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Effect of Osmotic Dehydration as a Pre -Treatment on Air Fried Sweet Potato (*Ipomoea batatas*) Chips

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ABSTRACT

Air frying is a modern frying technique that promises low oil content of fried products. However, the main limitation of air frying is that it requires a longer operating time than deep fat frying. Previous studies found that osmotic dehydration is beneficial as frying pre-treatment to improve the quality of fried products and reduce frying time, but to date, there is no study investigating its application in air frying. Therefore, this study aims to examine the effect of osmotic dehydration as pre-treatment on the quality of air-fried sweet potato chips. Sweet potatoes were cut into slices with the same thickness, and then soaked in distilled water, 5% sodium chloride solution, and 10% sodium chloride solution for one hour. The potato slices were then air fried at two temperatures: 160° and 180°C for 3, 6, 9, 12, and 15 minutes. Then, moisture content, colour, texture, diameter shrinkage and thickness expansion were analysed. The moisture content of air fried chips decreased with the increasing of frying time. The osmo-dehydrated sample showed lower moisture content which could the reduce frying time from 12 mins to 9 mins at 160°C. Osmo-dehydrated sweet potato slices produce paler chips, but the treatment preserved the red and yellow colour of the sample. Air fried sweet potatoes that were osmotically dehydrated samples shrank more in diameter than the control samples. The increased thickness of chips was caused by crust formation and the bubbles formed at the surface due to the barrier formed by the tight surface, resulting in vapour expansion inside the pores of the chips. The hardness of pre-treated chips increased significantly with decreasing moisture content. Using osmotic dehydration pre-treatment in the air frying process can yield promising results in less frying time and better retention in terms of red and yellow colour.

Keywords: Air frying, osmotic dehydration, sweet potato, pre-treatment

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INTRODUCTION

Frying is one of the oldest and quickest cooking techniques for foods such as fish, meat, and vegetables by putting them in heated oil or fat for a period of time, whether raw or prepared (Andrés et al., 2013). Deep-fat frying is one of the popular methods in which food is partially or completely submerged in hot oil, typically between 177˚C and 191˚C (Schiffmann, 2017). Deep-fat frying is a quick process with simultaneous transfer of heat and mass. However, it is also complicated since two mass transfer activities occur opposite directions between the heating medium and the material when it is fried (Asokapandian et al., 2019).

Factors that affect the deep-frying process include the type of oil used, the ratio of oil to food, the interfacial tension between the oil and the product, the temperature and time of frying, and the size of food. These factors affect the amount of oil entrained within the food. Firstly, the ratio of oil to food relates to the oil uptake amount by food during frying process. Research showed that a higher ratio of oil to food leads to higher oil uptake, with thicker crust formed (Oke et al., 2018).

Air frying is a new and alternative method to produce fried products with lower fat content (Andrés et al., 2013). In air frying, raw food materials are effectively heated in hot air containing fine droplets of oil, attempting to impart the attributes of traditionally manufactured fried products but with a considerably lower level of fat absorbed in the products. Air frying can reduce the oil content of the fried products, but a longer frying time is required. Pre-treatment methods such as osmotic dehydration is known to minimise water content of food and also contributes to reduce the duration of operating processes such as drying and frying (Nurhidayah Hanim Mohamad et al., 2020; Krokida et al., 2001a).

Osmotic dehydration is the removal of water from a water-containing cellular solid by immersing it in a concentrated aqueous solution (Tortoe, 2010). The primary purpose of food dehydration is to reduce water content in order to reduce deterioration rates due to microbial activity and make distribution and storage easier. During osmotic dehydration, foods are immersed or soaked in a saline or sugar solution (Tortoe, 2010). It involves simultaneous counter-current mass transfer between solution inside tissue sample and a concentrated solution outside. First, due to driving force from higher osmotic pressure of the hypertonic solution, water flows out from the food tissue into the osmotic solution. Simultaneously, the diffusion of water is accompanied by the solute infusion from the osmotic solution into the food tissue. Previous studies showed that osmotic dehydration decreases moisture and oil content of food products. This pre- treatment provides advantages in producing high-quality products with lesser flavour loss and tissue damage. Most previous researches (Dehghannya & Abedpour, 2018; Ren et al., 2018) reported the advantages of osmotic dehydration as a pretreatment on the deep frying in reducing frying time and oil content on the potato strips and mushroom chips, but no study has focused on the air frying treatment. Therefore, this study aims to investigate the potential of osmotic dehydration using sodium chloride solution as pretreatment on the sweet potato chips produced using air frying method to reduce the operating time. The effect of frying temperatures at 160^{o}C and 180^{o}C on the quality of sweet potato chips also was examined.

