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Impact of Using Alternative Sweetener as Osmotic Agent on Mass Transfer, Colour and Texture Properties During Dip Dehydration of Apple Slice

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ABSTRACT

Previous study has explored dip dehydration as a novel variant of osmotic dehydration to reduce solid gain, which is the main problem of osmotic dehydration. However, this dehydration process commonly uses sucrose solution as osmotic agent which might contribute to the increase in glycaemic index and can also be linked to different diseases such as diabetes and obesity. Therefore, this study aims to investigate the effect of using alternative sweeteners as an osmotic agent on mass transfer, colour, and texture profiles during dip dehydration of apple slices. Three alternative sweeteners, i.e., erythritol, sorbitol and xylitol with 30% (w/v) concentration were used in this study. Apple slices with 1.5 mm thickness and diameter of 55 mm were dipped multiple time in the same concentrated solution every 40 minutes until 200 minutes before samples were analysed. Findings showed that different type of sweetener affect water loss and solid gain. Xylitol and sorbitol gave highest water loss about 36% and 40%, respectively. Lowest total colour different with fresh apple has been observed in sample treated with xylitol. As for texture, there is no remarkable effect of using alternative sweetener as osmotic agent at all processing times. Overall, the best alternative sweetener for sucrose is xylitol considering the mass transfer and quality of apple slices.

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

INTRODUCTION

Drying is a well-known ancient method that is still used to preserve the food products. Drying is a combination of heat and mass transfer when energy is supplied to sample. It is one of the preservation methods to prevent food degradation due to chemical or microbial reactions by reducing the water available in food by vaporization or sublimation and thus, prolong the shelf life. (Guiné, 2018; Muliterno et al., 2017).

Osmotic dehydration is one of the drying methods that removes water from material without being exposed to high temperature. It is commonly used as a pre-treatment prior to further processing process. In this process, materials like fruits and vegetables are immersed in a hypertonic aqueous solution with a particular concentration. The concentrated solution that is usually used for this process is sucrose and sodium chloride

(NaCl). Mass transfers occur due to the driving osmotic force generated by the tissue and concentrated solution. Three phenomena occur during mass transfer, which are the removal of water from tissue, an influx of solute from hypertonic solution into the tissue and leaching out other components from the tissue (Akbarian et al., 2014; Chandra & Kumari, 2015; Wan Mokhtar et al., 2019).

According to Yadav and Singh (2014), this method can reduce about 50% of the actual moisture content of the material and further drying or processing is needed to prolong the shelf life. Bioactive compounds like vitamin and mineral, colour, flavour, and taste property can be maintained even after processing (Ahmed et al., 2013). Hence, due to these advantages, osmotic dehydration is preferred as pre-treatment prior to drying. As mentioned earlier, osmotic dehydration will retain most of the food properties compared to the conventional air-drying method. Moreover, this method is economical because it does not require much energy compared to other drying methods. However, osmotic dehydration also has some limitations. Leaching out of food constituent, solute uptake, and water outflow from the food during osmotic dehydration can affect the content of the osmotic solution, nutritional profile, and sensory attributes of the final product. Leaching out of organic acids of food will reduce the acidity level of the food, thus affecting the properties of final products Besides, the water outflow and leaching of product's own solute will dilute the solution and reduces the osmotic driving force. Solute uptake during dehydration will form a concentrated solid layer under the surface of the fruit and affect the osmotic pressure thus reduce the driving force between the food material and osmotic solution. (Ahmed et al., 2016; Tortoe, 2010).

A recent study by Wan Mokhtar et al. (2019), explores an alternative to the osmotic dehydration method to reduce solute uptake. This method involves dipping material or sample in a concentrated solution for a short time and followed by simple exposure to ambient conditions. Through this study, dip dehydration seems to be effective in lowering moisture content of food material, but with significantly lower of solute uptake compared to material treated with osmotic dehydration. Despite that, this study only focuses on using sucrose and NaCl as osmotic agent.

