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Preparation of Osmotically Dehydrated Tender Jackfruit Cube

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Abstract

A laboratory experiment was conducted during 2014–16, in Department of Pomology and Post Harvest Technology, Uttar Banga Krishi Viswavidyalaya for preparation of osmotically dehydrated tender jackfruit cube. India is the second largest producer of fruits and vegetables after China, but 70% of fruits and vegetables output is wasted, accounting for 40% of the total cost. Jackfruit is one of the leading wasted commodities in India. Due to presence of high moisture content, the fruit is very perishable in nature and being a bulky fruit its transportation is not very easy and is costly as well. Keeping the above points in view, the present investigation was carried out to make this nutritious food available through out the year, to check its rapid wastage and to increase its shelf life. For the preparation of osmotically dehydrated jackfruit cube, independent variables were Salt concentration (1–15%), time (30.00–240.00 min) and $Ca(OH)_2$ concentration (0 and 1%), and the response variable were Water loss (%), mass reduction (%), change in dry matter content (%), water activity and rehydration ratio. For this experiment the highest amount of water loss (90.54%) was observed in run 13, mass reduction was highest (91.61%) in Run 18, highest amount of Change in dry matter (37.26%) was found in run 19 and rehydration ratio (3.77) was in Run 10. The lowest amount of water activity (0.724 a_w), was observed in run 15. For the evaluation of storage study of immature jackfruit cube, water activity, rehydration ratio and total plate count were estimated as experimental parameter and was recorded for 6 month at 1 month interval.

Keywords: Jackfruit cube, osmotic dehydration, $Ca(OH)_2$, Nacl, water activity

1. Introduction

The world wide, there is a heavy reliance of population on rice, wheat and maize to meet food requirement of the mankind. These three crops altogether meet more than 50% of the total dietary energy requirement across the globe. There are many other crops which can grow well in marginal soil with low inputs. Jackfruit is one of them. (Singh et al., 2015).

Jackfruit (*Artocarpus heterophyllus* L.), is a dicotyledonous compound fruit and is a member of the family Moraceae which encompasses about 1,000 species in 67 genera, mostly tropical shrubs and trees. (Bailey, 1949; Merill, 1912). Jackfruit is the largest tree borne fruit in the world, reaching up to 50 kg in weight and 60–90 cm in length (Sidhu, 2012). India is the second biggest producer of the fruit in the world and is considered as the motherland of jackfruit. India accounts for an area of 0.10 mha, with an annual production of 1436 thousand ton and 11.40 t ha^{-1} productivity. The whole part of the plant has a lot of economic importance. Jackfruit is referred as "poor man"s fruit" as well as "nutrients of giant" (Singh et al., 2015). The fruit can consumed both as ripe (raw fruit or by means of prepared processed products) and unripe or immature (as vegetable) condition. Both tender and ripe fruits and the seeds are rich in minerals and vitamins. Hossain and Haq (2006) reported that ripe fruits are rich in vitamin A, B complex and Iron. Apart from the above, they also showed that 100 g of jackfruit pulp contain- 77.2% moisture, 18g carbohydrate, 1.9 g protein, 0.1 g fat, 540 IU Vitamin A. According to the Global Hunger Index 2013 (GHI), India ranks 63rd, out of the 78 hungriest countries, significantly worse than neighboring Sri Lanka (43rd), Nepal (49th), Pakistan (57th), and Bangladesh (58th). Despite India's considerable improvement over the past quarter-century – its GHI rating has risen from 32.6 in 1990 to 21.3 in 2013 – the United Nations Food and Agricultural Organization believed that 17% of Indians are still too undernourished to lead a productive life. In fact, one-quarter of the world's undernourished people live in India, more than in all of Sub-saharan Africa. India is the second largest producer of fruits and vegetable (1st China) but 70% of fruit and vegetable output is wasted, accounting for 40% of the total cost. The Indian Institute of Management in Kolkata estimated that cold-storage facilities are available for only 10% of perishable food products, leaving around 370 million tons of perishable products at risk. So proper post harvest handling can check the massive wastage of most of the perishable fruits and vegetable and can also meet the food demand. (World economic forum, 2014). Among various fruit, which are wasted abundantly, jackfruit is one leading fruit of them. Mondal et al. (2013) reported that the fruit is perishable in nature due to presence of high amount of moisture and cannot be stored for long time because of its inherent compositional and textural characteristics. A considerable amount of jackfruit, specially obtained in the glut season (June-July) in every year goes waste due to lack of proper postharvest knowledge during harvesting, transporting and storing both in quality and quantity. Jackfruit is a heavy and bulky fruit and hence transportation is not very easy and is costly as well. According to different research work, it is found that various processed products can be prepared from jackfruit at different maturity level. In this proposed work emphasise was given on osmotically dehydrated jackfruit cube prepared from immature fruit. As dehydration is avery primitive and oldest form of fruit and vegetable preservation. Sutar and Sutar (2013) reported that dehydration is an ideal process of water removal by immersion of water containing cellular solids in a concentrated aqueous solution of sugar/salt. Ertekin and Cakaloz (1996); Khin et al., 2006 reported that osmotic dehydration can removed 30 to 40% moisture from the product. This resulted in intermediate moisture product with lower water activity. At low water activity, most of the chemical reactions which deteriorated the food as well as the growth and toxins production by microorganisms were ceased. Moreira and Sereno (2003) and Shelef and Seiter (2005) reported that osmotic dehydration (OD) of fruits as a pretreatment has been reported to reduce energy consumption and improved product quality with a high content of naturally occurring vitamins and microelements. The main advantages of osmoticdehydration included better color, texture and flavor retention along with minimum heat damage (Ponting et al., 1996; Kilcast and Den, 2007, Duche et al. (2002; Guinee and Kenedy, 2007).