MATERIALS AND METHODS

Raw materials

Orange sweet potato and commercial sodium chloride (NaCl) were purchased from local store in Besut, Terengganu. Orange sweet potatoes were stored at room temperature a day before processing. Orange sweet potatoes weighing around 180 – 250 g were selected for experiments.

Preparation of sweet potato chips

The sweet potatoes were washed, peeled, and then sliced into thickness of 2 mm using domestic slicer machine. A cylindrical domestic cutter was used to cut the samples into 50 mm diameter round shape. The sweet potato slices were rinsed with distilled water for 10 seconds immediately to eliminate excess starch on the surface and control browning reactions. The water on the sweet potato slices was removed using tissue paper.

Osmotic dehydration treatment

Sodium chloride solution was prepared by dissolving commercial NaCl in distilled water. Two concentrations of sodium chloride solutions were used, which are 5 % and 10 %. An amount of 150g of sweet potato slices were immersed in 500 ml osmotic solution for 60 minutes. Another 150 g of sweet potato slices were immersed in 500 ml distilled water for 60 minute and used as control treatment.

Air frying process

The sweet potato chips were air-fried at two different temperatures (160˚C and 180˚C) for 3, 6, 9, 12 and 15 minutes to evaluate the effects of process temperature and time on the product. Sweet potato slices (30 g) were air fried for each cycle.

Moisture content determination

Moisture content of the sample was determined using oven method. The samples were placed into oven (Brad Venticall, Model LSIS-B2V/VC5C) at 105˚C until constant weight was achieved. Then, the percentage of moisture was calculated using the following equation:

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

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

Colour and texture measurement

The colour of air-fried sweet potato chips was determined using a colorimeter (Konica Minolta Chromameter). The colour parameters L^*, a^* and b^* represents lightness, redness and yellowness. The reading of colour parameters was taken three times to obtain average value.

The texture analysis of air-fried sweet potato chips was evaluated with a Double Arm Texture Analyzer (Stable Micro System, Surrey, UK). The hardness of the sweet potato chips was determined. The break probe was used with three-point bend rig to measure the hardness. The texture analyser was set with essential parameters such as pre-test speed: 1.50mm/sec, test speed: 1.50mm/sec, post-test speed: 10.00mm/sec, trigger force 40g and distance of 30.0mm.

Diameter shrinkage and thickness expansion

A steel caliper was used to measure the diameter and thickness of potato chips. One slice from each frying time was measured, and a total of three readings were taken. The degree of diameter shrinkage (D) was calculated using the following equation:

$$D(\%) = \frac{d_o - d_t}{d_o}\ x\ 100 \qquad \textbf{Eqn. 2}$$

where d_o is an initial diameter of the raw slice (mm) and d_t is diameter of fried slice at time t (mm).

Meanwhile, the degree of thickness expansion (L) was calculated using the following equation:

$$L\,(\%) = \frac{l_o - l_t}{l_o}\; x\; 100 \qquad \textbf{Eqn. 3}$$

where l_o is an initial thickness of the raw slice (mm) and l_t is thickness of fried slice at time t (mm).

Statistical analysis

The data collected were analysed using a single factor one-way ANOVA and the significant means separated by Duncan method ($p \leq 0.05$). The statistical analysis was conducted by using SPSS 2.0 statistical software (IBM Corp., SPSS, Statistic, Armonk, NY, USA).

RESULTS AND DISCUSSION

Moisture content

Fig. 1 shows the moisture content of air fried sweet potato chips for both osmo-dehydrated and control samples. Based on the results, the moisture content of all samples shows a decreased trend with increasing frying time. According to ANOVA analysis, osmo-dehydrated sample gave significantly lower moisture content of air fried sweet potato chips than control sample throughout the frying time. For instance, frying sweet potato chips at 180°C for 6 mins resulted 34 % of moisture content for control sample, which is significantly different ($p < 0.05$) from the moisture content of the pre-treated samples in 5% NaCl solution (16.7%) and 10% NaCl solution (12.3 %). The similar result also reported by Campos et al. (2012) who studied the effect of process variables on the osmotic dehydration of star-fruit slices, in which higher concentration of osmotic solution increased water loss and solids gain of the star-fruit samples.