Sucrose is a common osmotic solution used for osmotic dehydration and usually associated with health issues such as diabetes and obesity. The simple molecular structure of sucrose is quickly digested and increases blood glucose level, thus cause rapid release of insulin which might be worn out fast and cause diabetes type II. Besides, a previous study found that a person can be triggered to eat more because sucrose is quickly digested (Emily, 2018). Nowadays, consumer is more conscious about health issues. Using alternative sweeteners as osmotic might be a great idea to reduce the risk of disease associated with sucrose and a better quality and healthier food product can be produced. Therefore, it raised our interest to investigate effect of alternative sweetener i.e. xylitol, erythritol and sorbitol as osmotic agent on mass transfer and also product quality during dip dehydration of apple slices as food sample.

MATERIALS AND METHODS

Raw materials

Red Royal Gala apple, sucrose and sweeteners in powder form (xylitol, erythritol and sorbitol) were purchased from local market in Besut, Terengganu.

Preparation of sample and osmotic solution

Apples were washed, peeled, and sliced into 1.5 mm thick slices using meat slicer (SL-300ES) to achieve a uniform thickness of apple slices. Then, the slices were cut into round shape with 55 mm of diameter using kitchen moulder. In order to avoid enzymatic browning, the apple slices were immersed in a 0.5% citric acid solution for about 5 min. Then, the excess solution on the apple slices were removed by blotted gently with tissue paper and the initial weight were recorded. Osmotic solution with concentration of 30% (w/v) was prepared by dissolving sucrose and alternative sweetener (erythritol, sorbitol and xylitol) in distilled water.

Dip dehydration

Dip dehydration process was conducted according to Wan Mokhtar et al. (2019). Similar size of apple slices was dipped in 30% concentration of osmotic solution for 0.5min then let dry at ambient conditions for 40 min. Multistage dip dehydration was done with solution of the same concentration (30%) at every 40 min for total processing time of 80, 120, 160 and 200 min. After total processing time of 40, 80, 120, 160 and 200 min, the apple slices were gently blotted using tissue paper to remove adhering solution on the surface. The final weight was recorded, and the apple slices were analysed.

Mass transfer determination

Determination of mass transfer was done by using oven-drying method. Samples were weighed and dried at 105℃ in a convection oven (Oven with Fan MMT-UF110 Memmert) for ~24 h until a constant weight was obtained (Wan Mokhar et al., 2019; Horwitz, 2000). Moisture content in wet basis was determined using the following equation:

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

where M_{wet} is a mass of the wet sample (g) and M_{dry} is a mass of dried sample (g).

Meanwhile, water loss and solute gain can be determined through following equations (Wan Mokhtar et al., 2019; Li & Ramaswamy, 2006):

$$WL\ (\%) = \frac{(M_0X_0 - M_tX_t)}{M_0} \times 100 \qquad \textbf{Eqn. 2}$$

$$SG\ (\%) = \frac{(M_ts_t - M_0s_0)}{M_0} \times 100 \qquad \textbf{Eqn.3}$$

where M_0 and M_t are the mass of sample initially and at time *t* respectively; X_0 and X_t are the moisture fractions (g/g wet basis) initially and at time *t* respectively; s_0 and s_t are the solid fractions (g/g) initially and at time *t*. The equations above assume there is no solute transferred from the sample to the solution.

Texture and colour measurement

Texture of fresh and dipped apple slices after 40, 80, 120, 160 and 200 min were analysed using a Texture Analyzer, Stable Micro Systems. Probe used for this analysis was blade set with knife. The maximum peak was expressed as a firmness value in kilogram (kg). Treated apple slices under different sweeteners at different times were subjected to the analysis.

Colour of fresh and treated samples were measured by using colorimeter (Konica Minolta Chromameter, CR-400). Total colour difference was calculated using equation below (Kowalska et al., 2020).

$$\Delta E = \sqrt{(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2} \qquad \textbf{Eqn. 4}$$

Where ΔE is total colour difference, parameters between fresh and dip dehydrated sample. L* indicates lightness, a* is the red or green coordinate while b* is the yellow or blue coordinator.

Statistical analysis

Triplicate data were collected for each different type of sweeteners (erythritol, sorbitol, xylitol) at different total processing times (40, 80, 120, 160 and 200 min). The experimental data reported in figures and tables are the mean and standard values that calculated by using Microsoft Excel 365 and were evaluated using SPSS statistic software. One-way analysis of variance (ANOVA) with Duncan's test was used to determine the significant difference involving more than two sample (each sample with triplicate data) at 95% confidence level.

