Formulation and optimization of foam mat dried grape bar

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Abstract: A five level four factors central composite rotatable design under response surface methodology was used to optimize process conditions of the foam mat drying process i.e. egg albumen (0%-12%), methyl cellulose (0.1%-0.5%), drying bed thickness (3-7 mm) and drying temperature (55-75℃) to develop grape bar with final moisture content of 14%±1% (dry-base). Contour and response graphs were generated and the effect of foaming parameters on the quality parameters namely drying time, color change, texture, non-enzymatic browning, total sugars (%), titratable acidity (%), protein (%) and overall acceptability (%) were studied. Significant regression models were established with the coefficient of determination, R^2 ($\geq$0.90). Optimization of process for grape bar was performed to result minimum drying time, color change, cutting force, non enzymatic browning and maximum overall acceptability and optimized process conditions were 5.51% egg albumen, 0.31% methyl cellulose, 4 mm drying bed thickness and 60℃ drying temperature with desirability 0.74.

Keywords: foam mat drying, grape bar, quality parameters

Citation: Gupta, K., and M. S. Alam. 2014. Formulation and optimization of foam mat dried grape bar. Agric Eng Int: CIGR Journal, 16(4): 228−239.

1 Introduction

Fruits are rich in antioxidants that help to lower the incidence of degenerative diseases such as acceleration of aging, cancer, arthritis, arteriosclerosis, heart disease, inflammation, brain dysfunction, etc. (Gordon, 1996; Halliwell, 1996; Feskanich et al., 2000). A grape, botanically a true *berr*y, which grows on the perennial and deciduous woody vines of the genus *Vitis*. Most grapes come from *cultivars* of *Vitis vinifera*, the European grapevine native to the Mediterranean and Central Asia. The major varieties of grapes grown in India are Thomson Seedless, Sonaka, Anab-e-Shahi, Perlette, Banglore blue, Pusa seedless, Beauty seedless etc. (Anonymous, 2012). More than 70% of the total production is harvested in March-April, but as cold storage facilities are currently inadequate there are frequent market gluts. Development of grape bar is an important alternative for the prevention of crop from deterioration and increasing its shelf life. Fruit bar is the term used for the products prepared by dehydration of fruit puree (Raab and Oehler, 1976). Preparation of fruit leather from pulpy fruits such as mango, guava, banana, chiku, jack fruit and papaya individually or in combination with different fruits has been reported by various workers (Lodge, 1981; Chan and Cavaletto, 1978; Che Man and Raya, 1983; Che Man et al., 1992; Chauhan et al., 1993; Che Man and Taufik, 1995; Irwandi and Che Man, 1996).

Major problems associated with air-dehydration are the considerable shrinkage caused by cell collapse during the water loss, the poor rehydration characteristics of the dried product, and the unfavorable changes in color, texture, flavor and nutritive value caused by drying (Mazza, 1983). Foam-mat drying techniques can overcome these shortcomings by accelerating the moisture removal process compared to other drying methods such as spray-drying or drum-drying, as it requires lower drying temperatures resulting in shorter drying times due to the increase in surface area during air dehydration (Brygidyr et al., 1977).

Received date: 2014-04-13 **Accepted date:** 2014-09-25

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Foam-mat drying is a process by which a liquid or semi-liquid is whipped to form a stable foam, and subsequently dehydrated by thermal means. The application of foam-mat drying to many heat-sensitive food materials, including fruit juices was reported (Hertzendorf and Moshy, 1970). Foam-mat drying which leads to the increase of drying rate and significant reduction in drying time, improved the sensory, nutritional and functional properties of the product. The foam-mat dried products are highly stabile against deteriorative microbial, chemical and biochemical reactions. Shorter drying time not only reduces the dryer load but also increases the dryer throughput by 32% and 22% for foamed pulp (Rajkumar et al., 2006). The foam-mat drying variables i.e. foam formation, density and stability are affected by chemical nature of the fruit, soluble solids, pulp fraction, type and concentration of foaming agent, and type and concentration of foam stabilizer (Hart et al., 1963).

Foaming conditions of various tropical fruits such as pineapple, passion fruit, guava puree, banana fruit, papaya puree and mango puree have been reported (Bates, 1964). However, to the best of the knowledge, no work has been reported on the foam drying of grape juice concentrate. Thus, present study was undertaken to evaluate and optimize the foam-mat drying condition of grape juice concentrate to develop grape leather on the basis of its quality analysis.

2 Materials and methods

The grapes of variety: ‘Thomson seedless’ were procured from the market and sorted based on the uniform size, color and physical damage. The grapes were thoroughly washed with water and spread on cloth to drain the excess water. Blanching of grapes was carried out in hot water by performing peroxidase test.

2.1 Sample preparation

Blanched grapes were crushed and pressed in the juicer and filtered through the muslin cloth to get the clear juice (TSS: 19-21 °B). The clarified grape juice was boiled for 3–5 minutes and divided into two fractions: first fraction contained 3/4 part of juice which was boiled to obtain concentrated juice and simultaneously glucose was added with constant stirring in order to raise the juice TSS to 40 °Brix. The scum formed on the surface of the juice during boiling was removed. Whereas, the left fraction (1/4 part of juice) was added with the wheat starch and mixed properly by stirring. Both the fractions were then mixed together and boiled again to raise the TSS of the juice to 40^{0}Brix to prepare final grape juice concentrate with density of 1.2 g/cm^3.

2.2 Experimental design for foam-mat drying of grape bar

The foaming treatment was given to the prepared juice concentrate by adding foaming agent (egg albumen: 0%-12%), foaming stabilizer (Methyl cellulose: 0.1%-0.5%) and whipping it for eight minutes at constant speed of 421 rpm. The foamed grape concentrate was spread on the trays and convectively dehydrated at different levels of thickness (3-5 mm) and temperature (55^{0}C-75^{0}C). The process conditions for foam-mat drying were designed by Central Composite Rotatable Design (CCRD) under RSM. Central composite design is the most popular of the many classes of RSM designs (Verseput, 2001). The second order Central Composite Rotatable design was conducted to work out the range of independent process variables and their levels for foamed grape concentrate. Four independent variables had four levels, which were -2, -1, 0 and +1+2. A total of 30 different combinations (including five replicates of the centre point each sighed the coded value 0) were chosen in random order according to a CCD configuration for four factors (Cochran and Cox, 1957). The experimental design in the coded and actual levels of variables is shown in Table 1. The second order polynomial equation was fitted to experimental data of each dependent variable as given in equation (1):

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

where, Y_k (drying time, color change, texture (cutting force), non-enzymatic browning, total sugars (%) protein (%), water activity (a_w) and overall acceptability (%); β_{ks} (β_{ko}, β_{ki}, β_{kii}, β_{kij}) are constant coefficients and x_i are the coded independent variables.

