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Optimization of osmotic drying as a pre-treatment for making papaya candy

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ABSTRACT

Papaya is a perishable fruit; drying is an economical method of food preservation. In the present study, papaya (variety Red Lady) candy was prepared using a combination of osmotic drying (OD) and conventional air drying (CAD). The central composite design was used to optimize time, temperature and sucrose concentration to achieve maximum water loss (WL) and minimum solute gain (SG) in papaya slices. The optimized conditions for osmotic dehydration of papaya slices were time (2.6 h), temperature (41°C) and sucrose concentration (60°Brix) for obtaining a water loss of 28.73 (g/100 g) and solute gain of 6.98 (g/100 g). Best selected OD papaya slices were further dried by CAD for making papaya candy. Combined drying (OD + CAD) significantly reduced the drying time and had better retention of sensory attributes.

Key words: Papaya; osmotic dehydration; OD; CAD; RSM; low-cost technology

INTRODUCTION

Papaya (*Carica papaya*) is a perishable fruit grown in tropical and sub-tropical areas. It is mostly consumed in fresh form. Papaya is rich in phytonutrients such as carotene, lycopene, vitamins A and C and minerals such as iron and calcium (Santana et al 2019). However, due to the perishable nature of papaya, post-harvest losses are high. Economic technologies for the preservation and value addition of local varieties would be a boon for the farming community and small entrepreneurs. Dehydration is one of the simple and economical methods of food preservation. It involves removing water from the food; in conventional drying, exposure to high temperatures during drying affects the nutritional and organoleptic properties of the fruit (Berk 2018). Osmotic dehydration is widely used for fruits and vegetables for water reduction. Osmotic dehydration is a non-thermal process, therefore, it reduces the moisture content without altering fruits' and vegetables' nutritional and physical properties (Rastogi et al 2014). Osmotic dehydrated products are shelf-stable and can be used during the off-season. The quality of osmotically dehydrated fruits is superior in terms of colour and flavour as compared to conventionally dried products. However, further water reduction is impossible in osmotic dehydration after reaching equilibrium. Therefore, osmotic dehydration is often used as a pre-treatment as it reduces the drying time and preserves the quality characteristics of the food.

Many factors influence the water removal from fruits, such as the time of drying process, temperature of the osmotic solution and type of osmotic solution. In the present study, response surface methodology (RSM) was used to optimize the parameters for the osmotic dehydration of papaya slices. RSM is a statistical technique used to optimize and analyze the relationship between independent variables and their effect on a dependent variable. In this study, the independent variables were time of drying process, temperature of the osmotic solution and type of osmotic solution used. By employing RSM, it was aimed to identify the optimal combination of these variables to achieve the best results in terms of papaya preservation and quality. After osmotic dehydration, the partially dehydrated papaya slices are subjected to cabinet drying, which further reduces their moisture content until they reach the desired level of moisture content for preservation.

MATERIAL and METHODS

Papaya (under-ripe) fruits of the variety Red Lady were collected from the papaya growers (3) of Bathinda district, Punjab. The initial moisture content of papaya was 86.34 ± 0.15 per cent; no blanching was done before osmosis. The fruits were washed and sliced (2-3 cm long and 0.5 cm thick). The moisture content of papaya was calculated as per Anon (1991). The cumulative effect of immersion time (h), temperature (°C) and sucrose concentration (°Brix) was studied using central composite design (CCD) and response surface methodology using design Expert software version 13.0 (Stat-Ease Inc, Minneapolis, USA). Independent variables were immersion time (1-4 h), temperature (35-45°C) and sucrose concentration (50-70°Brix). The variation for each variable spaced around the center point along with the equation relating the actual and coded ratio are presented in Table 1.

The software generated 20 experimental runs, out of which six were at the central values (Table 2). The statistical significance was calculated by analysis of variance (ANOVA), coefficient of determinations and lack of fit tests. Further, the responses of the dependent variables were estimated with the help of polynomial equation (1), where a variance of all the variables was divided into linear, squared, quadratic and interactive terms.

$$Y=b_0+b_1x_1+b_2x_2+b_3x_3+b_{12}x_1x_2+b_{13}x_1x_3+b_{23}x_2x_3+b_{11}x_{12}+b_{22}x_2+b_{33}x_3^2 \ldots (1)$$

where Y = Predicted response; x_1, x_2 and x_3 = Coded levels of independent parameters b_0, b_1, b_2 and b_3, b_{11}, b_{22} and b_{33}; b_{12}, b_{13} and b_{23} = Offset term, linear effects, squared effects and interaction effects respectively.

