3. **Part III: Persimmons Product Development using Osmotic dehydration as a Pre-treatment**

3.1 Osmodehydrated Whole Fruit

3.1.1 Optimization Condition for Osmotic Treatment

The graphical optimization technique was used to determine the workable optimum concentrations of osmotic agent for the osmotic dehydration of persimmon. Optimum conditions were worked out under which the maximum water loss could be achieved with lower solid uptake, which corresponds to high ratio of *WL/SG*. Regression analysis of the experimental data obtained from the various treatments at immersion time of 6, 12 and 24 h yielded the following second order polynomial models for *WL/SG* ratio:

$$WL/SG\ (6h) = -5.823 + 0.66X_1 + 0.229X_2 - 0.007X_1^{\,2} + 0.021X_2^{\,2} - 0.007X_1X_2$$

$$WL/SG\ (12h) = 4.652 + 0.31X_1 - 0.582X_2 - 0.005X_1^{\,2} + 0.016X_2^{\,2} - 0.005X_1X_2$$

$$WL/SG\ (24h) = -2.612 + 0.583X_1 - 0.094X_2 - 0.008X_1^{\,2} - 0.013X_2^{\,2} + 0.001X_1X_2$$

The concentration parameters were optimized using response surface methodology (RSM). An acceptable compromise area was made based on the selection of superimposed area for the constraint of *WL/SG* ≥ 8. The constant ratio of *WL/SG* ≥ 8 which represents possible working concentration of NaCl and sucrose are shown as response surface contour plots in Figures 67 a)-c). The superimposed contour plot of Figure 67 d) is shown and the optimum area is generated. Four points from the optimum area were selected and the combination concentration sets (A, B, C, D) were shown in Table 13.