With regard to the frying times, it is clearly seen in Fig. 1(a) that the control sample took longer (12 mins) to reach the desired final moisture content of approximately at 9 %, which is generally the ideal final moisture content of potato chips for acquiring crispiness (Brigatto Fontes et al., 2011). Meanwhile, osmo-dehydrated chips at 5% NaCl and 10 % NaCl required a shorter time of 9 mins to reach the same final moisture content. The same trend was also found for air frying at 180°C, where osmotic dehydration could reduce the frying time.

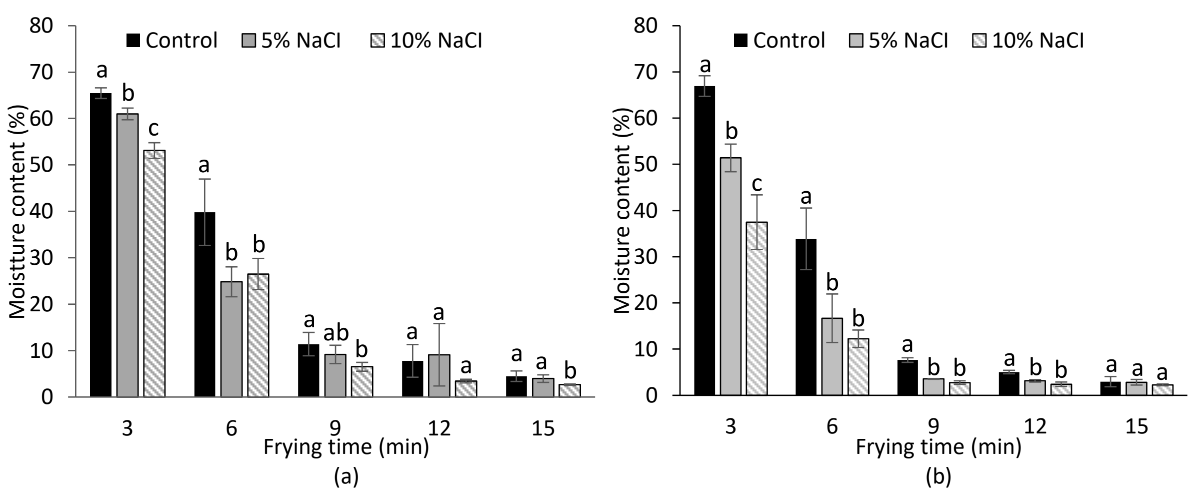

Fig. 1. Moisture content of control and osmo-dehydrated sweet potato chips at (a) 160°C and (b) 180°C. Bar graph with different lower-case letters is significantly different at $p \leq 0.05$.

Colour measurement

Fig. 2 shows the colour properties of all air fried sweet potato chips at 160°C and 180°C. The L*, a* and b* values of air fried sweet potato chips showed a decreasing trend for all samples with the increasing of frying time. The decrease of L*, a* and b* values may be attributed to brown pigment formation during frying process. The L* value of chips for the control sample is significantly different ($p < 0.05$) with sweet potato chips treated under an osmotic solution. The L* value of the control sample was always higher than osmo-dehydrated samples. This is because the osmotic pretreatment technique can prevent the enzymatic and oxidative browning, and thus making it possible to retained good colour with reduced the lightness of potato strips and produced paler chips (Pedreschi et al., 2007; Krokida et al., 2001a).

Meanwhile, the redness of chips (a* value) for the control sample is much lower than chips pretreated with sodium chloride solution. For samples treated in distilled water (control experiment) and air fried at 160˚C, the mean a* values for the air frying time at 12 and 15 minutes were 7.26 ± 0.55 and 5.93 ± 0.69, respectively.

On the other hand, for samples pre-treated in 5% NaCl solution, the mean a* values for the air frying time at 12 and 15 minutes were 7.79 ± 1.28 and 7.36 ± 1.62, respectively. Osmo-dehydrated sample preserves the red colour of sweet potato chips, resulting in a higher redness value. Soaking in NaCl has been reported to improve the colour of fried products (Pedreschi et al., 2007).

At 160˚C, for the air frying time of 3 mins, the b* value of control, 5% NaCl, and 10% NaCl were 39.26 ± 2.51, 26.75 ± 5.10 and 27.46 ± 6.21, respectively. Meanwhile, for the air frying time of 15 minutes, the mean value of control, 5%, and 10% were 25.42 ± 6.38, 18.88 ± 3.98, and 17.08 ± 2.96, respectively. The statistical analysis showed no significant difference ($p > 0.05$) between the b* parameter for different salt solution concentration, indicating that the different osmotic solution concentration does not affect the yellowness of potato slices while frying.

