Studies on Osmotic Dehydration of Beetroot (*Beta vulgaris*)

Wungshim Zimik[1], Chitrasen Lairenjam[2*], Manda Devi Ningthoujam[1], Grace Nengzouzam[1], Mary N Odyuo[3], Lamneithem Hangshing[4]

[1]*Department of Agricultural Engineering and Technology, School of Engineering and Technology, Nagaland University, India*

[2*]*Department of Agricultural Engineering,*

[3]*Associate professor, Department of Agricultural Extension, School of Agricultural Sciences, Nagaland University, India*

[4]*Department of Agricultural Engineering, Pali Shiksha Bhavana, Visva-Bharati, Santiniketan, West Bengal, India*

Corresponding Author: Chitrasen Lairenjam

Abstract

The study investigated the effect of osmotic dehydration parameters on moisture content, bulk density, weight reduction and solute gain of beetroot (*Beta vulgaris*). Fresh, well matured and firm beetroots procured from Dhobinalla grocery market, Dimapur, Nagaland, were osmotically dehydrated using sugar solution concentration (40, 50 and 60 %), temperature (50, 60 and 70^{o}C), and time (60, 120 and 180 min). Fruit to sugar solution concentration ratio (1:10) was kept constant for all the experiments. The osmotic dehydration process was optimized for moisture content, bulk density, weight reduction and solute gain. The optimum values of sugar solution concentration, temperature and time were 60%, 50^{o}C and 120 min respectively. The desirability optimized parameters with various responses were found to be 0.910 (91.00%). The result obtained showed that the highest moisture content was at 60 ^{0}C temperature, 40% concentration and time 60 min with a value of 155.89 % (db), bulk density at 60°C temperature, 60% concentration and time 180 min with a value of 1.43 gm/ml, weight reduction at 60°C temperature, 60% concentration and time 60 min with a value of 61.745 gm/ml and solute gain at 70°C temperature, 60% concentration and time 120 min with a value of 40.78 gm/ml respectively. A Design Expert trial version 8.0.7.1 was employed for the experimental design and statistical analysis. A Box-Behnken design was used for the data analysis.

Keywords: Beetroot; osmotic dehydration; Response Surface Methodology

Introduction

Beetroot (*Beta vulgaris*) is a versatile winter root vegetable which is grown for their edible taproots. The usually deep red roots of beetroot are eaten raw, cooked, or powdered for its health benefits and vibrant color. They are also a rich source of valuable helpful active plants compounds such as betacyanins, folates, Glycine betaine, Betanin, polyphenols, flavonoids, saponins and carotenoids (Patkai *et al.,* 1997; Jastrebova et al., 2003; de Zwartet *et al.,* 2003; Atamanova *et al.,* 2005; Dias *et al*., 2009). Therefore, beetroot is packed with high nutrition values and the consumption of it can be considered a factor in cancer prevention (Kapadia *et al.,* 1996). Betanin, obtained from the roots, is used industrially as red food colorants to improve the colour and flavour of tomato paste, sauces, jams, jellies etc. Beetroot is grown all over the world in temperate areas for its high health benefts. In India, Karnataka annually produces over 41,000 tonnes of beetroot on a crop area of 2,400 hectares (Anonymous 2014). In Nagaland, beetroot is produced at Tuensang, Zunheboto and higher areas of Mokokchung.

Osmotic dehydration is a partial drying technology for foods with high water content (Cornillon, 2000). Osmotic dehydration (OD) can be considered as an important stepprior to drying, since it provides a reduction in nutrient losses and an improvement in product quality (Mandala *et al.,* 2005; Riva *et al.,* 2005), besides promoting energy saving. The shelf life quality of the final product is better than without such treatment dueto the increase in sugar/acid ratio, the improvement in texture and the stability of the colour pigment during storage (Lombard *et al.*, 2007).

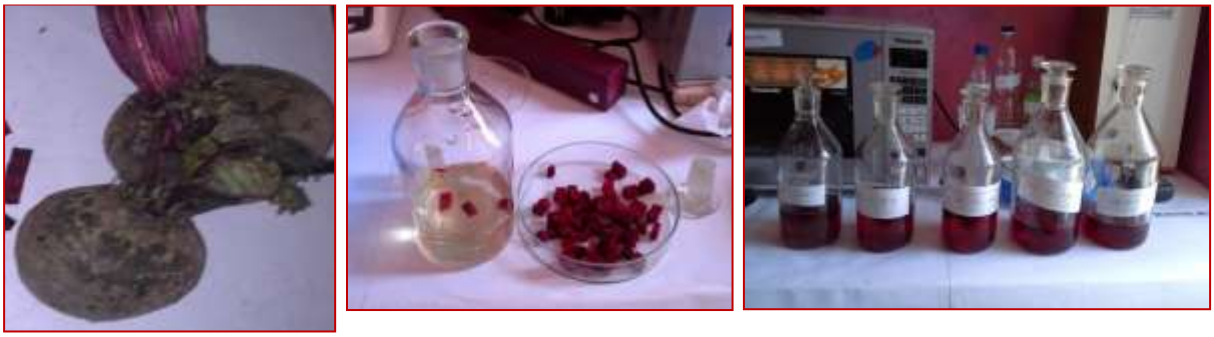
Osmotic dehydration is an efficient preservation technology in the food industry. Many researchers have reported the importance and advantages of the osmotic dehydration method as compared to any other drying method. It helps in the minimization of thermal damage, prevention of enzymatic browning, and preservation of higher nutritional contents during subsequent air drying (Raoult-Wack; 1994: Khin *et al.*, 2005). Farmers can adopt osmotic dehydration methods for preserving their produce without losing the nutritional properties. Sun drying can also be done after the osmotic dehydration which will help in reducing the use of electrical appliances. Hence the present study has been taken to study the effect of osmotic dehydration on the quality parametersof the locally available beetroot of Dimapur Market, Nagaland.

