3.2 Osmodehydrofrozen Cubes

3.2.1 Optimization Condition for Osmotic Treatment

Response surface graphical optimization technique was used to determine the workable optimum condition for osmotic treatment, before further processing by cryogenic freezing. Diffusion coefficient is the quantitative measure of the rate at which a diffusion process occurs. Diffusion coefficient is a good indicator of the extent to which the osmotic solution succeeds in eliminating water and gaining solid. The regression equations obtained from D_{ew} and D_{es} can be used to find the optimum concentrations for osmotic treatment. In practice, D_{ew} must be sufficiently high in order to achieve a high rate of water removal. But this inevitably increases D_{es}, resulting in a high concentration of osmotic salts in the product. Thus a maximum acceptable limit has to be set on D_{es} whereas a minimum acceptable value has to be set on D_{ew}. The diffusivity criteria; which in this case is $D_{ew} \geq 2.6 \times 10^{-10}$ $m^2 s^{-1}$ and $D_{es} \leq 1.7 \times 10^{-13}$ $m^2 s^{-1}$. The constant diffusivity which represents possible working concentration of NaCl and sucrose are shown as response surface contour plots in Figures 73 a) and b). The two plots were superimposed to identify a common area which represents the operating conditions shown in Figure 73 c). Any concentration of sucrose and NaCl falling within this region will satisfy. Five conditions (A, B, C, D and E) from the optimum area were selected and the combination concentration sets were shown in Table 17.