RESULTS AND DISCUSSION

Water loss (WL)

Fig. 1 shows water loss (WL) as a function of the total time of dipping and holding times. The apple slices were dipped in sucrose (control) and different type of alternative sweeteners (xylitol, erythritol, sorbitol) for a brief moment (0.5 min), taken out and left to dehydrate at the ambient condition at 40, 80, 120, 160 and 200 min. In general, water loss trend exhibits rapidly increases at initial time for all treatments and become consistent over the total time. This pattern is similar as discussed in the previous study conducted by Wan Mokhtar et al. (2019) which depicts an increase in WL initially and progressively lower value at longer processing time. For example, WL of samples treated with xylitol increases to 36% at 40 min and become at constant value over period of time. Based on the previous study by Wan Mokhtar et al. (2019), the surface of the fruit material affecting the driving force between the tissue and surrounding solution, thus lowering the rate of water lost. Finding also shows that there was insignificant difference between control sample and samples treated under sweeteners. However, sample treated under xylitol and sorbitol retained at high water loss than control sample. For example, at 40 min, water loss of control sample was only 30%, while water loss for both samples treated under xylitol and erythritol was 36%.

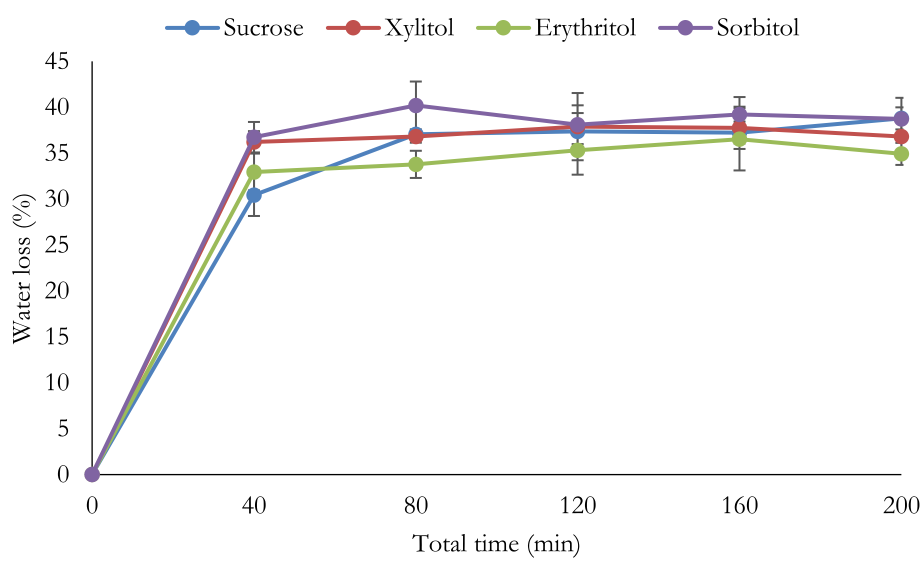

Fig. 1. Water loss of apple slice treated a in different type of sweeteners as a function of time

Solid gain (SG)

Previous study by Wan Mokhtar et al. (2019) stated that by briefly dipping potato samples and allowing the dehydration occur outside of the solution results in a lower solute uptake compared to the conventional osmotic dehydration method. Besides, the study also discovered that solid gain increased as processing time increases for potato slices treated with sucrose. Table 1 shows that through some points. the value of solid gain of apple treated with alternative sweetener was lower than control.

Water loss and solid gain are corelated and affected by the properties of the solute used as an osmotic agent during the treatment. Most of the previous studies observed erythritol gives the best effect in water removal due to its low molecular weight, however it can also leads to a higher solid gain. According to study by Mendonca et al. (2017), sorbitol and xylitol were found to be the most effective osmotic agent during osmotic dehydration of yacon slices compared to erythritol. Although, erythritol was found to give a great water removal effect but with increasing processing time, SG value also increases. In this study, at 80 min sample treated with sorbitol was found to have the highest water loss (40%) with the lowest solid gain (3.84%) compared to xylitol and erythritol. At 120 min, sorbitol also exhibits the highest water loss (38.10%) and lowest solid gain (7.21%) than sucrose and erythritol. Mendonca et al. (2017) stated that molecular weight of the solute affects the water removal and solute uptake. However, the result from this study is contrary to a study by Kowalska et al. (2020) which erythritol was found to give the best water removal effect in apple instead of sorbitol during osmotic dehydration. Cichowska et al. (2018) also reported a similar result in which erythritol was found to be more impactful on lowering water content in apple during osmotic dehydration compared to xylitol and maltitol. Both studies mentioned that the low molecular weight of erythritol has better diffusivity and easily pentrates into the tissue compared to other sweeteners.