Materials and Methods

Fresh, well matured and firm beetroots (*Beta vulgaris*) were procured from Dhobinalla grocery market, Dimapur, Nagaland, Imdia for the experiment (Fig. 1(a)) The experimental work was carried out in the departmental laboratory. Sugars used for the preparation of osmotic solutions were also purchased from the local market.

Preparation of samples

The skins of beetroots were peeled manually and cut into a size of 10mm * 5mm * 5mm (l*b*t) by using a sharp knife. During the osmotic treatment, beetroot samples (40 g) were submerged in an osmotic solution filled in the beakers (Fig. 1(b and c)). In order to avoid dilution of osmotic solution and subsequent decrease of driving force for osmotic dehydration, the weight ratio between the sample and osmotic solution was kept as 1:10 (Saputra, 2001). For each of the experiments, fresh osmotic solutions were used. At each sampling time sample were taken out and the samples were drained and gently blotted with adsorbent paper and weighed. All experiments were done in replications.



(a) Beetroot sample (b) Osmotic dehydration of sample

 https://doi.org/10.5281/zenodo.13902492

(c) Osmotic sample

Fig. 1: Preparation of sample for osmotic dehydration

Analysis of Quality Parameters

Estimation of Moisture content

40gm of beetroot sample was accurately weighed into a Petri-dish. Moisture and dry matter content of the samples was determined by drying at 110 ^{o}C for 16 hr (AOAC, 2000) in an oven. The moisture content was calculated from the loss of mass after 16h drying on dry basis.

$$M = \frac{w-d}{d} X\ 100$$

Where, M = Moisture content in dry basis

w = total weight

d = dry weight

Estimation of Bulk density

20ml of distilled water was filled in 100-ml cylinder and 5gm of beetroot sample (after osmotic dehydration) was dipped into the cylinder. The initial and final volume was then taken to calculate the bulk density. The bulk density was calculated as the weight of the sample divided by the volume and expressed in grams per mille litre (gm/ml).

Estimation of Weight reduction

Weight reduction (WR) was expressed based on initial mass of sample and massof the sample after osmotic dehydration (Le Marguer, 1988).

$$WR\ (\%) = \frac{Mo-M}{Mo} \times 100$$

Where, Mo = initial mass of the sample (g)

M = mass of the sample after dehydration (g)

Estimation of Solute gain

Solute gain (SG) was calculated as the net uptake of solids by osmosis sample based on initial sample weight (Le Marguer, 1988)

$$SG\ (\%) = \frac{St-So}{W0} \times 100$$

Where, W_0= initial weight of beetroot (g)

S_o= initial weight of solid (dry matter) beetroot

S_t= weight of solid after osmotic dehydration (dry matter)

 https://doi.org/10.5281/zenodo.13902492

Experimental design

The experimental design and statistical analysis were performed by using design expert 8.0.7.1 trial version. A Box-Behnken design was used for the data analysis. The effect of independent variable temperature (50, 60, 70ºC), concentration (40, 50, 60 %), and time (60, 120, 180 min) on responses parameter namely moisture content, bulk density, weight reduction and solute gain were evaluated. The Box-Behnken designconsists of 3 centre points.

$$y_k = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \beta_{ij} x_i x_j$$

Where, y_k is the response variable; β_o, β_i, β_{ii} and β_{ij} are regression coefficients for interception, linear, quadratic and interaction terms respectively; x_i and x_j represent the independent variables.

$2^{(\text{no. of independent variables})}$ + (2 * no. of independent variables + no. of central points)

For three variables, Total number of experiments = 2^3+ 2 * 3 + 3 = 17. The experiment was conducted according to the requirement of response surface methodology. The above equation is used for optimizing the number of experiments theoretically. Optimization of the number of experiment with varying independent variables done by using the design expert software is given in Table 1 below. From the table, we can see that the total number of experiments to be carried out after optimizing is found to be 17.

Table 1: Optimization of the number of experiments

Run	Temperature (^{0}C)	Concentration (%)	Time (min)
1	50	50	180
2	60	40	180
3	60	60	60
4	60	50	120
5	70	50	60
6	50	50	60
7	60	40	60
8	60	50	120
9	60	50	120
10	50	40	120
11	60	60	180
12	70	50	180
13	60	50	120
14	50	60	120
15	70	60	120
16	60	50	120
17	70	40	120

Statistical analysis

Quadratic model was used to determine the Analysis of Variance (ANOVA) for different responses. The Fisher F-test with a very low probability value (prob > F) demonstrates a very high significance for the quadratic model. The values of "prob > F" less than 0.0500 indicate model terms are significant. The goodness of fit of the model is checked by the determination

 https://doi.org/10.5281/zenodo.13902492

coefficient (R^2). If the model was adequate, then the effects of independent variables on responses were interpreted. Design-Expert 8.0.7.1 software was used for the study of the effect of osmotic dehydration on the quality parameters of beetroot.