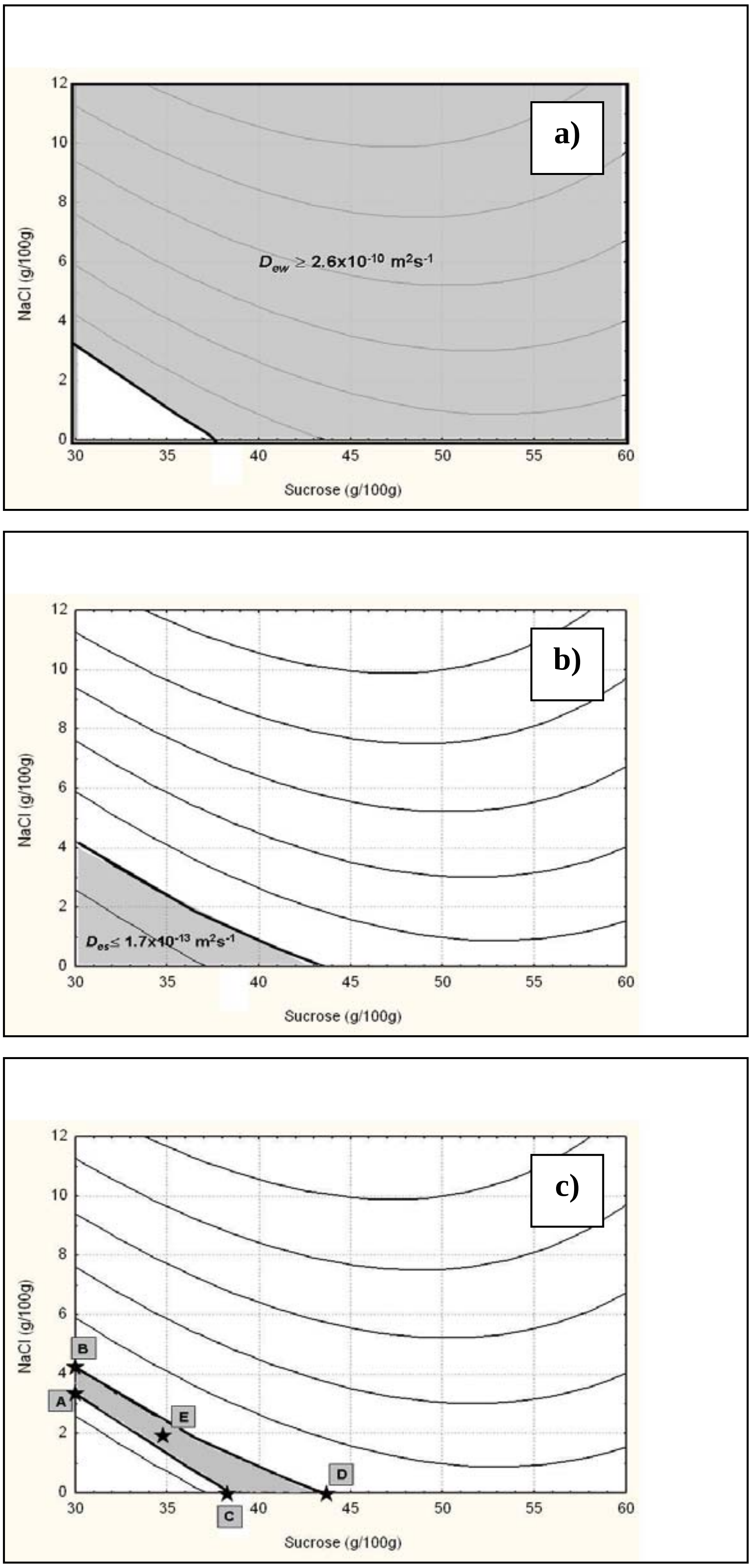

Figure 73 Response surface contour plots of the constant diffusivity as a) $D_{ew} \geq 2.6 \times 10^{-10}$ m^2 s^{-1} and b) $D_{es} \leq 1.7 \times 10^{-13}$ m^2 s^{-1}, and c) super imposed contour plots showing the shaded overlapping for possible working area.

Table 17 Optimum concentrations for osmotic dehydration of persimmon cube

Factor	**Optimum concentrations**				
	A	**B**	**C**	**D**	**E**
Sucrose conc.(g/100g)	30.00	30.00	38.40	43.63	35.00
NaCl conc.(g/100g)	2.90	4.24	0	0	2.00
Predicted value					
D_{ew} x 10^{10}(m^2 s^{-1})	2.29	2.86	2.94	2.83	2.72
D_{es} x 10^{10}(m^2 s^{-1})	1.17	1.59	1.16	1.52	1.45
Experimental value					
D_{ew} x 10^{10}(m^2 s^{-1})	2.48±0.12	3.06±0.11	2.75±0.09	2.64±0.14	2.67±0.13
D_{es} x 10^{10}(m^2 s^{-1})	1.14±0.09	1.53±0.08	1.18±0.07	1.46±0.08	1.41±0.08
E (%)for D_{ew}	4.42	7.17	6.55	5.71	4.09
E (%)for D_{es}	5.47	5.50	2.32	5.23	3.94

3.2.2 Verification and Final Selection of Optimum Conditions for Osmotic Treatment

The suitability of the model equations for predicting the optimum responses values was tested using optimized set conditions. The adequacy of the model was checked by estimating the average relative error *E*.

$$E\ (\%) = \frac{1}{N}\sum_{i=1}^{N}\left|\frac{V_E - V_P}{V_E}\right|100$$

where *N* is the number of experimental data, V_E is the experimental value and V_P is the value calculated from the model.

It was found that *E* values for D_{ew} and D_{es} were in 4.09 to 7.17, and 2.32-5.50 %, respectively which less than 10% (Lomauro *et al*., 1985). The optimized set was verified and the models were able to predict D_{ew} and D_{es} satisfactory (Table 17). The sensory quality attributes were used to evaluate the osmotically treated product. The organoleptic scores for the attributes are presented in Table 18. There were no statistically significant differences in colors attribute. Samples observation treatment E got the highest rating (*P*<0.05) for all attributes.

