ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2017; 3(2): 393-400
www.allresearchjournal.com
Received: 14-12-2016
Accepted: 16-01-2017

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Quality analysis of mechanical dried cabbage

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Abstract
The present study was conducted with an objective to evaluate the quality parameters of cabbage in mechanical dryer. The independent parameters for drying were exposure area, loading density and moisture content. Maximum rehydration ratio, ascorbic acid content, total phenolic content and overall acceptability were 6.35, 11.5mg/100g, 69 mg/ GAE 100g and 7.84 respectively. The minimum color change and shrinkage ratio was 18.12 and 0.57 respectively.

Keywords: Cabbage, mechanical drying, quality assessment

1. Introduction
Drying is a classical method to preserve agricultural produce. It is noted that over 20 per cent of the world perishable crops are dried to increase shelf-life and promote food security (Grabowski *et al.* 2003) [4]. Drying is the process of moisture removal due to simultaneous heat and mass transfer. Drying, reduce the moisture to certain level and inhibits the growth of bacteria and has been practiced worldwide since ancient time to preserve food. Initially, salting and drying in the sun, an open room or on stove tops were accepted methods. The first dehydrator was introduced in France in 1795 for drying fruits and vegetables. The first known record of drying involved vegetables and appeared in the 18th centuary (Van and Copley 1963) [12]. Value addition to perishable fresh fruits and vegetables is done by drying process, greatly extend product shelf life and reduce postharvest losses, as well as it also contributes to great cost reduction in transportation and storage cost. Dried foods are good source of quick energy and wholesome nutrition, since the only thing lost during preservation is moisture. Dried nuts and seeds are good sources of protein for snack or meal. The food leather and chips provide plenty of energy. Drying of fruits and vegetables has been principally accomplished by convective drying. Drying of fresh produce, which contains up to 85 – 90% water, to a safe moisture content of 5-6% requires the application of flow heat and ventilation for the best results. Cereals are often dried to 14% w/w while oil seeds dried to 12.5% (soybeans), 8% (sunflower) and 9% (peanuts) respectively. The most common dried vegetables are dried to target moisture content of below 10% depending upon the shelf life required. Various kinds of parameter affect the drying rate of agricultural produce. Drying air characteristics (air flow rate, drying air temperature and humidity), product variables (product throughput, slices thickness and initial and final moisture contents), dimensional variables (length, width, height of dryer) these operational parameters influence the capacity and performance of dryer (Purohit *et al.* 2006) [8]. Mechanical dryers has been used for the preservation of agricultural produce since generations all over the world.

2. Materials and Methods
2.1 Preparation of sample
Fully cured cabbage were procured from local market, Ludhiana. The crops was washed thoroughly in fresh water to remove any dirt and dust as well as any residual chemicals sprayed on them. Washed cabbage crop was manually prepared for further process. Blanching was done at 85 °C for 1 min. after blanching dipped in the 0.25% potassium meta-bisulphite.

A general flow process was explained for preparation of dried product in fig.-

Raw crop
↓
Sorting, washing, cleaning
↓
Cutting of cabbage across into 5mm thick pieces
↓
Blanching to inhibit enzymatic browning (at 85° temperature for 1 min)
↓
Dipping of blanched slices in 0.25% conc. of Potassium Meta-bisulphite(KMS)
↓
Loading on tray
↓
Double layer forced convection solar dryer
↓
Dried product
↓
Packaging

Fig 1: Flow chart of the preparation of dried cabbage product.

2.2 Quality parameters
Samples of raw and dried product was analysed for quality parameters. These parameters showed affect of drying on properties. The quality parameters like Initial moisture content, Shrinkage ratio, Rehydration Ratio, Color, Polyphenols content, Ascorbic acids content, Overall acceptability.