Results and Discussions

For the osmotic dehydration of beetroot, the levels of temperature, concentration and time were optimized. The different responses i.e. moisture content, bulk density, weight reduction and solute gain for the independent variables have been shown in Table 2 below.

Table 2: Responses for the optimization

	Factor 1	Factor 2	Factor 3	Response 1	Response 2	Response 3	Response 4
Run	A= Temperature(ºC)	B= Concentration(%)	C= Time (min)	Moisture Content (%db)	Bulk Density (gm/ml)	Weight reduction(%)	Solute Gain (%)
1	70	60	120	85.17	1.26	55.069	40.78
2	70	50	180	50.79	1.27	44.825	37.14
3	70	50	60	104.93	1.03	49.621	25.37
4	70	40	120	102.68	1.23	44.391	25.70
5	60	60	180	88.32	1.43	56.075	29.70
6	60	60	60	54.39	1.26	61.745	39.61
7	60	50	120	84.27	1.25	52.926	26.82
8	60	50	120	84.27	1.25	52.926	26.82
9	60	50	120	84.27	1.25	52.926	26.82
10	60	50	120	84.27	1.25	52.926	26.82
11	60	50	120	84.27	1.25	52.926	26.82
12	60	40	180	119.33	1.11	45.037	20.45
13	60	40	60	155.89	1.26	42.732	16.61
14	50	60	120	62.71	1.33	59.421	34.89
15	50	50	180	80.12	1.27	55.780	29.75
16	50	50	60	99.93	1.27	47.364	24.60
17	50	40	120	129.62	1.02	42.842	20.70

Effect of temperature, concentration and osmotic time on moisture content

From the data obtained in table 2, it was observed that for the temperature at 50°C, concentration of 40-60% and osmotic time from 60 to 180 min, the moisture content was observed to be in between 62.71-129.62 (% db). For temperature 60°C, the moisture content was in the range of 54.39-155.89 (% db). For temperature of 70ºC, the moisture content was in the range of 50.79-104.93 (% db). The temperature; concentration and time relationship for moisture content are shown in Fig. 4.16.

The equation of the model fitted for moisture content in actual form of process variables after elimination of non-significant terms at 5% level of significance is shown below:

Moisture Content = + 938.22625 + 1.04038 * Temperature - 29.30362 * Concentration
- 1.07350 * Time + 0.12350 * Temperature * Concentration -

 https://doi.org/10.5281/zenodo.13902492

$$0.014304 * \text{Temperature} * \text{Time} + 0.029371 * \text{Concentration} * \text{Time} - 0.048825 * \text{Temperature}^2 + 0.15657 * \text{Concentration}^2 + 1.26528\text{E-}003 * \text{Time}^2$$