Table 18 Organoleptic scores for quality attribute of osmosed persimmon cubes, made from optimum concentration solutions of NaCl and sucrose

Treatment	**Color**[ns]	**Taste**	**Flavor**	**Texture**	**Overall acceptability**
A (30.00,2.9)	6.30±0.12	6.05±0.11[b]	6.21±0.12[b]	7.31±0.31[a]	5.58±0.11[c]
B (30,4.24)	6.37±0.17	5.85±0.31[c]	6.02±0.13[c]	7.04±0.13[a]	5.35±0.10[c]
C (38.40,0)	6.40±0.25	6.38±0.11[a]	6.43±0.14[a]	6.12±0.24[b]	7.10±0.22[a]
D (43.63,0)	6.13±0.22	6.15±0.14[b]	6.27±0.16[b]	6.05±0.1[1b]	6.35±0.18[b]
E (35.00,2.00)	6.31±0.22	6.49±0.28[a]	6.52±0.16[a]	7.25±0.02[a]	7.11±0.03[a]

[abc] Mean in the same column with different letters is significantly different (*P*≤0.05)

[ns] Non-significant (*P*>0.05)

3.2.3 Combined Osmotic and Cryogenic Freezing

Osmotic pre-treatment was done by immersing the cube in the osmotic solution containing of 35 g/100g of sucrose and 2 g/100g of NaCl for 6 h. After that osmotically treated samples were sealed in polyethylene bag. Samples were frozen at -40 °C in cryogenic freezer and stored at -18 °C for 30 days. Samples were withdrawn from storage condition weekly. Thawing was carried out at 4 °C for 10 h. The picture of osmodehydrofrozen persimmon final product is shown in Appendix Figure 8.

3.2.4 Measurement of Osmodehydrofrozen Persimmon Product Quality

Table 19 shows the quality assessment of frozen and osmodehydrofrozen persimmon products. It was observed that the frozen sample showed a significantly higher drip loss than the osmodehydrofrozen sample. It was indicated that applied osmotic treatment before freezing, significantly reduced the drip loss after thawing. The lower water content of the products protects the tissues from freezing damage. As for firmness, thawed osmodehydrofrozen sample is more than the frozen thawed sample, due to osmotic treatment affects the mechanical behavior of plant tissue. Changes in color induced by freezing in the different (frozen and osmodehydrofrozen) samples can be observed in Table19. An increase in a* value occurs in osmodehydrofrozen sample while L* and b* values were non-significantly different between osmodehydrofrozen and frozen persimmon product.

The changes in drip loss, firmness and color values of osmodehydrofrozen persimmon during storage at -18°C for 4 weeks are presented in Figures 74 and 75. It was observed that drip loss tends to increase with storage time while firmness decreases. However, at the end of 4 weeks storage, the drip loss increases only about 1.3% whereas the firmness decreased from 19 N to 3 N. Color values a* and b* were slightly increased with storage time, while L* decreased (Figure 75).

Table 19 Quality assessment of frozen and osmodehydrofrozen persimmon product

Persimmon Product	**Drip loss (%)**	**Firmness (N)**	**Color**		
			L*^{ns}	**a***	**b*^{ns}**
Frozen	16.32±0.42^{a}	16.69±0.34^{b}	32.16±0.25	9.15±0.22^{a}	22.22±0.36
Osmodehydrofrozen	6.23±0.23^{b}	19.23±0.23^{a}	30.06±0.24	12.85±0.23^{b}	24.22±0.12