Table 1. Solid gain of apple slice treated a in different type of sweeteners as a function of time

Time (min)	Solid Gain (%)			
	Sucrose	Xylitol	Erythritol	Sorbitol
40	1.46 ± 0.58^{a}	0.27 ± 1.70^{a}	0.23 ± 0.50^{a}	0.52 ± 0.19^{a}
80	6.55 ± 1.84^{bc}	5.60 ± 1.67^{bc}	5.29 ± 0.35^{b}	3.84 ± 0.40^{b}
120	8.40 ± 0.55^{d}	6.94 ± 0.62^{cd}	7.74 ± 0.14^{c}	7.21 ± 0.57^{d}
160	4.58 ± 0.36^{b}	5.25 ± 0.68^{b}	5.36 ± 0.73^{b}	6.27 ± 0.51^{c}
200	13.37 ± 1.68^{e}	7.47 ± 1.00^{d}	7.03 ± 0.83^{c}	7.49 ± 0.86^{d}

Values in the same column with different superscripts are statistically significant different from each other ($p<0.05$).

Polyols generally have lower molecular weight compared to sucrose. Among the alternative sweeteners, erythritol has the lowest molecular weight followed by xylitol and sorbitol with the value of 122.120 g/mol, 152.15 g/mol, and 182.178 g/mol, respectively. According to Chauhan et al. (2011), solutes with high molecular weight are more likely to remain on the surface of the tissue, creating a greater osmotic concentration, thus boosting the water removal effect during the treatment. In addition, as it does not penetrate easily into the tissue. Therefore, lower solute uptake than smaller molecules that easily diffuse into the tissue. Dehydration of sample treated with high molecular weight solute occurs because of the concentration difference between the surface and interior product. Meanwhile, the study stated that low molecular weight solutions would have higher corresponding osmotic pressure, which leading to cell plasmolysis. Cell plasmolysis is a process by which the cell loses water in a hypertonic solution. This process occurs gradually throughout the different tissue layers and eventually cause dehydration of the tissue cell. Rapid penetration of smaller molecule of solute causes the concentration gradient to gradually decrease. Besides, diffusion of smaller solute into the tissue will cause a concentrated solid layer to develop under the surface of the fruit. This will cause a decrease in the osmotic pressure gradient across the fruit-medium interface, thus lowering the driving force for water flow. The limited water driving force accelerate the uptake of the smaller solute molecule (Chauhan et al., 2011).

Moisture content

Table 2 shows the moisture content of samples treated with a different type of sweeteners. From the table, moisture content of apple slices treated under sucrose and sweeteners reduced over the time. According to Wan Mokhtar et al. (2019), moisture content of sample treated with dip dehydration was found to be similar to those treated with osmotic dehydration. Water loss due to dip dehydration contributes to the decreasing of moisture content throughout total time. The higher water loss during treatment, the lower moisture obtained.

Table 2. Moisture content (% wet basis) of apple slice treated a in different type of sweeteners as a function of time

Time (min)	Moisture Content (% wet basis)			
	Sucrose	Xylitol	Erythritol	Sorbitol
0	88.63 ± 0.40^{e}	88.39 ± 0.20^{e}	88.31 ± 0.10^{d}	88.37 ± 0.15^{e}
40	81.59 ± 1.16^{d}	81.94 ± 0.72^{d}	82.74 ± 0.71^{c}	81.06 ± 0.81^{d}
80	75.08 ± 1.87^{c}	76.18 ± 0.31^{c}	75.91 ± 1.00^{b}	75.66 ± 0.29^{c}
120	69.94 ± 1.96^{b}	73.03 ± 0.55^{a}	73.16 ± 0.87^{a}	72.65 ± 0.38^{b}
160	67.98 ± 0.70^{a}	74.99 ± 0.63^{b}	73.17 ± 2.29^{a}	70.83 ± 1.26^{a}
200	67.33 ± 1.16^{a}	73.63 ± 0.54^{a}	74.14 ± 0.48^{a}	72.94 ± 0.54^{b}

Values in the same column with different superscripts are statistically significant different from each other ($p<0.05$).