The thickness of the grape concentrate was selected based on the amount of grape concentrate in g/mm and was calculated as the product of tray area and grape concentrate density. The samples were convectively dehydrated in hot air tray drier to final moisture content (14±1% db). The prepared grape bar was taken out and further analyzed for its quality attributes i.e. color change, texture (cutting force in g-f), non-enzymatic browning, total sugars (%), titratable acidity (%), protein (%), water activity and overall acceptability (%).

Table 1 Experimental design for four factor- four level response surface analysis

Sample No.	Egg albumen, %		Methyl cellulose, %		Thickness, mm		Temperature, ℃	
	Coded	Un coded	Coded	Un coded	Coded	Un coded	Coded	Un coded
1	-1	3	+1	0.4	-1	4	+1	70
2	-1	3	-1	0.2	+1	6	+1	70
3	0	6	0	0.3	0	5	0	65
4	-1	3	+1	0.4	+1	6	+1	70
5	0	6	0	0.3	0	5	0	65
6	0	6	0	0.3	0	5	0	65
7	0	6	+2	0.5	0	5	0	65
8	+2	12	0	0.3	0	5	0	65
9	0	6	0	0.3	+2	7	0	65
10	0	6	0	0.3	0	5	+2	55
11	0	6	0	0.3	0	5	-2	75
12	0	6	-2	0.1	0	5	0	65
13	+1	9	+1	0.4	+1	6	+1	70
14	-2	0	0	0.3	0	5	0	65
15	+1	9	+1	0.4	-1	4	-1	60
16	+1	9	+1	0.4	-1	4	+1	70
17	-1	3	-1	0.2	+1	6	-1	60
18	0	6	0	0.3	0	5	0	65
19	+1	9	-1	0.2	-1	4	-1	60
20	-1	3	-1	0.2	-1	4	-1	60
21	+1	9	-1	0.2	+1	6	-1	60
22	+1	9	-1	0.2	-1	4	+1	70
23	+1	9	-1	0.2	+1	6	+1	70
24	0	6	0	0.3	0	5	0	65
25	-1	3	+1	0.4	-1	4	-1	60
26	0	6	0	0.3	0	5	0	65
27	+1	9	+1	0.4	+1	6	-1	60
28	0	6	0	0.3	-2	3	0	65
29	-1	3	+1	0.4	+1	6	-1	60
30	-1	3	-1	0.2	-1	4	+1	70

2.3 Quality analysis

The color of developed grape bar was measured by using Miniscan XE plus Hunter lab colorimeter (Hunter Associates Laboratory, Inc., Reston, Va., U.S.A.). Texture of the samples was determined with the help of Texture Analyzer TA-Hdi in terms of cutting force (g-f). Non-enzymatic browning (NEB) as optical density (OD) of alcoholic extract of sample was determined by Ranganna (1986). Total sugars (%) were determined by using phenol- sulfuric acid method (Dubois et al., 1956). Titratable acidity was analyzed by using reagents i.e. 90% alcohol, 0.1 N NaOH solution and phenolphthalein indicator (AOAC, 2000). Protein content of the grape leather was estimated by the Kjeldhal method (AOAC, 2000). Water activity was measured by placing the sample in hygrometer. Overall acceptability of developed product was evaluated in terms of appearance, color, taste, texture, flavor and overall acceptability on a nine point hedonic scale. Semi-trained panels of ten judges were selected for the evaluation. Overall acceptability was evaluated as an average of color, appearance, taste, flavor and texture score and was expressed in percentage.

2.4 Optimization of foam mat drying process

The foam-mat drying was assumed to be a system affected by four independent variables, also called input factors, ξ_i (egg albumen, methyl cellulose, thickness and temperature), which were closely controlled and accurately measured. The analysis was done independently for each response variable by using a commercial statistical package, 'Design Expert DX 8.0.4 (Statease Inc., Minneapolis, USA, Trial Version 2010). The regression coefficients were estimated through least squares method. The adequacy of the fitted model was tested through the analysis of variance showing lack of fit and coefficient of correlation (R^2). The process conditions for foam-mat drying were optimized by response surface methodology. In order to optimize the process variables, only those responses were selected for optimization, which were found to have non-significant lack of fit. Three-dimensional plots and contour plots (graphical method) according to the fitted model and fixed variable were drawn. To localize an optimum condition, the superposition technique was employed for optimization of different process variables by Response Surface Methodology. Desirability function was used to solve the problem as a constrained optimized problem.

3 Results and discussion

The experimental data of all quality parameters of developed grape leather from concentrated grape juice with the combination of egg albumen, methyl cellulose, drying bed thickness and drying air temperature are given in Table 2 as per the design CCRD using response surface methodology. The fitted second order polynomial equation for all responses with R^2 presented in Table 3. The response surface and contour graphs were generated for interactions of two varibles while keeping other two as constants at their centre point for all reponses (drying time, color change, texture (cutting force), non-enzymatic browning. total sugars (%) protein (%), water activity (a_w) and overall acceptability (%). The three-dimensional surfaces have given accurate geometrical representation and provided useful information about the behavior of system within the experimental range.

