Osmosis dehydration of sweet corn (*Zea mays saccharata*) kernel with trehalose solution

B Susilo*, M Lutfi and H E Lu’ay

Department of Agricultural Engineering, Faculty of Agricultural Technology, Universitas Brawijaya, Veteran St., Malang City, Jawa Timur, Indonesia

*Email: susilo@ub.ac.id

Abstract: Osmosis dehydration is a process of reducing water content by immersing the material in a hypertonic solution. It usually uses a sugar solution like mono-saccharide or disaccharide. Trehalose is one type of disaccharide that can be used as a solute. Trehalose is able to maintain the nutrition content of food material and the aroma of horticulture products because it maintains and stabilizes complex molecules. Immersing of sweet corn kernel in trehalose solution was expected to maintain kernel sweet corn quality in relation to the next process. The objective of the research is to investigate the effects of the different immersing temperatures and trehalose concentrations on the physical quality of sweet corn. This study used solution with concentrations of 4%, 8%, and 12% trehalose. The variations of immersing temperature were 30°C, 40°C, and 50°C. The experiment was done with a factorial completely randomized design. The first factor was immersing temperature and the second factor was the concentration of trehalose solution. The data was analyzed using Duncan Multiple Range Test (DMRT) method. The temperature treatment of 50°C and trehalose concentration of 12% showed the highest weight reduction (6.18%), solid gain (4.5%), and water loss (10.38%). The lowest water content of corn kernel was also obtained in this treatment i.e 78.7%.

1. Introduction

Sweet corn (*Zea mays saccharata*) is very popular in Indonesia. Sweet corn is widely consumed because it has a sweeter taste than other varieties. Sweet corn kernels are preferred because they are more practical for further processing and consumption than whole corn. The demand for sweet corn is always increasing. This market opportunity has not been fully fulfilled by Indonesian farmers & entrepreneurs due to various obstacles. One of them is the low shelf life of sweet corn after harvest because sweet corn is a type of perishable vegetable, has a high water content and a high respiratory rate. One of the best pre-treatment, in order to maintain sweet corn's shelf life and quality, is a treatment with osmotic dehydration.

Osmotic dehydration technology is widely used to produce semi-wet processed meat, candied fruit, and vegetables where the aim is to preserve ingredients and extend shelf life [1]. Osmotic dehydration is a process of reducing water content by immersing the material in a hypertonic solution (a solution that has a high concentration). This hypertonic solution can encourage the release of water from the material towards the media through cell walls which are semipermeable membranes to balance the osmotic pressure. The high concentration of an osmotic solution affects the water loss and solids gain of sapodilla fruit [2]. This is as natural preservation of product quality i.e. color, aroma, fruit texture,
even improve the taste of product that the mass transfer process of water from the material was without a phase change.

Factors that affect mass transfer during the osmotic dehydration process are temperature, solution concentration, and immersion time [3]. The higher the temperature and concentration of the osmosis media solution, the higher the decrease of the water content of the material. The concentration difference can push the water out of the material network to the outside to reach the concentration balance point [4]. However, if the temperature is above 50°C, it can cause browning and decrease the taste. The solution commonly used in the osmotic dehydration process in fruits and vegetables is a sugar solution. The sugar used is the disaccharide sucrose. However, there is another type of disaccharide that can be used in the process of osmotic dehydration, namely trehalose.

Trehalose is an unreduced disaccharide that can be found in animals or plants that can maintain cell walls that are damaged by heat [5]. Trehalose is used to maintain the quality of nutritional content, fruit and vegetable aromas, and maintain and stabilize complex molecules [6]. Therefore, the immersion of sweet shelled corn in trehalose solution is expected to maintain the quality of shelled sweet corn in the following treatment stage.

2. Material and methods

2.1. Tools and materials

The tools used in this research were an electric heater, large glass cup, basin, analytical scale (Mattler PM460), thermometer, stopwatch, hot plate stirrer (Thermolyne SP131320-33Q), beaker glass, measuring cup, aluminum foil cup, label paper, and electric ovens. The material used in this study was fresh sweet corn obtained from Blimbing Market, Malang which was peeled on the same day and the mass of fresh shelled sweet corn was calculated. The next ingredient was trehalose obtained from one of the chemical Store in Sukoharjo District, Central Java.

