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Combined Osmotic and Microwave-vacuum Dehydration of Persimmon (*Diospyros kaki*)

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ABSTRACT

Whole fruit persimmons were dehydrated osmotically by immersion in a ternary solutions consisting of sucrose and NaCl at a constant temperature (30°C). A second-order central composite design (CCD) with two variables was used involving combinations of sucrose concentration from 30 to 60 g / 100g and NaCl concentration from 0 to 10 g / 100g. The mass transfer parameters were experimentally determined by measuring Weight Reduction (*WR*), Water Loss (*WL*) and Solid Gain (*SG*). After impregnation soaking for 48 h the *WR* and *WL* were more than 0.4 kg/kg and the *SG* was less than 0.13 kg/kg. The mathematical models as a function of osmotic solution concentration were fitted to a 2^{nd} order polynomial. The optimum sets were selected from the superimposed response surface plots. The best osmotic treatment condition was immersion of fruit in an osmotic solution containing 40 g/100g sucrose and 1 g/100g NaCl for 12 h 45 min to reach 35% solid content. The combined osmotic and microwave-vacuum dehydration could produce an osmo-dehydrated persimmon product which accepted by 81% of consumers and 61% of consumers would consider purchasing it.

Key words: osmotic, microwave-vacuum, dehydration, persimmon

INTRODUCTION

Persimmon (*Diospyros kaki*) is a tropical and subtropical fruit with cultivars that are either non-astringent and astringent. The non-astringent or firm and sweet persimmon is consumed fresh, while the astringent persimmon contains highly soluble tannin, which must be removed before consumption (Kitagawa and Glucina, 1984). The leading astringent persimmon cultivars (P2) grown in Thailand can be generally preserved by a drying process. But the quality of the product is not entirely satisfactory. Therefore, the preservation technology that produces a high quality product needs to be developed.

Osmotic dehydration is an important technology for the removal of water from product plant tissues such as fruits and vegetables. During the process there is a direct contact of food with a hypertonic solution, that acts as a driving force for dewatering arises between solution and food, (Lerici *et al*., 1985). It is effective even at ambient temperature, so heat damage to texture, color, and flavor of food are minimized (Torreggiani, 1993). Up to 50% of dewatering from the product to the surrounding solution and solutes infusion into the

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product occurs. Consequently, changes in composition could create modified properties of the final product. Unfortunately, the water activity attained by the osmotic dehydration alone is still rather high. Osmotic dehydration is generally used as a pre-treatment step for the dehydration of food prior to further processing such as vacuum drying (Dixon and Jen, 1997), microwave-vacuum drying (Erle and Schubert, 2001) and freezing (Ponting, 1973). Microwave-vacuum drying can achieve water activity lower than 0.75. The products quality obtained preserves a fresh tasting quality. The advantages of both unit operations combination provide no phase transition occurred and low energy consumption. Even microwaves require electricity, cost at the final stages of drying, where they can be used more efficiently than hot air drying (Gunasekaran, 1999).

The objective of this work was to study the osmotic dehydration of persimmon as a function of osmotic concentrations through regression analysis. Response surface methodology (RSM) was used in order to identify the optimum concentration of osmotic dehydration which use as a pre-treatment combined with microwave-vacuum dehydration. The hypothesis test was that persimmons could be added value by development of combined osmotic and microwave vacuum dehydration method.

MATERIALS AND METHOD

Materials

Persimmons, P2 cultivar, astringent type, having 70% ripeness were packed in Nylon-LDPE bag under vacuum and stored at 4-6 °C for 4 weeks to remove the astringency before used. Fruit sampling is based on ripeness grade which contained 17-19 °Brix and 80% ripeness level. The sizes of the fruits were also uniform and their weights varied between 110-120 g. The fruit were trimmed the calyx by scissor, washed and hand peeled.