2.2.1 Estimation of moisture content
The moisture was determined from time to time for keeping the proper record and identification of the samples. The hot air oven method (AOAC 2006) [1] was used to determine the moisture content of cabbage

$$\text{Moisture content (\% db)} = \frac{\text{Wetweight} - \text{Bonedryweight}}{\text{Bonedryweight}} \times 100 \quad (3.13)$$

2.2.2 Shrinkage ratio
The shrinkage ratio of dried sample was measured by toluene displacement method. Shrinkage ratio was calculated as the percentage change from the initial apparent volume (Mohsenin 1986) [6].

$$\text{Shrinkage ratio} = \frac{V_r}{V_0} \quad (3.14)$$

Where, V_r= Volume displaced by rehydrated sample, ml
V_0 = Volume displaced by fresh sample, ml

2.2.3 Rehydration ratio
Reconstitutional quality was evaluated by soaking known weight (5-10 g) of each sample in sufficient volume of water in a glass beaker (approximately 30 times the weight of sample) at 95 °C for 20 minutes. After soaking, the excess water removed with the help of filter paper and samples were weighed. In order to minimize the leaching losses, water bath was used for maintaining the set temperature (Ranganna 1986) [9]. Rehydration ratio (RR) of the samples was computed as follows:

$$\text{Rehydration ratio} = \frac{W_r}{W_d} \quad (3.15)$$

Where,
W_r = Drained weight of rehydrated sample, g
W_d = Weight of dried sample used for rehydration, g

2.2.4 Estimation of color
Colour was determined using Hunter Lab Miniscan XE Plus Colorimeter (Hunter 1975). For determination of colour, colorimeter was put on the sample and the values of L, a, b were measured. The sample was filled in petridish provided with no light is allowed to pass during the measuring process. The colour change was determined using the formula:

$$\text{Colour change } \Delta E = \sqrt{(\Delta L^2 + \Delta a^2 + \Delta b^2)}$$

Where
ΔL, Δa and Δb are deviations from 'L', 'a' and 'b' values of fresh sample.
ΔL = L dried sample – L fresh sample;
+ ΔL means sample is lighter than fresh, - ΔL means sample is darker than fresh.
Δa = a dried sample- a fresh sample;
+ Δa means sample is redder than standard, - Δa means sample is greener than standard
Δb = b dried sample –b fresh sample,
+ Δb means sample is yellower than standard, - Δb means sample is bluer than standard

2.2.5 Estimation of Ascorbic Acid
The ascorbic acid content was analysed by using method Tewari *et al.* 2017 [11].

Preparation of chemicals
MP-AA Solution: 40 ml of acetic acid and 15g of metaphosphoric acid were dissolved in 450 ml of distilled water.

Dye solution: 52 mg of 2,6 dichlorophenol indophenols and 42 mg of sodium bicarbonate in 200ml of dw and solution was filtered.

Std Ascorbic acid: 20 mg of vitamin C was dissolved in 100 ml of MP-AA solution.
Estimation of ascorbic acid:- 1g of sample was crushed using MP-AA solution and then filter. 5ml extract was titrating against the dye. Volume of dye used to oxidize vitamin C in sample was noted.

$$\text{Ascorbic acid content (mg/100g)} = \frac{\text{Titer value} \times \text{D.F} \times \text{vol.made}}{\text{wt.of sample} \times \text{aliquat}} \times 100 \quad (3.17)$$

D.F= Dye factor = (0.5/titer value)

2.2.6 Estimation of polyphenols
Total phenolic content was determined by Singleton *et al.* 1999 method. 1gram sample was refluxed with 80% aqueous methanol for 3 hours at 40 ^{0}C and residue was then further refluxed for 1 hour. After filtration of extracts, the final volume was made to 100ml with 80% aqueous methanol. For estimation of total phenol, 0.5 ml of this extract was mixed with 5 ml Folin-Ciocalteu reagent. The contents were mixed by manual shaking. After 3 min, 4ml of saturated sodium carbonate solution was added. After standing for 30 min at room temperature, the absorbance was measured at 765 nm. The values were reported as mg of

Gallic acid equivalent (GAE) by reference to gallic acid standard curve. The results were expressed as milligrams of GAE per 100 ml (Kamath *et al.* 2015) [5].

$$\text{Phenol conc.} \left(\frac{\text{mg}}{100\text{g}}\right) = \frac{\text{phenol value from graph} \times \text{final vol.made} \times 100}{\text{wt of sample} \times \text{aliquate}}$$

2.2.7 Estimation of overall acceptability

Overall acceptability was evaluated as an average of colour, appearance, taste is expressed in percentage. The average scores of all the 10 panellists were computed for different characteristics.

2.3 Statistical analysis

The data was analysed statistically by using univariate analysis of variance (UNI-ANOVA) in general linear model using Statistical Package for Social Sciences (SPSS, version 22). Means were computed and tested at 5% level of significance.