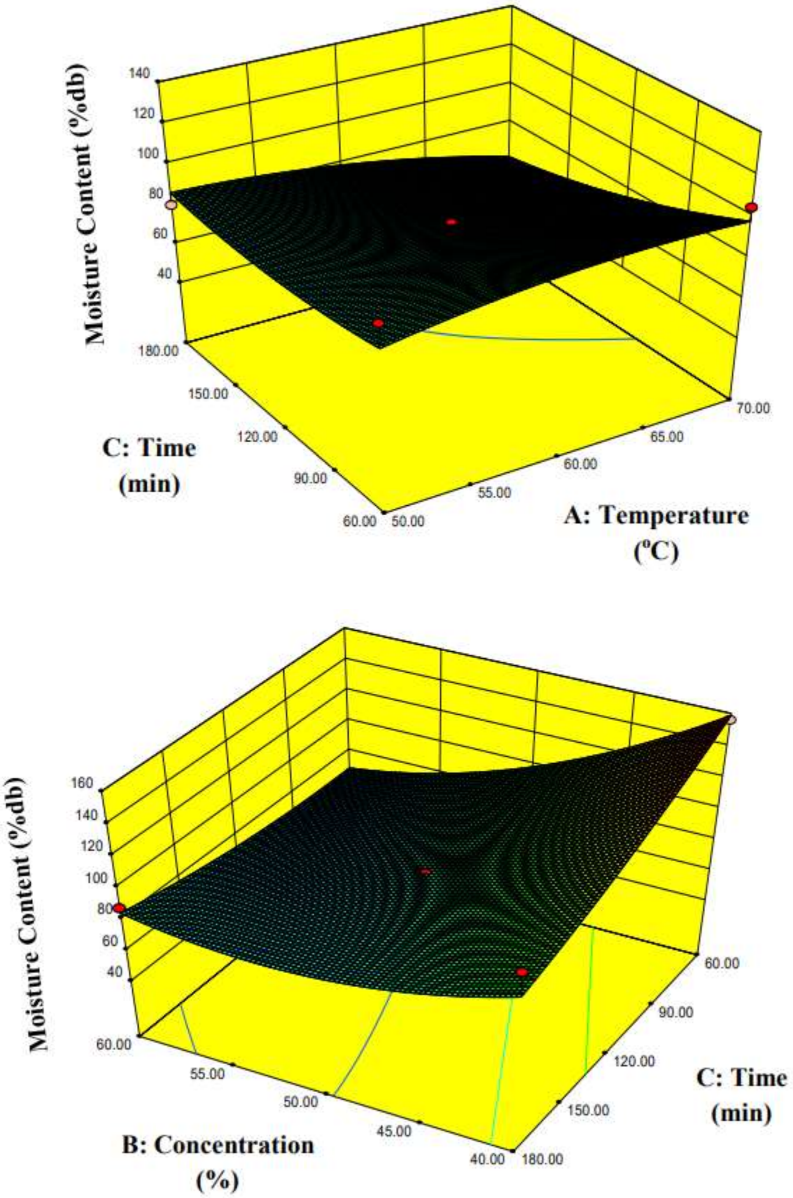


Fig. 2 Response surface plot for moisture content of osmotic dehydrated beetroot

The effect of temperature, concentration and osmotic time on the moisture content of the osmotic dehydrated beetroot was studied and shown in Fig 2. It was observed that with an increase in temperature and time, the moisture content decreases. This may be due to higher moisture diffusion at higher temperatures. The moisture content also decreases with an increase in the concentration of sugar. The reason is that the sugar solute on osmosis will diffuse in the beetroot and consequence it will move or push the water out. The moisture was found to be highest at a temperature of 60°C, concentration of 40 % and time of 60 min with a value of 155.89 % (db), whereas the lowest percentage of moisture content was observed at a temperature of 70°C,

 https://doi.org/10.5281/zenodo.13902492

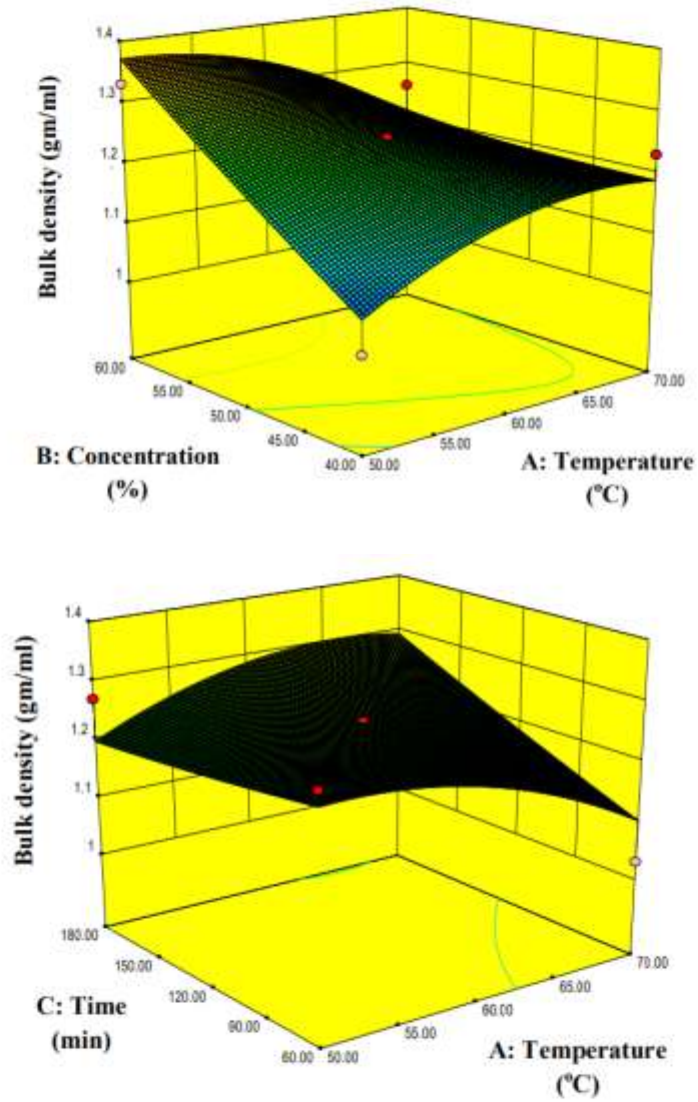
concentration 50 % and time 180 min with a value of 50.79 % (db).

Effect of temperature, concentration and osmotic time on Bulk density

From the data obtained, it was observed that for the temperature at 50°C, concentration of 40-60% and osmotic time from 60 to 180 min, the bulk density was observed to be in between 1.02-1.33 (gm/ml). For temperature of 60°C, the bulk density was in the range of 1.11-1.43 (gm/ml). For the temperature of 70ºC, the bulk density was in the range of 1.03-1.27 (gm/ml). The temperature, concentration and time relationship for bulkdensity are shown in Fig. 3.