Keeping the above in view, the experiment entitled "Preparation of Osmotically Dehydrated Tender Jackfruit Cube"was conducted to prepare a self stable osmotically dehydrated tender jackfruit product and to find out a optimized process condition for preparation of dehydrated Jackfruit product.

2. Materials and Methods

The present lab experiments were conducted during 2014-16 in the laboratory of the Department of Pomology and Post-harvest Technology, Faculty of Horticulture, Uttar Banga Krishi Viswavidwalaya, Pundibari, Coochbehar. Fresh jackfruits for the experiments were collected from Instructional Farm of Uttar Banga Krishi Viswavidyalaya at tender stageas per the requirement of the experiment and were immediately brought to the laboratory for necessary treatments.

2.1. Treatment of the fruits by blanching

For preparation of dehydrated Jackfruit cube, blanching was done firstly by hot water at boiling temperature for 3 min to control the enzymatic browning for all the treatment.

2.2. Treatments with $Ca(OH)_2$

Solid lime was bought from local market of Pundibari and brought into laboratory. Solid lime was powdered and 10 g of powder was poured into 1 liter of water to prepare the treatment solution. Treatments with $Ca(OH)_2$ was done in those treatment runs only where $Ca(OH)_2$was considered as a categoric variables (Table 2). The purpose of the treatment was to improve the textural quality and to avoid blackening of the dehydrated cubes.

2.3. Treatments of fruits with NaCl

For treatments of immature fruit with NaCl, edible salt was bought from local market of Pundibari. Different amount of NaCl was poured in 1 liter of water for preparing solution of different concentration as per the requirement of the experiment. After preparation of different NaClsolution jackfruit cube were dipped for given period of time as given in Table 2.

2.4. Subsequent drying

After completion of osmotic dehydration process, the cubes from all treatment runs were dried in a cabinet drier at 60 ^{o}C for 6 hr.

2.5. Experimental design

For dehydrated jack cube, the experiment was carried out to study the response surface using Central Composite Rotatable Design with 26 run of which 10 were at central points. The design was generated by software Design-Expert® version 7.1.6. The details of the variable studied is given in Table 1.