3. Result and Discussion

The experimetal data of quality parameters of dried cabbage for exposure area, moisture content and loading density (g/cm^3) combination were presented in Table 1. The response surface plots were generated for interactions of three variables (exposure area, moisture content &loading density) for all responses (rehydration ratio (RR), shrinkage ratio (SR), color (ΔE value), polyphenols content (%), ascorbic acid content (%) and overall acceptability) were shown in Fig. 1- 6. Such three dimensional surfaces has given accurate geometrical representation and provided useful information about the behavior of system within the experimental range. The second order polynomial equation was fitted to the experimental data and it was observed that the model fitted to all the responses were found statistically significant. It is clear from stastistically analyzed data presented in Table 2 that the exposure area, moisture content and loading density significantly affected the quality parameters.

Table 1: Experimental data of drying of cabbage for response surface analysis by mechanical drying

A: Exposure area	B:loading density	C: Moisture content	R R	S R	Color	Ascorbic acid	Polyphenol	OA
40	0.40	7	5.32	0.95	26.25	7.5	57.5	7.82
40	0.60	6	5.42	0.75	24.05	11.5	34	7.34
20	0.6	7	5.39	0.68	23.32	7.35	31.5	7.32
60	0.4	6	5.12	0.98	24.35	9.55	64	7.79
40	0.6	6	6.02	0.7	20.35	9.55	35	7.35
40	0.6	6	5.88	0.73	22.24	9.75	32	7.38
60	0.8	6	6.23	0.56	19.33	7.95	45	6.88
40	0.8	7	6.28	0.58	18.25	7.6	47	6.86
20	0.6	5	5.56	0.66	22.35	8.55	59	7.3
20	0.8	6	6.35	0.76	17.56	7.65	46	6.92
60	0.6	7	5.32	0.63	23.05	11.25	38	7.42
40	0.4	5	5.19	0.91	25.15	7.25	69	7.84
60	0.6	5	5.67	0.67	21.56	10.95	39	7.32
40	0.8	5	6.26	0.57	18.12	7.85	43	6.82
20	0.4	6	5.22	0.93	24.86	7.35	68	7.9

Table 2: Analysis of Variance (ANOVA) for model fitting of mechanical drying for cabbage

Fitting of model on	Sum of Squares	F value	p-value (Prob> F)
Rehydration Ratio	1.02	162.24	0.0001
Shrinkage ratio	0.63	37.38	0.0006
Color (ΔE)	5.35	4.92	0.0403
Ascorbic acid	226.57	12.99	0.0069
Polyphenols content	62761.88	263.71	0.0001
OA	1.58	5.24	0.0256

Rehydration ratio

The rehydration ratio of tray dried cabbage varied in the range of 5.12 to 6.35. The maximum rehydration ratio 6.35 was found for 0.8g/cm^3 loading density of sample dried at 60 sq cm exposure area.

The effect of temperature and loading density on rehydration ratio (RR) of cabbage are presented in Table 4.6 and the trend is shown in Fig. 4.6. From exposure area, moisture content and loading density plot (Fig.1), it was observed that at a constant loading density (0.8 g/cm^3) rehydration ratio increased with increasing exposure area. Higher RR indicated lesser damage to cells during dehydration, which helped in better retention of water during rehydration.

The results were corroborated from the Analysis of Variance (ANOVA) Table 3 showing that the quadratic term of exposure area (p value: 0.0001) are significant at 5% level of significance.

Table 3: Analysis of variance (ANOVA) results for rehydration ratio of Cabbage

Source	Sum of Squares	df	Mean Square	F Value	p – value Prob> F	
Model	1.02	5	0.22	162.24	<0.0001	Significant
A – Exposure area	0.67	1	0.67	456.76	0.0035	
B – loading density	0.08	1	0.08	68.65	<0.0001	
C – Moisture Content	0.03	1	0.03		0.0022	
Residual	0.015	5	0.00			

Lack of fit	0.001	3	0.00	2.36	0.2654	non significant
Pure Error	0.00	2	0.00			
Cor total	1.07	10				

Final equation predicting RR as affected by exposure area, moisture content and loading density is given below:
Rehydation ratio=-0.80833-0.45625 * loading density+0.040896* exposure area+1.7625 * moisture content + 6.25000E-004 * loading density * exposure area – 0.025000 * loading density * moisture content – 2.25000E-003 * exposure area * moisture content + 2.73598 * loading density^2- 3.63542E-004 * exposure area^2- 0.14292 * moisture content^2

Shrinkage ratio

The shrinkage ratio of tray dried cabbage varied in the range of 0.56 to 0.98. The minimum SR (0.56) was found for 0.8 g/cm^3 loading density sample dried for 20 sq cm exposure area.