The equation of model fitted for bulk density in actual form of process variables after elimination of non-significant terms at 5% level of significance is shown below:

Bulk Density = - 1.11250 + 0.074250 * Temperature + 0.028625 * Concentration - 0.012937 * Time - 7.00000E-004 * Temperature * Concentration + 1.00000E-004 * Temperature * Time + 1.45833E-004 * Concentration * Time - 4.37500E-004 * Temperature^2 + 3.75000E-005 *Concentration^2 + 1.04167E-006 * Time^2



 https://doi.org/10.5281/zenodo.13902492

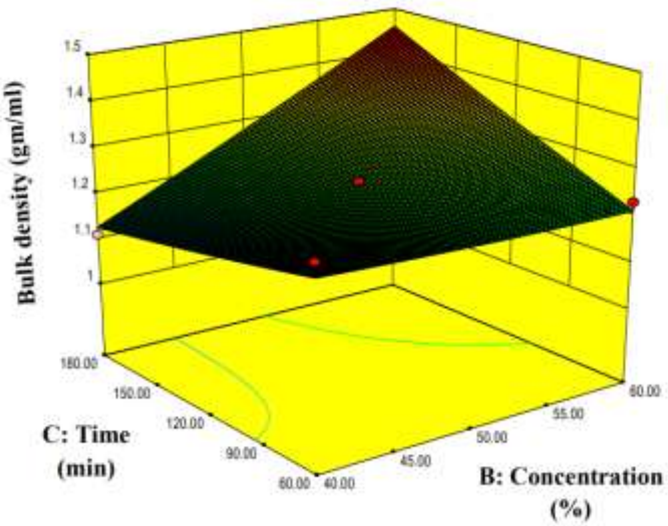


Fig. 3 Response surface plot for bulk density of osmotic dehydrated beetroot

The effect of temperature, concentration and osmotic time on the bulk density of the osmotic dehydrated beetroot was studied and shown in Fig 3. It was observed that with an increase in temperature, concentration and time, the bulk density increases. This may be due to higher diffusion of solute into the sample and shrinking the sample which reduces the volume. The bulk density was found to be highest at temperature 60°C, concentration of 60 % and time 180 min with a value of 1.43 gm/ml, whereas the lowest value of bulk density was observed at temperature 50°C, concentration 40 % and time 120 min with a value of 1.02 gm/ml.

Effect of temperature, concentration and osmotic time on Weight reduction

From the data obtained, it was observed that for the temperature at 50°C, concentration of 40-60% and osmotic time from 60 to 180 min, the weight reduction was observed to be in between 42.842-59.421 (%). For temperature 60°C, the weight reduction was in the range of 42.732-61.745 (%). For temperature of 70°C, the weight reduction was in the range of 44.391-55.069 (%). The temperature, concentration andtime relationship for weight reduction are shown in Fig. 4.

The equation of the model fitted for water loss in actual form of process variables after elimination of non-significant terms at 5% level of significance is shown below:

Weight reduction = -170.37362 + 3.95225 * Temperature + 2.24687 * Concentration + 0.58225 * Time - 0.014752 * Temperature * Concentration - 5.50125E-003 * Temperature * Time - 3.32292E-003 * Concentration * Time - 0.022486 * Temperature^2 - 2.46625E-003 * Concentration^2 - 3.56146E-004 * Time^2