Table 2 Experimental data of quality paramerters of foamed grape leather

Sample	Egg	Methyl	Thickness,	Temperature,	Drying	Color	Texture	Non	Total	Protein,	Titrable	Water	Overall
1	3	0.4	4	70	255	6.36	790	0.255	28.3	1.13	5.76	0.352	68.89
2	3	0.2	6	70	360	8.15	1010.6	0.293	28.88	0.88	5.12	0.422	69.44
3	6	0.3	5	65	330	5.58	730.3	0.197	27.83	1.87	5.12	0.352	72.22
4	3	0.4	6	70	345	8.21	1028.7	0.265	28.53	0.93	4.48	0.381	69.22
5	6	0.3	5	65	330	5.58	733.8	0.196	27.83	1.87	5.12	0.35	72.22
6	6	0.3	5	65	330	5.58	728.9	0.198	27.83	1.87	5.12	0.351	73.33
7	6	0.5	5	65	340	5.75	741.2	0.217	27.95	1.88	5.12	0.365	72.78
8	12	0.3	5	65	255	3.75	1076.8	0.172	26.91	3.78	4.48	0.338	71.67
9	6	0.3	7	65	450	6.94	836.9	0.269	29.92	1.63	5.76	0.394	71.67
10	6	0.3	5	55	405	3.69	629.7	0.171	26.91	2.38	6.4	0.4	79.11
11	6	0.3	5	75	210	8.23	1342	0.391	29.92	1.13	5.76	0.347	66.67
12	6	0.1	5	65	330	5.38	746.1	0.205	28.18	1.88	3.84	0.403	70
13	9	0.4	6	70	300	4.51	1215.3	0.23	29.11	2.25	5.12	0.397	68.33
14	0	0.3	5	65	375	7.1	503.9	0.214	29.46	1.13	5.12	0.382	72.78
15	9	0.4	4	60	270	2.58	728.2	0.149	27.14	2.83	6.4	0.347	69.44
16	9	0.4	4	70	180	3.48	1129.5	0.213	29.69	2.48	5.12	0.325	69.44
17	3	0.2	6	60	490	6.35	975.3	0.231	26.1	1.33	5.12	0.356	75.89
18	6	0.3	5	65	330	5.58	730	0.197	27.83	1.87	5.12	0.353	72.78
19	9	0.2	4	60	300	2.66	744.3	0.156	29.11	2.89	4.48	0.333	63.33
20	3	0.2	4	60	330	4.73	670.3	0.194	29.46	1.43	6.4	0.411	74
21	9	0.2	6	60	390	3.39	834	0.162	27.95	2.78	6.4	0.38	67.22
22	9	0.2	4	70	195	3.43	1150.3	0.21	28.06	2.43	5.12	0.374	60.56
23	9	0.2	6	70	300	4.46	1278.6	0.243	29.8	2.25	4.48	0.357	63.89
24	6	0.3	5	65	330	5.58	730	0.197	27.83	1.87	5.12	0.352	75.56
25	3	0.4	4	60	315	4.66	674.3	0.21	27.6	1.45	5.12	0.369	73.56
26	6	0.3	5	65	330	5.58	729	0.196	27.83	1.87	5.12	0.352	75.55
27	9	0.4	6	60	390	3.44	855.5	0.167	28.3	2.78	5.12	0.41	70.55
28	6	0.3	3	65	210	4.23	661.9	0.157	27.6	2.01	2.56	0.376	71.67
29	3	0.4	6	60	480	6.73	949.7	0.225	27.95	1.33	5.12	0.372	72.78
30	3	0.2	4	70	240	6.3	779.4	0.249	29.46	1.15	3.2	0.338	62.78

Table 3 Adequacy of fitted model

Parameter	Fitted model	Model Equation	R^2	*p* value	Lack of fit
Drying time, min	Quadratic	$\text{Drying time (minutes)} = -536.77-4.16667*EA-452.08*MC+151.46*Th+23.71*T-4.17*EA*MC-2.08333*EA*Th+0.17*EA*T+12.5*MC*Th+5*MC*T-1.25*Th*T-0.43*EA^{2}+114.58*MC^{2}-0.10417*Th^{2}-0.23*T^{2}$	0.9895	0.0001*	0.0783**
Color Change, Δ*E*	Quadratic	$\text{Color change (E)} = -17.76+0.93*EA+6.55*MC+1.75*Th+0.28833*T-0.075*EA*MC-0.07*EA*Th-0.01*EA*T+0.36*MC*Th-7.5\times10^{-3}*MC*T+6\ x10^{-3}*Th*T-0.01*EA^{2}-11.52*MC^{2}-0.11*Th^{2}-6.58\times10^{-4}*T^{2}$	0.9202	0.0001*	0.2153**
Texture(cutting force)	Quadratic	$\text{Cutting force (g-f)} = 14164.41-288.33*EA-809.17*MC+22.31*Th-421.38*T-17.87*EA*MC-12.9*EA*Th+5.3*EA*T-16.87*MC*Th-4.9*MC*T-1.41*Th*T+3.67*EA^{2}+2142.29*MC^{2}+22.86*Th^{2}+3.27*T^{2}$	0.9000	0.001*	0.176**
Non enzymatic browning	Quadratic	$\text{Non enzymatic browning}= 3.08-0.02*EA+0.38*MC-0.02*Th-0.09*T-3.18\times10^{-17}*EA*MC-6.6\times10^{-4}*EA*Th+2.5\times10^{-4}*EA*T-0.03*MC*Th-5\times10^{-3}*MC*T+3.5\times10^{-4}*Th*T-2.68\times10^{-4}*EA^{2}+0.21*MC^{2}+2.58\times10^{-3}*Th^{2}+7.83\times10^{-4}*T^{2}$	0.8986	0.0001*	0.0812**
Total sugars, %	Quadratic	$\text{Total sugar (\%)} = 80.64-0.72*EA-29.28*MC-6.92*Th-1.01*T+0.16*EA*MC+0.09*EA*Th+4.82\times10^{-4}*EA*T+2.82*MC*Th+0.13*MC*T+0.04*Th*T+0.01*EA^{2}+7.61*MC^{2}+0.25*Th^{2}+6.51\times10^{-3}*T^{2}$	0.5384	0.3361**	0.165**
Protein, %	Quadratic	$\text{Protein (\%)}= -5.59+0.15*EA-0.34*MC+0.55*Th+0.21*T-0.01*EA*MC+2.8\times10^{-3}*EA*Th-1.68\times10^{-3}*EA*T+0.03*MC*Th+0.01*MC*T-6.18\times10^{-3}*Th*T+0.01*EA^{2}-1.12*MC^{2}-0.02*Th^{2}-1.69\times10^{-3}*T^{2}$	0.9922	0.0001*	0.128**
Titrable acidity, %	Quadratic	$\text{Titrable acidity (\%)}= 57.46-0.22*EA-4.13*MC+2.41*Th-1.72*T+0.13*EA*MC+0.01*EA*Th+2.6\times10^{-3}*EA*T-2.8*MC*Th+0.4*MC*T+8\times10^{-3}*Th*T-3.7\times10^{-3}*EA^{2}-11.33*MC^{2}-0.19*Th^{2}+0.01*T^{2}$	0.4971	0.4548**	0.678**
Water activity	Linear	$\text{Water activity} = 0.41-2.31\times10^{-3}*EA-0.04*MC+0.01*Th-1.15\times10^{-3}*T$	0.2748	0.0799**	0.0001*
Overall acceptability, %	Quadratic	$\text{Overall acceptibility (\%)} = 3.10-5.23*EA-3.72*MC+11.68*Th+2.20*T+4.25*EA*MC-0.02*EA*Th+0.07*EA*T-10.14*MC*Th+1.67*MC*T+0.03*Th*T-0.10*EA^{2}-111.11*MC^{2}-1.04*Th^{2}-0.02*T^{2}$	0.7783	0.0078*	0.0663**