Response surface methodology (RSM) was used to determine the best conditions for preparation of dehydrated jackfruit cube from tender jack. Central Composite Rotatable Design (CCRD) was performed to evaluate the effect of NaCl concentration, time and $Ca(OH)_2$ concentration on five responses, viz. Water Loss (WL), Mass Reduction (MR), Change in Dry Matter (CDM), Water Activity (a_w) and Rehydration Ratio (RR). The lower and upper levels for each variable were chosen for the RSM based on the results of a preliminary study: NaCl concentration (3.05-12.95%), time (60.75-209.25 min) and $Ca(OH)_2$ concentration (0-1%). Table 1 provides the details of threeprocess variables along with their coded values five levels (-α, -1, 0, 1, +α). Table 2 gives the details of run-wise experimental variable in actual terms.

The experimental data for RSM were fitted to the second order regression equation:

$$Y=\beta+\Sigma^{k}_{i=1}\beta_i X_i+\Sigma^{k}_{i=1}\beta_{ii}X^2_{ii}+\Sigma^{k-1}_{i=1}\Sigma^{k}_{j=1}\beta_{ij}X_iX_j$$

where, Y is the predicted response, β_0 is the intercept, β_i, β_{ii} and β_{ij} are linear, quadratic and interaction coefficients, respectively, and X_i and X_j are the coded independent variables.

2.6. Response variables recorded

Table 1: Experimental variables and their range

Factors	Name	Units	Type	-α	-1	0	1	+α
A	Salt concentration	%	Numeric	1	3.05	8	12.95	15
B	Time	Min	Numeric	30	60.75	135	209.25	240
C	$Ca(OH)_2$	%	Categoric	-	0	-	1	-

Table 2: Treatments for preparation of osmotically dehydrated jackfruit cube

Run	Categoric factors	Numeric factors	
	$Ca(OH)_2$ concentration (%)	Salt concentration (%)	Time (min)
T_1	0	15.00	135.00
T_2	1	3.05	60.75
T_3	1	1.00	135.00
T_4	0	8.00	135.00
T_5	1	8.00	135.00
T_6	0	12.95	60.75
T_7	0	8.00	135.00
T_8	1	12.95	209.25
T_9	1	12.95	60.75
T_{10}	0	3.05	209.25
T_{11}	1	8.00	135.00
T_{12}	0	8.00	240.00
T_{13}	0	12.95	209.25
T_{14}	1	15.00	135.00
T_{15}	1	8.00	30.00
T_{16}	0	8.00	30.00
T_{17}	0	3.05	60.75
T_{18}	0	8.00	135.00
T_{19}	1	8.00	135.00
T_{20}	0	8.00	135.00
T_{21}	1	8.00	135.00
T_{22}	0	8.00	135.00
T_{23}	1	8.00	135.00
T_{24}	1	3.05	209.25
T_{25}	1	8.00	240.00
T_{26}	0	1.00	135.00

2.6.1. Moisture content

Moisture content of the raw materials and the final products were determined gravimetrically using a laboratory vacuum oven by drying to constant weight at 60 °C according to the method described in AOAC, 1997.

2.6.2. Percentage of water loss (WL)

Total water removal from the raw materials during the process of obtaining final products through two stages of dehydration viz. osmotic dehydration and cabinet drying was calculated and expressed as percentage of raw material.

2.6.3. Mass reduction (MR) (%)

Mass reduction after obtaining final product was calculated as a percentage of initial raw material mass. Mass reduction gives us an idea about the probable final product yield.

2.6.4. Change in dry matter

Percentage change in dry matter was determined to indicate a relative difference in dry matter content of raw material and final product.

2.6.5. Water activity (a_w)

Water activity (a_w) was measured with a water activity meter (Model: AquaLab series 3 TE, Make: Decagon Devices, Inc, Pullman, Washington, USA) at 25 °C with an accuracy of ±0.003.

2.6.6. Rehydration ratio

Rehydration ratio of the dried sample was measured by rehydration technique. 5 g dried sample were taken and dipped into 1 lt of boiling water (containing 15 g salt) for 30 min and finally the weight of the 5 g sample were measured.

