Optimization of Osmotic Dehydration Process of whole Aonla Fruit

Srishti Saxena[1], Amee Ravani[2], Sanjay Akbari[3], Dineshchandra Joshi[4]
[1, 2, 3, 4] Anand Agricultural University, Anand – 388110 (Gujarat), India

Abstract*- For optimization of osmotic dehydration process of whole Aonla fruit in sugar solution by response surface methodology, experiments were conducted according to Box and Behnken design. The process parameters for osmotic dehydration process were ultrasonication time, solution to fruit ratio, sugar syrup concentration and osmotic time. The optimum conditions for maximum mass reduction and water loss as well as minimum solid gain and ascorbic acid loss were 30 min ultrasonication time, 6:1 solution to fruit ratio, 58°Bx sugar syrup concentration and 50 h osmotic time.*

Keywords- Osmotic dehydration, aonla, response surface methodology, ultrasonication time.

I. INTRODUCTION

Aonla commonly known as Indian Gooseberry (Emblicaofficinalis.Gaertn syn. PhyllanthusemblicaL.), is an important fruit crop of India for its medicinal properties. Aonla is a rare example of an edible material, which is rich in tannins as well as ascorbic acid (Kalra, 1988). The vitamin C content in Aonla varies from 200-900mg/100g depending upon the variety and size of the fruit (Prajapatiet al., 2011). It is a potent antioxidant, hypolipidemic, antibacterial, antiviral and antacid. It is a very powerful anti-inflammatory herb. The fresh Aonla fruits are not popular as a table fruit due to their high astringency and its storability after harvesting is also limited due to its high perishable nature (Kumar and Nath, 1993).

New methodologies, such as ultrasound-assisted osmotic dehydration, have been implemented as an alternative pretreatment associated to drying procedures on several fruits and vegetables (Fernandes and Rodrigues, 2007 and Fuente-Blanco et al. 2006). Ultrasound has been recently studied and applied as a pretreatment to air drying and freeze drying and has shown to increase the mass transfer rate during drying (García-Pérez et al. 2009).

Combination of osmotic dehydration and ultrasound process can be applied as a non-thermal pretreatment for saving energy, ameliorating drying rate and minimizing product quality damage. Ultrasound power produces cavitations of bubbles, causes making microscopic channels, which leads to lower resistance to water diffusion and subsequently enhancing drying rate (Garcia-Perezaet al. 2007).Osmotic dehydration of whole Aonla is novel phenomena to keep the fruit intact after drying. The purpose of this study was to optimize the osmotic dehydration process of Aonla in salt solution by using response surface methodology and also to study the effect of osmotic process parameters (ultrasonication time, solution to fruit ratio, sugar syrup concentration and osmotic time) on quality responses (mass reduction, water loss, solid gain and ascorbic acid loss).

II. MATERIALS AND METHODS

A. Experimental design

Response Surface Methodology (RSM) is a collection of mathematical and statistical techniques that are useful for modeling and analysis of problems in which the response is influenced by several variables. It is reported to be an efficient tool for optimizing a process when the independent variables have the joint effect on the responses. Hence, response surface methodology was used to design the experiments. The Box- Behnken design of four variables and three levels each with three-center point combination was used (Box and Behnken, 1960). This design was taken as it fulfills most of the requirements needed for optimization of the pretreatment (osmotic dehydration) process prior to convective drying.

A second order Box-Behnken design was conducted to work out the range of osmotic process variables for osmotic drying of Aonla. The independent osmotic process variables and their levels in the form of coded variables for four-factor three level response surface analyses are given in Table1.

The low level and high level in the actual (un-coded) were 0-30 min, 4:1-8:1, 40-70°Bx and 24-72 h for ultrasonication time, solution to fruit ratio, sugar syrup concentration and osmotic time, respectively (Pant et al., 2002; Kumar et al., 2006; Singh et al., 2007; Goyalet al., 2007; Kumar and Sagar, 2009; Alam and Singh, 2010; Nayaket al., 2011;).