Sorbitol was found to has the highest water loss at 80 min and 160 min and lowest solid gain at 80 min. It also can be seen that longer processing time increases solid gain of sample for all treatment. However, longer processing time leads to the insignificant effect to the water loss for all treatment. Water loss and solid gain is corelated with each other and affected by the properties of solute used as osmotic agent. Molecular weight could be the factor that facilitates water removal in apple slice. Hence, it can be concluded that using alterntive sweeteners during dip dehydration and longer processing time gives effect on water loss and solid gain. Moisture content of apple slices treated with alternative sweeteners shows similar trend with sucrose-treated sample at most of processing times.

Colour measurement

Colour is one of the indicators in the determination of a good quality of food products. Fig. 2 illustrates the colour properties and total colour difference of both fresh and treated samples. Finding shows that the colour properties are insignificant difference between control and treated samples and exhibited the similar trends for all cases. In general, the lightness (L*) colour of all samples decreased over time due to sign of enzymatic browning (Kowalska et al. 2020). Xylitol was seen to cause the least total colour differences between fresh apple which is in line with the study made by Kowalska et al. (2020). However, in a study by Cichowska et al. (2018) using polyols (erythritol, xylitol, and maltitol), erythritol was found to increase brightness of the surface tissue of apple samples. Based on the study, the increase in lightness is caused by the removal of water from the sample. Cichowska et al. (2018) stated that sugar coating due to osmotic dehydration of apple could be the reason of increasing in brightness. Erythritol has a high crystallization capacity compared to other sweeteners giving the effect of brightening when light is reflected on the surface of the erythritol-treated sample.

Texture measurement

From the Table 4.3, it can be seen that firmness of all samples decrease over processing time. This may be explained by considerable changes of cellular tissue involving plasmolysis, filling or air spaces with concentrated solution and degradation of the cellular structure (Najafi et al., 2014; Prinzivalli et al., 2006). Finding shows that firmness of sample treated with sucrose was found to be higher as compared to sample treated with xylitol, erythritol and sorbitol. This finding is similar to the work done on the cantaloupe slice by Naknean et al. (2013). The hardness in sucrose-treated cantaloupe is the highest, while polyols (sorbitol and maltitol) treated cantaloupe have the lowest value of hardness. Based on the study, hardness in sucrose-treated sample might be caused by the formation of sucrose crystal coating on the sample surface. Besides, polyols were known to act as a humectant that bind with water molecules,thus reducing the hardness (Chauhan et al., 2011; Naknean et al., 2013).