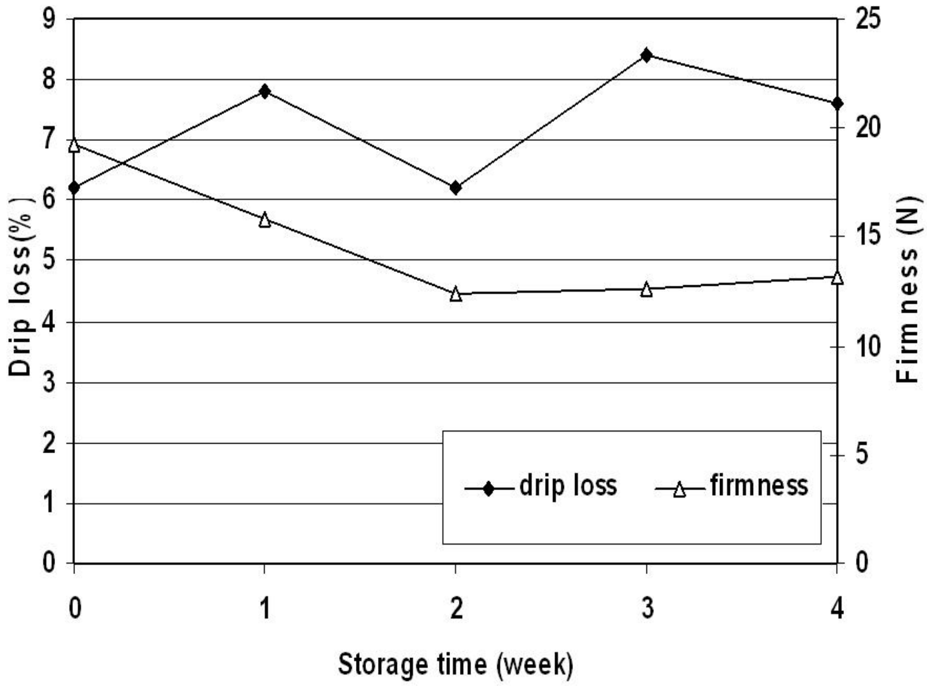

Figure 74 Drip loss and firmness of osmodehydrofrozen persimmon during storage at -18 °C.

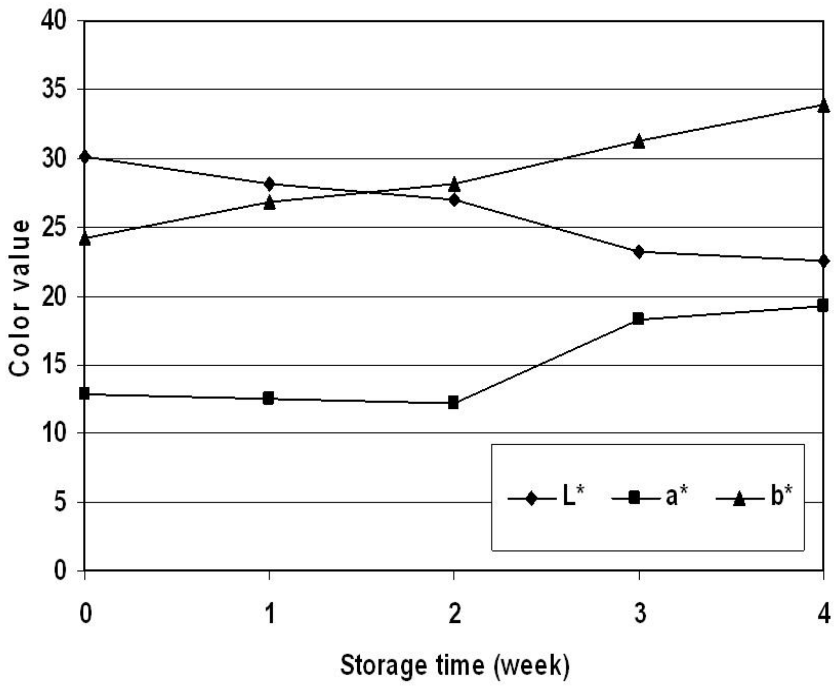

Figure 75 Color values (L*, a* and b*) of osmodehydrofrozen persimmon during storage at-18 °C.

Sensory analysis was carried out on two consecutive days by 30 panelists, using 9-point hedonic scaling test. Randomly coded samples were scored for color, texture, taste, flavor and overall acceptability. The results showed in Table 20 indicate that all attributes except texture were insignificantly different over the storage time. The overall acceptability scores were greater than 6 in 0, 2 and 4 weeks storage time.

Table 20 Organoleptic scores for quality attributes of osmodehydrofrozen persimmon after thawing

Storage time (week)	**Color^{ns}**	**Taste^{ns}**	**Flavor^{ns}**	**Texture**	**Overall acceptability^{ns}**
0	6.04±0.32	6.14±0.13	5.81±0.21	6.59±0.23^{b}	6.31±0.14
2	6.03±0.22	6.17±0.22	5.95±0.15	6.55±0.24^{b}	6.45±0.24
4	6.16±0.18	6.19±0.12	5.73±0.15	5.09±0.32^{a}	6.38±0.22

^{abc} Mean in the same column with different letters are significantly different ($P \leq 0.05$)

^{ns} Non significantly different ($P > 0.05$)