Based on the graphs in Fig. 2, the lightness of air-fried sweet potato chips at 180˚C was lower than 160˚C. The L* value decreases with increasing frying temperature because the slices get darker. This is because non-enzymatic browning reactions are temperature-dependent (Troncoso et al., 2009). A study from Bunger et al. (2003) also found that L* trended lower for the frying of potato strips.

Texture measurement

The effects of osmotic dehydration treatment on the texture of air-fried sweet potato chips were evaluated in terms of hardness. Fig. 3 shows the change in the hardness of air-fried sweet potato chips as a function of frying time for control and osmo-dehydrated samples. Based on statistical analysis, the hardness of osmo-dehydrated samples was significantly higher than from the control sample. This finding is in agreement with a previous study on potato sticks by Bunger et al. (2003) due to increased NaCl diffusion into the tissue. Due to penetration of salt into sweet potato chips, it might be leads to the surface resistance and required high force to crush the chips. Meanwhile, an increase in the concentration of NaCl from 5% to 10% was not significantly affected the hardness value. As shown in Fig. 3, the hardness increased as the frying time increased for all cases. This is caused by higher reduction of moisture in all samples when the frying time increased (as shown in Fig. 1) which leads to higher resistance in cracking of the sample. According to Karizaki et al. (2013), there are two stages of changes in hardness during the frying process. The lowest hardness value at the initial frying stage indicates the softening of the sample tissue originated by lamella media solubilization and starch gelatinization prior to the formation of rigid crust. The crust formation and increase in the tissue resistance leads to the progressive hardness value after 9 mins of frying process in all cases.