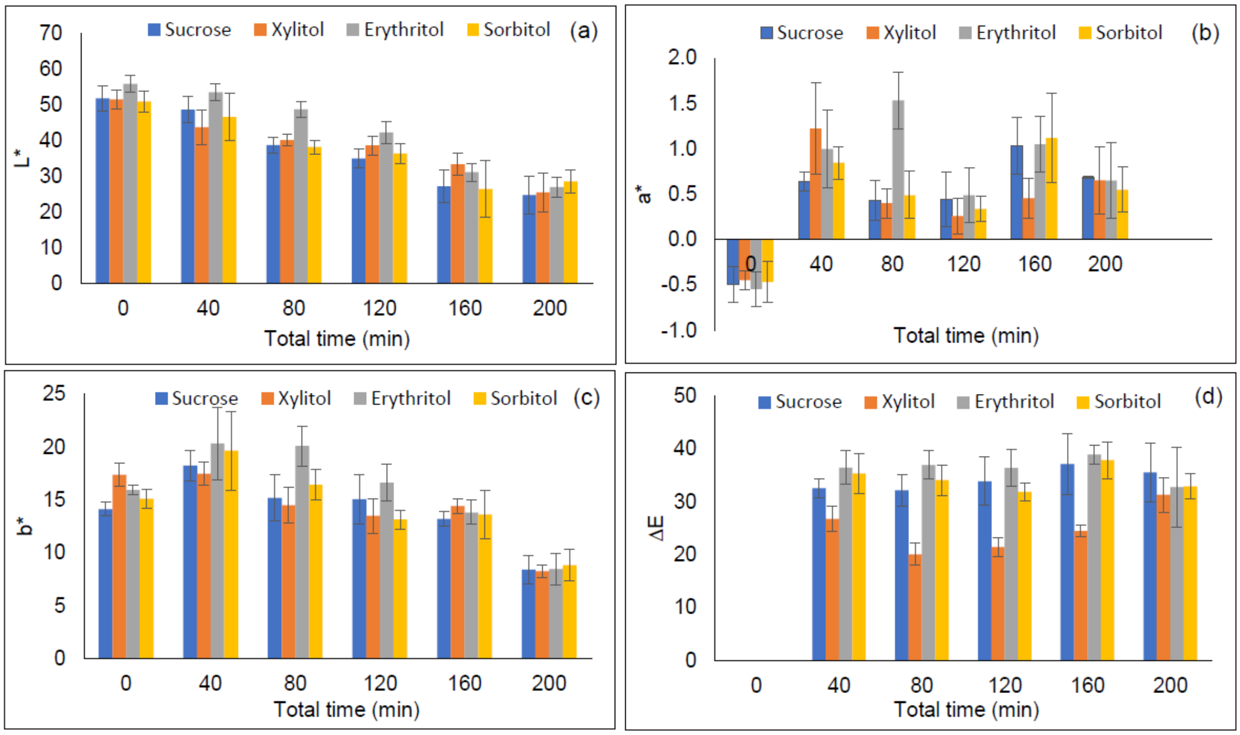

Fig. 2. Colour properties of apple slice treated a in different type of sweeteners as a function of time

Table 3. Firmness of apple slices treated with different types of sweeteners at different total processing times.

Time (min)	Firmness			
	Sucrose	Xylitol	Erythritol	Sorbitol
40	1.84 ± 0.72^{b}	1.76 ± 0.57^{c}	0.71 ± 0.34^{b}	1.16 ± 0.45d
80	1.63 ± 0.62^{b}	0.46 ± 0.11^{ab}	0.48 ± 0.19^{ab}	0.94 ± 0.22^{cd}
120	1.48 ± 0.40^{b}	0.32 ± 0.15^{ab}	0.41 ± 0.26^{ab}	0.82 ± 0.25^{c}
160	1.11 ± 0.69^{b}	0.27 ± 0.03^{a}	0.38 ± 0.21^{a}	0.45 ± 0.09^{ab}
200	0.40 ± 0.11^{a}	0.21 ± 0.11^{a}	0.31 ± 0.24^{a}	0.28 ± 0.04^{a}

Values in the same column with different superscripts are statistically significant different from each other ($p<0.05$).

CONCLUSION

In this study, alternative sweeteners were used to observe its effect on the mass transfer and properties of apple slices during dip dehydration. This study focuses on using xylitol, erythritol, and sorbitol as an alternative osmotic agent to sucrose solution. In general, water loss was observed to increase at initial time and decreases at longer processing time for all treatment. There was no significant different between alternative sweeteners and sucrose on solid gain trend. However, solid gain was observed to increase for all treatment at longer processing period and control sample retained highest solid gain as compared other treatments which is undesirable. Lowest total colour difference has been observed in xylitol-treated sample and there is no remarkable effect of using alternative sweetener as an osmotic agent on the texture throughout the processing time.

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REFERENCES

Ahmed, I., Qazi, I. M., & Jamal, S. (2016). Developments in osmotic dehydration technique for the preservation of fruits and vegetables. *Innovative Food Science and Emerging Technologies*, *34*, 29–43. https://doi.org/10.1016/j.ifset.2016.01.003

Ahmed, N., Singh, J., Chauhan, H., Gupta, P., Anjum, A., & Kour, H. (2013). Different Drying Methods: Their Applications and Recent Advances. *International Journal of Food Nutrition and Safety*, *4*(1), 34–42.