Note: * Significant at 5%; **Non Significant at 5%.

3.1 Effect of foam mat drying process parameters on drying time

The drying time was observed for the development of grape leather formed from grape concentrate till the desired moisture content was achieved (14% db). The fitted second order polynomial equation for drying time was presented in Table 3 with R^2 0.9895 with non-significant lack of fit. The drying time varied from 180 to 490 minutes (Table 2). The negative value of egg albumen and methyl cellulose ($p<0.1$) showed the significant effect (Table 4). With increase in egg albumen concentration, the drying time was reduced. The samples having composition 6% and 12% egg albumen with 0.3% methyl cellulose, 5mm drying bed thickness and dried at 65℃ took 330 min and 255 minutes of drying time respectively. Similarly the samples with 3% and 9% egg albumen, 0.4% methyl cellulose dried with 4 mm thickness at drying temperature 60℃ recorded 315 min and 270 minutes drying time respectively. This reduction in drying time with increase in egg albumen concentration could be due to the porous nature of the foamed juice concentrate.

The drying time was also influenced by the air temperature. The positive value of temperature also showed significant effect (Table 4). With increase in drying air temperature, the drying time was reduced due to the increase in drying rate. The drying time for the sample having composition 6% egg albumen, 0.3% methyl cellulose, drying bed thickness of 5 mm dried at 55℃ and 75℃ recorded 405 and 210 minutes respectively, thus reducing the drying time by almost 50%. The interaction term of temperature and drying bed thickness had significant effect ($p<0.1$), which results in the drying time increased with increase in the drying bed thickness irrespective of drying temperature (Table 4). At constant drying temperature of 60℃ the samples with 3% egg albumen, 0.2% methyl cellulose dried at 4 mm and 6 mm drying bed thickness witnessed 330 and 490 minutes of drying time respectively. The similar results were reported for banana slices dried at different drying bed thickness at 60℃ (Maskan, 2000), potato slices (Yusheng and Poulsen, 1988) and apple slices (Roman et al., 1979).

It is also clear from Figure 1 that with the increase in egg albumen concentration and temperature, the drying time was decreased except for the increase in drying bed thickness of foamed grape concentrate. The significant effect of egg albumen %, drying bed thickness and temperature on drying time ($p<0.01$) was observed whereas, no significant effect on drying time was observed for methyl concentration.

Table 4 Statistically analyzed data for the selected responses

Coefficients	Drying time, min		Color		Texture (cutting force),		Non enzymatic		Total sugars, %	
	Coeff. Value	F value	Coeff. Value	F value	Coeff. value	F value	Coeff. value	F value	Coeff. value	F value
Intercept	-536.77*	101.06	-17.76*	12.35	14164.41**	9.64	3.08*	9.50	80.64	1.25
Egg albumen (A)	-4.17**	183.97	0.93*	97.38	-288.33*	23.86	-0.02*	20.16	-0.72	0.23
Methyl Cellulose (B)	-452.08	0.86	6.55	0.16	-809.17	0.03	0.38	0.00	-29.28	0.34
Thickness (C)	151.46**	725.83	1.75*	28.85	22.31*	16.49	-0.02*	14.52	-6.92	0.29
Temperature (D)	23.71**	480.69	0.28*	40.24	-421.38*	56.01	-0.09*	72.73	-1.01	9.85
A*B	-4.17	0.21	-0.075	0.02	-17.87	0.05	-3.18×10^{-17}	0.00	0.16	0.05
A*C	-2.08*	5.18	-0.07	2.23	-12.9**	2.83	-6.667×10^{-4}	0.14	0.09	1.48
A*D	0.17	0.83	-0.01	1.20	5.3*	11.94	2.5×10^{-4}	0.48	4.82×10^{-4}	0.001
B*C	12.5	0.21	0.36	0.05	-16.87	0.01	-0.03	0.48	2.82	1.48
B*D	5.00	0.83	-7.5×10^{-3}	0.00	-4.9	0.01	-5.00×10^{-3}	0.21	0.13	0.08
C*D	-1.25*	5.18	6×10^{-3}	0.04	-1.41	0.09	$+3.5\times10^{-4}$	0.10	0.04	1.06
A^2	-0.43**	3.38	-0.01	1.58	3.67**	3.55	-2.68×10^{-4}	0.34	0.01	0.35
B^2	114.58	0.30	-11.52	0.93	2142.29	1.49	0.21	0.25	7.61	0.18
C^2	-0.11	0.00	-0.11	0.85	22.86	1.69	2.58×10^{-3}	0.39	0.25**	1.99
D^2	-0.23*	7.46	-6.58×10^{-4}	0.02	3.27*	21.75	$7.83\times10^{-4**}$	22.47	6.51×10^{-3}	0.85

Note: * Significance at 5%; **Significance at 10%.