3. Results and Discussion

Table 3 presents the results of the Central Composite Design with twenty-six runs for the five responses. Experimental analysis resulted in water loss (WL), Mass reduction (MR), Change in dry matter (CDM), Water activity (a_w), Rehydration ratio (RR) varying between (85.85-90.54%), (86.93- 91.61%), (-35.10–37.26%), (0.724-0.804a_w) and (3.24-3.77), respectively.

From Table 3. it can be concluded that the highest amount of Water loss (90.54%) was observed in treatment 13, and the lowest amount of water loss was (85.85%) in treatment 22. Similarly treatment 18 resulted the highest amount of mass reduction (91.61%) and the least amount of mass reduction (86.93%) was found in treatment 24. Similarly treatment 19 showed the highest positive impact on change in dry matter content (37.26%) and treatment 15 showed the highest negative impact (-34.20%) on change in dry matter content. In this proposed plan, the aim was to reduce the amount of Water activity for osmotically dehydrated jackfruit cube, as it enhance the post harvest period of the products. So as per the requirements, the least amount of Water activity (0.724

Table 3: Effect of factors on different responses for osmotically dehydrated jackfruit cube

Run order	Factor A: salt conc (%)	Factor B: Time (min)	Factor C: $Ca(OH)_2$ (%)	Water loss (%)		Mass reduction (%)		Change in dry matter (%)		Water activity		Rehydration ratio	
				Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1	8.00	135.00	0	88.83	89.03	88.57	88.62	6.98	10.35	0.774	0.758	3.640	3.569
2	12.95	60.75	1	90.21	90.03	89.77	89.62	5.14	7.84	0.774	0.775	3.696	3.704
3	8.00	135.00	1	88.91	88.71	87.21	87.68	21.77	21.35	0.761	0.763	3.712	3.681
4	3.05	60.75	1	90.08	89.99	89.70	90.30	16.98	11.93	0.766	0.762	3.446	3.431
5	8.00	135.00	0	89.12	89.03	88.57	88.62	23.05	10.35	0.750	0.758	3.484	3.569
6	1.00	135.00	1	90.26	90.15	88.15	88.22	26.44	27.73	0.804	0.807	3.474	3.480
7	8.00	135.00	0	88.78	89.03	88.13	88.62	8.44	10.35	0.751	0.758	3.516	3.569
8	12.95	60.75	0	88.90	88.47	89.71	90.51	-20.34	-26.43	0.753	0.762	3.668	3.605
9	8.00	135.00	1	89.08	88.71	87.42	87.68	18.64	21.35	0.762	0.763	3.655	3.681
10	15.00	135.00	1	89.01	89.05	89.21	89.64	-2.15	-3.31	0.797	0.791	3.770	3.750
11	1.00	135.00	0	89.96	90.26	89.50	88.75	19.60	27.00	0.803	0.804	3.240	3.271
12	8.00	240.00	0	89.64	89.42	88.70	89.53	-3.50	-7.83	0.745	0.745	3.628	3.639
13	3.05	209.25	0	90.54	90.56	87.65	87.91	31.18	26.22	0.787	0.791	3.504	3.478
14	8.00	135.00	1	88.68	88.71	87.41	87.68	22.53	21.35	0.761	0.763	3.674	3.681
15	8.00	30.00	0	86.93	87.15	91.19	90.97	-35.10	-30.71	0.724	0.722	3.292	3.354
16	3.05	60.75	0	88.41	88.13	90.12	90.63	-2.70	-7.82	0.747	0.751	3.252	3.194
17	8.00	135.00	0	89.68	89.03	89.30	88.62	6.24	10.35	0.763	0.758	3.531	3.569
18	12.95	209.25	0	89.36	89.26	91.61	91.18	-34.20	-28.12	0.748	0.754	3.748	3.725
19	8.00	135.00	1	88.97	88.71	88.89	87.68	37.27	21.35	0.764	0.763	3.682	3.681
20	15.00	135.00	0	89.10	89.58	91.45	90.98	-24.87	-24.59	0.791	0.786	3.704	3.736
21	3.05	209.25	1	88.48	88.36	87.13	86.93	13.42	13.97	0.792	0.786	3.568	3.600
22	8.00	240.00	1	85.85	86.23	88.58	88.12	-23.62	-19.45	0.742	0.739	3.712	3.669
23	8.00	30.00	1	89.38	89.70	91.38	90.50	-0.67	2.92	0.741	0.738	3.528	3.546
24	8.00	135.00	1	87.89	88.71	86.93	87.68	8.90	21.35	0.749	0.763	3.714	3.681
25	8.00	135.00	0	88.74	89.03	89.06	88.62	4.69	10.35	0.770	0.758	3.642	3.569
26	12.95	209.25	1	87.00	86.76	89.58	89.63	-22.13	-25.85	0.750	0.752	3.662	3.709