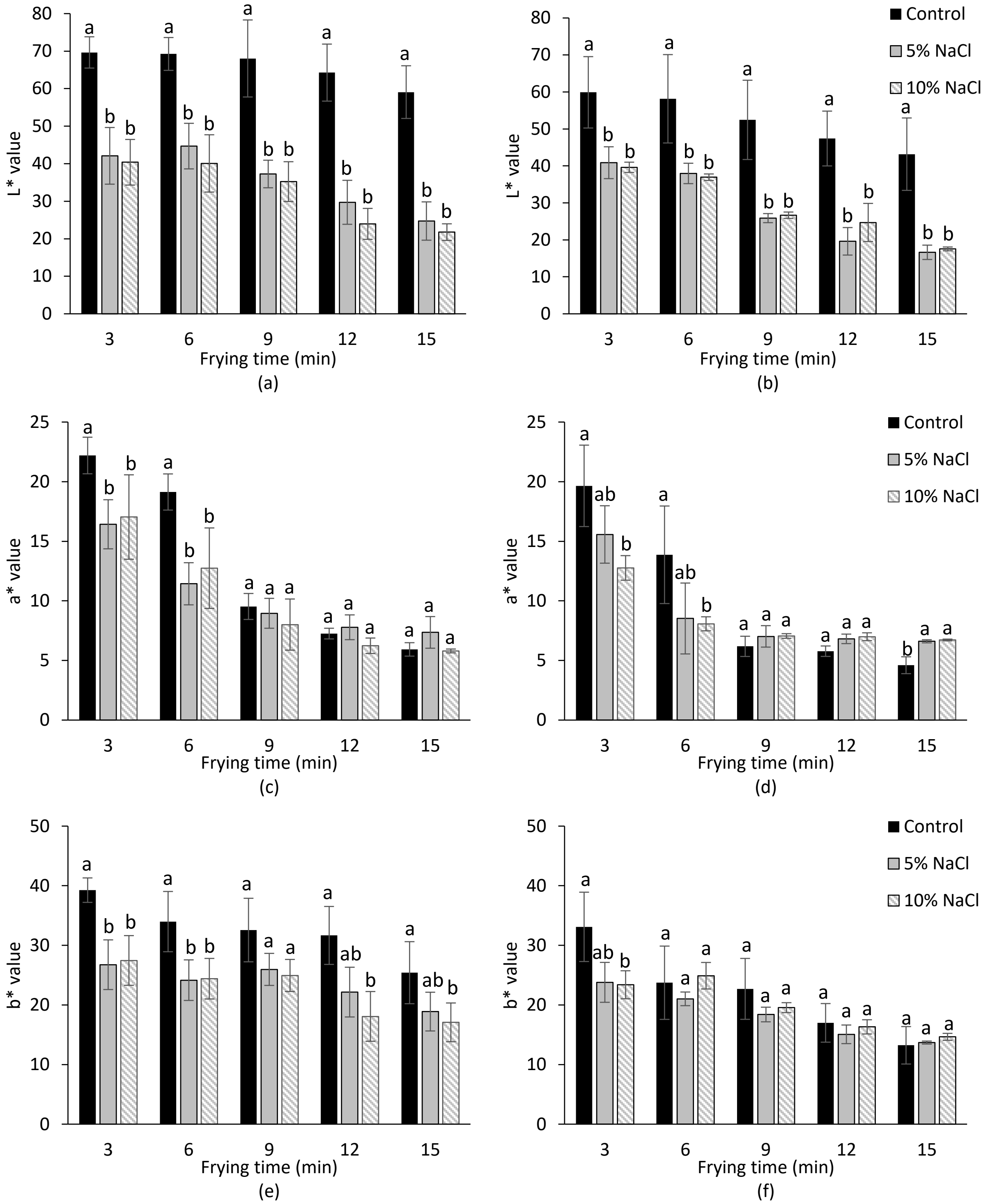

Fig. 2. Colour properties of (a) L* value at 160°C, (b) L* value at 180°C, (c) a* value at 160°C, (d) a* value at 180°C, (e) b* value at 160°C and (f) b* value at 180°C for air fried sweet potato chips as a function of frying time. Bar graph with different lower-case letters is significantly different at $p \leq 0.05$.

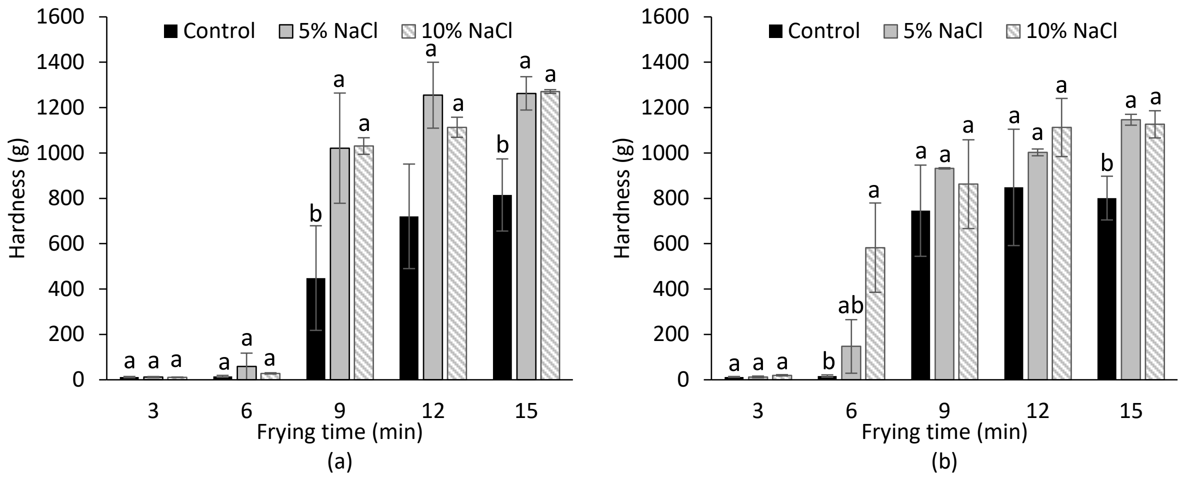

Fig. 3. Hardness value of control and osmo-dehydrated sweet potato chips at (a) 160°C and (b) 180°C. Bar graph with different lower-case letters is significantly different at $p \leq 0.05$.

Diameter shrinkage and thickness expansion

Fig. 4 shows the diameter shrinkage of control and osmo-dehydrated of air fried sweet potato chips. In general, the result shows an increasing trend in diameter shrinkage as air frying time increased, which means that the sweet potato chips shrank more as a function of frying time for both frying temperatures. For instance, the diameter shrinkage values of control chips, chips pretreated with 5%, and 10% NaCl solutions at the frying temperature of 160°C for 3 mins were 9.7 %, 25.1 % and 23.4 %, respectively. At the end of frying time (15 mins), the diameter shrinkage values of control chips, chips pretreated with 5%, and 10% NaCl solution increased to 23.3 %, 32.9 % and 33.5 % respectively. Shrinkage occurred at the surface and gradually went inwards as the frying time increased (Taiwo & Baik, 2007). Due to the rapid evaporation of water during the first frying stage, sweet potato chips shrank faster (Ravli et al., 2013).

