Biological Forum – An International Journal ***(Special Issue 2015)*** **7**(2): 15-19(2015)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Freezing Point Prediction of Minimally Processed Food with Different Sucrose Content

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(Received 10 May, 2015, Accepted 01 July, 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: During years freezing progressed and new methods investigated which insure high quality and increase acceptability of products. Osmosis treatment before freezing is a novel method which by lowering water content before freezing can limit damages caused by ice expansion during ice formation. The current study was carried out to determine osmotically dehydrated cantaloupe characteristic and introduce a model to predict its freezing point. Samples were washed, peeled and cut into cubes of 4 2.5 × 2 Cm. The cubes were submerged in sucrose syrup (40, 55 and 70%) for the periods of (1.5, 3 and 4.5 h.). At room temperature (25 °C). The fruit to syrup ratio was 1:3 in all treatments. Moisture content, total soluble solids, freezing point, specific heat of product and required energy for freezing process were measured and calculated. Results indicated that water content decreased with time and increased syrup concentration on the other hand brix increased due to syrup concentration. Freezing point, specific heat and required energy for freezing process decreased according to above changes. Perhaps by reducing the freezing point of fruits, they can be kept without freezing at temperatures slightly above the freezing point. This prevents disadvantage of the freezing process. If it is possible through microbial and biochemical point of view.

Keywords: Osmotic dehydration, Freezing point, Cantaloupe, specific heat

INTRODUCTION

The osmotic dehydration of fruits and vegetables is used to process and produce a variety of products, such as minimally processed products (Alzamora *et al.,* 2000) Or osmotic dehydration may be a applied as a pretreatment before air drying (Alvarez *et al.,* 1995; Nieto *et al.,* 1998a; Nieto *et al.,* 1998b) or freezing (Forni *et al.,* 1987; Giangiacomo *et al.,* 1994; Pinnavaia *et al.,* 1988). In the case of osmosis process used before freezing it will protect the fruit tissues against freezing damage due to reduced water content or solute uptake into the fruit which bothe of these phenomena decrease the amount of water for freezing and (Bolin *et al.,* 1993; Crowe *et al.,* 1998; Torreggiani, 1995). Freezing is the One of the food preservation methods in this way the temperature of the food is decreased to below of freezing point freezing (Zhang, 1998) Thus, freshness, color, flavor and nutritional value of the product is maintained. Also the method is an appropriate technique for maintaining of fruit quality in their long-term storage (Ancos et al., 2000). Raw material, the use of the pretreatments before freezing, freezing method and after freezing treatments such as transportation, distribution and defrosting are the parameters that influence the quality of the frozen fruit.

Due to the benefits mentioned for the osmotic dehydration In recent years, more attention has been paid to this technique as a pretreatment before freezing. Application of this method before freezing can minimize the damages caused by frozen water during freeze storage of foods as possibility of ice crystal formation is reduced during freezing of foods due to the dehydration treatment of food materials before freezing (Robbers *et al.,* 1997).

Chiralt *et al.* have studied the Effects of osmosis process on mechanical properties of kiwi fruit and the protective effects of the treatment against freezing. In this study, kiwi slices with a diameter of 4 cm and thickness of 1 cm were emerged in the solutions of sucrose at concentrations of 35, 45, 55, 60 and 65° brix at 30°C until the kiwi fruit slices reaching the total soluble solids of 30° brix. Osmosis process was carried out at atmospheric pressure and under vacuum (50 mbar for 5 minutes at the beginning of the process). After that the samples were frozen at -40°C where the cooling rate was 4 °C/min then all samples were kept at -18°C. The samples analyzed after 24 h and 1 month. The results showed that time has affected the mechanical properties of the samples but the application of vacuum had any effect on the mechanical properties and protection against freezing (Chiralt *et al.,* 2001).

In another research the effect of freezing condition was studied on the okra quality. The okra samples were immersed in solution of sodium sulfite at concentrations of 0.5, 1.5 and 2% for 10, 20 and 30 minutes and in the citric acid solutions at concentrations of 1.5, 2.5, and 3.5% for 5, 15 and 25 minutes before freezing.

Freezing process was performed using liquid nitrogen to reach -25 °C from 18 °C in during 3 minutes. The results showed that treatment of okra samples by 2% sodium sulfate solution for 20 to 30 minutes improved apparent properties of okra and increased the shelf life of frozen product. Also treating of okra by 2.5% citric acid solution for 15 minutes improves the color of the product color (Zhang *et al.,* 2004).