Osmotic pre-treatment

A second-order central composite design (CCD) with two variables was used to study the response pattern of variables. The variables were sucrose concentration (30 to 60 g / 100g) and NaCl concentration (0 to 10 g / 100 g) each at five levels as shown in Table 1. The solutions were prepared by dissolving sucrose and NaCl in water under the proportion mentioned. The samples were weighted and placed in a stainless steel basket then fully immersed in a glass jar containing the osmotic solution. The ratio of sample to osmotic solution was 1:3 (w/w).The solution temperature was maintained at 30 °C by using a water bath. Samples were removed from the osmotic solution

Table 1 Second-order central composite design (CCD).

Treatment no.	Code value		Sucrose Conc.	NaCl Conc.
	X_1	X_2	(S,g/100g)	(N, g/100g)
1	-1	-1	34.40	1.47
2	1	-1	55.60	1.47
3	-1	1	34.40	8.53
4	1	1	55.60	8.53
5	-1.414	0	30.00	5.00
6	1.414	0	60.00	5.00
7	0	-1.414	45.00	0
8	0	1.414	45.00	10.00
9	0	0	45.00	5.00

after 3, 6, 12, 24, 36 and 48 hr. After removal from the solution, samples were rinsed under flowing cold water, drained and blotted with an absorbent paper in preparation for assessment of posterior weight and physical testing. In order to optimizing the osmotic dehydration using as a pre-treatment step before microwave-vacuum drying the optimized osmotic solutions combinations were selected. The criterion was the high ratio of *WL/SG* which is a good indicator of the extent to which the osmotic solution succeeds in maximising water loss and minimising solid gain.

Combined osmotic and microwave-vacuum dehydration

Peeled whole fruit persimmons were placed in 2% $CaCl_2$ solution for 2 hr before osmotic dewatering to improve the texture of the product. The osmotic solution were also added 100 ppm of sorbic acid and sodium metabisulphite to prevent fermentation during the osmotic process. The persimmons were osmosed to 30%, 35% and 40% solid content (the immersion time was determined according to the drying curve). Drying process of the fresh and osmotically treated fruits was carried out in a microwave vacuum dryer (Marchcool Industry Co., Ltd). The fruits were placed on the microwave glass disk which the dryer is operated as the following continuous programs: 640 W for 10 min, 320 W for 15 min and 160 W for 10 min. at vacuum pressure gage of -600mmHg.Water activity lower than 0.75 were achieved in all cases and the soft texture like fresh fruit were attained.

Calculations

For each experiment, the weight reduction (W_R), water loss (W_L) and solid gain (S_G) as a function of their contact time in the solution were determined under the assumption that the solutes in the fruit samples would not diffuse into the solution (Ade-Omowaye *et al*., 2002; Moreira and Sereno, 2003). The calculation was as following:

$$W_R = (w_o - w_t) / w_o$$

$$S_G = (s_t - s_o) / w_o$$

$$W_L = W_R + S_G$$

Where: w_o = initial weight of sample (kg); w_t = weight of osmosed sample at time t (kg); s_o= initial solid content of sample (kg/kg of initial dry solid); s_t = solid content of osmosed sample at time *t* (kg/ kg of initial dry solid).

Statistical analysis

Data were analyzed by multiple regressions through the least square method to fit the model. A quadratic model was chosen for description of the response variables (*Y*) to the factor variables: sucrose concentration (*S*) and NaCl concentration (*N*):

$$Y = \beta_0 + \beta_1 S + \beta_2 N + \beta_{11} S^2 + \beta_{22} N^2 + \beta_{12} SN \quad (1)$$

The adequacy of the model was checked by estimating the average relative error *E* (Eq (2)) and the determination coefficient R^2.

$$E(\%) = \frac{1}{N}\sum_{i=1}^{N}\left|\frac{V_E - V_P}{V_E}\right|100 \quad (2)$$

Where *N* is the number of experimental data, V_E is the experimental value and V_P is the value calculated from the model (Eq(1)). Values of *E* less than or equal to 10% are considered to fit the experimental data satisfactority (Lomauro *et al*., 1985).

Quality assessment

Moisture and solid content were determined by vacuum dryer at 60°C for 18 h. Texture properties were analysed through a compression test using a texture analyzer (TA.XT2 Texture analyzer). Color measurements were made by means of L* a* and b* value using a handy colorimeter (BYK-Gardner). Water activity was measured using a water activity meter (Novasina). Sensory evaluation for the flavor, texture, color and overall acceptability were tested by a 30 member untrained panel using 9 point hedonic scale (9: like extremely to 1: dislike extremely). Consumer acceptance testing was conducted by 100 panels. Aerobic plate count, yeast and molds of osmo-dehydrated finished product were conducted using standard techniques (B.A.M., 1984).