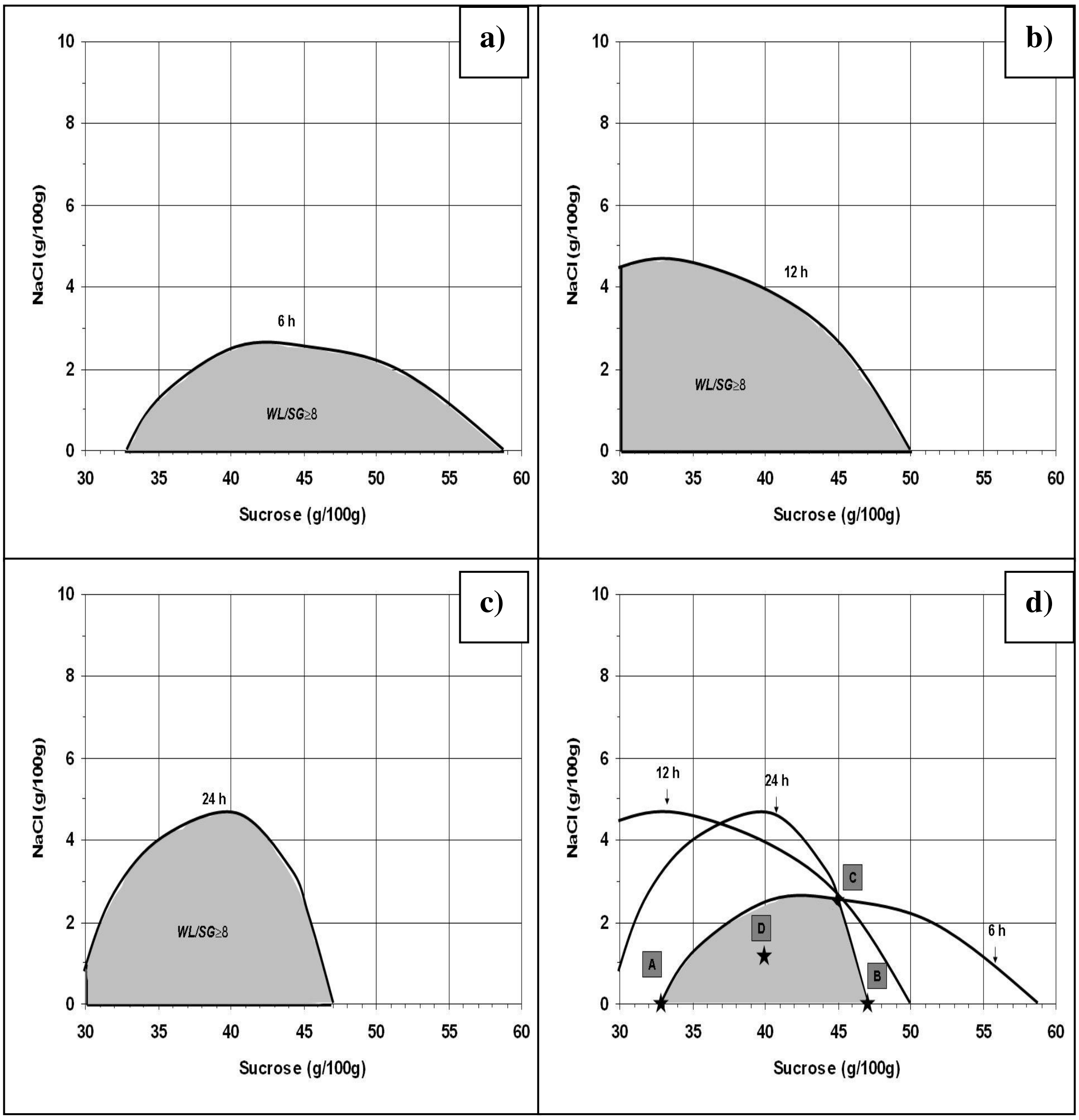

Figure 67 Response surface contour plots of the constant ratio of *WL/SG* ≥ 8 at the immersion time of a) 6 h, b) 12 h, c) 24 h, and d) super imposed contour plots showing the shaded overlapping area for *WL/SG* ≥8 of osmosed product.

3.1.2 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*.

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

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* value equal to 1.32, 0.51, 0.76 and 1.09 which less than 10% are considered to fit the experimental data satisfactorily (Lomauro *et al*., 1985). The optimized set was verified and the models were able to predict *WL/ SG* with satisfactory values (Table 13).

Table 13 Optimum concentrations for 12 h osmotic dehydration of whole fruit persimmon

Factor	**Optimum concentrations**			
	A	**B**	**C**	**D**
Sucrose conc.(g/100g)	32.85	47.31	45.00	40.00
NaCl conc.(g/100g)	0	0	2.53	1.00
Predicted value				
WL/ SG	8.30	9.73	9.62	9.35
Experimental value				
WL / SG	8.50±0.05	9.67±0.06	9.81±0.06	9.42±0.10
E (%)	1.32	0.51	0.76	1.09

The sensory quality attributes were used to evaluate the osmotically treated product. The organoleptic scores for the attributes of osmotically product are presented in Table 14. Samples of treatment D were rated by panelists with a significantly higher score (P<0.05) for all attributes except texture. However, all mean organoleptic scores for treatment D were greater than 6.

Table 14 Organoleptic scores for quality attribute of osmosed product from optimum concentration solutions

Treatment	**Color**	**Taste**	**Flavor**	**Texture**	**Overall acceptability**
A (32.85,0)	$7.20{\pm}0.10^{a}$	$6.65{\pm}0.13^{c}$	$6.11{\pm}0.12^{b}$	$5.91{\pm}0.11^{c}$	$5.98{\pm}0.11^{b}$
B (47.31,0)	$7.07{\pm}0.17^{a}$	$7.35{\pm}0.21^{a}$	$7.42{\pm}0.13^{a}$	$6.04{\pm}0.13^{c}$	$6.15{\pm}0.17^{b}$
C (45.00,2.53)	$7.45{\pm}0.15^{c}$	$7.08{\pm}0.11^{b}$	$6.39{\pm}0.14^{b}$	$7.12{\pm}0.14^{a}$	$6.10{\pm}0.12^{b}$
D (40.00,1.00)	$7.11{\pm}0.12^{a}$	$7.65{\pm}0.14^{a}$	$7.77{\pm}0.16^{a}$	$6.65{\pm}0.12^{b}$	$6.31{\pm}0.18^{a}$