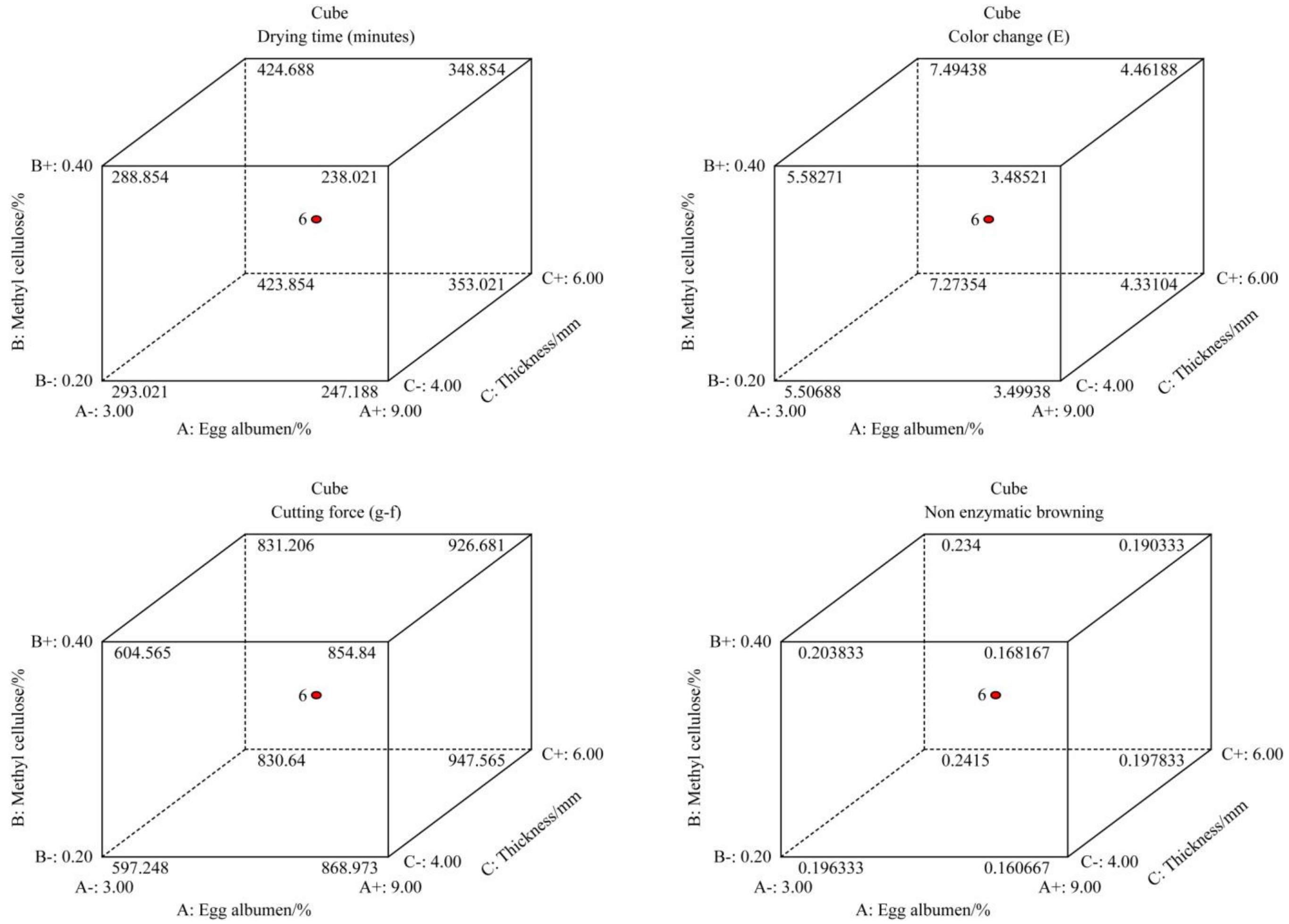

Figure 1 Response surface plots for drying time, color change, cutting force, and non-enzymatic browning of foam mat drying process parameters at stationary point of (a)thickness 5 mm and temperature 65°C (b) egg albumen 6% and methyl cellulose 0.3%

3.2 Effect of foam mat drying process parameters on color change

The color of fruit leather is a very important parameter with respect to consumer preference. The color values (L, a and b) of the fresh prepared non-foamed grape concentrate were 44.68, 10.16 and 21.68. The color of the foamed grape concentrate changes due to the incorporation of egg albumen and methyl cellulose resulting the decrease in ‘a’ and ‘b’ value increase in ‘L’ value in comparison of fresh grape concentrate. During drying the color change was observed in all samples. This might be due to higher percentage of egg albumin basically contributing towards the white color causing increase in L value (Kadam and Balasubramanian, 2011). The color change values varied from 2.58 to 8.23 (Table 2). The egg albumen showed the significant effect on color change whereas the methyl concentration has no significant effect on color change (Table 4). The color change for sample having composition 0% and 12% egg albumen; 0.3% methyl cellulose; 5 mm drying bed thickness and dried at 65℃ was 7.1 and 3.75 respectively. The sample having composition 3% and 9% egg albumen with 0.4% methyl cellulose, 6 mm thickness at 70℃ was 8.21 and 4.51 reported respectively. Thus, color change was more in lower concentration of egg albumen as compared with higher concentration of egg albumin. The color change was not only influenced by the egg albumen concentration but it was also affected by the change in the temperature. With increase in drying air temperature, the color change was also increased significantly (p<0.05). It might be due to the Maillard reactions at the higher temperatures, the more brownish color was observed (Figure 1). The color change values at 55℃, 65℃ and 75℃ for composition (6% egg albumen, 0.3% methyl cellulose, 5 mm thickness) were 3.69, 5.58 and 8.23 respectively (Table 2). The drying bed thickness resulted with significant effect (p<0.05) but less effect as compare to drying temperature as more F value because frequent time is required to dry thick concentrate.

3.3 Effect of foam-mat drying process parameters on texture (cutting force)

The cutting force values varied from 629.7 to 1,278.9 g-f. The cutting force required for cutting the grape leather having composition 0% and 12% egg albumen was 503.9 g-f and 1,076.8 g-f observed respectively (Table 2). It is clear from Figure 1 that as the egg albumen concentration increased, the force required for cutting also increased. Similarly, drying temperature also increased the cutting force. Cutting force is negatively related to linear terms egg albumen and drying temperature (p<0.05) where as positively related to drying bed thickness (p<0.05). The interaction terms and quadratic terms showed the significant effect. This might be due to the hard texture of the product. Moreover, the sticky nature of the leather prepared at higher level of the egg albumen concentration, temperature and drying bed thickness caused the removal of leather from the tray quite difficult.