2.2. Research method

The design used in this experiment was a Completely Randomized Factorial Design. The design in this study used two treatment factors, namely the concentration of the trehalose solution and the immersion temperature. Each factor consisted of three treatment levels with three repetitions. The parameters of water content, water loss, weight reduction, and solid gain were measured by weighing the sample mass before immersion, after immersion, and after drying the sample.

2.2.1. Water content calculation. The water content measurement method used in this study is the gravimetric/oven method [9]. The moisture content of the sweet corn shell before and after the soaking process was calculated using the oven drying method. The initial mass of the material is weighed and then put in the oven at 105°C for 4 hours. After 4 hours, the dried samples were put in a desiccator for 15 minutes. The mass of the dried material was weighed. This mass data will be used as data for calculating the water content of the material with the formula:

\[
\text{Water Content (\%)} = \frac{W_o - W_d}{W_o} \times 100\%
\]

Description :
\(W_o\) = initial sample mass (g)
\(W_d\) = final sample mass (g)

2.2.2. Water loss. Water loss is the amount of water that comes out of the sample during the osmotic dehydration process [10]. The method used to measure WL in this study is by using the water content of the sample before and after immersion and the mass data of the sample before and after immersion which is entered in the Water Loss formula. The amount of water that comes out of the material can be
calculated using previous data, namely weight reduction and solids that enter the material (SG) with the formula according to Ponjičan et al. namely:

\[
WL = \frac{W_{0}M_{o} - W_{d}M_{d}}{W_{o}}
\]

Description:
\(WL\) = the amount of water that comes out of the material in the sample \(x\) (%)
\(M_{0}\) = water content before immersion (%)
\(M_{d}\) = water content after immersion (%)

2.2.3. Weight reduction. Weight reduction is the reduction in sample weight in the osmotic dehydration process due to reduced water content in the sample [9]. The weight difference between before and after soaking is the loss value of the sample.

The sample was weighed before soaking, first \((WR_{o})\), the sample that had been soaked for 60 minutes was then drained and weighed.

\[
WR = \frac{WR_{o} - WR_{t}}{WR_{t}} \times 100\%
\]

Description:
\(WR\) = weight reduction (%)
\(WR_{o}\) = initial sample mass (g)
\(WR_{t}\) = final sample mass at \(t\) (g)

2.2.4. Solid gain calculation. Solid Gain (SG) is the amount of dissolved solids that enter to the material [10]. SG is expressed in grams of sample per gram of initial sample. The method for calculating SG is using the mass data of dry samples before and after treatment.

The dried samples before immersed and soaked for 60 minutes was weighed. This dry sample was obtained from samples that were dried using a temperature of 105°C for 4 hours.

\[
SG = \frac{SG_{o} - SG_{t}}{SG_{t}} \times 100\%
\]

Description:
\(SG\) = solid gain (g)
\(SG_{o}\) = dry sample mass before immersion (g)
\(SG_{t}\) = mass of dry sample after immersion at \(t\) (g)

3. Result and discussions

3.1. Kernel sweet corn’s characteristics before treatment
The sweet corn used was obtained from a seller in the Blimbing traditional market, Malang City. The sweet corn was then kerneled in the laboratory before being treated. This kernel sweet corn on Fig.1 is pale yellow, odorless, and has a fairly hard texture based on initial measurements. The fresh kernelled sweet corn's water content was 84.2%, with the initial sample mass being ± 20g.
3.2. Water content

The water content of 60 minutes immersed Fresh kernel decreased. Samples without immersion treatment had a water content of 84.2%. The highest water content was 83.9% resulted from immersion with temperature of 30°C and a concentration of 4% trehalose solution. The lowest water content was 78.7% resulted from immersion with a temperature of 50°C and a 12% trehalose solution concentration. Figure 2 shows that the greater the concentration of the immersion solution, the lower the water content.

