KOREAN J. FOOD SCI. TECHNOL.
Vol. 22, No. 5, pp. 497~502 (1990)

Mass Transfer and Optimum Processing Conditions for Osmotic Concentration of Potatoes prior to Air Dehydration

Myung-Hwan Kim

Department of Food Engineering, Dankook University, Seoul

Abstract

The effect of sugar concentration, immersion time and temperature on water loss, solid gain or loss, and sugar molality of potatoes during osmotic concentration was analyzed by a response surface methodology (RSM), and those values were predicted by using a second degree polynomial regression model. Effect of osmotic concentration and blanching on vitamin C retention of air dried potatoes (6% MC: wet basis) was also evaluated. The most significant factor was sugar concentration for water loss, solid gain or loss, sugar molality, rate parameter and retention of vitamin C. Second and third factors were immersion time and temperature respectively. Water loss and solid gain were rapid in the first 10 min and then levelled off. A 44.6% of water loss was observed during osmotic concentration using a sugar solution (60 Brix, 80 °C) with 20 min of immersion time. Dried potatoes after osmotic concentration had higher vitamin C content than dried potatoes after blanching. Optimum regions for osmotic concentration process of potatoes were 60-70 °C of immersion temperature, 60 Brix of sugar solution and 16-20 min of immersion time based on above 30% of water loss and 50% of vitamin C retention.

Key words: potatoes, osmotic concentration, optimum regions, vitamin C retention

Introduction

Osmotic concentration is a water removal process which is based on placing foods in a concentrated osmotic solution or in a dry osmotic material. A driving force for water removal arises between solution and foods, in which the natural cell wall acts as a semi-permeable membrane. As the membrane is only partially selective, there is always some leakage of solute from the solution into the food and from the food into the solution.[1]

The quantity and the rate of water removal depend on several variables and processing parameters. In general, it has been shown that the water loss in osmosed foods is increased by increasing solute concentration of the osmotic solution, immersion time, temperature, solution/food ratio, specific surface area of the food and by using a low pressure system.[2-4]

Optimum conditions for osmotic concentration of potatoes would use a 50 Brix sugar solution at a solution/solid ratio of 4. Uptake of soluble solid during sucrose based osmotic concentration resulted in 75% of the soluble solid in the equilibrated potatoes coming from the sugar solution.[5,6]

Some of the stated adventages of direct osmosis in comparison with other drying processes include minimized heat damage to color and flavor, less discoloration of fruit by enzymatic oxidative browning and volatile retention during second drying step.[7-9]

The objectives of this study were to find important factors, develop predictive models and determine the optimum processing conditions for osmotic concentration process of potatoes using a response surface methodology (RSM).[10]

Materials and Methods

Materials

Potatoes (*Solanum tuberosum*) from the 1989 harvest were used. The moisture content of potatoes was 82.4% on a wet basis. The potatoes were manually peeled and sliced to 3 mm thickness using a food processor (Sunbeam, oskar). Commercial white sugar was obtained from a local supermarket as a osmotic agent.

Experimental design

In this study a three level, three factor design was adopted.[11] RSM designs were undertaken with immersion temperature (°C), sugar concentra-

Corresponding author: Myung-Hwan Kim, Department of Food Engineering, Dankook University, Cheonan, Chungnam, 330-714

tion (Brix) and immersion time (min). Observation were made on water loss, solid gain or loss, sugar molality and vitamin C content.

The regression coefficients (Ai) for the combined effects of the independant variables were estimated with second degree polynomial regression model using Stastical Analysis System (SAS).[10]

Where, independent variables, X_1, X_2 and X_3 were immersion temperature (°C), sugar concentration (Brix) and immersion time (min), respectively for water loss (g water/100g wet potatoes), solid gain or loss (g solid gain or loss/100g wet potatoes) and sugar molality (sugar moles/kg water).

Independent variables, X_2 and X_3 were changed for vitamin C (mg/100g potato solid).

Osmotic concentration

Approximately 100g of wet weight of potato slices were to a 1 liter beaker containing 400 m*l* of distilled water (0 Brix) or sugar solution (30 and 60 Brix), which was agitated and maintained at a constant temperature (60, 70 and 80°C) using a water bath for a desired length of immersion time (10, 15 and 20 min).

When the potato slices were removed from the sugar solutions, they were rinsed for a few seconds to remove excess sugar, placed on filter paper to remove excess water and weighed.

Air dehydration

Potatoes on a 0.5g/cm^2 tray load were dried at 70°C with a 3 m/s air velocity directly after blanching (0 Brix) or osmotic concentration (30 and 60 Brix) to a 6% moisture content (wet basis).