3.4 Effect of foam-mat drying process parameters on non-enzymatic browning

The non-enzymatic browning determines the Maillard reactions. The negative value of linear terms egg albumen, drying bed thickness and drying temperature showed the significant effect on non-enzymatic browning (p<0.05) (Table 4). At the higher levels of temperature the non-enzymatic browning was more but with the addition of egg albumen in grape concentrate reduced the drying time and color change values resulting the non-enzymatic browning were also reduced (Figure 1) thus the quadratic term of temperature showed the negative effect. The thickness of grape concentrate also influenced the non-enzymatic browning. The drying time was increased as the thickness increased eventually non-enzymatic browning was increased due to caramelization of sugars caused by maillard reactions. The non-enzymatic browning values varied from 0.156 to 0.391. The non-enzymatic browning of grape leather prepared without using foaming treatments was 0.235 at 65℃ where as for the foamed grape leather was found to be 0.197 having the egg albumen concentration of 6% at 65℃. The non-enzymatic value at 55℃ and 75℃ having the composition of 6% egg albumen, 0.3% methyl cellulose, 5 mm thickness were 0.171 and 0.391 repectively (Table 2). The methyl cellulose concentration had no such effect as the function of methyl cellulose was to stabilize the foam structure.

3.5 Effect of foam-mat drying process parameters on total sugars (%)

Sugar content of foam-mat dried grape leather ranged from 26.10% to 29.92% (Table 2). The fitted model to total sugars was found to be non-significant. The decrease in the sugar content noticed in some samples might be due to concentrations of egg albumen and methyl cellulose. Similar decline in sugar content was also reported for the preparation of dehydrated chips (Marwaha and Pandey, 2006). With increase in egg albumen concentration, the total sugars were increased (Figure 2). Similarly with the increase in the temperature and thickness, the total sugars also increased. It might be due to caramelization of sugars caused by maillard reactions at higher levels of temperatures.

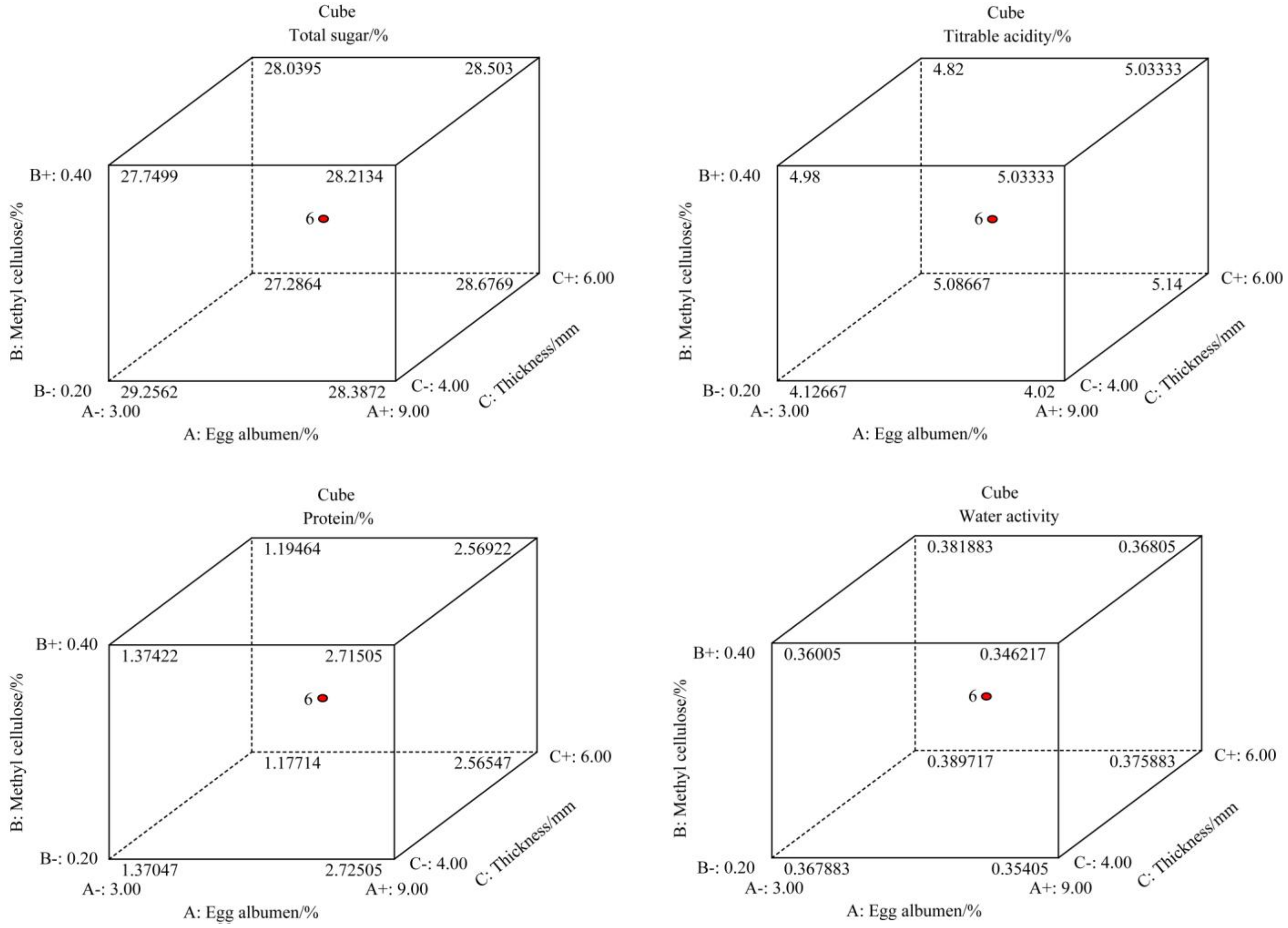

Figure 2 Response surface plots for total sugars, protein, titrable acidity and water activity of foam mat drying process parameters at stationary point of (a)thickness 5 mm and temperature 65^{o}C (b) egg albumen 6% and methyl cellulose 0.3%

3.6 Effect of foam mat drying process parameters on protein content (%)

Protein content of fresh grape concentrate was 1.38% was observed. The protein content of foam dried grape leather was ranged from 0.88% to 3.78% (Table 2). Protein showed the positive related to linear terms of egg albumen, thickness and drying temperature. The interaction terms quadratic terms of drying bed thickness and drying temperature showed the significant effect (p<0.1) (Table 5). An increasing trend in protein was noticed with increase in the concentration of egg albumen because egg albumen itself has higher protein content. But decline trend was observed at higher levels of temperatures as denaturation of protein occurred (Figure 2). Similar results were reported by Kadam et al. (2010) that increase in protein content in form of milk and at higher temperatures the protein was decreased resulting decrease in sugar content.