RESULTS AND DISSCUSSION

The moisture content of osmosed persimmon decreased and the solid content increased with increasing immersion time during osmotic treatment. The rate of decrease in moisture content was highest initially followed by a progressively declining in the later stages, was observed. The initial rate observed when the sample is placed into the osmotic solution there may be attributed to a high concentration difference between the solution and the fruit. After this initial mass transfer, the concentration of solutes in the sample increase, decreasing the concentration difference between osmotic solution and the fruit. A similar trend has been reported by several authors (Torreggiani, 1993; Pointing, 1973; Lerici *et al*., 1985). It was found that after 48 h of contact, the moisture content had fallen to values between 0.3687 and 0.8603 kg/kg whereas the solid content had increased to values between 1.2062 and 1.4904 kg/kg (initial dry matter basis), depending on the treatment concentrations (Figure 1 and 2). Sucrose and NaCl were shown to have a synergistic effect on water removal and solid gain. However, NaCl causes a significantly higher change in osmotic pressure than sucrose. Isse and Schubert (1991) reported that at the cellular level, sucrose and NaCl can both pass through the cellular membrane while only NaCl can diffuse through cytoplasmic membrane. NaCl produces concentration gradients at the vacuole level and in the cytoplasm, thus allowing transfer of more water from deep inside the cell. After contact for 48 h, the net weight reduction and water loss

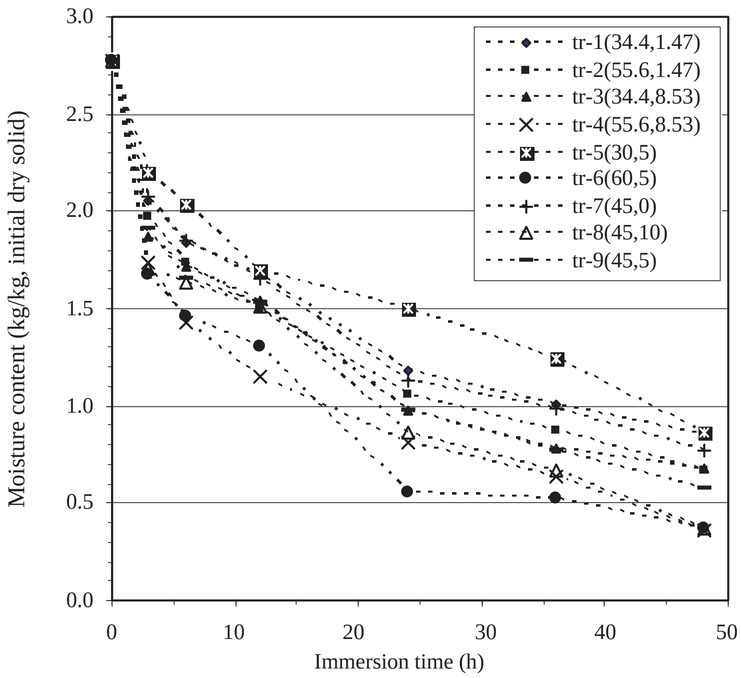

Figure 1 Change in moisture content with time during osmotic treatment of whole fruit.

ranged from 0.3887 to 0.5073 kg/kg and from 0.4521 to 0.6022 kg/kg, respectively. The net solid gain was relatively modest, ranging between 0.0546 and 0.1298 kg kg^{-1} for all treatment concentrations at the same period (data not shown). Low solute infusion into the fruit implies that the weight reduction mainly depended on the water loss. Since sucrose molecules are larger, they could not diffuse easily through the cell membrane, thus the approach to osmotic equilibrium was achieved primary by water loss from the fruit tissue.