^{abc} Mean in the same column with different letters is significantly different (P≤0.05)

3.1.3 Combined Osmotic and Microwave-vacuum Dehydration

Peeled whole fruits were placed in 2% $CaCl_2$ solution for 2 hrs before osmotic dewatering to improve the texture of the product. Osmotic dehydration of $CaCl_2$ treated persimmons showed a little higher value of mass transfer parameters (*WR*, *WL*, and *SG*) in comparison with that of untreated persimmons during 16 h of immersion time (Figures 68-70). However, *WR*, *WL* and *SG* of $CaCl_2$ treated persimmons were non-significantly difference with untreated persimmons. In fact, pre-treatment with $CaCl_2$ can cause the penetration of calcium ions and formation of bridges between pectin molecules stiffened the tissue and added resistance to deformation. An open structure was formed, and the resistance to water and solute transport was much lower than that obtained in raw fruit upon osmosis (Lewicki *et al*., 2002). Hence, open structure promoted water and solute diffusion and resulted in faster rate of mass transfer during osmotic dehydration. In this case the soaking time of persimmons in $CaCl_2$ solution not quite long (2 h) so that the mechanism by which calcium ion may be not shown the highly effective in the fruit tissue. Rodrigues *et al*. (2003) reported that calcium salt as additive should be preferred for shorter process times (up to 2 hr); after that, samples become too hard.

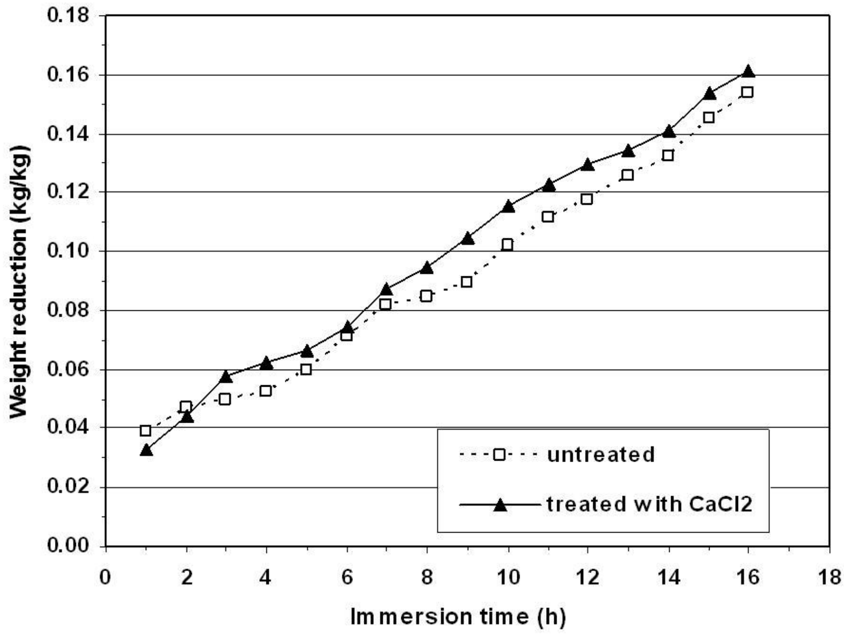

Figure 68 Weight reduction during osmotic dehydration of whole fruit persimmons untreated and treated with $CaCl_2$.