The quality of the model was estimated by $R^2_{predict}$ (Predicted R^2), and R^2 (coefficient of determination). Numerical optimization with design expert software was used to obtain the optimal solutions.

Food grade sugar was used at 50, 60 and 70°Brix to prepare osmotic solutions. Fifty grams of papaya fruit slices were immersed in different osmotic solutions for each trial at a particular time and temperature as per the designed experiment (Table 2). Fruit to osmotic solution ratio (1:4) was kept at a constant level. All the experiments were run in triplicates for accurate results.

Solute gain (SG) and water loss (WL) were calculated by using the procedures of Chauhan et al (2011):

Weight reduction (WR) = $W_0 - W_t$

After osmotic dehydration, solute gain at time (t):

SG = $(St - S_0)$

WL = Weight reduction + solute gain

$$SG\ (g/100\ g\ of\ fruit) = \frac{(S_t - S_0) \times 100}{W_0}$$

$$WL\ (g/100\ g\ of\ fruit) = \frac{(W_0 - W_t) + (S_t - S_0) \times 100}{W_0}$$

where W_0, W_t, S_0 and S_t = Initial weight (g) of papaya slices, weight (g) of the osmotically dehydrated papaya after time t (h), initial weight of solids content in papaya slices (g) and weight of solids of the osmotically dehydrated papaya slices after time t (h) respectively

Osmo-dried papaya slices under optimized conditions were conventionally dried in a cabinet drier at 60°C. After the conventional drying, the slices were cooled in a desiccator and weighed in an analytical balance. During the sensory evaluation, the combined dried (OD + CAD) papaya slices were subjected to a comparison with papaya slices that were solely dried using a conventional air drier (CAD). For sensory studies, panelists (50) were untrained and selected

Table 1. Coded and uncoded values of variables and their levels

Variable	Value/level					
Independent variable	– 1.68	Coded level	– 1	0	1	1.68
Time (h)	0.02	A	1	2.5	4	5.02
Temperature (°C)	31.59	B	35	40	45	48.41
Sucrose concentration (°Brix)	43.18	C	50	60	70	76.82

randomly. Each panelist received two samples and assigned scores through a hedonic scale of nine-points from 1 (disliked extremely) to 9 (liked very much) for the attributes: colour, flavour, texture, taste and overall acceptability which were calculated by the given scores for sensory attributes. The data were analyzed using ANOVA at $p \leq 0.05$ significance level using SPSS 19.0 statistical software. The results were expressed as the mean ±SD of three replications.

RESULTS and DISCUSSION

The independent variables (time, temperature and sucrose concentration) and responses of dependent variables (WL and SG) are given in Table 2. The analysis of variance (ANOVA) for all the studied responses is shown in Table 3. F-values of 24.94 and 14.55 for WL and SG respectively and non-significant lack of fit suggested the significance of the models ($p \leq 0.05$); the predicted and the actual R^2 (the coefficient of determination) values were 0.91 and 0.95 for water loss and 0.86 and 0.92 for solute gain respectively, which depicted the adequacy of the models for predicting the studied responses.

The regression coefficients developed a relationship between the independent and dependent variables. The time of osmotic dehydration had the most significant ($p \leq 0.01$) and positive role in WL followed by temperature and sucrose concentration. Immersion time was found to be the most significant factor in WL during the osmotic dehydration of Chinese ginger (An et al 2013). In case of SG, all the linear coefficients resulted in the accumulation of solid gain in the fruit. But the quadratic effect of time and sucrose concentration had no significant role in solute gain.