B. Sample Preparation

Fresh and good quality Indian Gooseberry (Aonla) fruits of cultivar Gujarat Aonla-II were procured from Horticultural Research Farm of Anand Agricultural University, Anand for the research work and fine crystalline food grade sugar was purchased from market was used for the experimental purpose. The initial moisture content of the fresh Aonla was 83.77 % (w.b).

Table1: Process variables and levels

Independent Variables	Symbol		Levels	
	Coded	Un-coded	Coded	Un-coded
			1	30
Ultrasonication time (min)	X_1	US	0	15
			-1	0
			1	8:1
Solution to fruit ratio	X_2	STFR	0	6:1
			-1	4:1
			1	70
Sugar syrup concentration (°B)	X_3	SSC	0	55
			-1	40
			1	72
Osmotic Time (h)	X_4	OT	0	48
			-1	24

C. Osmotic Dehydration

Selected fruits were thoroughly washed under tap water to remove adhering impurities The Aonla fruits were blanched in boiling water under pressure to inactivate the enzymes with 1:5 ratio of fruit to water(Singh et al., 2007).The blanched Aonla fruits were subjected to ultrasound treatment in ultrasonic bath (Make: Life-Care Equipments Pvt. Ltd, Mumbai) without mechanical agitation at operation frequency of 33 Khz and 120 W power output. An experimental set up of 100 g sample was immersed in distilled water and subjected to ultrasound waves for 0-30 minutes. The experiments with ultra sound treatment were carried out in separate 500 ml Erlenmeyer flask to avoid interference between the samples and runs. After removal from distilled water, the ultrasound treated samples were drained and blotted with absorbent paper to remove the excess water. Then the samples were transferred to osmotic solution, for the specified time. The osmotic solution used in each experiment was prepared by mixing food-grade sugar with distilled water to give the desired concentration. After removal from the osmotic solution, the osmotically pretreated samples were drained and blotted with absorbent paper to remove the excess solution. Weight and moisture content were measured individually to calculate the response variables of the experimental planning.

D. Water loss, mass reduction and solid gain during osmotic dehydration

The mass transfer parameters i.e. water loss (WL), mass reduction (MR) and solid gain (SG) were calculated by the following equations (Lenart and Flink; 1984).

$$WL = \frac{W_i . X_i - W_\Theta X_\Theta}{W_i}$$

$$MR = \frac{W_i - W_\Theta}{W_i}$$

$$SG = \frac{W_\Theta(1-X_\Theta) - W_i(1-X_i)}{W_i} \times 100$$

W_Θ= Mass of slices after time θ, g
W_i= Initial mass of slices, g
X_Θ= Water content as a fraction of mass of slices at time θ
X_i= Water content as a fraction of initial mass, fraction

From above equations, the solid gain (SG) can be correlated with mass reduction(MR) and water loss (WL) as,

$$SG \text{ (solid gain, g per 100g mass sample)} = WL - MR$$

E. Ascorbic acid loss

Ascorbic acid loss (AAL) was calculated by the following equation:

$$\%AAL = \frac{AA_1 - AA_2}{AA_1} \times 100$$

Where,

AA_1= Initial ascorbic acid of fresh Aonla
AA_2= Final ascorbic acid after osmotic time

F. Optimization of osmotic process parameters

Response surface methodology was applied to the experimental data using a commercial statistical package, Design Expert 7.1.2 (StateaseInc., Minneapolis, USA, Trial version). The same software was used for the generation of response surface plots, superimposition of contour plots and optimization of process variables. Such three-dimensional surfaces could give accurate geometrical representation and provide useful information about the behavior of the system within the experimental design (Cox and Cochran, 1964). The optimization of the osmoticdehydration process aimed at the levels of independent variables viz. ultrasonication time, solution to fruit ratio, sugar syrup concentration and osmotic time, which could give maximum possible mass reduction (MR) and water loss (WL); and lowest solid gain (SG) and ascorbic acid loss (AAL).