The result also showed that osmotic dehydration significantly affected ($p < 0.05$) the diameter shrinkage during frying process. Shrinkage rate is higher for osmo-dehydrated chips than those from the control samples. Nahimana et al. (2011) reported that water loss and solid gain are associated with the shrinkage of osmotically dried fruits and vegetables. Higher osmotic solution concentration leads to more water loss. The author also states that a substantial rate of dehydration was achieved by utilising an osmotic agent with a high molecular weight and a high solution concentration. The dewatering effectivity was improved by increasing the molecular weight of the solution's osmotic active component. The degree of permeability of cell membranes to small molecules and ions significantly impacts the dewatering effect and solute gain.

Fig. 5 shows the thickness expansion of air fried sweet potato chips for control and treated under osmotic dehydration. A negative value indicates the increase of thickness of chips, whereas a positive value indicates the decrease of thickness. By comparing the thickness expansion between osmotic solution concentrations, the chips treated with 10% NaCl expanded the highest value to -38.55%, for frying temperature at 160°C. Meanwhile for chips air fried at 180°C, the chips expanded the most to -23.46% for the slices pre-treated in 5% NaCl solution. The osmotic effect causes moisture to loss more at higher concentration, increase the porosity of chips and create higher pressure within the pores during frying. Although Taiwo & Baik (2007) reported that lower initial moisture content and higher initial porosity have a greater tendency to create pressure within the pores during frying, resulting in an increase of the intercellular gaps, yet the statistical analysis showed no significant difference ($p > 0.05$) between the thickness expansion of chips pretreated with 5% and 10% solutions for both air frying temperatures.

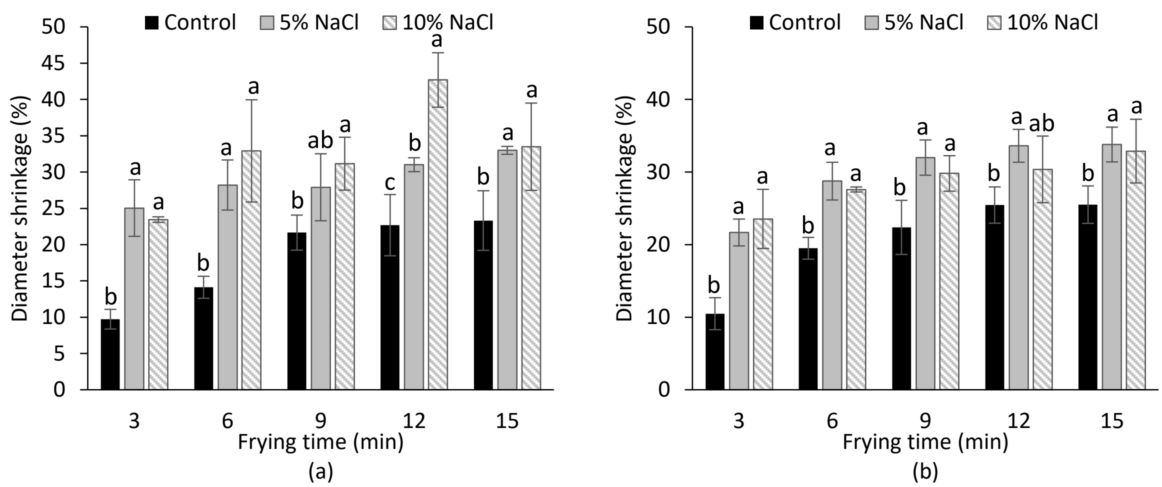

Fig. 4. Diameter shrinkage of control and osmo-dehydrated sweet potato chips at (a) 160°C and (b) 180°C. Bar graph with different lower-case letters is significantly different at $p \leq 0.05$.

At the early stage of air frying, the puffing of chips does not occur in a short frying time (3 and 6 mins) and the thickness shows positive values. For pre-treated samples, the value was reduced to negative for chips air fried after 6 mins of frying as the chips started to puff for both frying temperatures. The result is similar to the study by Ravli et al. (2013) where the thickness of sweet potato chips suddenly reduced to negative values for the early frying time and gradually increased. Although higher temperatures promote faster shrinkage, the equilibrium thickness values were not affected by temperature (Costa et al., 2001).