 https://doi.org/10.5281/zenodo.13902492

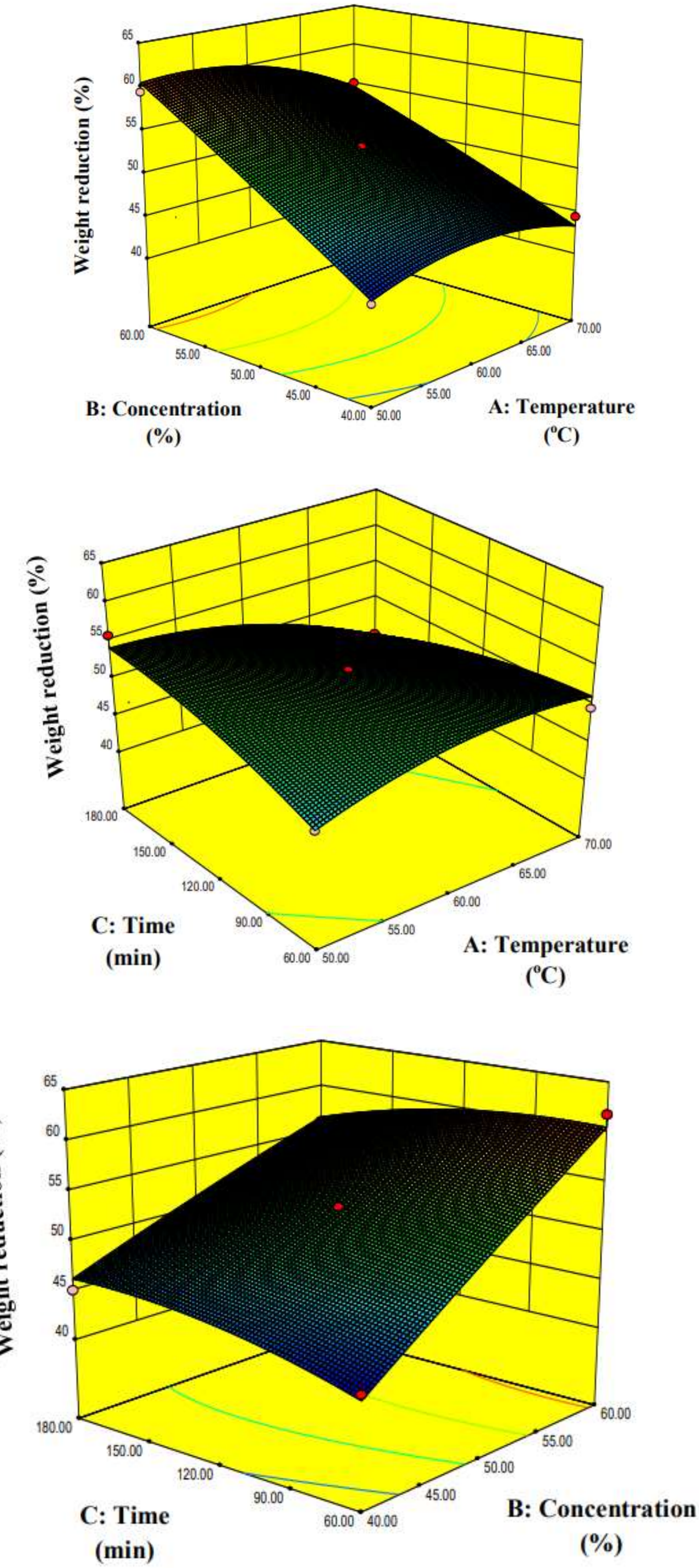


Fig. 4 Response surface plot for weight reduction of osmotic dehydrated beetroot

 https://doi.org/10.5281/zenodo.13902492

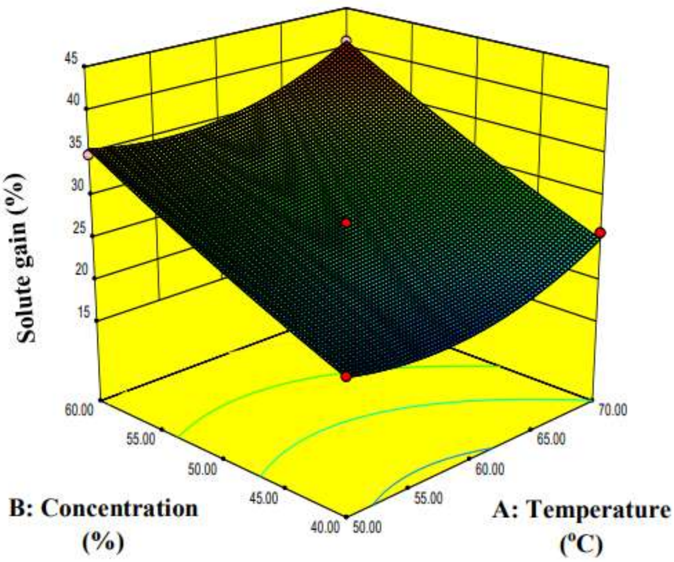
The effect of temperature, concentration and osmotic time on weight reduction of the osmotic dehydrated beetroot was studied and shown in Fig 4. It was observed that with an increase in temperature, concentration and time, the weight reduction increases. This may be due to higher diffusion of solute into the sample and diffusing out of the water from the sample. Similar results were illustrated by Manivannan and Rajasimmam (2008) in osmotic dehydration of beetroot using a salt solution. The weight reduction was found to be highest at temperature 60°C, concentration of 60 % and time 60 min with a value of 61.745%, whereas the lowest value of bulk density was observed at temperature 60°C, concentration 40 % and time 60 min with a value of 42.732%.

Effect of temperature, concentration and osmotic time on Solute gain

From the data obtained, it was observed that for the temperature at 50°C, concentration of 40-60% and osmotic time from 60 to 180 min, the solute gain was observed to be in between 20.70-34.89 (%). For temperature 60°C, the solute gain was in the range of 16.61-39.61 (%). For temperature of 70^{o}C, the solute gain was in the range of 25.37-40.78 (%). The temperature, concentration and time relationship for solid gain are shown in Fig. 5.

The equation of model fitted for solute gain in actual form of process variables after the elimination of non-significant terms at 5% level of significance is shown below:

Solute Gain = + 87.66750 - 3.99612 * Temperature + 0.78550 * Concentration + 0.19456 * Time + 2.22500E-003 * Temperature * Concentration + 2.75833E-003 * Temperature * Time - 5.72917E-003 * Concentration *Time + 0.031600 * Temperature^2 + 5.37500E-003 * Concentration^2 - 2.12500E-004 * Time^2