In the form of coded independent process variables, the developed models were formulated in equations 2 and 3:

$$WL = 26.91 + 4.29A + 3.53B + 0.96C + 1.93AB + 0.42AC - 0.23BC - 1.96A^2 + 0.14B^2 - 1.32C^2 \quad .....(2)$$

$$SG = 6.71 + 1.77A + 0.89B + 0.83C + 0.11AB + 0.14AC + 0.58BC + 0.014A^2 + 0.63B^2 + 0.14C^2 \quad .....(3)$$

where WL= Water loss (g/100 g of fresh weight), SG = Solid gain (g/100 g of fresh weight), A = Immersion time (h), B = Temperature (°C), C = Solute concentration (°Brix)

The main criteria for optimization were maximum water loss with minimum solute gain. Using the given criteria, optimized conditions were optimized at a time of 2.6 h, temperature (41°C) and sucrose concentration (60°Brix) for a water loss of 28.73 (g/100 g) and solute gain of 6.98 (g/100 g).

Osmotic dried papaya slices were subjected to conventional air drying (CAD) for further reduction in the moisture content, as shown in Fig 1. Combined drying (OD + CAD) significantly reduced the drying time of papaya slices. The initial moisture content of papaya slices was 86.34 ± 0.15 per cent (wet basis) and osmotic dehydration reduced the moisture content to 49.76 per cent (wet basis). Further drying was performed in a cabinet drier and a total time of 6.2 hours was taken to reach a final moisture content of 17.34 per cent (wet basis). However, papaya slices dried only by CAD method took 14 hours to reach the final moisture content (18.23%).

The results showed a reduction of around 37.14 per cent for the total drying time and the retention of sensory attributes of the dried papaya slices. A decrease of 41.8 per cent in drying time was observed when osmotic drying was combined with conventional drying in pears (da Costa Ribeiro et al 2016). Better retention of colour and appearance of papaya candy prepared by combined drying (OD + CAD) is depicted in Plate 1. Less drying time results in better retention of sensory attributes, nutritional quality and bioactive components.

Papaya candy prepared by combining osmotic drying (OD + CAD) was analyzed for colour, flavour, taste, texture and overall acceptability using 9-point hedonic scale (Fig 2).

Conventionally air-dried papaya slices were used as control to compare the data. Significant ($p \leq 0.05$) variation between combined, dried sample and control was observed for all the sensory quality attributes.

Papaya slices dried by combining osmotic and conventional air drying had a better overall acceptability score (8.1) than the control samples (6.5). Conventional drying took more time than combined drying (OD + CAD) and more prolonged exposure to high temperatures had a negative impact on colour, texture and other sensory attributes. Combined dried papaya

Table 2. Experimental designs of independent variables and studied responses for osmotic dehydration of papaya slices

Time (h)	Temperature (°C)	Sucrose concentration (°Brix)	Water loss (g/100g of fresh weight)	Solute gain (g/100g of fresh weight)
1.0	35	50	17.34	4.67
4.0	35	50	21.45	7.67
1.0	45	50	22.45	5.34
4.0	45	50	32.34	8.67
1.0	35	70	18.45	4.67
4.0	35	70	22.34	8.12
1.0	45	70	20.67	7.56
4.0	45	70	34.24	11.56
0.25	40	60	15.34	4.32
4.75	40	60	30.09	9.89
2.5	32.5	60	22.78	7.42
2.5	47.5	60	32.12	9.56
2.5	40	45	20.89	5.78
2.5	40	75	27.45	8.98
2.5	40	60	25.45	6.32
2.5	40	60	26.45	8.21
2.5	40	60	27.67	6.36
2.5	40	60	26.34	6.34
2.5	40	60	27.14	6.12
2.5	40	60	28.12	6.34

Table 3. Analysis of variance for response variables

Source	df	Water loss		Solute gain	
		SS	p-value	SS	p-value
Model	9	487.30	<0.0001*	65.13	0.0001*
A	1	229.71	<0.0001	39.20	< 0.0001
B	1	155.80	<0.0001	10.05	0.0012
C	1	11.44	0.0446	8.59	0.0020
AB	1	29.88	0.0040	0.0968	0.6685
AC	1	1.50	0.4257	0.1568	0.5869
BC	1	0.4418	0.6615	2.71	0.0416
A^2	1	39.67	0.0016	0.0022	0.9481
B^2	1	0.2093	0.7626	4.09	0.0167
C^2	1	17.83	0.0168	0.1931	0.5472
Residual	10	21.71		4.98	
Lack of fit	5	16.96	0.0944^{NS}	1.88	0.7003^{NS}
Pure error	5	4.75		3.09	
Total	19	509.01		70.11	

A: Immersion time (h), B: Temperature (°C), C: Sucrose concentration (°Brix), *Significant, ^{NS}Non-significant, df: Degrees of freedom

slices had better retention of colour, flavour and texture (Plate 1), therefore, they received a higher score for overall acceptability than the control sample. Osmotic dehydration helps in reducing the harmful effects of long-duration exposure to oxygen and temperature and many authors have reported benefits of combined drying methods for better retention of quality characteristics (Fernandes et al 2006, Liu et al 2014, Ruiz-Lopez et al 2010).