The effect of exposure area, moisture content and loading density on shrinkage ratio (SR) of cabbage shown in Fig. 2. From exposure area, moisture content and loading density plot (Fig. 2), it was observed that at a constant loading density (0.8) shrinkage ratio decreased with increasing exposure area.

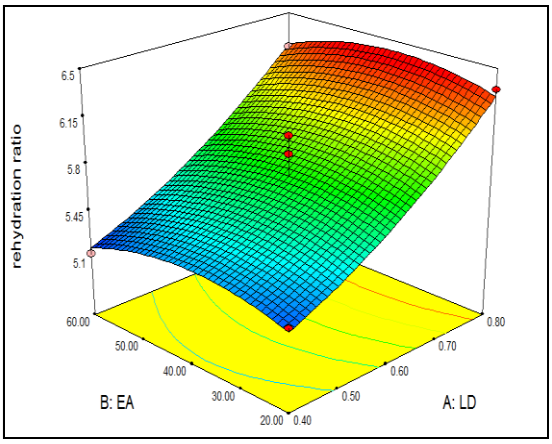

Fig 1: Response surface plot for rehydration ratio during thin layer drying of cabbage

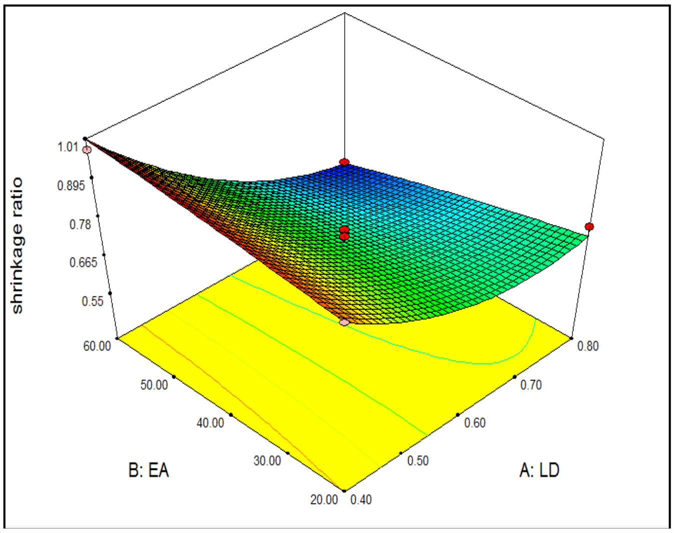

Fig 2: Response surface plot for shrinkage ratio during thin layer drying of cabbage

The results were corroborated from the Analysis of Variance (ANOVA) Table 4 showing that quadric term of loading density (p value: 0.0001) and cross product term of loading density and exposure (p value: 0.0132) are significant data 5% level of significance.

Table 4: Analysis of variance (ANOVA) results for shrinkage ratio of Cabbage

Source	Sum of Squares	Df	Mean Square	F Value	p – value Prob> F	
Model	0.63	5	0.13	67.24	0.0007	Significant
A – Exposure area	0.09	1	0.09	26.76	0.0095	
B – loading density	0.41	1	0.41	148.65	<0.0001	
C – Moisture Content	0.06	1	0.06		0.0022	
Residual	0.015	5	0.00			
Lack of fit	0.001	3	0.00	11.36	0.1654	non significant
Pure Error	0.00	2	0.00			
Cor total	0.65	10				

Final equation predicting SR as affected by exposure area, moisture content and loading density is given below:
Shrinkage ratio =-0.88417-2.56250 * loading density+0.013854 * exposure area+0.78625* moisture content -0.015625 * loading density * exposure area-0.037500 * loading density * moisture content-7.50000E-004 * exposure area * moisture content+2.16667 *loading density^2-1.45833E-005* exposure area^2-0.060833 * moisture content^2.

Color (ΔE)

The color change of tray dried cabbage from fresh cabbage varied in the range of 17.56 to 26.25 with an average value of 79.05. The maximum color (26.25) was found for 0.4 g/cm^3 loading density sample dried at 20 sq cm area and moisture content at 7% (db).