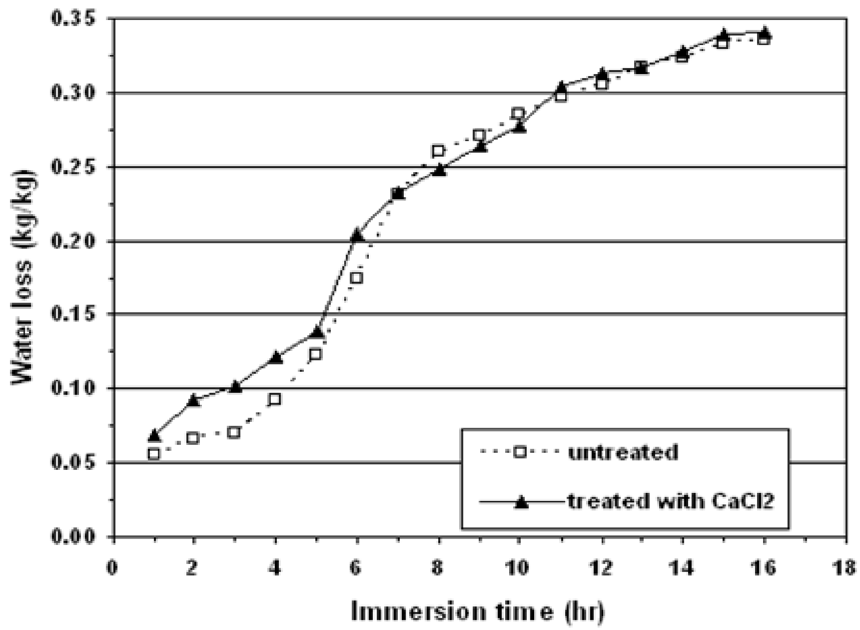

Figure 69 Water loss during osmotic dehydration of whole fruit persimmons untreated and treated with $CaCl_2$.

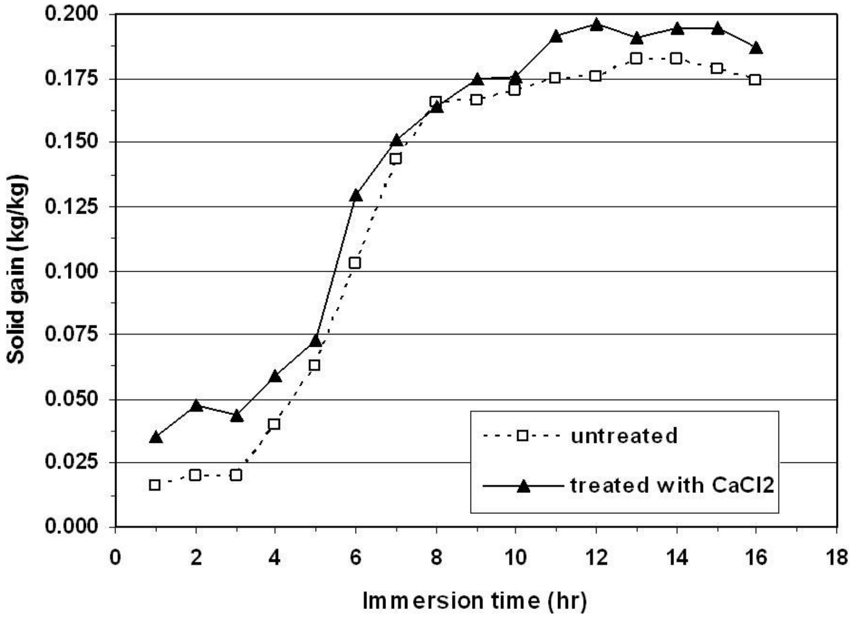

Figure 70 Solid gain during osmotic dehydration of whole fruit persimmons untreated and treated with $CaCl_2$.

Further, 100 ppm of sorbic acid and sodium metabisulphite were also added to the solution in order to prevent fermentation during the osmotic process. The fruits were osmosed to 30%, 35% and 40% solid content and the immersion time was determined from the drying curve (Figure 71). According to the equation which related solid content with immersion time, it was found that the fruit reached solid contents of 30%, 35% and 40% after soaking for 6.420 h (6 h 25 min), 12.760 h (12 h 45 min) and 21.003 (21 h), respectively.