The graphical optimization technique was used to determine the workable optimum concentrations of osmotic agent for the osmotic dehydration of persimmon. Optimum conditions should be achieved by the maximum water loss with lower solid uptake, corresponding 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:

$$WL/SG\ (6h) = -5.823 + 0.66S - 0.229N - 0.007S^2 + 0.021N^2 - 0.007SN$$

$$WL/SG\ (12h) = 4.652 + 0.31S - 0.582N - 0.005S^2 + 0.016N^2 - 0.005SN$$

$$WL/SG\ (24h) = -2.612 + 0.583S - 0.094N - 0.008S^2 - 0.013N^2 + 0.001SN$$

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 $WL/SG \geq 8$. The superimposed contour plot of Fig.3 is shown and the same optimum concentrations sets were observed. The optimized set was verified and the models were able to predict water loss and solid gain with satisfactory average deviation values (Table 2).

The sensory quality attributes of the osmotically treated product were evaluate by the organoleptic scores presented in Table 3. Samples of treatment D were rated by panelists with a

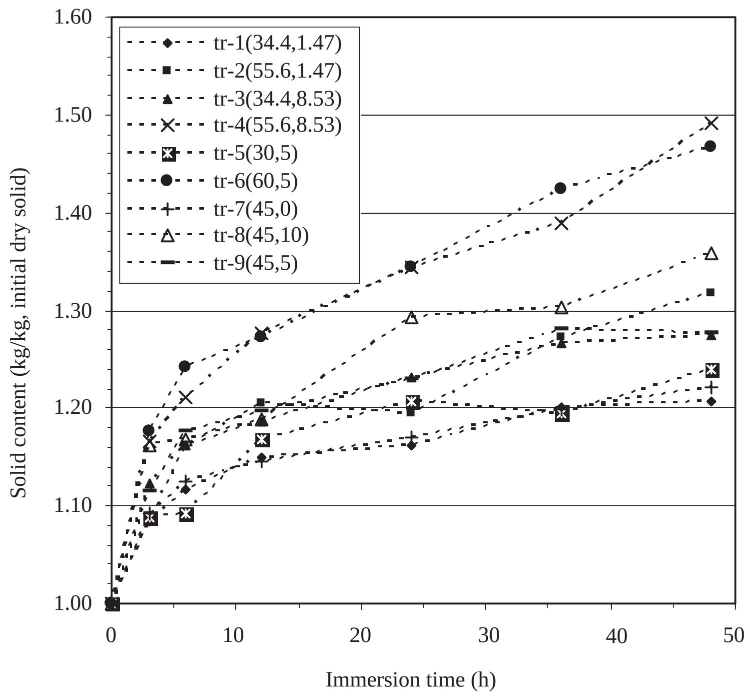

Figure 2 Change in solid content with time during osmotic treatment of whole fruit.

significantly higher score (P<0.05) for all attributes except texture. However, all mean organoleptic scores of treatment D were given more than 6. The condition of treatment D was selected for development of osmo-dehydrated product by impregnation soaking to reach the different solid contents (30, 35 and 40%) and drying in the microwave vacuum dryer. The results of the quality assessment and the organoleptic scores of dehydrated product were shown in table 4 and 5. It was found that the products made from the fresh fruit had a lowest firmness and the product made from 40% solid content of osmosed persimmon showed the highest firmness. This due to the