https://doi.org/10.5281/zenodo.13902492

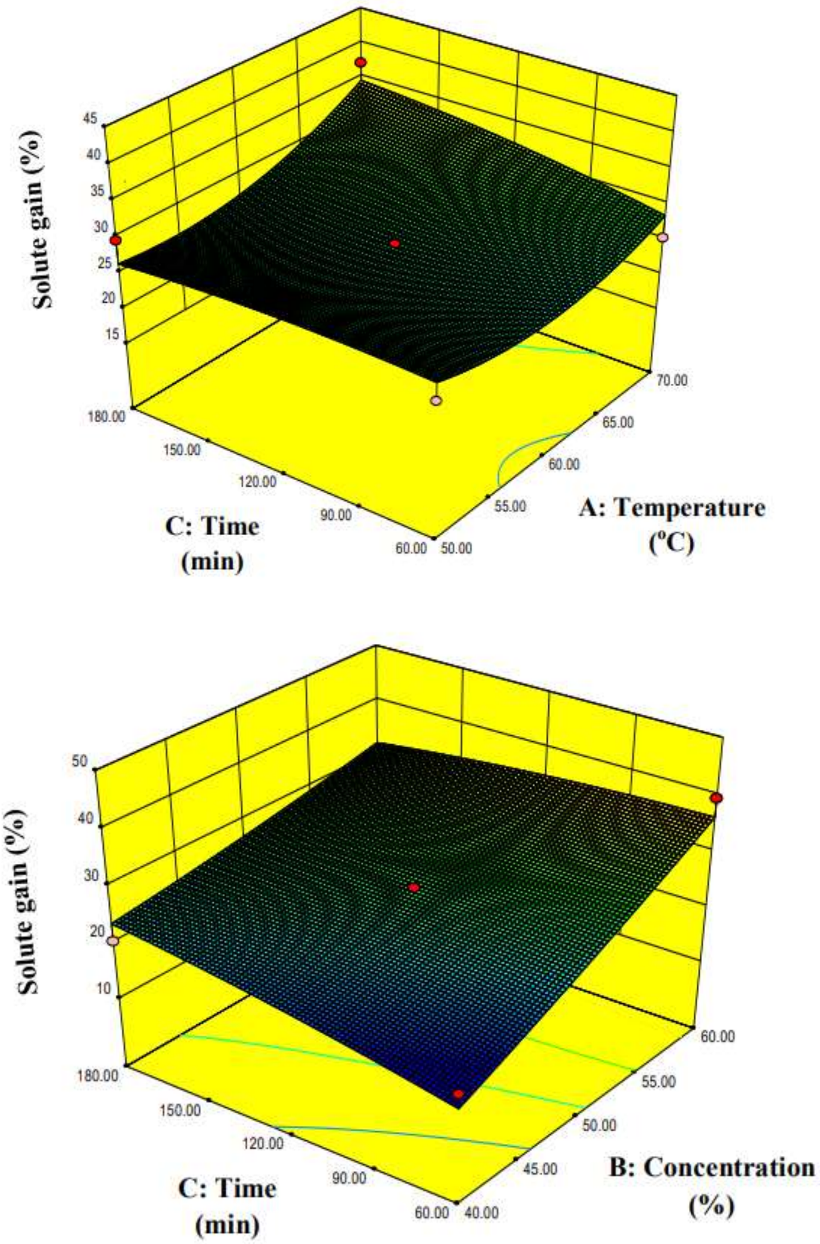


Fig. 5 Response surface plot for a solute gain of osmotic dehydrated beetroot

The effect of temperature, concentration and osmotic time on solute gain of the osmotic dehydrated beetroot was studied and shown in Fig 5. It was observed that withaincrease in temperature, concentration and time, the solute gain increases. This may bedue to higher diffusion of solute into the sample. The solute gain was found to be highest at temperature of 70°C, concentration of 60 % and time 120 min with a value of 40.78 gm/ml, whereas the lowest amount of solid gain was observed at temperature of 60°C, concentration of 40 % and time 60 min with a value of 16.61 gm/ml.

https://doi.org/10.5281/zenodo.13902492

Fitting models

Experiments were performed according to the Box-Behnken experimental design given in Table 2 in order to find the optimum combination of parameters for the osmotic dehydration of beetroot. Quadratic model was used to determine the Analysis of Variance (ANOVA) for different responses. The Fisher F-test with a very low probability value (prob > F) demonstrates a very high significance for the quadratic model. The values of "prob > F" less than 0.0500 indicate model terms are significant. The goodness of fit of the model is checked by determination coefficient (R^2). The coefficient of determination and Analysis of variance are shown in Table 3. For a good statistical model, the coefficient of determination should be closed to 1. From the result, it implies that more than 95% of experimental data were compatible with the model and only less than 5% of the total variation are not explained by the model.

Table 3 Analysis of variance (ANOVA) for model fitting

Fitting of models on	Sum of squares	df	Mean squares	F value	p-value Prob > F	R-Squared value
Moisture content	10080.35	9	1120.04	8.05	0.0059	0.9119
Bulk density	0.13	9	0.015	4.56	0.0290	0.8543
Weight reduction	525.68	9	58.41	35.72	<0.0001	0.9787
Solute gain	637.05	9	70.78	7.27	0.0079	0.9034

Optimization of temperature, osmotic concentration and time

Responses were optimized using response surface methodology. It is clear from the Figures 2- 5 that the optimum value of each dependent variable (response) had a unique set of temperature, concentration and time. The optimization was done with the following targets.

- Moisture content should be minimum.
- Bulk density should be in range.
- Weight reduction should be maximum.
- Solute Gain should be maximum.

The optimized processing conditions for different responses are given in Table 4.