The effect of exposure area, moisture content and loading density on color of cabbage is shown in Fig 3. From exposure area, moisture content and loading density plot (Fig 3), it was observed that at a constant loading density (0.4 g/cm^3) change in color (L value, a value, b value) increased with increasing moisture content.

The results were corroborated from the ANOVA Table 5 showing that the linear term of exposure area (p value: 0.2145) and linear term of loading density (p value: 0.0220) are significant at 5% level of significance.

Table 5: Analysis of variance (ANOVA) results for change in color (ΔE) of Cabbage at different loading densities, exposure area and moisture content

Source	Sum of Squares	df	Mean Square	F Value	p – value Prob> F	
Model	5.73	2	2.93	7.24	0.0507	Significant
A – Exposure area	1.09	1	1.09	2.76	0.2952	
B – loading density	5.41	1	5.44	9.65	0.0262	
C – Moisture Content	3.06	1	6.23	7.24	0.3022	
Residual	5.35	8	0.76			
Lack of fit	4.21	6	0.65	1.07	0.7654	non significant
Pure Error	1.67	2	0.71			
Cor total	11.65	10				

Final equation predicting color as affected by exposure area, moisture content and loading density g/cm^3 is given below:

Color (L value) ==38.15917 +4.21875 * loading density-0.11717 * exposure area-3.17625* moisture content+0.14250 * loading density * exposure area-1.21250 * loading density * moisture content-6.50000E-003 * exposure area * moisture content-16.44792*loading density^2-7.60417E-005* exposure area^2-0.38708 * moisture content^2.

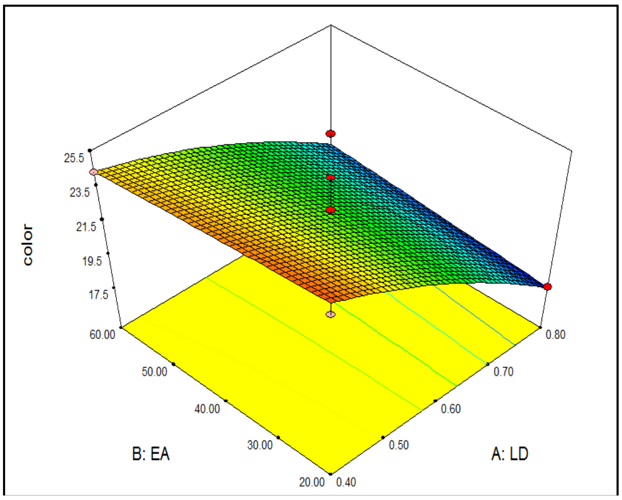

Fig 4.8: Response surface plot for color(ΔE) during thin layer drying of cabbage

Ascorbic acid

The ascorbic acid content of fresh cabbage was 48.75 mg/100g. After tray drying reduction in ascorbic acid was observed. The rate of degradation of ascorbic acid is affected by several factors such as temperature, water activity, pH, storage time and metal ions (Fennema 1997, Pardio *et al.* 1994) [7]. Drying air temperature had major affect on ascorbic acid content. Trend of ascorbic acid values are shown in Fig. 4.7. As shown in Table 4.6 the maximum reduction of ascorbic acid at 0.8 g/cm^3 loading density. Ascorbic acid value was varied from 7.5 to 11.25 as loading density increased from 0.4 to 0.8 g/cm^3 because of increase in drying time. This indicates that ascorbic acid degradation increase with drying time (Sanchez *et al.* 2012).

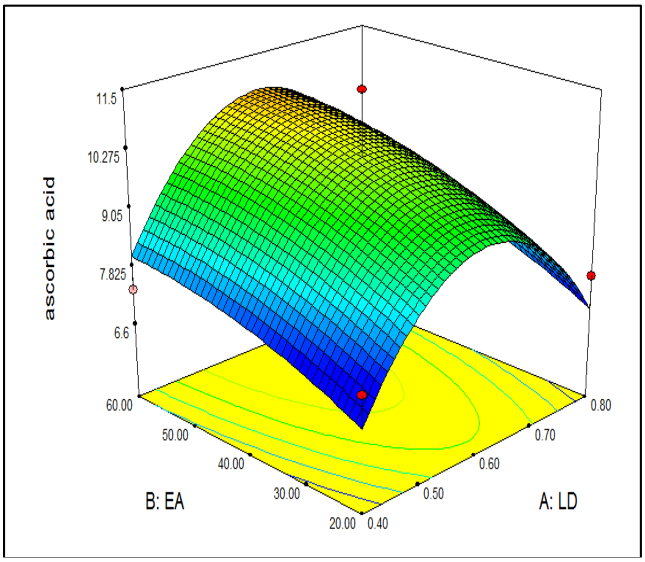

Fig 4: Response surface plot for ascorbic acid content during thin layer drying of cabbage