One of the important points in the freezing process of food is freezing point of the food materials, due to various composition of food materials the freezing point is vary from one product to another one. By Knowing the exact freezing point the temperatures can be set correctly, otherwise there is probability of incomplete freezing of the product. In addition, it is also important from the point of view of energy consumption. On the other hand The freezing point has a major role in determining the appropriate storage temperature. In the case of cold storage if the temperature falls to below of freezing point the product will be frozen and will be damaged. Therefore, it is necessary to maintain temperature of storage condition under control. Jie *et al.* have studied the relationship of fruit freezing point ant the soluble solid content of the fruit they also have provided a model for determining the freezing point of fruits (Jie *et al.*, 2003).

During of osmotic dehydration there is a counter current flow of water and solutes between food material and osmosis solution both of these flows lead to soluble solid content change in the food (Talens *et al.,* 2003). In this study, cantaloupe emerged in different concentrations of sucrose solution for different periods of time. At the end of the experiment the samples properties were measured and freezing point of the samples as well as the amount of energy required for freezing process of the product were calculated.

MATERIALS AND METHODS

Osmosis solution of sucrose at concentrations of 40, 55 and 70% (w/w) were prepared and cantaloupe cut into pieces with dimensions of 4×2.5×2 cm. Samples were emerged at osmosis solutions for 1.5, 3 and 4.5 h at 25°C, the fruit to solution ratio was 1:3.

After the process was completed to measure the moisture content of the samples they were dried in the oven at 100°C until the constant weight was reached according to by AOAC (1980) method. Total soluble solid content of samples were determine by the abbe refractometer (Carl Zeiss Germany). For the untreated sample the same techniques were used to determine the moisture and total soluble solids content.

The freezing point of control sample and treated samples by osmotic dehydration treatment was calculated by the following equation (Jie *et al.*, 2003):

$$Y = 0.146694 - 0.19555X \quad \dots (1)$$

Y is the freezing point °C, X is the total soluble solids.

Specific heat of the product above and below the freezing point were calculated by Equations 2 and 3 respectively (Alzamora *et al.*, 2000):

$$C_1 = 2990 \times xw + 1200 \quad \dots (2)$$

$$C_2 = 1256 \times xw + 837 \quad \dots (3)$$

C_1: specific heat above the freezing point (kj/kg°C), C_2: specific heat below the freezing point (kj/kg°C), x_w: water fraction in food.

The energy required to cool the product and The energy required to freeze of the product were obtained by the below equations (Seid razavi, 1997):

$$Q = mc(t_2 - t_1) \quad \dots (4)$$

$$Q = m\lambda \quad \dots (5)$$

Q: required energy (kj), m: foos mass (kg), c: specific heat (kj/kg°C), λ: latent heat of water: (334 kj/kg), t_1 and t_2: initial and final temperature of food repectively (°C).

The experiment was conducted in a completely randomized design based on factorial. To obtain the regression equations Sigmastat was used. All graphs were drawn in the Slide write (version 2).

RESULTS AND DISCUSSION

Total soluble solid content of control samples and treated samples in osmotic solutions is shown in figures 1A and 1B as surface and contour plots. Regression equations were obtained to explain the effects of treatment time and osmotic solution concentration on total soluble solid content of the samples.

$$Bx = -9.285 + 0.531c + 4.52t + 0.0237ct - 0.00415c^2 - 0.799t^2 \qquad R^2 = 0.91 \quad \dots (6)$$

Bx: total soluble solids, *c*: concentration, *t*: time.

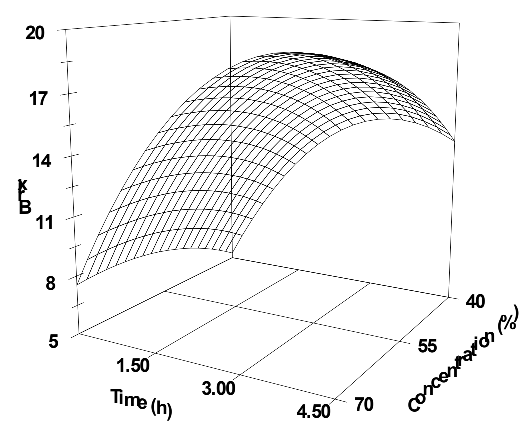

Fig.1.

The freezing point of the product for different samples with different soluble solids content are shown in Figure 2, Due to the presence of dissolved solids in the samples the freezing point of cantaloupe equals to -1.08 °C and like other fruits it is vary of pure water freezing point.