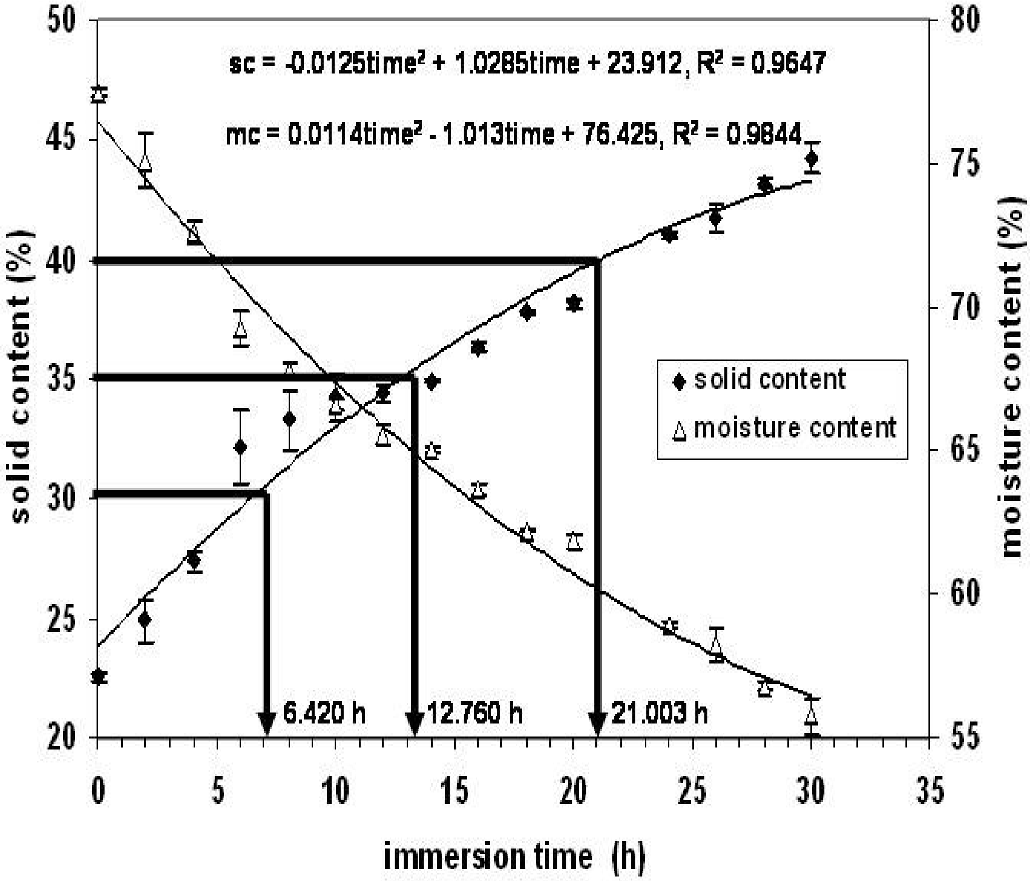

Figure 71 Solid and moisture content of persimmon whole fruit during osmotic treatment in sucrose (concentration 40 g/100g) and NaCl (concentration 1 g/100g) solutions.