3.7 Effect of foam-mat drying process parameters on titratable acidity (%)

Total acid (%) of foamed dried grape leather ranged from 2.56% to 6.4% (Table 2). The decline trend was observed for titratable acidity with increase in temperature (Figure 2). This decline in total acid (%) was also reported for foam-mat dried mango powder (Kadam et al., 2010), mandarin powder (Kadam and

Balasubramanian, 2011), peanuts (Tsai et al., 2007), apples (Pereira et al., 2008) and tomatoes (Radwan and Lobna, 2002). The analysis of variance showed non-significant effect of all process parameters on titratable acidity.

3.8 Effect of foam-mat drying process parameters on water activity (%)

The water activity of foamed dried grape leathervaried from 0.33-0.42 a_w (Table 2). The water activity for all samples were approximate same because all samples were dried to the desired moisture content of 14%db (Figure 2). Reduced water activity can inhibit microbial growth and prolong shelf life of the product. The grape leather had low water activity so it can be stored for longer time period. The analysis of variance showed that the model fitted to experimental data had no significance because the water activity of all samples was dependent on the final moisture content of grape leather. Thus all process parameters showed non-significant effect on water activity (Table 5)

Table 5 Statistically analyzed data for the selected responses

Coefficients	Protein, %		Titratable acidity, %		Water activity, aw		Overall acceptability, %	
	Coeff. value	F value	Coeff. Value	F value	Coeff. value	F value	Coeff. Value	F value
Intercept	-5.59*	136.29	57.46	1.06	0.41	2.37	3.103*	3.76
Egg albumen (A)	0.15*	1588.79	-0.22	0.02	$-2.31\ x10^{-3}$	2.10	-5.239*	7.22
Methyl Cellulose (B)	-0.34	0.01	-4.13	1.17	-0.04	0.67	-3.726*	5.24
Thickness (C)	0.55*	24.54	2.41	1.94	0.01*	5.24	11.682	1.31
Temperature (D)	0.21*	199.67	-1.72**	2.90	-1.15×10^{-3}	1.45	2.202*	19.47
A*B	-0.01	0.03	0.13	0.04			4.258**	3.49
A*C	2.8×10^{-3}	0.16	0.01	0.04			-0.018	0.01
A*D	-1.68×10^{-3}	1.46	2.6×10^{-3}	0.04			0.073**	2.58
B*C	0.03	0.03	-2.8	1.76			-10.141**	2.20
B*D	0.01	0.12	0.4	0.90			1.667	1.49
C*D	-6.18×10^{-3}**	2.18	$8\ x10^{-3}$	0.04			0.038	0.08
A^2	0.01*	69.18	-3.7×10^{-3}	0.04			-0.100*	2.99
B^2	-1.12	0.49	-11.33	0.49			-111.108*	4.53
C^2	-0.02**	2.55	-0.19	1.44			-1.042**	3.98
D^2	-1.69×10^{-3}*	7.03	0.01**	3.16			-0.029**	1.99

Note: * Significance at 5%; **Significance at 10%.

3.9 Effect of foam mat drying process parameters on overall acceptability

The sensory quality of foam dried grape leather evaluated on nine point hedonic scale for various attributes namely appearance, color, texture, taste and overall acceptability was determined. The grape leather prepared from foam-mat drying was acceptable in all sensory quality parameters with overall acceptability more than 60% (Table 2). However, the acceptability score exhibited slight decrease with the increase in egg albumen concentration (Figure 3). The grape leather prepared at higher temperatures didn't have good appearance; the texture was hard, sticky and difficult to remove from the trays. The chewability of the product was difficult. The sample having high egg concentration gave some off flavors.

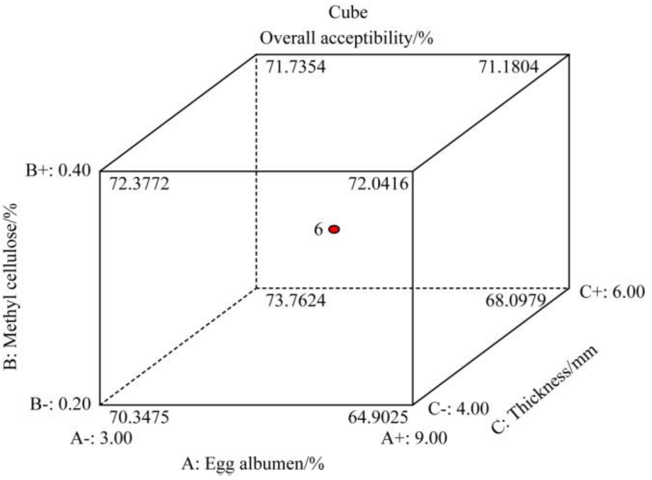

Figure 3 Response surface plots for overall acceptability of foam-mat drying process parameters at stationary point of (a)

thickness 5 mm and temperature 65℃ (b) egg albumen 6% and methyl cellulose 0.3%

The grape leather formed at lower levels of temperatures and egg albumen concentrations had acceptable appearance and more easy to remove from trays. The impact of methyl cellulose concentration on overall acceptability was not much as it did not impart the flavor to the product. These results were also satisfied statistically that egg albumen and temperature (p<0.01) significantly affected the overall acceptability.

3.10 Optimization of foam-mat drying process for the development of grape leather

The quality parameters of foamed dried grape leather namely total sugars (%), protein (%), water activity, non-enzymatic browning, texture (cutting force), color change, titratable acidity (%) and overall acceptability were determined. All quality parameters were studied for determining the more impact on nutritional value of grape leather and analyzed for finding significant fitted model and non-significant lack of fit. Based on this, drying time, color change, texture (cutting force), non-enzymatic browning and overall acceptability were taken for optimization of foam-mat drying process for the development of grape leather. These dependent parameters were used for finding optimized levels of drying process parameters.