Table 4 Optimum values of process parameters and responses

Process parameters	Goal	Lower Limit	Upper Limit	Importance	Optimization Level	Desirability
A: Temperature (^{o}C)	is in range	50	70	3	50	
B: Concentration (%)	is in range	40	60	3	60	
C: Time (min)	is in range	60	180	3	120	
Responses					**predicted value**	0.910
Moisture content	Minimize	50.79	155.89	3	50.79	
Bulk density	In range	1.02	1.43	3	1.33	
Weight reduction	Maximize	42.732	61.745	3	59.22	
Solute gain	Maximize	16.61	40.78	3	37.58	

Conclusion

The highest moisture content was found at 60 ^{0}C temperature, 40% concentration andtime 60 min with a value of 155.89 30% db. It was observed that with increase in concentration and temperature with time the moisture content reduces. The highest bulk density was found at 60°C temperature, 60% concentration and time 180 min with a value of 1.43 gm/ml. It was observed that with an increase in concentration, temperature and time the bulk density increases. The weight reduction was found highest at 60°C temperature, 60% concentration andtime 60 min with a value of 101.30 gm/ml. It was observed that weight reduction washigher at higher temperatures and concentrations of sugar. The solute gain was found highest at 70°C temperature, 60% concentration and time 120 min with a value of 40.78 gm/ml. It was observed that solute gain was lowest at lower concentrations of sugar, temperature and time. The optimum value of temperature, concentration and time were found out to be 50^{o}C, 60% db and 120 min respectively**.** The desirability of the optimization of parameters with various responses was found to be 0.910 (91.00%). Therefore, osmotic dehydration could be one of the effective pretreatment which has the potential to remove water at low temperature. It is also an energy efficient method with quality improvement in terms of colour, flavour, or aroma and texture.

References

Anonymous (2014). *www.Directorate Agricultural Information Service.com*, visited on 17/02/2014.

AOAC (2000). Official methods of analysis of the Association of Official Analytical Chemists, 17th Ed., AOAC, Maryland USA.

Atamanova, A., Brezhneva, T. A., Slivkin, A. I., Nikolaevskii, V. A., Selemenev, V. F., Mironenko, N. V. (2005). Isolation of saponinsfrom table beetroot and primary evaluation of their pharmacological activity. *Pharmaceutical Chemistry Journal* **39** (12): 650–652.

https://doi.org/10.5281/zenodo.13902492

Cornillon, P. (2000). Characterization of Osmotic Dehydrated Apple by NMR and DSC. *LWT - Food Science and Technology, **33(4):** 261-267*

de Zwart, F. J., Slow, S., Payne, R. J., Lever, M., George, P. M., Gerrard, J. A., Chambers, S. T., (2003). Glycine betaine and glycine betaine analogues in common foods. *Food Chemistry* **83**, 197–204.

Dias, M. G., Camoes, M. F. G. F. C., Oliveira, L., (2009). Carotenoids in traditional Portuguese fruits and vegetables. *Food Chemistry* **113**: 808–815.

Jastrebova, J., Witthoft, C., Grahn, A., Svensson, U. and Jagerstad, M. (2003). HPLC determination of folates in raw and processed beetroots. *Food Chemistry,* **80**: 579–588.

Kapadia, G. J., Tokuda, H., Konoshima, T. and Nishino, H. (1996). Chemoprevention of lung and skin cancer by Betavulgaris (beet) root extract. *Cancer Letters,* **100**: 211–214.

Khin, M. M., Zhou, W. and Perera, C. (2005). Mass development in the combined treatment of coating and osmotic dehydration of food – a review. *International Journal of Food Engineering,* **1 (1):** 423–432.

Le-Marguer, M. (1988). Osmotic dehydration: review and future directions. *Proceedings of the symposium in food preservation process, Brussels: CERFCI,* **1:** 283–309.

Lombard, G. E., Oliveira, J.C., Fito, P. and Andres, A. (2007). Osmotic dehydration of pineapple as a pre-treatment for further drying. *Journal of Food Engineering,* **85(2)**: 277- 284.

Mandala, I. G., Anagnostaras, E. F. and Oikonomou, C. K. (2005). Influence of osmotic dehydration conditions on apple air-drying kinetics and their quality characteristics. *Journal of Food Engineering,* **69(3):** 307–316.

Manivannan, P. and Rajasimman, M. (2008). Osmotic Dehydration of Beetroot in Salt Solution: Optimization of Parameters through statistical Experimental Design. *International Journal of Chemical and Biomolecular Engineering,* **1(4):** 215-222.

Patkai, G., Barta, J. and Varsanyi, I. (1997). Decomposition of anticarcinogen factors of the beetroot during juice and nectar production. *Cancer Letters* **114**: 105–106.

Raoult-Wack, A. L. (1994). Recent advances in the osmotic dehydration of foods. *Trends in Food Science and Technology,* **5(8):** 255–260.

Riva, M., Campolongo, S., Leva, A. A., Maestrelli, A. and Torreggiani, D. (2005). Structure-property relationships in osmo-air-dehydrated apricot cubes. *Food Research International,* **38(5):** 533–542.

Saputra, D. (2001). Osmotic dehydration of pineapple. *Drying technology,* **19:** 415–425.

 https://doi.org/10.5281/zenodo.13902492