III. RESULTS AND DISCUSSION

Optimization of osmotic dehydration parameters; ultrasonication time (UT), sugar syrup concentration (SSC), solution to fruit ratio (STFR) and duration of osmotic dehydration (OD) as pretreatment was carried out. The experiments for optimization for osmotic dehydration of Aonla were conducted as per the experimental design and responses were collected which are given in Table 2.It was observed that mass reduction, water loss, solid gain and vitamin C loss ranged from 4.46 to 17.77 %, 30.06 to 50.32 %, 19.22 to 37.78 % and 60.80 to 70.81 %, respectively.

Effect of process variables on mass reduction

The maximum mass reduction i.e., 17.77 % was observed for experimental condition of 30 min ultrasonication time; 6:1 solution to fruit ratio, 55 °Brix sugar syrup concentration for 72 h osmotic time. It was observed that ultrasonication and sugar syrup concentration had highly significant ($p<0.01$) effect on mass reduction of Aonla. While, osmotic time was significant ($p<0.05$) for its effect on mass reduction and there was non-significant effect of solution to fruit ratio on mass reduction. The quadratic term, SSC^2 had highly significant ($p<0.01$) effect and $STFR^2$ had significant ($p<0.05$) effect, and UT^2 and OT^2 on mass reduction of Aonla were found to be non-significant. The quadratic model developed in the uncoded form of process variables is:

$$\text{Mass Reduction (\%)} = 14.94 + 1.78 \times UT + 2.18 \times SSC + 1.26 \times OT - 4.13 \times UT \times SSC - 2.07 \times STFR^2 - 3.84 \times SSC^2 \quad (R^2 = 0.8689)$$

Table 2: Variables and responses for optimization of different pretreatments for osmotic dehydration of whole Aonla

No.	Variables				Responses			
	UT (min)	STFR	SSC (°Brix)	OT (h)	MR (%)	WL (%)	SG (%)	AAL (%)
1	0.0	6.0	55.0	72.0	12.61	45.68	33.08	65.21
2	0.0	4.0	55.0	48.0	5.83	36.35	30.53	64.95
3	15.0	4.0	70.0	48.0	8.90	39.72	30.81	69.06
4	0.0	8.0	55.0	48.0	12.36	38.31	25.95	65.21
5	0.0	6.0	55.0	24.0	9.88	32.11	22.23	64.59
6	15.0	4.0	40.0	48.0	5.68	34.39	28.72	60.80
7	30.0	6.0	40.0	48.0	4.46	33.34	28.89	62.39
8	15.0	6.0	55.0	48.0	15.51	39.18	23.67	64.93
9	15.0	6.0	70.0	72.0	14.43	46.76	32.33	70.81
10	15.0	8.0	55.0	72.0	15.27	50.32	35.05	66.01
11	15.0	6.0	40.0	72.0	11.13	47.46	36.33	62.79
12	15.0	6.0	40.0	24.0	4.54	30.05	25.52	60.81
13	15.0	6.0	55.0	48.0	14.56	41.59	27.04	65.19
14	30.0	6.0	55.0	24.0	14.30	33.52	19.22	63.78
15	15.0	6.0	55.0	48.0	15.79	40.83	25.04	64.40
16	30.0	4.0	55.0	48.0	15.49	39.55	24.06	64.76
17	0.0	6.0	40.0	48.0	13.40	38.52	25.12	61.74
18	0.0	6.0	70.0	48.0	8.21	32.65	24.44	68.86
19	15.0	6.0	70.0	24.0	15.16	35.69	20.53	68.42
20	30.0	6.0	70.0	48.0	15.77	42.71	26.95	69.16
21	30.0	8.0	55.0	48.0	15.89	40.06	24.17	64.85
22	15.0	8.0	40.0	48.0	8.47	35.28	26.81	62.20

23	30.0	6.0	55.0	72.0	17.77	48.94	31.17	65.57
24	15.0	6.0	55.0	48.0	13.10	37.90	24.80	64.93
25	15.0	4.0	55.0	24.0	12.74	35.89	23.15	63.37
26	15.0	4.0	55.0	72.0	12.09	49.87	37.78	66.06
27	15.0	8.0	70.0	48.0	11.35	37.98	26.63	69.34
28	15.0	6.0	55.0	48.0	15.72	40.17	24.45	64.99
29	15.0	8.0	55.0	24.0	11.55	34.47	22.92	63.52

The effect of sugar syrup concentration and osmotic time on mass reduction is shown in Fig1. It can be seen from the graphical presentation that with increase in sugar syrup concentration, the mass reduction increased and it remains almost constant with the change in osmotic time.