The optimization of the foam-mat drying was aimed at finding the levels of independent variables i.e. egg albumen (%), methyl cellulose (%), drying bed thickness and drying air temperatture which would give minimum drying time, minimum color change, mimimum force for cutting (texture), minimum non-enzymatic browning and maximum overall acceptability. The statistical analysis for overall effect of each process variables on all responses were performed by separating the contribution of each independent variable to the total sum of squares.

Graphical multi-response optimization technique was adopted to determine the workable optimum conditions for foam-mat drying process. The contour plots for all responses were superimposed and regions that best satisfy all the constraints were selected as optimum conditions. These constraints resulted in 'feasible zone' of the optimum conditions (shaded area in the superimposed contour plots). The superimposed contour plots having common superimposed area for all responses are shown in Figure 4.

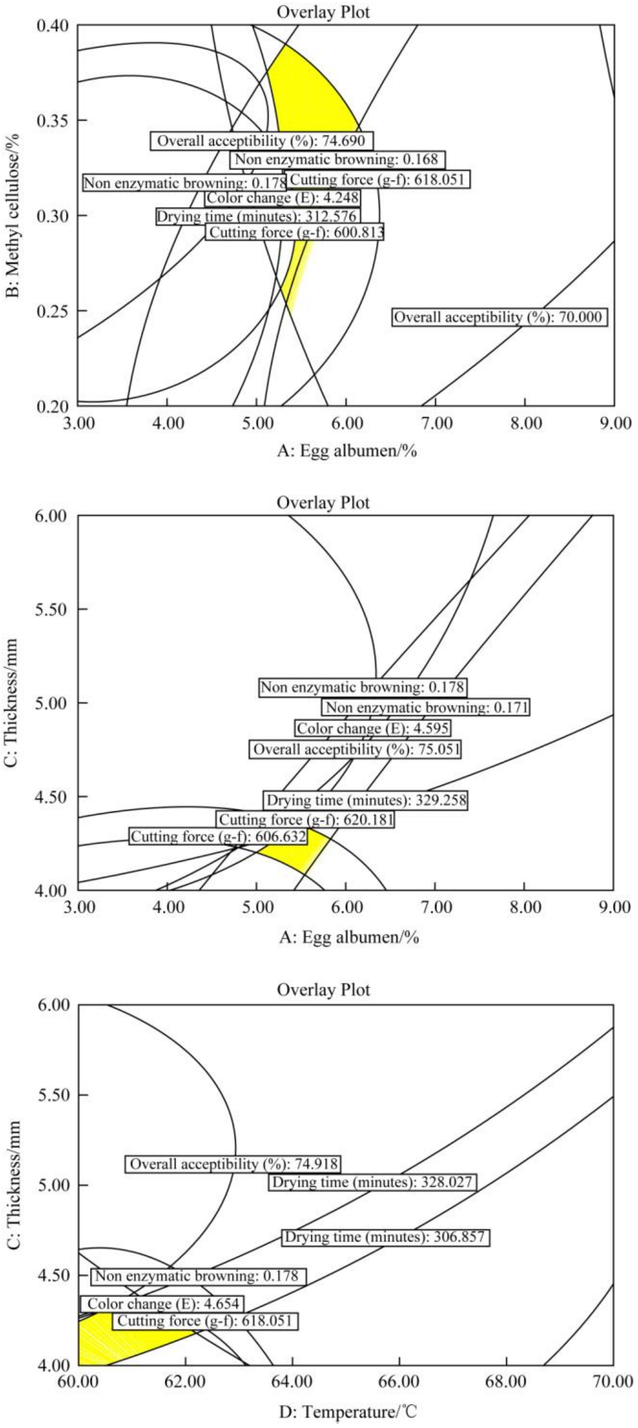

Figure 4 Superimposed contour plots of different responses for optimization of foam mat drying process for the development of grape leather

The optimum range of process parameters for foam-mat drying process was: 5% to 6% egg albumen concentration, 0.25% to 0.0.38% methyl cellulose concentration, 4 to 4.5 mm of drying bed thickness and 60℃ to 63℃ drying air temperature. In order to optimize the process parameters for preparation of foam-mat drying process by numerical optimization; which finds a point that maximizes the desirability function; equal importance of ‘3’ were given except for overall acceptability was given ‘4’ because it includes a number of parameters like appearance, color, flavor and taste. The optimum operating conditions for egg albumen concentration, methyl cellulose concentration, drying bed thickness and drying temperature was 5.51%, 0.31%, 4mm and 60 ℃. Corresponding to these values of process variables, the value of drying time was 330 minutes, color change was 5.58, cutting force was 730.33 g-f, non-enzymatic browning was 0.19 and overall acceptability was 73.61% (Table 6). The overall desirability was 0.74.

Table 6 Optimum solutions for various process parameters of grape leather from foam mat drying process

Process parameter	Target	Experimental range		Importance	Optimization	
					Optimum conditions	Desirability
Egg albumen, %	in range	0	12	3	5.51	0.74
Methyl cellulose, %	in range	0.1	0.5	3	0.31	
Drying bed thickness, mm	in range	3	7	3	4	
Drying temperature, ℃	in range	55	75	3	60	
Responses					Predicated values	
Drying time, min	Minimum	180	490	3	330	
Color change, Δ*E*	Minimum	2.58	8.23	3	5.58	
Texture (cutting force), g-f	Minimum	503.9	1342	3	730.33	
Non- enzymatic browning	Minimum	0.149	0.391	3	0.19	
Overall acceptability, %	Maximum	60.56	79.11	4	73.61	

4 Conclusions

This study exhibited the foam-mat drying is other alternative for development of grape leather. The egg albumen concentration and drying air temperature had a highly significant effect on the quality parameters of grape leather. The optimum conditions obtained for development of foamed grape leather considering minimum drying time, minimum color change, minimum cutting force, minimum non-enzymatic browning and maximum overall acceptability were 5.51% egg albumen concentration, 0.31% methyl cellulose, 4 mm drying bed thickness and 60 ℃ drying temperature with desirability of 0.74.

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