samples. The efficiency index value is influenced by the water loss rate at the initial process, while the solid gain has more influence on the efficiency index at the end of the process. According to Mokhtar et al. (2019), the main advantage of dip dehydration, which substantially lower the SG contributes to the higher WL/SG values. Therefore, dip dehydration is the best treatment with less sugar or salt uptake during the process.

CONCLUSION

Mass transfer during dip dehydration of cellulosic (apple) and starchy (potato and sweet potato) plant materials was investigated, and the results were compared to the osmotic dehydration method. In all cases, the water loss was more significant at the initial stage but slowed down at a later stage under both treatments. It was found that the water loss of samples treated under dip dehydration is comparable to the osmotic dehydration but with a lower solid gain. The water loss of the samples could be achieved about 0.53 ± 0.01, 0.50 ± 0.02 and 0.22 ± 0.02 for potato, sweet potato and apple, respectively. Meanwhile, in term of process efficiency index, the cellulosic plant material (apple slices) had the highest value and thus apple is the most suitable plant material treated under dip dehydration method.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

The manuscript was written by RAZ and WMFWM. WAFWM reviewed the final manuscript. The experiment was designed by WMFWM and RAZ was performed experiment and collected data. All authors read and approved the final version.

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