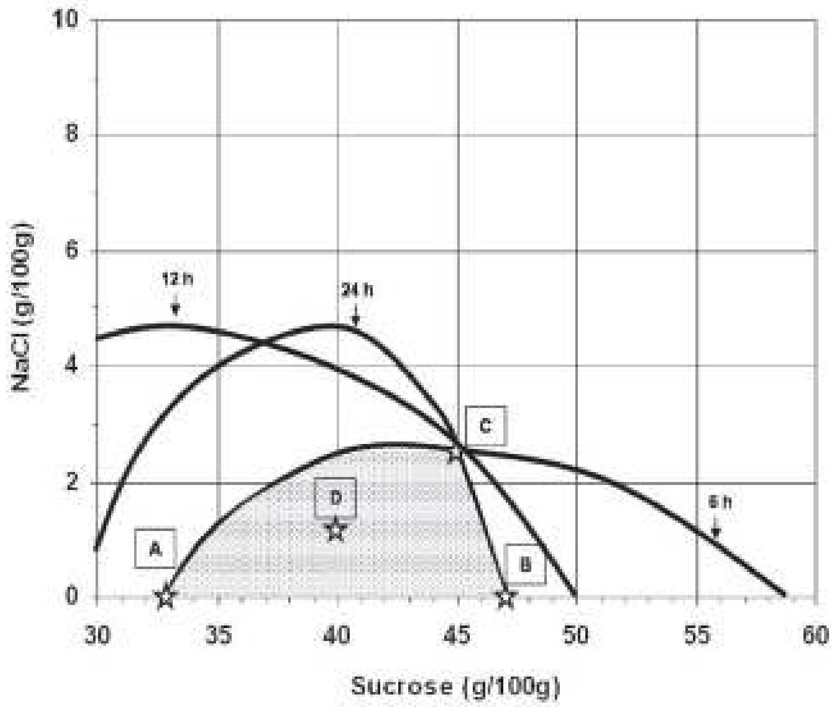

Figure 3 Super imposed contour plots showing the shaded overlapping area for *WL/SG* ≥8 of osmosed product.

Table 2 Optimum concentrations for 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 (kg/kg)	0.5273	0.8512	0.8139	0.6931
SG (kg/kg)	0.0558	0.0612	0.0535	0.0542
Experimental value				
WL (kg/kg)	0.5787	0.7733	0.8741	0.6227
SG (kg/kg)	0.0522	0.0669	0.0518	0.0528
E (%)	9.29(*WL*)	5.37(*SG*)		

mechanical behavior of plant tissue was affected during osmotic pretreatment affecting which caused the loss of cell turgor and alteration of cell wall. The quality in terms of color 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 activity of the osmo-dehydrated products were decreased to the range between 0.7 and 0.82 after microwave-vacuum dehydration and also the moisture content of the product made from osmosed samples were decrease to the range between 54% and 72%. However, the color likeness score were no significantly difference. The product that made from the 35% solid content osmosed sample got

Table 3 Organoleptic scores for quality attributes of osmosed product from optimum concentration solutions.

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

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

Table 4 Quality assessment of osmo-dehydrated product.

Solid content (%)	Firmness (N)	Color			a_w	Moisture content (%)
		L*	a*	b*		
30	17.2±0.4[c]	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	20.4±0.6[b]	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	25.4±0.3[a]	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]
23 (Fresh)	14.8±0.2[d]	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]

[abcd] Means in the same column with different letters are significantly different (*P*≤0.05)

Table 5 Organoleptic scores for quality attributes of osmo-dehydrated persimmon product.

Solid content (%)	Color [ns]	Taste	Flavor	Texture	Overall acceptability
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]
23 (Fresh)	6.26±0.18	7.19±0.19[a]	7.03±0.12[a]	4.51±0.13[b]	5.62±0.17[c]

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

[ns] Non significantly different (P>0.05)

the highest organoleptic scores in terms of taste, flavor, texture and overall acceptability. So that the best procedure of osmotic pretreatment was done by immersion the fruit in the osmotic solution containing of 40 g/100g of sucrose and 1 g/100g of NaCl for 12 h 45 min to reach 35% solid content. After osmotic pretreatment the fruit were microwave-vacuum dehydrated to attained the lower water activity of 0.75 for extended the shelf life. The microbial growths (aerobic plate count, yeast and moulds) in product stored at 5?C overcome the limit count (104-105 CFU/g) at 14 days. The results from the consumer acceptance test shown that the average likeness score of the osmo-dehydrated persimmon product was 6.01. The osmo-dehydrated product was accepted by 81% of consumers and 61% would consider purchasing it.

CONCLUSION

The study results for the mass transfer during osmotic treatment showed that the rates of weight reduction and water loss were much higher than the rate of solid gain during the osmotic processing. *WL/SG* determined in this study can be used as a constraint to optimise concentrations of the osmotic solutions for the osmotic dehydration step. It can use the osmotic as a pre-treatment step combined with microwave-vacuum dehydration to produce the value added osmo-dehydrated persimmon product.

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