The results were corroborated from ANOVA Table 6 showing that quadric term of loading density (p value: 0.0075) and cross product term of loading density, exposure area and moisture content (p value: 0.7377) are significant at 5% level of significance.

Table 6: Analysis of variance (ANOVA) results for Ascorbic acid of Cabbage at different loading densities, exposure area and moisture content

Source	Sum of Squares	df	Mean Square	F Value	p – value Prob> F	
Model	275.73	5	62.93	14.74	0.0077	Significant
A – Exposure area	92.09	1	94.23	34.56	0.0052	
B – loading density	75.43	1	76.41	19.65	0.0061	
C – Moisture Content	63.76	1	66.96	17.87	0.5622	
Residual	23.35	5	4.34			
Lack of fit	16.17	3	5.32	4.86	0.3654	non significant
Pure Error	2.69	2	1.96			
Cor total	261.75	10				

Final equation predicting ascorbic acid as affected by temperature and thickness is given below:

Ascorbic acid=-24.65417-75.857 * loading density+0.011042* exposure area+3.67500 * moisture content +0.018750 * loading density * exposure area -0.62500 * loading density * moisture content +0.012500 * exposure area * moisture content -59.89583* loading density^2-7.39583E-004* exposure area^2-0.32083* moisture content^2

Polyphenol Content

The polyphenols content was about 240 mg GAE/100ml in fresh cabbage. The value of polyphenols content decreased on drying. The value of polyphenols content varied from 39 – 69 mg GAE/100ml. The maximum polyphenol content of 69 mg GAE/100ml at loading density 0.4 g/cm^3. The trend of polyphenols content has been shown in Fig 5. The decline in the phenolic content during blanching- by leaching into water, degradation during drying – by effect of heat, oxidation by polyphenoloxide and immersion (Arslan and Ozcan 2010) [1].

The results were corroborated from the Analysis of Variance Table 7 showing that quadric term of loading density (p value: 0.0001) and cross product term of loading density and exposure area and moisture content (p value: 0.0001) are significant at 5% level of significance with R squared value 0.996.

Table 7: Analysis of variance (ANOVA) results for polyphenol content of Cabbage at different loading densities, exposure area and moisture content

Source	Sum of Squares	df	Mean Square	F Value	p – value Prob> F	
Model	96925.73	5	19657.93	7.24	<0.0001	Significant
A – Exposure area	67888.09	1	67888.09	2.76	<0.0001	
B – loading density	21345.41	1	21345.41	9.65	<0.0001	
C – Moisture Content	34658.06	1	34658.06	7.24	0.0003	
Residual	542.35	5	0.76			
Lack of fit	214.21	3	0.65	0.64	0.8634	non significant
Pure Error	341.62	2	0.71			
Cor total	10611.65	10				

Final equation predicting ascorbic acid as affected by temperature and loading density is given below:

Polyphenols=540.77083-687.18750 * loading density-3.19896* exposure area-68.87500 * moisture content +0.18750 * loading density * exposure area +19.37500 * loading density * moisture content +0.33125 * exposure area * moisture content +429.16667* loading density^2+0.012292* exposure area^2-+3.29167* moisture content^2