a_w) was observed in Treatment 15 and the highest amount of water activity (0.804 a_w) was observed in Treatment 6. Rehydration ratio which is very important for the product,was found highest (3.77) in Treatment 10 and lowest amount (3.24) in Treatment 11.

The treatment for osmotically dehydrated jackfruit cube enlisted in Table 3. In which 10 were at central point which were 8% Salt concentration, 135 min time. $Ca(OH)_2$ concentration was categoric factor in this design. Considering Water loss (WL), the average actual values for all the central points (8% salt concentration and 135.00 min Time period) was found to be 88.86±0.44 (Mean±Standerd daviation) and the predicted value was 89.03. It can be observed that the actual value of Water loss is very close to the predicted value. For mass reduction (MR), the average actual values for central point was 88.14±0.85, where as the predicted value for central point estimated by Software Design-Expert® version 7.1.6. was 88.62. It was found that here also the actual value and predicted value was more or less similar in range. In case of change in dry matter content the average actual values for central point was 15.84±10.52, and the predicted value of change in dry matter content at central point was 10.35. As well as the above two factors, the mean of actual values of change in dry matter content was near to the predicted value for central points. Similar result was found in case Water activity, where the average actual value for central point was 0.760±0.008, and was very close to the predicted value (0.758). In case of Rehydration ratio the mean of all the actual values for 10 central points was 3.622±0.08. The predicted value of rehydration ratio for central point were 3.569. From the above it can be concluded that the average actual value was very close to the predicted value of Rehydration ratio for central points.

The experimental data were fitted into the second order polynomial model in terms of actual factors. The second order polynomials and the correlation coefficients for actual and predicted values are presented in Table 4.

Where, A=Salt concentration (%); B=Time (min)

3.1. Influence of process variable on different response

Analyses of variance of the process variables on different response variable were studied to evaluate the adequacy of model fittings. The ANOVA is along with coefficients of estimates are presented in Table 5.

3.1.1. Influence of process variable on water loss

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 5 it can be concluded that in this case individual effect of Salt concentration and Time, interaction effect of salt concentration and Time, Time and $Ca(OH)_2$ concentration and quadratic terms of Salt concentration and Time are significant model terms. Lack of Fit F- value 0.62 implies that the Lack of Fit is not significant. As per the value of Coefficient of estimates enclosed in Table