Drying of fresh and osmotically treated fruits was conducted in a microwave vacuum dryer operated at the following power settings: 640 W for 10 min, 320 W for 15 min and 160 W for 10 min. at vacuum pressure gage of -600mmHg. Table 15 shows the quality assessment of dehydrated and osmodehydrated products. Osmotic pretreatment for each interval immersion time increased the solid content of osmosed persimmon in different level. It was observed that the osmodehydrated product with 40% solid content showed the least firmness whereas the dehydrated persimmon product had the highest. This due to during osmotic pretreatment affecting mechanical behavior of plant tissues which are loss of cell turgor and alteration of cell wall (Alzamora *et al*., 1993). Furthermore, in general the fresh plant contains more water within a rigid cell wall structure, which is responsible for their crisp and firm texture. So that the firmness of osmodehydrated product is decreased compared to the dehydrated product. The quality in terms of color (L* a* and b* value) was significantly different between treatments. The L* value of osmodehydrated product decreased with increasing in solid content of the osmosed product whereas a* value are increased. The water activities of the osmodehydrated product decreased in range between 0.7 and 0.75. The moisture content of the osmodehydrated product decreased to a value between 54% and 63% whereas the dehydrated product reached about 72%. It’s mean that osmotic pretreatment tend to beneficial helping to extend shelf life potential by lowering the water activity and moisture content.

Table 15 Quality assessment of dehydrated and osmodehydrated persimmon product.

Persimmon Product	Solid content (%)	Firmness (N)	Color			a_w	Moisture content (%)
			L*	a*	b*		
Dehydrated	23	25.4±0.3[a]	33.45±0.9[a]	11.54±2.5[b]	32.47±6.2[a]	0.82±0.02[a]	71.6±0.7[a]
Osmodehydrated	30	20.4±0.6[b]	31.06±0.3[a]	10.85±1.5[c]	24.22±4.2[c]	0.75±0.01[b]	62.8±0.7[b]
	35	17.2±0.4[c]	29.11±0.8[b]	12.85±1.8[b]	22.89±2.8[c]	0.71±0.01[c]	57.2±0.3[c]
	40	14.8±0.2[d]	27.06±0.7[b]	18.21±1.2[a]	29.12±2.2[b]	0.69±0.02[c]	54.4±0.6[c]

[abcd] Mean in the same column with different letters are significantly different ($P \le 0.05$).

Though there were significant difference in color values (L*, a* and b*) between samples, the liking scores for color were not different (Table 16). The osmodehydrated product made from the 35% solid content osmosed sample got the highest organoleptic scores in terms of taste, flavor, texture and overall acceptability indicating that an osmotic step improved the fruit quality characteristics such as texture and taste. So the best procedure to obtain osmodehydrated product was shown in Figure 72. The whole fruit was immersed in 2%$CaCl_2$ for 2 h and then immersed in an osmotic solution containing of 40 g/100g of sucrose and 1 g/100g of NaCl for 12 h 45 min, until the solid content reached 35%. The osmosed product was then subjected to microwave-vacuum dehydration to obtain the final product (Appendix Figure 7).

3.1.4 Microbial Analysis of the Osmodehydrated Persimmon Product

Osmotic pretreatment is a mild treatment that does not cause the negative quality changes. After osmotic pre-treatment step, drying method is necessary to produce shelf-stable persimmon product. Microwave-vacuum drying induced microbial stability by the reducing of the initial aerobic plate count from $6x10^6$ CFU/g of osmosed persimmon to $5x10^4$ CFU/g of osmodehydrated product. Yeast and mould counts also dropped from $4x10^4$ CFU/g of osmosed persimmon to $7x10^3$ CFU/g of osmodehydrated persimmon product. The total microbial growth (aerobic plate count, yeast and moulds) in the product stored at 5°C for 14 days exceeds the limiting count (10^4–10^5 CFU/g).

Table 16 Organoleptic scores for quality attributes of osmodehydrated persimmon product

Persimmon Product	Solid content (%)	Color [ns]	Taste	Flavor	Texture	Overall acceptability
Dehydrated	23	6.26±0.18	7.19±0.19[a]	7.03±0.12[a]	4.51±0.13[b]	5.62±0.17[c]
Osmo-dehydrated	30	6.14±0.13	6.84±0.14[b]	6.51±0.11[b]	5.24±0.19[b]	6.18±0.23[b]
	35	6.19±0.15	7.75±0.17[a]	7.12±0.10[a]	6.01±0.16[a]	7.45±0.20[a]
	40	6.23±0.15	7.47±0.23[a]	6.45±0.14[b]	5.91±0.23[a]	6.14±0.13[b]