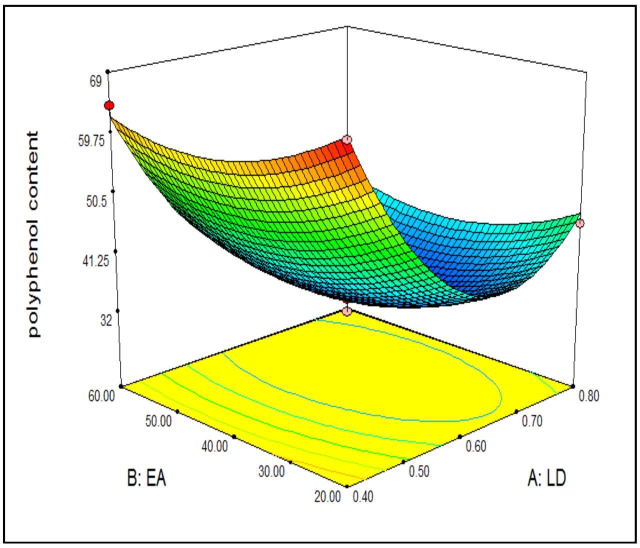

Fig 5: Response surface plot for polyphenols content during thin layer drying of cabbage

Overall Acceptability

The OA of tray dried of cabbage varied in the range of 6.82 to 7.9. The maximum OA (7.9) was found at 7% (db) and 0.4 g/cm^3 loading density. The effect of exposure area, moisture content and loading density on OA of cabbage are presented in Table 4.6 and the trend is shown in Fig. 6. From exposure area, moisture content and loading density plot (Fig. 6).

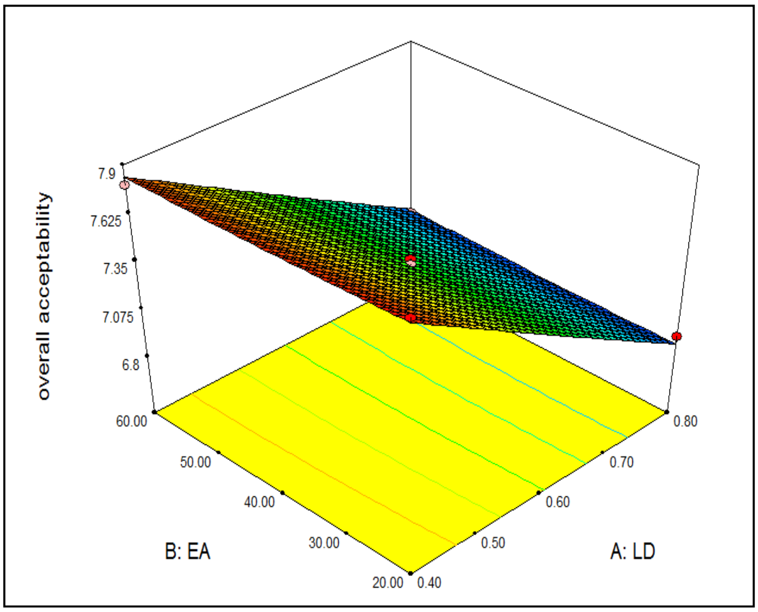

Fig 6: Response surface plot for overall acceptability during thin layer drying of cabbage

The results were corroborated from ANOVA Table 8. showing that the quadratic terms of exposure area and moisture content (p value: 0.2424) and loading density (p value: 0.0001) are significant at 5% level of significance level. The value of R square obtained was 0.9853.

Table 8: Analysis of variance (ANOVA) results for overall acceptability of Spinach at different loading densities, exposure area and moisture content

Source	Sum of Squares	df	Mean Square	F Value	p – value Prob> F	
Model	3.12	5	0.67	7.56	0.0012	Significant
A – Exposure area	0.09	1	0.09	1.13	0.4234	
B – loading density	1.73	1	1.73	19.45	0.0113	
C – Moisture Content	0.08	1	0.08	1.24	0.0201	
Residual	0.65	5	0.04			
Lack of fit	0.43	3	1.03	1.88	0.4264	non significant
Pure Error	0.12	2	0.07			
Cor total	3.86	10				

Final equation predicting OA as affected by temperature and loading density is given below:

OA =8.44083-3.20625 * loading density-0.010896* exposure area+0.25750 * moisture content +4.37500E-003 * loading density * exposure area +0.075000 * loading density * moisture content +1.00000E-003* exposure area * moisture content +0.13542 * loading density^2+2.60417E-005 * exposure area^2-0.027083* moisture content^2.

Conclusion

The quality analysis of mechanical dried cabbage was possessed good quality parameters. The independent parameter i.e. exposure area 20-60 cm2, moisture content 5-7% db and load density 0.4-0.8 g/cm3 were enough for optimize the drying process. With such independent parameters the overall acceptability obtained maximum 7.9.

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