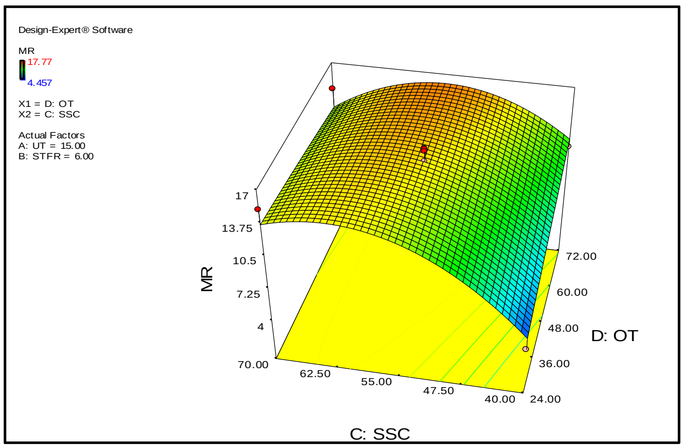

Fig 1: Effect of sugar syrup concentration and osmotic time on mass reduction at 15 min ultrasonication and 6 solution to fruit ratio

Effect of process variables on water loss

The maximum water loss i.e., 50.32 % was observed for experimental condition of 15 min ultrsonication time, 8:1 solution to fruit ratio, 55 ° Brix sugar syrup concentration for 72 h osmotic time. It was observed that effect of ultrasonication, osmotic time and sugar syrup concentration had highly significant ($p<0.01$) on water loss of Aonla. The quadratic term UT^2, SSC^2 and OT^2 had highly significant ($p<0.01$) effect on water loss of Aonla. The quadratic model developed in the uncoded form of process variables is:

$$\text{Water Loss (\%)} = 39.94 + 1.21 \times UT + 1.37 \times SSC + 7.27 \times OT + 3.81 \times UT \times SSC - 1.58 \times SSC \times OT - 1.40 \times UT^2 - 2.30 \times SSC^2 + 2.23 \times OT^2 \quad (R^2 = 0.9770)$$

It can be seen from Fig. 2 that with increase in sugar syrup concentration, the water loss also increased, while drastically increase in water loss with increase in osmotic time. This may be due to more time of interaction between the fruit and the solution, thus, more water loss can occur through that tissues pores.

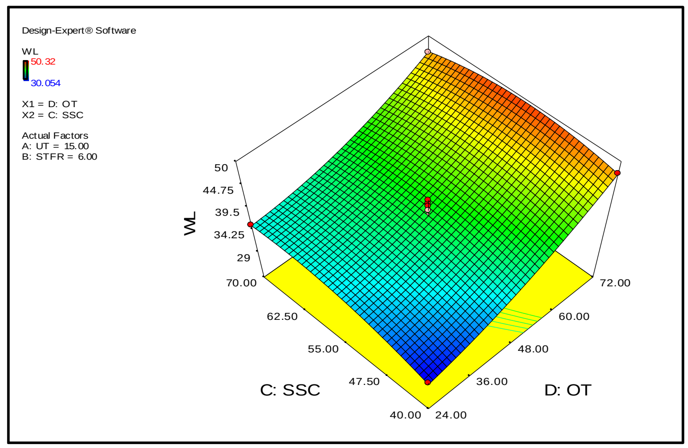

Fig 2: Effect of sugar syrup concentration and osmotic time on water loss at 15 min ultrasonication time and 6 solution to fruit ratio