Table 4: Predicted second order polynomial equation and statistical parameters

Response Variable	Final equation in terms of actual factors	R^2	Adj-R^2	Pred-R^2	CV%	Adequate Precision
Y_1: Water loss (%)	Without $Ca(OH)_{2-}$ Y1=+86.69-0.189×A+0.037857×B-1.11×10^{-3}×A×B+0.0182×A^2-6.71×10-5×B^2 With- $Ca(OH)_{2-}$ Y1=+90.30-0.219×A+0.010×B-1.11×10^{-3}×A×B+0.018×A^2	0.9097	0.8672	0.7933	0.44	18.775
Y_2: Mass reduction (%)	Without $Ca(OH)_{2-}$ Y2=+95.08-0.558×A-0.065×B+2.29×103×A×B +0.025×A^2+1.48 × 10^{-4} × B^2 With- Ca(OH)2- Y2=+95.20-0.615×A-0.069×B+2.29×10^{-3}×A×B+0.025×A^2	0.8384	0.7642	0.5731	0.75	10.824
Y_3: Change in dry matter (%)	Without Ca(OH)2- Y3=-62.03+2.582×A+1.028×B-0.024×A×B-0.186×A^2-2.686×10^{-3}×B^2 With-$Ca(OH)_{2-}$ Y3=-33.67+4.049×A+0.813×B-0.024×A×B-0.186×A^2	0.9075	0.8639	0.8081	189.59	13.355
Y_4: Water activity	Without $Ca(OH)_{2-}$ Y4=+0.726-8.77×10-3×A+9.64×10-4×B-3.23×10-5×A×B+7.42×10-4×A^2-2.21×10-6×B^2 With- $Ca(OH)_{2-}$ Y4=+0.743-8.62×10-3×A+8.61×10-4×B-3.23×10-5×A×B+7.42×10-4×A^2	0.908	0.8647	0.8165	1.01	18.682
Y_5: Rehydration ratio	Without $Ca(OH)_{2-}$ Y5=+2.793+0.069×A+4.03×10-3×B-1.11×10^{-4}×A×B-1.34×10^{-3}×A^2-6.59×10^{-6}×B^2 With- $Ca(OH)_{2-}$ Y5=+3.120+0.055×A+3.26×10-3×B-1.11×10-4×A×B-1.34×10^{-3}×A^2	0.918	0.8795	0.8036	1.44	18.269

Where, A: Salt Concentration (%); B: Time (min)

5 quadratic effect of Salt concentration and interaction effect of Salt concentration and Time and have a large impact on Water loss. It can be concluded that with the increase in quadratic effect of Salt concentration amount of Water loss was increased and with the increase in Salt concentration and Time, the amount of water loss was decreased.

It can be concluded from Figure 1 that at lower salt concentration, with the increase in time, the amount of Water loss was also increased and the effect was linear. At higher salt concentration, time has a quadratic effect on Water loss. Antonio et al. (2004) reported that water loss was increased with the increase in time in papaya, and decreased water loss with increase in temperature. Salt concentration also has beneficial effect on water loss. Higher salt concentration ranging from 5-15% in 50 °B sucrose solution at temperature of 45 °C with solution to fruit ratio of 5, caused higher water loss in case of carrot (Singh et al., 2007). Manivannan and Rajasimman (2008) also observed that higher salt concentration increased water loss in beetroot.

Table 5: Analysis of variance of different studied responses

Source	Water loss			Mass reduction			Change in dry matter		
	Coefficient of estimate	F-value	p-value	Coefficient of estimate	F-value	p-value	Coefficient of estimate	F-value	p-value
Model	88.87	21.41	<0.0001	88.15	11.03	<0.0001	15.85	20.84	<0.0001
A	-0.31	10.30	0.0051	0.65	15.00	0.0012	-14.61	61.71	<0.0001
B	-0.21	4.66	0.0454	-0.68	16.44	0.0008	0.089	2.28×10-3	0.9624
C	-0.16	4.41	0.0510	-0.47	12.88	0.0023	5.50	14.23	0.0015
AB	-0.41	8.78	0.0087	0.84	12.81	0.0023	-8.93	11.54	0.0034
AC	-0.076	0.60	0.4495	-0.14	0.74	0.4027	3.63	3.81	0.0675
BC	-1.01	107.45	<0.0001	-0.16	0.97	0.3381	-8.00	18.51	0.0005
A^2	0.45	18.10	0.0005	0.62	12.19	0.0028	-4.57	5.26	0.0349
B^2	-0.37	12.44	0.0026	0.82	20.87	0.0003	-14.81	55.16	<0.0001
Lack of fit	-	0.62	0.7557	-	1.23	0.3920	-	0.42	0.8929

Table 5: Continue...