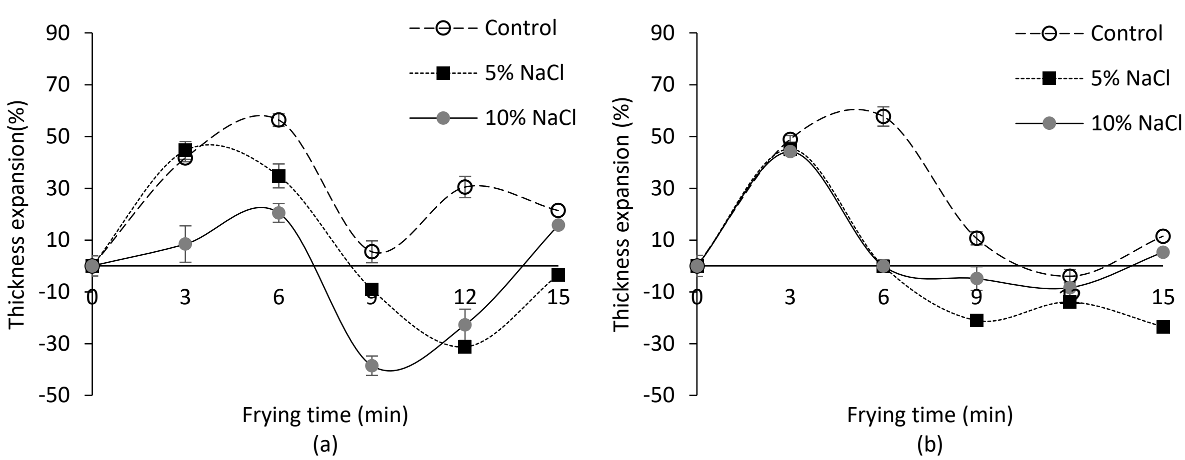

Fig. 5. Thickness expansion of control and osmo-dehydrated sweet potato chips at (a) 160°C and (b) 180°C

A study conducted by Kawas and Moreira (2001) showed that the diameter of tortilla chips continued to shrink, though slowly. The thickness of the tortilla chips did not change for the first 30 seconds, then increased by 10% and remained constant until the end of the frying process. The author also reported that the increment of thickness was caused by crust formation and the bubbles formed at the surface due to the barrier formed by the tight surface, resulting in vapour expansion inside the pores of the chips. Increased porosity has been correlated to decreases in sample thickness and bulk density, as well as crust development (Taiwo & Baik, 2007).

CONCLUSION

Sweet potato chips that were treated under osmotic dehydration exhibited lower moisture content than control sample and thus, significantly reduced the air frying time. Colour analysis revealed that the lightness of chips from all samples decreased, but osmotic dehydration preserves the red and yellow colour of chips. Findings also showed that osmotic dehydration pre-treatment significantly affects the hardness of sweet potato chips because of lower moisture content of sample. Treated samples exhibited more shrinkage in diameter than the untreated samples because water is drawn out more in high concentration osmotic solution. In term of thickness expansion, the thickness of chips increased over frying time due to crust formation and the bubbles formed at the surface for all samples. In summary, results of this study showed that the use of osmotic dehydration pre-treatment led to reducing moisture content and thus reduced frying time during the air frying process. However, osmotic dehydration caused shrinkage of the air-fried sweet potato chips that resulted in the texture quality, and thus further investigation regarding sensory analysis is required.

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REFERENCES

Andrés, A., Arguelles, Á., Castelló, M. L., & Heredia, A. (2013). Mass transfer and volume changes in french fries during air frying. *Food and Bioprocess Technology*, *6*(8), 1917–1924. https://doi.org/10.1007/s11947-012-0861-2

Asokapandian, S., Swamy, G. J., & Hajjul, H. (2019). Deep fat frying of foods: A critical review on process and product parameters. *Critical Reviews in Food Science and Nutrition*, *60*(20), 1–14. https://doi.org/10.1080/10408398.2019.1688761

Brigatto Fontes, L. C., Oliveira, F. G., & Collares-Queiroz, F. P. (2011). Optimization of deep rying process on sweet potato. *American Journal of Food Technology, 6*(5), pp. 348–361.