Moisture content

Moisture content was determined after drying potatoes using a vacuum oven (Yamato vacuum drying oven, DP-41) at 70°C and 27 in Hg. for 24 hr.

Vitamin C

Vitamin C was determined by modified AOAC methods[12] in which 2g of the sample is extracted with 100 m*l* of 2% (w/v) oxalic acid an aliquot of this extract is titrated with 2,6-dichlorophenol-indophenol.

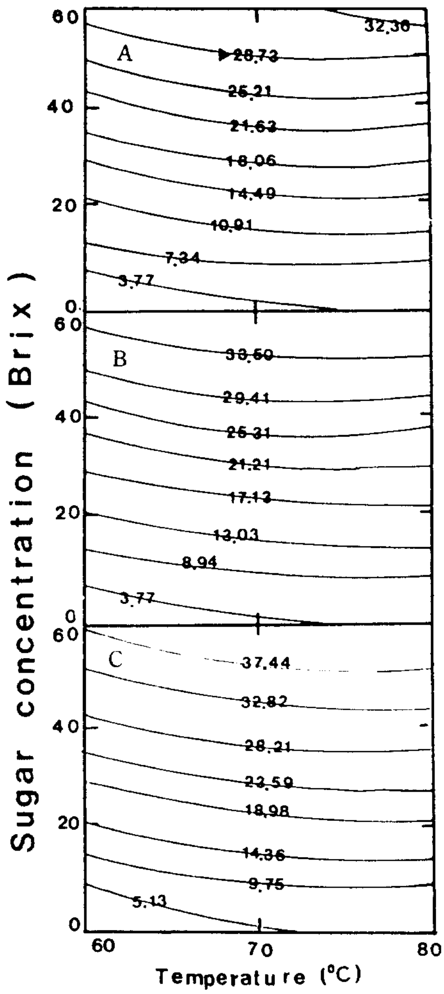

Fig. 1. Water loss as a function of immersion time and temperature, and concentration of sugar solution

A, B and C represent 10, 15 and 20 minutes of immersion time, respectively.

▶ g water loss/100g wet potatoes

Kinetics of osmotic concentration

Kinetics of osmotic concentration for water loss, solid gain or loss, sugar molality and parameter were calculated by previous studies.[13]

Results and Discussion

Effect of temperature, concentration and time on water loss

Fig. 1 shows that the effect of immersion tem-

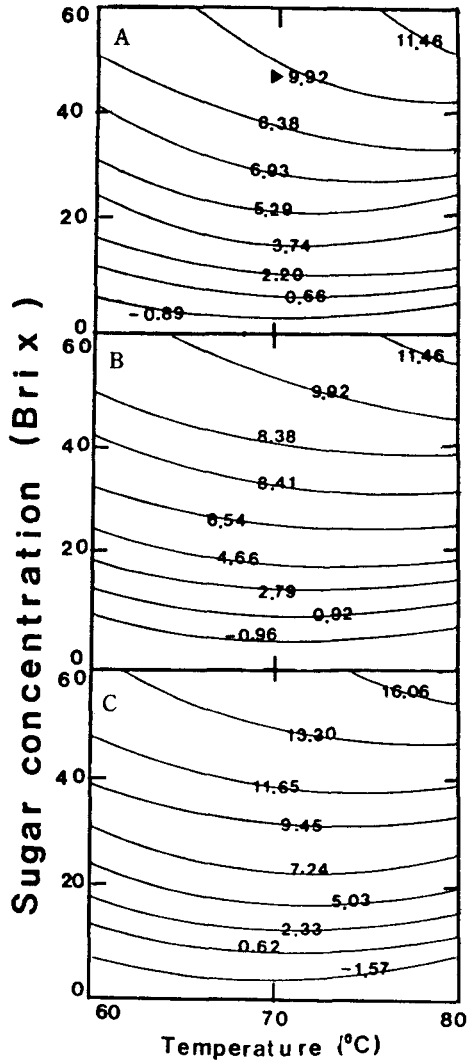

Fig. 2. Solid gain or loss as a function of immersion time and temperature, and concentration of sugar solution

A, B and C represent 10, 15 and 20 minutes of immersion time, respectively.