CONCLUSION

Response surface methodology effectively optimized the conditions for the osmotic dehydration of papaya slices. Optimized conditions were time (2.6 h), temperature (41°C) and sucrose concentration (60°Brix) for a water loss of 28.73 (g/100 g) and solute gain of 6.98 (g/100 g). Osmotic drying as a pre-treatment significantly reduced the drying time by 37.14

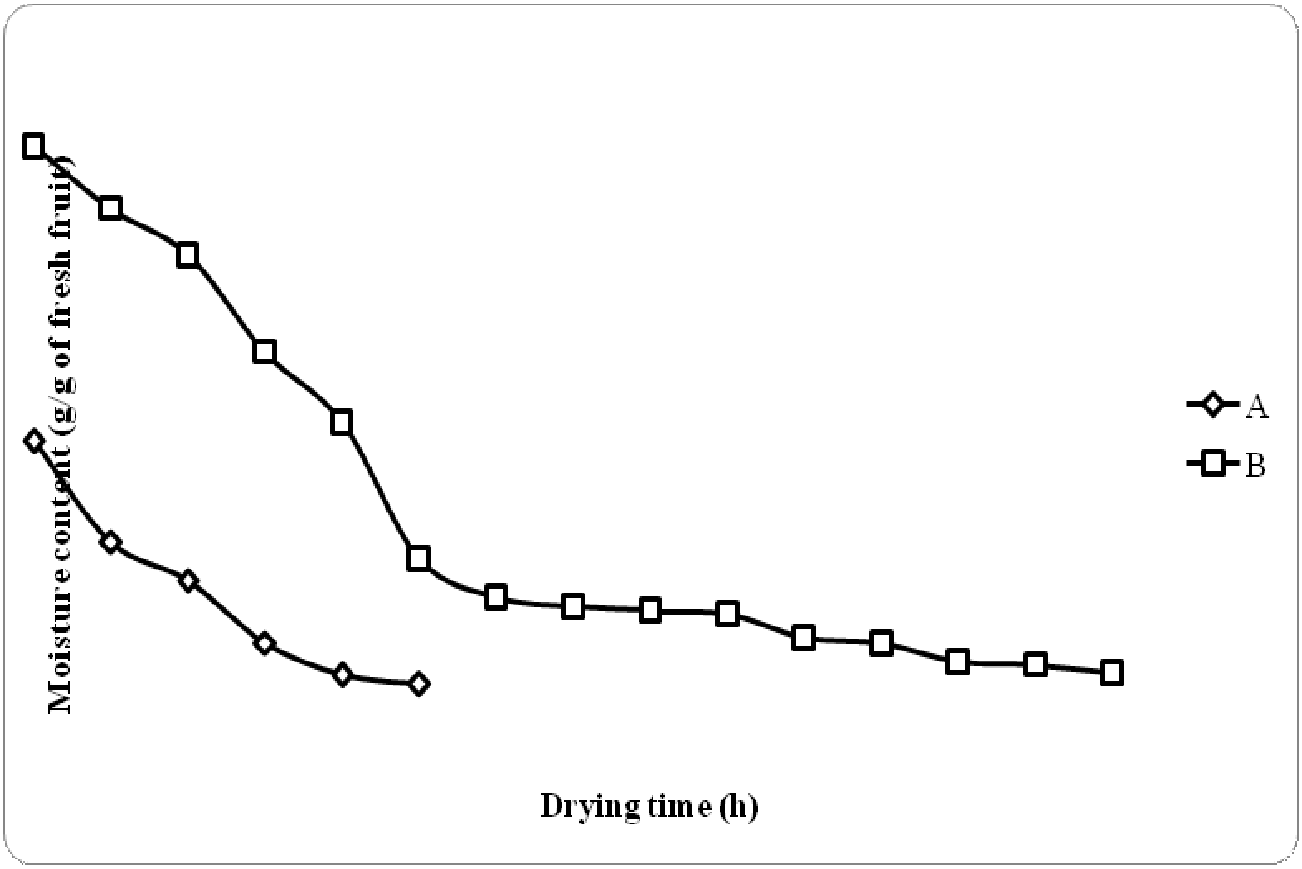

Fig 1. Moisture content (g water/g dried mass) of papaya slices at 60°C in cabinet drier, A: Previously osmo-dried using optimized conditions followed by CAD, B: Papaya slices dried only by CAD