![Figure 2. Sample water content chart.](image)

The F test showed that the immersion temperature treatment of the water content obtained a significant difference from the samples with temperatures of 30°C, 40°C, and 50°C with the lowest water content values at 50°C of treatment. Furthermore, in the treatment of the concentration of the solution to the water content value, there was also a significant difference from the sample with a concentration of 4%, 8%, and 12%, with the lowest water content value at 12% concentration treatment. The decrease in water content is caused by the osmotic dehydration process that occurs in kernel sweet corn. This result is supported by [3], that the carrots drying with combined vacuum and osmotic dehydration accelerate the drying process. This is because the immersing solution with a higher concentration results in osmotic pressure so that the water in the kernel sweet corn will come out [11].
3.3. Weight reduction (WR)
The highest weight reduction occurred in samples with an immersion temperature of 50°C and a 12% trehalose solution concentration, where the weight reduction value was 6.18%. Conversely, the lowest weight reduction occurred in samples with an immersion temperature of 30°C and a 4% trehalose solution concentration, where the weight reduction value was 2.08%. Figure 3 shows that the higher the concentration of the trehalose solution used, the greater the weight reduction value.

The F test showed that there were very significant differences between the samples. This is indicated by a different letter notation on each line. This shows that the concentration of trehalose solution and the temperature of immersion affect the weight reduction of the sample. According to Askabarian [12], the higher the concentration of the osmotic solution used, the higher the weight reduction of the material. According to Lamona [12], the temperature can significantly affect the value of weight reduction because the temperature can affect water displacement. The higher the temperature used, the more water out of the material will increase.

3.4. Solid gain (SG)
The calculations were performed to show that the sample after treatment increases the value of solid gain. The highest solid gain occurred in samples with an immersion temperature of 50°C with a 12% trehalose solution concentration. The highest solid gain occurred in samples with an immersion temperature of 30°C with a 4% trehalose solution concentration. Figure 4 shows that the higher the concentration of the trehalose solution used, the greater the solid gain.
Figure 4. Sample solid gain chart.

The F test showed that the immersion temperature treatment against the solid gain value obtained significant differences from samples with temperatures of 30°C, 40°C, and 50°C with the lowest solid gain value at 30°C treatment. In the treatment of the concentration of the solution to the solid gain value, there was also a significant difference from the sample with a concentration of 4%, 8%, and 12%, with the lowest solid gain value at the concentration of 4%. According to Sari et al [14], material soaked with heat treatment will open the pores of the material's surface. So that the process of exchanging substances in the hypertonic material and solution will be faster. Meanwhile, the hypertonic solution concentration affects the potential difference between the solution in the material and the immersion solution, which has different concentrations [15].

3.5. Water loss (WL)
The results of the calculations have conducted indicate that the sample with the immersion treatment experienced water loss. The highest water loss occurred in samples with an immersion temperature of 50°C with a 12% trehalose solution concentration. The highest water loss occurred in samples with an immersion temperature of 30°C with a 4% trehalose solution concentration. Figure 5 shows that the higher the concentration of the trehalose solution used, the higher the water loss.

Figure 5. Sample water loss chart.
The F test showed that the results of the DMRT calculation on the immersion temperature treatment of the water loss value obtained a significant difference from the samples with temperatures of 30°C, 40°C, and 50°C with the lowest water loss values at 30°C of treatment. In the treatment of the concentration of the solution to the water loss value, there was also a significant difference from the sample with a concentration of 4%, 8%, and 12%, with the lowest water loss value at a concentration of 4%. According to Sucahyo et al. [16], the water loss value will increase as the concentration increases. This is because when the solution gets thicker, the water in the material will quickly come out of the material. So that if the immersion is carried out for the same time, the material soaked with a higher concentration of the solution will have a higher water loss value. In addition, the higher the immersion temperature, it can open pores in the sample. When the pores of the surface, which are considered semipermeable membranes, open wider, the more significant the amount of water that comes out of the material [3].

3.6. Kernel sweet corn’s characteristics after treatment
In this study, the pre-treatment of the sample was conducted by the blanching process with boiling water (temperature ± 95°C) for 60 seconds. After the blanching process, the sample is slightly dark yellow (figure 6). In addition, the texture of the sample becomes softer.

![Figure 6. Sample after blanching process.](image)

After the blanching process, the samples were immersed in trehalose solution with the specified temperature and solution concentration for 60 minutes. Samples that have been immersed have a darker color than the samples before immersion. According to Dhake and Bari [17] carotene pigments in materials can experience degradation during processing due to an oxidation process at high temperatures that converts carotene compounds into ionic compounds in the form of ketones. However, in this study, the yellow color of corn was still maintained even though there was a temperature treatment. This is due to the nature of trehalose itself which can act as a stabilizing agent [6].