Bunger, A., Moyano, P., & Rioseco, V. (2003). NaCl soaking treatment for improving the quality of french-fried potatoes. *Food Research International*, *36*(2), 161–166. https://doi.org/10.1016/S0963-9969(02)00131-X

Campos, C. D. M., Sato, A. C. K., Tonon, R. V., Hubinger, M. D., & Cunha, R. L. da. (2012). Effect of process variables on the osmotic dehydration of star-fruit slices. *Food Science and Technology*, *32*(2), 357–365. https://doi.org/10.1590/s0101-20612012005000034

Costa, R. M., Oliveira, F. A. R., & Boutcheva, G. (2001). Structural changes and shrinkage of potato during frying. *International Journal of Food Science and Technology*, *36*(1), 11–23. https://doi.org/10.1046/j.1365-2621.2001.00413.x

Dehghannya, J., & Abedpour, L. (2018). Influence of a three stage hybrid ultrasound–osmotic–frying process on production of low-fat fried potato strips. *Journal of the Science of Food and Agriculture*, *98*(4), 1485–1491. https://doi.org/10.1002/jsfa.8617

Karizaki, V. M., Sahin, S., Sumnu, G., Mosavian, M. T. H., & Luca, A. (2013). Effect of ultrasound-assisted osmotic dehydration as a pretreatment on deep fat frying of potatoes. *Food and Bioprocess Technology*, *6*, 3554–3563. https://doi.org/10.1007/s11947-012-1012-5

Kawas, M. L., & Moreira, R. G. (2001). Characterization of product quality attributes of tortilla chips during the frying process. *Journal of Food Engineering*, *47*(2), 97–107. https://doi.org/10.1016/S0260-8774(00)00104-7

Krokida, M. ., Oreopoulou, V., Maroulis, Z. ., & Marinos-Kouris, D. (2001a). Effect of osmotic dedydration pretreatment on quality of french fries. *Journal of Food Engineering*, *49*(4), 339–345. https://doi.org/10.1016/S0260-8774(00)00232-6

Nahimana, H., Zhang, M., Mujumdar, A. S., & Ding, Z. (2011). Mass transfer modeling and shrinkage consideration during osmotic dehydration of fruits and vegetables. *Food Reviews International*, *27*(4), 331–356. https://doi.org/10.1080/87559129.2010.518298

Nurhidayah Hanim Mohamad, Asmaliza Abd Ghani, Nurul Zaizuliana Rois Anwar, Norzaida Yusof, & Yusof Nurhayati. (2020). Comparison of different drying methods and preservatives on the proximate composition, colour and total phenolic content of dried ginger. *Journal of Agrobiotechnology*, *11*(1S), 112–121. https://doi.org/10.37231/jab.2020.11.1s.240

Oke, E. K., Idowu, M. A., Sobukola, O. P., Adeyeye, S. A. O., & Akinsola, A. O. (2018). Frying of food: a critical review. *Journal of Culinary Science and Technology*, *16*(2), 107–127. https://doi.org/10.1080/15428052.2017.1333936

Pedreschi, F., Moyano, P., Santis, N., & Pedreschi, R. (2007). Physical properties of pre-treated potato chips. *Journal of Food Engineering*, *79*(4), 1474–1482. https://doi.org/10.1016/j.jfoodeng.2006.04.029

Ravli, Y., Da Silva, P., & Moreira, R. G. (2013). Two-stage frying process for high-quality sweet-potato chips. *Journal of Food Engineering*, *118*(1), 31–40. https://doi.org/10.1016/j.jfoodeng.2013.03.032

Ren, A., Pan, S., Li, W., Chen, G., & Duan, X. (2018). Effect of various pretreatments on quality attributes of vacuum-fried shiitake mushroom Chips. *Journal of Food Quality*, *2018*, 1–7.

Schiffmann, R. (2017). Microwave-assisted frying. In *The Microwave Processing of Foods: Second Edition* (Second Edition). Elsevier Ltd. https://doi.org/10.1016/B978-0-08-100528-6.00007-3

Taiwo, K. a., & Baik, O. D. (2007). Effects of pre-treatments on the shrinkage and textural properties of fried sweet potatoes. *LWT - Food Science and Technology*, *40*, 661–668. https://doi.org/10.1016/j.lwt.2006.03.005

Tortoe, C. (2010). A review of osmodehydration for food industry. *African Journal of Food Science*, *4*(6), 303–324.

Troncoso, E., Pedreschi, F., & Zúñiga, R. N. (2009). Comparative study of physical and sensory properties of pre-treated potato slices during vacuum and atmospheric frying. *LWT - Food Science and Technology*, *42*, 187–195. https://doi.org/10.1016/j.lwt.2008.05.013

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