▶ g solid gain or loss/100g wet potatoes

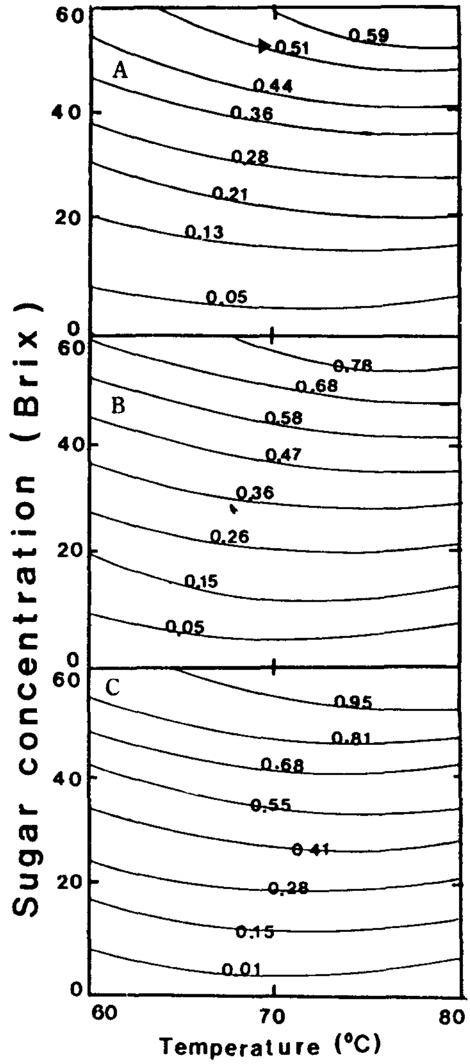

Fig. 3. Molality of sugar as a function of immersion time and temperature, and concentration of sugar solution

A, B and C represent 10, 15 and 20 minutes of immersion time, respectively.

▶ sugar moles/kg water

perature (60-80 °C), sugar concentration (0-60 Brix) and immersion time (10-20 min) on water loss. The effect of immersion temperature on water loss was not significant compared with sugar concentration. Water loss was rapid in the first 10 min and then levelled off.

Optimum regions of water loss, above 30% of water loss,[7] were 60-80% of immersion temperature, 50-60 Brix of sugar solution and 15-20 min of immersion time. Water loss was 44.67 after osmotic concentration using a sugar solution (60 Brix, 80 °C) with 20 min of immersion time.

Effect of temperature, concentration and time on solid gain or loss

The effect of immersion temperature (60-80 °C) on solid gain or loss was not significant compared to sugar concentration (0-60 Brix) as shown Fig. 2. Solid gain was also very early in the process and slowly there after.

Table 1. Rate parameter, K, as a function of concentration and temperature of sugar solution

		Immersion temperature		
		60 °C	70 °C	80 °C
Sugar	30 Brix	0.0688[a]	0.0965	0.1107
conc.	60 Brix	0.1939	0.2220	0.2535

[a] Sugar moles/kg water $min^{0.5}$

The initial region of the plots was attributed to the adsorption of sugar molecules on to the surface of the potato slices. In distilled water (0 Brix), water loss and solid loss were increased as the immersion temperature and immersion time increased as shown Fig. 1 and 2. Critical region of apparent solid gain or loss stopped, which was 6-8 Brix of sugar concentration.

Effect of temperature, concentration and time on sugar molality and rate parameter

Sugar molality was increased as the immersion temperature, sugar concentration and immersion time increased, which means water loss and sugar gain were increased as shown Fig. 3. The rate parameter, K, values were determined from the slopes of plots of sugar molality against square root of immersion time in minutes as shown Table 1.

The linearity of the plots ($0.971<r<0.996$) indicated that internal diffusion is the rate determining process.[13] Rate parameter, K, values were increased as the immersion temperature and sugar concentration increased.

Effect of temperature, concentration and time on vitamin C

Vitamin C levels were measured to compare the blanching (0 Brix) with osmotic concentration (30 and 60 Brix) after 70 °C air dehydration to a 6% (wet basis) moisture content as shown Fig. 4. Vitamin C loss of dried potatoes after blanching was increased as the immersion temperature and immersion time increased which occurred due to leaching during blanching, and vitamin C degradation during air dehydration steps in production of dehydrated potatoes compared to control (82.75 mg/100g potato solid).

Osmosis dried potatoes had higher vitamin C retention than dried potatoes after blanching. Vitamin C levels of dried potatoes after osmotic concentration were increased as the immersion time increased due to the solid gain. Optimum regions of vitamin C retention, above 50% of retention regions,[6] were 60-70°C of immersion temperature, 60 Brix of sugar solution and 16-20 min of immersion time.