4. Conclusions
The different immersing temperatures and trehalose concentrations have a significant effect on the mass loss of sweet corn. The higher the concentration of the solution and the immersion temperature, the lower the mass loss. However, there was no significant difference between the immersion temperature and the concentration of the trehalose solution on the value of water content, a solid gain, and water loss. Trehalose could maintain the color of kernel sweet corn from heat treatment during the osmosis dehydration process.

References
[1] Gupta P, Bhat A, Chauhan H, Ahmed N and Malik A 2015 Osmotic dehydration of button mushroom International Journal of Food Fermentation Technology 5 177–182
[2] Coimbra L M P, Arruda H A S, Machado E C L, Salgado S M, Albuquerque S S M C, and Andrade S A C 2017 Water and sucrose diffusion coefficients during osmotic dehydration of sapodilla (Achras zapota L.) Ciência Rural Santa Maria 47

[3] Sutar P P and Sures P 2011 Optimization of osmotic Dehydration of Carrots under Atmospheric and Pulsed Microwave Vacuum Conditions 29 371-380

[4] Moustafa, Sohair E, El-Hakim H I and Maatouk H I 2016 Osmotic dehydration of fig and plum Egyptian Journal of Agricultural Research 94 905 – 921

[5] Biernat E L 2019 Trehalose: Sources, Chemistry, and Applications (New York: Nova Science Publishers)

[6] Sedijani P 2014 The roles of trehalose metabolism at entire plant life (Peran trehalosa metabolism sepanjang kehidupan tanaman) Jurnal Biologi Tropis 14 139–152 [In Indonesian]

[7] Kirk, R E 2013 Experimental design: Procedures for the behavioral sciences (4th ed.) (Sage: Thousand Oaks, CA)

[8] Dean A, Voss D and Draguljic D 2017 Design and Analysis of Experiments Second Edition (Cham: Springer Nature)

[9] Magdalena A, Waluyo S and Sugianti C 2014 Effect of temperature and concentration of sugar solution in the process of osmotic dehydration of pumpkin (Curcubita moschata) (Pengaruh suhu dan konsentrasi larutan gula terhadap proses dehidrasi osmosis buah waluh (Curcubita moschata)) J. Rekayasa Pangan dan P. 2 1-8 [In Indonesian]

[10] Pojičan O, Sedlar A, Findura P, Szparaga A and Kocira S 2019 Optimisation of osmotic dehydration of plums sciendo 23 69-79

[11] Hiola S K Y 2018 Vegetable Processing Technology (Teknologi Pengolahan Sayuran) (Malang: INTI MEDIATAMA) [In Indonesian]

[12] Askabarian M, Ghasemkani N and Moayedi F 2014 Osmotic dehydration of fruits in food industrial: a review International Journal of Biosciences 3 1–16

[13] Lamona A 2015 Effect of different packaging and low temperature storage on the quality changes of fresh red curly chili (Pengaruh jenis kemasan dan penyimpanan suhu rendah terhadap perubahan kualitas cabai merah keriting segar) Jurnal Keteknikan Pertanian 3 145–152 [In Indonesian]

[14] Sari W P 2019 The process of making candied dried sweet potato (Ipomea batatas L.) with osmotic dehydration and oven drying (Proses pembuatan manisan kering ubi jalar (Ipomea batatas L) dengan dehidrasi osmotik dan pengeringan oven) Jurnal Keteknikan Pertanian 7 33–40 [In Indonesian]

[15] Aras L, Supratomo and Salengek 2019 Effect of temperature and concentration of sugar solution in the process of osmotic dehydration of papaya (Carica papaya L.) (Pengaruh suhu dan konsentrasi larutan gula terhadap proses dehidrasi osmosis pepaya (Carica papaya L.)) Jurnal AgriTechno 12 110-120 [In Indonesian]

[16] Sucahylo L, Nelwan L O, Walundadi D and Nabetani H 2013 Reconcentration of sugar solution in osmotic dehydration of mango slices (Mangifera indica L.) using direct contact membrane distillation (Rekonsentrasi larutan gula pada proses dehidrasi osmotik irisan mangga (Mangifera indica L.) dengan teknik distilasi membran dcmd) Jurnal Teknologi Industri Pertanian 23 174–183 [In Indonesian]

[17] Dhake E K P and Bari M R 2015 Osmotic dehydration of pineapple International Journal in IT and Engineering 3 11–20