[abc] Mean in the same column with different letters are significantly different ($P \leq 0.05$)

[ns] Non significantly different ($P > 0.05$)

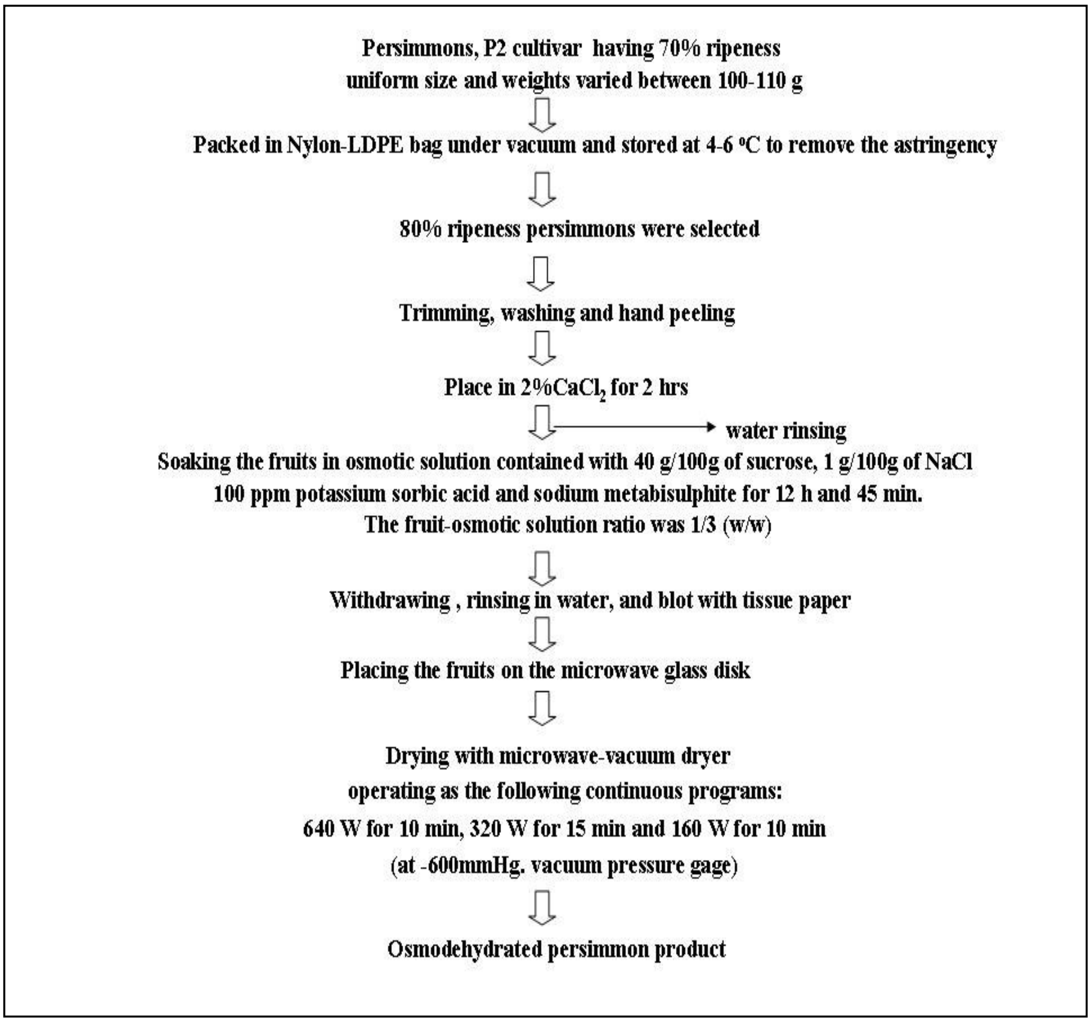

Figure 72 The flow diagram for processing osmodehydrated persimmon product.