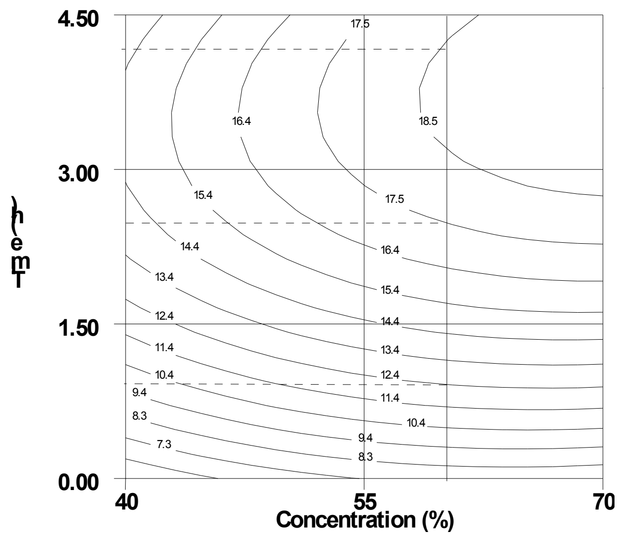

Fig. 1. Surface and contour plots of total soluble solids content of cantaloupe changes during osmotic dehydration.

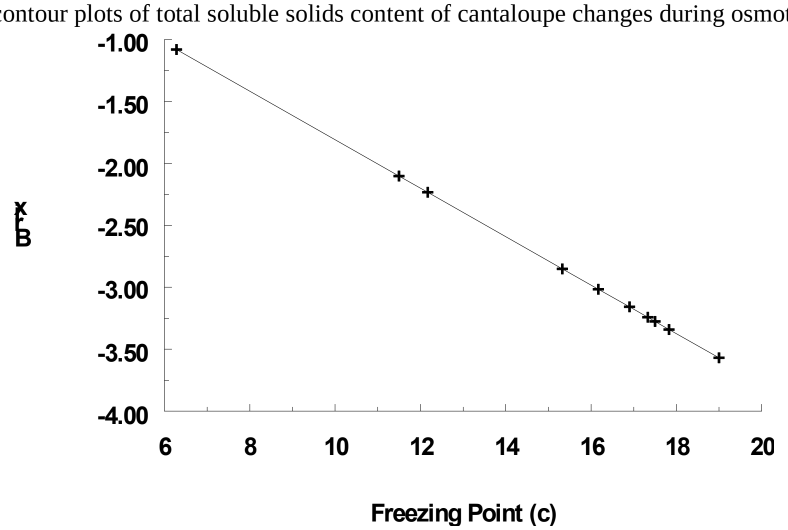

Fig. 2. Freezing point of cantaloupe in different soluble solid content.

As it can be seen by increasing Brix of product freezing point decreases. The difference between the freezing points of samples makes it obvious the need of carefully temperature control during the freezing process of samples. Regression equation between the freezing point and osmotic solution concentration and processing time according to the obtained data is as below:

$Fp=1.962-0.104c-0.883t-0.00464ct+0.000812c^2+0.156t^2$ $R^2=0.91$ … (7)

Fp: freezing point, c: concentration, t: time.

According to the above equation the effect of process parameters on the freezing point is shown in figures 3A and 3B. Using Equation 7 and Figures 3 (A) and (B) predicting of freezing point is possible based on the process parameters (concentration and time) as well as what was said about Brix. In general, it is possible to estimate the total soluble solids content and freezing point of samples in associate to osmotic solution concentration and treatment time. On the other hand it is possible to predict and determined one of the process parameters (concentration or time) or total soluble solids content and freezing point of the final product if other parameters are known or if there is a desired amount for one of the parameters.

As it can be seen by increasing concentration of sucrose solution and the process time Brix of samples is increased and the highest brix value is achieved after 4.5 h in concentrations of 70%. But it should be noted that the time does not have a significant effect on increasing Brix. Using the plots the brix of samples can be obtained in any combination of process concentration and time. This is easily done using the contour plots.

For example, at concentration of 60% sucrose solution (concentration that has not been used in experiment) by drawing a line from the point 60 and parallel to the axis of time (straight line in Figure 1B) the total soluble solids of the sample can be predicted for any process time. For processing time of 1, 2.5 and 4 h the total soluble solids content of samples are 12.4, 17.6 and 18.6 respectively As shown in Figure 1B by the intersection of dotted and straight lines by contour lines in the plot. Similarly, taking into account the specific total soluble solids, the desired concentration and time of process can be achieved.