Effect of process variables on solid gain

The minimum of solid gain i.e., 19.22 % was observed for experimental condition of 30 min ultrasonication time, 6:1 solution to fruit ratio, 55 °Brix sugar syrup concentration for 24 h osmotic time. It was observed that osmotic time had highly significant ($p<0.01$) effect on solid gain of sample and quadratic term $STFR^2$ and OT^2 had significant ($p<0.05$) effect on solid gain of Aonla. The quadratic model developed in the uncoded form of process variables is:

$$\text{Solid Gain (\%)} = 25.00 + 6.01 \times OT + 1.97 \times STFR^2 + 2.32 \times OT^2 \quad (R^2 = 0.9053)$$

It can be seen that with increase in osmotic time, the solid gain increased and it remains constant with change in ultrasonication time (Fig 3).This can be as with the increase in osmotic time, provided more time for the solid transfer to occur and thus, solid gain increases. Similar results were reported by Alam and Singh (2010) that sugar syrup concentration, temperature and steeping time had positive effect on solid gain values.

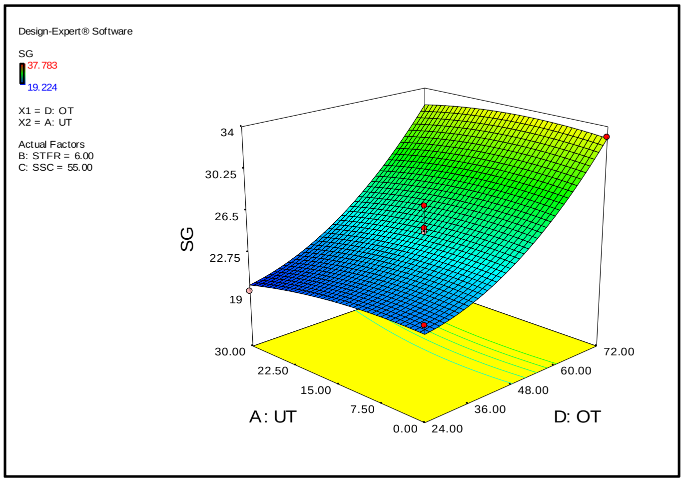

Fig 3: Effect of ultrasonication time and osmotic time on solid gain at 6 solution to fruit ratio and 55 sugar syrup concentration

Effect of process variables on ascorbic acid loss

The ascorbic acid loss was found to be significantly affected by sugar syrup concentration, osmotic time ($p<0.01$) and quadratic terms of sugar syrup concentration ($p<0.01$). The quadratic model developed in the uncoded form of process variables is:

Ascorbic acid loss (%)= 64.89 + 3.74 x SSC + 1.00 x OT + 0.68 x SSC^2 (R^2= 0.9851)

From graphical presentation (Fig 4), it can be seen that with increase in osmotic time, ascorbic acid loss also increased, while it was almost stable with increase in ultrasonication time. Alam and Singh (2010) reported that vitamin C loss increased with increase in sugar syrup concentration and osmotic time.

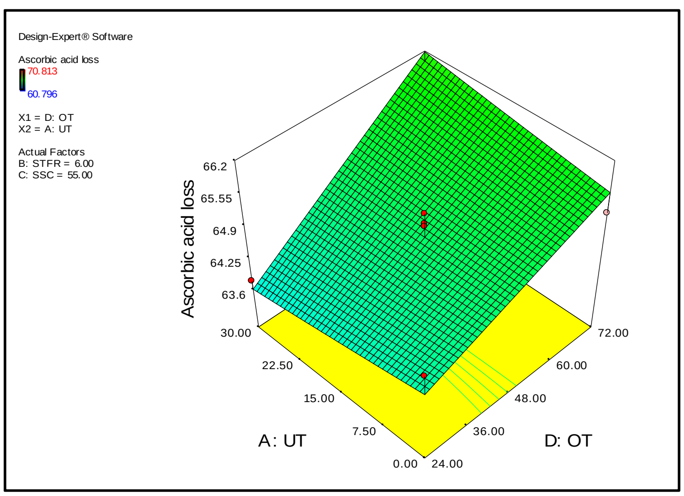

Fig 4: Effect of ultrasonication time and osmotic time on ascorbic acid loss at 6 solution to fruit ratio and 55 sugar syrup concentration

IV. CONCLUSION

Optimized osmotic dehydration process parameters of whole Aonla fruit was found at 30 min ultrasonication time, 58º Brix of sugar syrup, 6:1 solution to fruit ratio and 50 h osmotic time for the maximum mass reduction and water loss as well as minimum solid gain and ascorbic acid loss. The solution was found having mass reduction 17.11%, water loss 41.41%, solid gain 24.29% and vitamin C loss 65.73%.