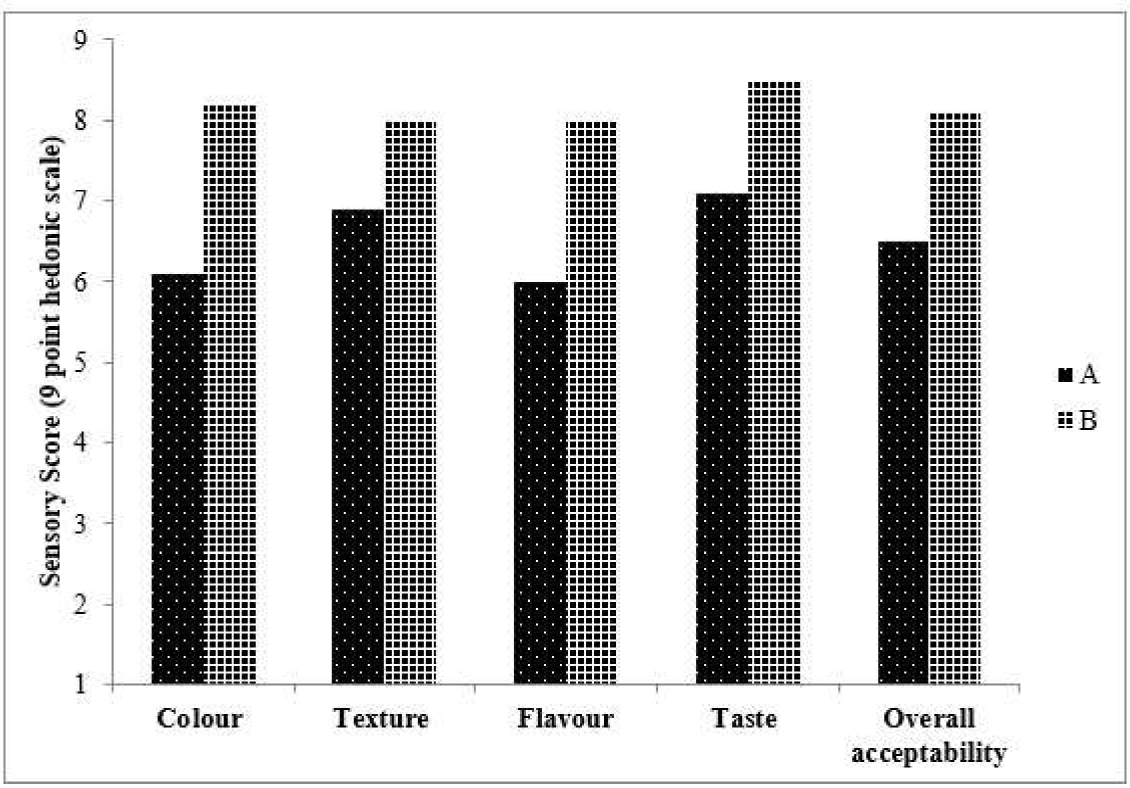

Fig 2. Sensory evaluation of papaya candy using 9-point hedonic scale, A: control (CAD dried only), B: Combined dried sample (OD + CAD)

a

b

Plate 1. Papaya candy a) Combined dried (OD + CAD), b) CAD dried

per cent compared to control samples (CAD). Papaya candy prepared by the combined drying method had better retention of sensory properties and thus accounted for a higher acceptability score than the control sample. Therefore, it was concluded that osmotic dehydration followed by conventional dehydration was an economical drying method to reduce drying time and to attain better quality papaya candy. This technology is economical and easy to be adopted by the farmers and small entrepreneurs for preservation and value addition of Red Lady variety of papaya.

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