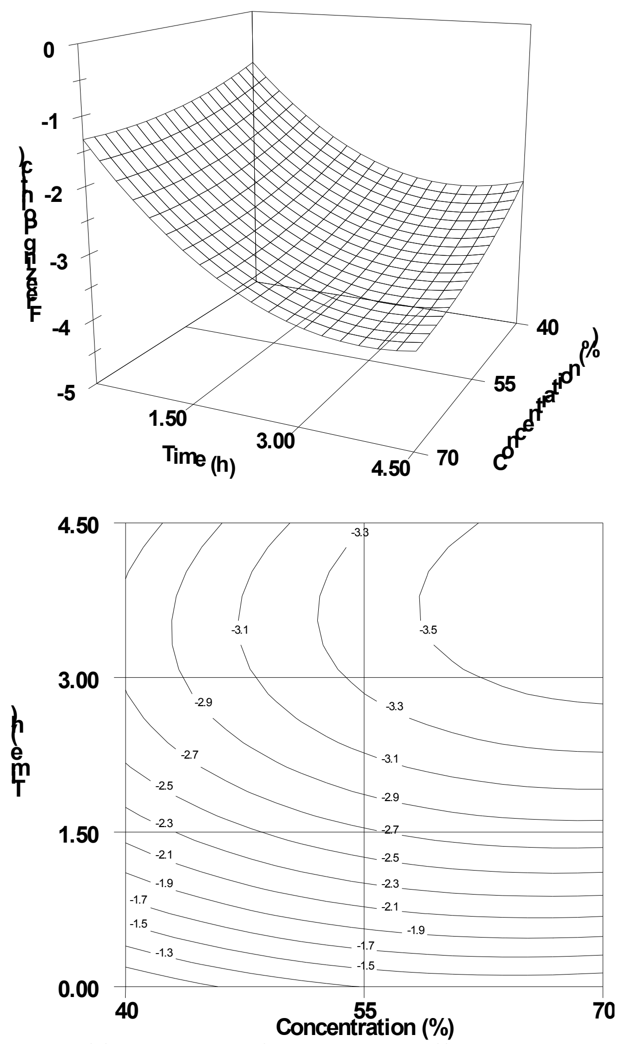

Fig. 3. Surface and contour plots of freezing point of cantaloupe at different solution concentrations and process time.

As it was expected the moisture content of the samples have decreased due to water removal from the cantaloupe and solute uptake by the cantaloupe during osmotic dehydration process of samples. The amount of moisture content decrease is affected by osmotic solution concentration and process time. Final moisture content was obtained 74.5% for samples that treated for 4.5 h at 70% solution while the initial moisture content of the cantaloupe was 93.5% (Table 1).

Specific heat of food is one of the important parameters of the food products this specification will be altered due to the changes are occurred in the cantaloupe samples during osmotic dehydration treatment. The amount of specific heat is different above and below of freezing point for foods.

Specific heat values for treated samples are calculated using Equations 2 and 3 and is reported in Table 1. This feature is used to calculate the energy required for the freezing process. With respect to temperature 25 °C (the temperature which experiment was done) the amount of required energy (Q1) to reduce the temperature of samples to the freezing point and the amount of required energy (Q2) to reduce the temperature of samples to -20 °C that is the storage temperature of frozen products (Archer, 2004) was calculated (Table 1). The total required energy (QT) per mass unit was calculated regarding to the energy required for cooling the product, freezing latent heat and the required energy to reduce the temperature of the product to the final temperature of storage (Table 1).

Table 1: Moisture content, specific heat and required energy for treated cantaloupe samples in osmotic solutions.

Solution concentration (%)	Time (h)	Water fraction	C_1 (kJ/kg°C)	C_2 (kJ/kg°C)	Q_1 (kJ/kg)	Q_2 (kJ/kg)	Q_3 (kJ/kg)
40	1.5	0.85383	3.752952	1.90977	101.713	34.18082	469.8938
	3	0.84179	3.716952	1.894648	101.2243	33.66193	468.8862
	4.5	0.82173	3.656973	1.869453	101.8507	32.05908	467.9098
55	1.5	0.8143	3.634757	1.860121	101.829	31.5935	467.4225
	3	0.78049	3.533665	1.817655	99.5013	30.61277	464.1141
	4.5	0.76702	3.49339	1.800737	98.66097	30.17642	462.8374
70	1.5	0.79594	3.579861	1.837061	101.2221	30.72405	465.9461
	3	0.7779	3.525921	1.814402	99.92447	30.22801	464.1525
	4.5	0.7453	3.428447	1.773457	97.94647	29.1401	461.0866
Control		0.93479	3.995022	2.011456	104.1956	38.05402	476.2496

CONCLUSION

According to the obtained data the engineering calculations of freezing process even before the osmosis process is possible this causes easiness of process design and has economical benefits. The fruits may be stored at temperatures slightly above the freezing point without freezing due to the reduced freezing point of the product To prevent disadvantage freezing process as well as freezing damages if there is no problem In the point of view of microbial and biochemical activities. Future researchs is needed to investigate the matter. Also by fine tuning the temperature in the cold storage the temperature fall below freezing point can be avoided and then the unwanted freezing will be prevented.

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