Source	Water Activity			Rehydration		
	Coefficient of estimate	F-value	*p*-value	Coefficient of estimate	F-value	*p*-value
Model	0.76	20.97	<0.0001	3.63	23.80	<0.0001
A	-5.86×10-3	9.30	0.0072	0.13	101.01	<0.0001
B	4.25×10-3	4.90	0.0409	0.072	31.20	<0.0001
C	2.19×10-3	2.11	0.1645	0.056	29.99	<0.0001
AB	-0.012	19.05	0.0004	-0.041	5.03	0.0385
AC	3.79-×10-4	0.039	0.8460	-0.035	7.16	0.0159
BC	-3.83×10-3	3.96	0.0628	-0.029	4.92	0.0404
A^2	0.018	77.73	<0.0001	-0.033	5.62	0.0298
B^2	-0.012	34.90	<0.0001	-0.036	6.88	0.0178
Lack of fit	-	0.57	0.7921	-	0.78	0.6427

A: Salt concentration (%); B: Time (min); C: $Ca(OH)_2$ concentration (%)

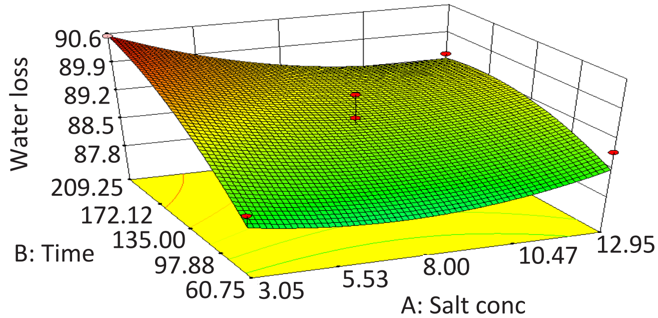

Figure 1: Influence of water loss without $Ca(OH)_2$ treatment

3.1.2. Influence of process variable on mass reduction

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 5 it can be concluded that in this case individual effect of salt concentration, time and $Ca(OH)_2$ concentration, interaction effect of salt concentration and time and quadratic terms of both salt concentration and time are significant model terms. The lack of fit F-value 1.23 implies that the lack of Fit is not significant relative to the pure error. Table 5 provides the information about coefficient of estimate for mass reduction. Combined effect of Salt concentration and time and quadratic effect of Time has a positive impact on Mass reduction.

It was observed from Figure 2. That salt concentration and Time has a quadratic effect on Mass reduction. At higher Salt concentration, mass reduction was increased with the increase in time, which is also supported by many other authors. Kaymak-Ertekin and Sultanoglu (2000) found that mass reduction was increased with the increase in time in case of apple.

3.1.3. Influence of process variable on change in dry matter

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 5 it can be said that in this case individual effect of Salt concentration and $Ca(OH)_2$ concentration, interaction effect of both salt concentration and time and time and $Ca(OH)_2$ concentration, quadratic terms of both Salt concentration and Time are significant model terms. The lack of Fit F-value 0.42 implies that the lack of fit is not significant relative to the pure error. From Table 5, it can be concluded that individual effect of salt concentration

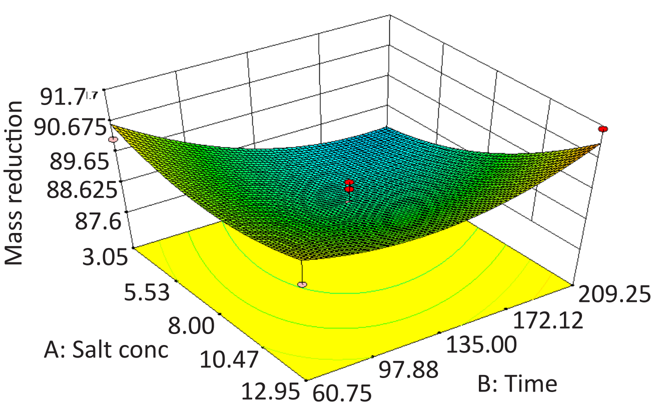

Figure 2: Influence of Mass Reduction without $Ca(OH)_2$ treatment

and quadratic effect of Time have negative effect on change in dry Matter content.