AUTHOR'S CONTRIBUTION

Srishti Saxena conducted experiments. Amee Ravani guided the overall experimental design. Sanjay Akbarihelped in statistical analysis. Dineshchandra Joshi is Unit head and arranged funding and sources as well as throughout guidance during experimentation.

REFERENCES

[1] Alam M.S. and A. Singh. 2010. Optimization of osmotic dehydration process of aonla fruit in salt solution. International Journal of Food Engineering. 6(1): 4-24.

[2] Box G.E. and D.W. Behnken. 1960. Some new three level designs for the study of quantitative variables. Technometrics. 2(4): 455-475.

[3] Cox, G.M. and W.G. Cochran. 1964. Experimental designs. New York: John Wiley & Sons, Inc.

[4] Fernandes F.A.N. and S. Rodrigues. 2007. Use of ultrasound as pretreatment for drying of fruits: Dehydration of banana. Journal of Food Engineering. 82: 261–267.

[5] Fuente-Blanco S., E.R.F.Sarabia, V.M.Acosta-Aparicio, A.Blanco-Blanco and J.A.Gallego-Juárez. 2006. Food drying process by power ultrasound. Ultrasonics Sonochemistry. 44: 523–527.

[6] García-Pérez J.V., J.A.Cárcel, E.Riera and A. Mulet. 2009. Influence of the applied acoustic energy on the drying of carrots and lemon peel. Drying Technology. 27: 281–287.

[7] Garcia-Pereza J.V., J.A.Carcela, J.Beneditoa and A.Mulet. 2007. Power ultrasound mass transfer enhancement in food drying. Food and Bioproducts Processing. 85: 247–254.

[8] Goyal R.K., A. R. P. Kingsly, P. Kumar and H. Walia.2007. Osmotic dehydration of aonla. In:

proceedings of the fifth Asia-Pacific drying conference. Hong-Kong.

[9] Kalra C.L. 1988. The chemistry and technology of aonla (Phyllanthusemblica L.)-A Review. Indian Food Packer. 42(4): 678-682.

[10] Kumar P.S. and V.R.Sagar. 2009. Effect of osmosis on chemical parameters and sensory attributes of mango, guava slices and aonla segments. Indian Journal of Horticulture. 66(1): 53-57.

[11] Kumar P. S., V. S. Sagar and U. Singh. 2006. Effect of tray load on drying characteristics of mango, guava and aonla. Journal of Scientific and Industrial Research. 65: 659-664.

[12] Kumar S. and V. Nath. 1993. Storage stability of amla fruits: a comparative study of zero energy cool chamber versus room temperature. Journal of Food Science and Technology. 30: 202-203.

[13] Lenart A. and J.M.Flink.1984. Osmotic concentration of potato, I. Criteria for the end point of the osmotic process. Journal of Food Technology. 19:45-63.

[14] Nayak P., D.K.Bhatt, D.K.Shukla and D.K.Tandon. 2011. Evaluation of aonla (phyllanthusemblica g.) segments-insyrup prepared from stored fruits. Research Journal of Agricultural Science. 43(2): 252-257.

[15] Pant K., S.S.Dhawanand H.Kalsi. 2002. Evaluation of pre-drying treatments for dehydration of aonla. Department of Horticulture. CCSHAU.Hisar.

[16] Prajapati V.K., P.K.Nema and S.S.Rathore. 2011. Effect of pretreatment and drying methods on quality of value-added dried aonla (EmblicaofficinalisGaertn) shreds. Journal of Food Science and Technology. 48(1): 45-52.

[17] Singh N., A. Saini and A. K. Gupta. 2007. Nutritional quality of osmotically dehydrated aonla (emblicaOfficinalis) fruit segments. Indian Journal of Agricultural Biochemistry. 20(2): 89-91.