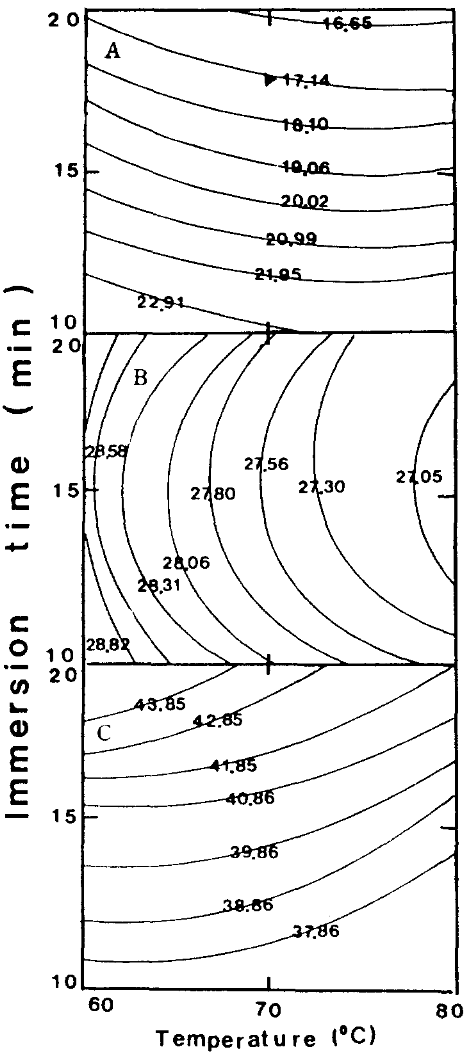

Fig. 4. Vitamin C as a function of immersion time and temperature, and concentration of sugar solution

A, B and C represent 0, 30 and 60 Brix of sugar concentration, respectively.

▶ mg/100g potato solid

Fitting the models and optimum processing regions

Equation (1) was fitted to the experimental data (Table 2) using SAS. Four models (Table 3) were

Table 2. RSM data points for water loss, solid gain or loss, sugar molality and vitamin C content of potatoes

Variables			Reaponse			
Immersion temp. (°C)	Sugar conc. (Brix)	Immersion time (min)	Water loss[a)]	Solid gain or loss[b)]	Sugar molality[c)]	Vitamin C[d)]
60	0	10	2.6905[e)]	-1.3671	—	25.2581
60	0	15	3.7030	-1.7238	—	22.0368
60	0	20	4.6518	-2.0286	—	20.8624
60	30	10	14.3021	4.8940	0.2047	27.8266
60	30	15	17.2340	6.4860	0.2767	26.5514
60	60	10	31.2674	9.5617	0.5174	41.2757
60	60	15	37.2213	12.1466	0.7520	42.1869
60	60	20	40.7337	13.6667	0.8838	47.5602
70	0	10	3.0867	-1.4384	—	23.4330
70	0	15	4.0257	-2.0629	—	21.7798
70	0	20	4.7836	-2.4029	—	19.2438
70	30	10	18.5899	6.9947	0.3073	31.0723
70	30	15	21.9480	8.4713	0.3882	27.9886
70	30	20	23.2112	9.1518	0.4218	23.2251
70	60	10	31.7903	10.5662	0.5974	31.5857
70	60	15	36.8558	13.0859	0.7774	39.7109
70	60	20	41.4146	15.4098	1.0632	47.7977
80	0	10	3.4898	-1.6343	—	19.8261
80	0	15	4.3124	-2.4951	—	18.4821
80	0	20	5.4646	-2.5944	—	15.8541
80	30	10	22.9146	8.4745	0.3899	34.4638
80	30	15	25.0013	9.4412	0.4499	29.9895
80	30	20	27.1465	9.7165	0.4750	27.7006
80	60	10	32.3297	11.3111	0.6322	35.4854
80	60	15	38.5634	15.2736	0.9633	36.3551
80	60	20	44.3614	17.0940	1.1752	43.0162

a)g water loss/100g wet potatoes b)g solid gain or loss/100g wet potatoes
c)sugar moles/kg water d)mg/100g potato solid e)Represented data were the mean values from three determinations.

Table 3. Regression coefficients of the second order polynomials for four response variables

Coefficient[a)]	Water loss[b)]	Solid gain or loss[b)]	Sugar molality[b)]	Vitamin C[c)]
A_0	-0.70741	-8.69082	-0.08245	56.28345
A_1	-0.10253	0.17706	0.00392	-0.53860
A_2	0.29141	0.06573	-0.01327	-1.24838
A_3	0.28817	0.16913	-0.00709	-0.16000
A_4	0.00135	-0.00132	-0.00005	0.00343
A_5	0.00106	0.00275	0.00017	-0.00064
A_6	-0.00042	-0.00252	0.00006	0.01876
A_7	0.00442	0.00094	0.00027	-0.00060
A_8	0.01416	0.00962	0.00076	0.02366
A_9	-0.01564	-0.01093	-0.00054	0.00296
R^2	0.98932	0.99424	0.98998	0.89382

a)These are coefficients of eq. (1).
b)Each independent variable, X_1, X_2 and X_3, represents immersion temperature, sugar concentration and immersion time, respectively.
c)Each independent variable, X_1, X_2 and X_3, represents immersion temperature, immersion time and sugar concentration, respectively.

obtained and tested to fittness by coefficients of determination, R^2, which almost approched to one. It means that equation (1) was highly fitted to the experimental data.