It can be stated from the above Figure 3. That as well as Mass reduction, time and salt concentration have a same quadratic effect on change in dry matter. change in dry matter was found highest at lower salt concentration and higher time period.

3.1.4. Influence of process variable on change in water activity

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 5 it can be concluded that in this case individual effect of salt concentration and Time, interaction effect of Salt concentration and Time, quadratic terms of both Salt concentration and time are significant model terms. The Lack of Fit F-value 0.57 implies that the Lack of Fit is not significant relative to the pure error. From the value of co-efficient of estimates enclosed in Table 5, it can be stated that the individual effect of both Salt concentration

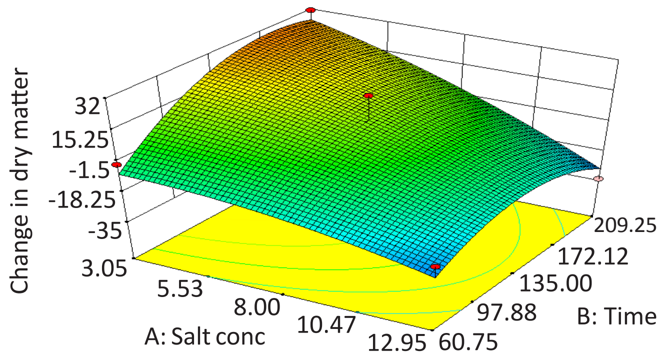

Figure 3: Influence of change in dry matter without $Ca(OH)_2$ treatment

and time have a large negative impact on water activity.

It can be observed that the effect of Salt concentration and Time are quadratic on water activity. As it is well known, the stability and safety of foods does improve if water activity (a_w) of the product decreases. The reduction of a_w to about 0.93 would be enough to suppress the growth of most pathogenic bacteria (Chirife and Favetto, 1992). Ozen et al., 2002, reported that water activity has a negative co relation with concentration of osmotic solutes as resulted with increase in concentration the water activity decreases.

3.1.5. Influence of process variable on change in Rehydration Ratio

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 5 it can be concluded that in this case individual effect of Salt concentration, Time and $Ca(OH)_2$ concentration, interaction effect of salt concentration and time, salt concentration and $Ca(OH)_2$ concentration and time and $Ca(OH)_2$ concentration, quadratic terms of both salt concentration and time are significant model terms. The lack of Fit F-value 0.78 implies that the lack of fit is not significant relative to the pure error.

From the above it can be stated that here the effect of both Salt concentration and time were to some extent linear. It can be concluded from the above that Rehydration ratio was increased with the increase in both Salt concentration and Time. In support of the above, Nishadh and Mathai (2014) reported that higher salt concentration increase the rehydration ratio in radish. Apart from the above, Singh et al. (2015) observed that higher rehydration coefficient with increase in solute concentration in papaya which was 60 °Brix (0.715) was highest followed by 55 °Brix (0.688), 50 °Brix (0.662), and control (0.255).

3.1.2. Optimization of process variable

After analyzing the response for ANOVA, the process variables were optimized by numerical optimization method using Design Expert 7.1.6 software. The details of the optimization criteria is given in Table 6.

Table 6: Optimization of the constrains

Name	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
Salt Conc.	Is in range	3.05025	12.9497	1	1	3
Time	Is in range	60.7538	209.246	1	1	3
Ca(OH)2	Is in range	0	1	1	1	3
Water loss	Maximize	85.85	90.54	1	1	3
Mass reduction	Minimize	86.93	91.61	1	1	3
Change in dry matter	Targeting "0"	-35.095	37.267	1	1	5
Water activity	Minimize	0.724	0.804	1	1	3
Rehydration ratio	Maximize	3.24	3.77	10	1	5

4. Conclusion

Considering the above discussed matter for optimizing the process variable as stated in Table 6. 12.95% salt concentration and 1% $Ca(OH)_2$ concentration for a time period of 155.57 min, was found ideal for maximizing water loss (88.28%) and rehydration ratio (3.740), for minimizing mass reduction (88.86%) and water activity (0.771) and for targeting change in dry matter content (9.41×10^{-5}).

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