Akbarian, M., Ghasemkhani, N., & Moayedi, F. (2014). Osmotic dehydration of fruits in food industrial: A review. *International Journal of Biosciences (IJB)*, *4*(1), 42–57. https://doi.org/10.12692/ijb/4.1.42-57

Chandra, S., & Kumari, D. (2015). Recent Development in Osmotic Dehydration of Fruit and Vegetables: A Review. *Critical Reviews in Food Science and Nutrition*, *55*(4), 552–561. https://doi.org/10.1080/10408398.2012.664830

Chauhan, O. P., Singh, A., Singh, A., Raju, P. S., & Bawa, A. S. (2011). Effects of osmotic agents on colour, textural, structural, thermal, and sensory properties of apple slices. *International Journal of Food Properties*, *14*(5), 1037–1048. https://doi.org/10.1080/10942910903580884

Cichowska, J., Żubernik, J., Czyżewski, J., Kowalska, H., & Witrowa-Rajchert, D. (2018). Efficiency of osmotic dehydration of apples in polyols solutions. *Molecules*, *23*(2). https://doi.org/10.3390/molecules23020446

Guiné, R. P. F. (2018). The Drying of Foods and Its Effect on the Physical-Chemical, Sensorial and Nutritional Properties. *ETP International Journal of Food Engineering*, *June*, 93–100. https://doi.org/10.18178/ijfe.4.2.93-100

Horwitz, W. (2000). *Official methods of analysis of AOAC International* (17th ed.). AOAC International.

Kowalska, H., Woźniak, Ł., Masiarz, E., Stelmach, A., Salamon, A., Kowalska, J., Piotrowski, D., & Marzec, A. (2020). The impact of using polyols as osmotic agents on mass exchange during osmotic dehydration and their content in osmodehydrated and dried apples. *Drying Technology*, *38*(12), 1620–1631. https://doi.org/10.1080/07373937.2019.1653319

Li, H., & Ramaswamy, H. (2006). Osmotic dehydration of apple cylinders: I. Conventional batch processing conditions. *Drying Technology*, *24*(5), 619–630. https://doi.org/10.1080/07373930600626545

Mendonça, K., Correa, J., Junqueira, J., Angelis-Pereira, M., & Cirillo, M. (2017). Mass Transfer Kinetics of the Osmotic Dehydration of Yacon Slices with Polyols. *Journal of Food Processing and Preservation*, *41*(1), 1–8. https://doi.org/10.1111/jfpp.12983

Muliterno, M. M., Rodrigues, D., de Lima, F. S., Ida, E. I., & Kurozawa, L. E. (2017). Conversion/degradation of isoflavones and color alterations during the drying of okara. *LWT - Food Science and Technology*, *75*, 512–519. https://doi.org/10.1016/j.lwt.2016.09.031

Najafi, A. H., Yusof, Y. A., Rahman, R. A., & Ganjloo, A. (2014). Effect of osmotic dehydration process using sucrose solution at mild temperature on mass transfer and quality attributes of red pitaya (Hylocereus polyrhizusis). *International Food Research Journal, 21(*2), 625 – 630.

Naknean, P., Maneyam, R., & Kam-Onsri, A. (2013). Effect of different osmotic agents on the physical, chemical and sensory properties of osmo-dried cantaloupe. *Chiang Mai Journal of Science*, *40*(3), 427–439.

Prinzivalli, C., Brambilla, A., Maffi, D., Lo Scalzo, R., & Torreggiani, D. (2006). Effect of osmosis time on structure, texture and pectic composition of strawberry tissue. *European Food Research and Technology*, *224*(1), 119–127. https://doi.org/10.1007/s00217-006-0298-9

Tortoe, C. (2010). A review of osmodehydration for food industry. *African Journal of Food Science*, *4*(6), 303–324. http://www.academicjournals.org/ajfs

Wan Mokhtar, W. M. F., Ghawi, S. K., & Niranjan, K. (2019). Dehydration of potato slices following brief dipping in osmotic solutions: Effect of conditions and understanding the mechanism of water loss. *Drying Technology*, *37*(7), 885–895. https://doi.org/10.1080/07373937.2018.1473418

Yadav, A. K., & Singh, S. V. (2014). Osmotic dehydration of fruits and vegetables : a review. *Journal of Food Science and Technology,* 51(9), 1654 – 1673. https://doi.org/10.1007/s13197-012-0659-2

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