From these data, optimum regions for osmotic concentration process of potatoes were 60-70°C of immersion temperature, 60 Brix of sugar solution and 16-20 min of immersion time based on above 30% of water loss[7] and 50% of vitamin C retention.[6]

References

1. Lerici, C.R., Pinnavaia, G., Dalla Rosa, M. and Bartolucci, L.: Osmotic dehydration of fruit; Influence of osmotic agents on drying behavior and product quality. *J. Food Sci.*, **50**, 1217 (1985)
2. Hawkes, J. and Flink, J.M.: Osmotic concentration of fruit slices prior to freeze dehydration. *J. Food*

Proc. & Pres., **2**, 265 (1978)

3. Bolin, H.R., Huxsoll, C.C., Jackson, R. and NG, K.C.: Effect of osmotic agents and concentration of fruit quality. *J. Food Sci.*, **48**, 202 (1983)
4. Conway, J., Castaigen, F. and Vovan, X.: Mass transfer concentration in the osmotic dehydration of apples. *Can Inst. Food Sci. Technol.*, **16**, 25 (1984)
5. Lenaot, A. and Flink, J.N.: Osmotic concentration of potato; 1, Criteria for the end-point of the osmosis process. *J. Fd. Technol.*, **19**, 45 (1984)
6. Jslam, M.N. and Flink, J.N.: Dehydration of potato; 2, Osmotic concentration and its effect on air drying behavior. *J. Fd. Technol.*, **17**, 387 (1982)
7. Ponting, J.D.: Osmotic dehydration of fruits recent modifications and application. *Process Biochem.*, **12**, 18 (1973)
8. Dixon, G.M., Jen, J.J. and Paynter, V.A.: Tasty apples slices results from combined osmotic dehydration and vaccum drying process. *Food Prod. Dev.*, **10**, 60 (1976)
9. Menting, L.C., Hoogstad, B. and Thijssen, H.A.C.: Diffusion coefficients of water and organic volatiles in carbonate-water system. *J. Fd. Technol.*, **5**, 111 (1970)
10. S.A.S.: *SAS Users Guide: Stastics.*, 2nd ed., SAS Institute Inc., Cary, NC., p. 91 (1982)
11. Neter, J. and Wasserman, W.: *Applied Linear Statistical Models.*, Richard D. Irwin Inc., 111., p. 273 (1974)
12. A.O.A.C.: *Official Methods of Analysis*, 10th ed., Association of Official Analytical Chemists, Washington, D.C., p. 747 (1965)
13. Kim, M.H.: Mass transfer during osmotic dehydration of carrots and its effect on browning reaction. *Korean J. Food Sci. Technol.*, **21**, 307 (1989)

(Received Feb. 22, 1990)

열풍건조 전 감자의 삼투압농축시 물질이동과 공정의 최적화

김 명 환

단국대학교 식품공학과

삼투압 농축중 설탕용액의 농도와 온도 및 침지시간에 따른 감자내부의 수분손실, 고형분 증가나 손실 및 몰랄농도를 반응 표면 분석법으로 조사하였고, 이차 다항 회귀 모델로써 예측하였다. 또한 삼투압 농축과 데치기가 6% 수분(wet basis)까지 열풍건조시 비타민 C 함량유지에 미치는 효과를 평가하였다. 감자내부의 수분손실, 고형분 증가나 손실, 몰랄농도, 속도 매개변수 및 비타민 C 함량에 가장 크게 영향을 미치는 요소는 설탕농도이었고 그 다음 침지시간과 침지온도 순이었다. 수분손실과 설탕흡수는 초기 10분간 침지과정에서 빠르게 이루어진 후 증가현상이 둔화되었다. 설탕용액(60 Brix, 80℃)에서 20분간 침지 후 44.6%의 수분손실이 되었다. 삼투압 농축 후 건조시킨 감자가 데치기 한 후 건조시킨 감자보다 높은 비타민 C 함량을 유지하였다. 30% 이상의 수분손실과 50% 이상의 비타민 C 함량유지의 관점에서 삼투압 농축공정의 최적조건은 60-70℃의 침지온도와 60 Brix의 설탕농도 및 16-20분간의 침지시간이었다.