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Optimization of egg powder by foam-mat tray drying using response surface methodology

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Abstract

Foam-mat drying studies were conducted with foamed egg liquids at different temperatures viz., 60, 65 and 70 °C, different whipping time of 1.5 and 2 min and at different foam thickness of 3 and 5 mm. Based on these experimental values, best treatment for the egg powder was optimized which carries a minimize possible drying time, maximize possible rehydration ratio, maximize possible solubility possible maximize values of L* and b* and minimize value of a* using Response Surface Methodology. From the statistical analysis of foam-mat dried egg powder, it was observed that by whipping of 1.5 min for 3 mm thickness sample dried at 60 °C temperature retained higher quality values when compared to samples dried at 65 and 70 °C of different foam thickness and whipping time, respectively. The rehydration ratio and solubility of foam were observed as 3.70 and 94.76 per cent, respectively.

Keywords: Foam-mat drying, response surface methodology, colour, rehydration ratio and solubility

1. Introduction

The per annum production of egg has been rising at the rate of 8 to 10 per cent. Due to breakage occurs during transportation of fresh eggs to different regions the considerable loss of egg is 2.5 per cent (Jayaraman *et al*., 1976) [3]. Therefore surplus eggs have to be utilized to greater extent possible to reduce wastages and also to protect price structure. Because of the increased production and the disadvantages in the storage of egg, there is a need to preserve the egg for domestic consumption and also to promote export (Rao *et al*., 1995) [4].

Foam-mat drying method is particularly suitable for viscous with sticky behaviour ingredients, thermally sensitive products or high-sugar foods. Such compounds are too hard to be dried by conventional spray-drying. Foam-mat drying usually performed under mild conditions of temperature possibly minor changes in quality or causes no damage. This explains why, in recent years, Foam-mat drying has met rising demand and found important applications as an alternating drying technique capable of being applicable on an industrial scale.

2. Materials and Methods

Hen’s Egg (Gallus Gallus) was used for this investigation. This was procured from local market of Udaipur. Eggs of “Hen” was procured and washed with clean water to remove adhering material on the surface.

2.1 Foam-Mat Tray Drying of egg

The initial moisture content of the fresh, as well as dried sample was determined using AOAC (2000) [1] method. The cleaned eggs were soaked in 2 per cent bleaching powder solution for 30 min. Finally they was washed and dried at room temperature to remove surface moisture. The eggs were broken and egg liquid was inspected visually for any spoilage. The egg liquid was filtered through muslin cloth to remove the shell pieces and any other foreign materials. The eggs liquid were weighed and mixed thoroughly in electric blender. (Thirupathi V. *et al*., 2008) [5]

For foam -mat tray drying, the foamed egg liquid, were evenly spread on the aluminium trays at a thickness of 3 and 5 mm.

The trays were placed on the tray stand in drying chamber. The temperature was maintained at 60, 65 and 70 °C. The trays were taken out of the drying chamber initially at 10 minutes interval after some time it was increases to 20 or 30 min for weight loss determination. The drying rate was computed at different moisture content.

Drying was continued till the moisture content of the samples recorded constant values.

2.2 Optimization of process variables: The response surface analysis involved fitting experimental values of Rehydration ratio, solubility, color and drying time to general quadratic polynomial equation and subsequently optimizing the values with suitable optimization software (RSM). Design-Expert version 11.0 software was used to evaluate coefficients of the Equation. The sum of squares for the models (regression) and total error were computed. The regression sums of squares were divided into 3 parts, namely, linear, quadratic and cross products as the terms appeared in Eq. The significance of these sources of sum of squares was determined by computing the F-value and comparing with the tabulated value for respective degrees of freedom under particular probability level.

Determination of optimum condition of independent variables *viz*. drying temperature, drying thickness and whipping time. At the stationary point, the slope of response surface is zero in all directions.

2.3 Numerical optimization: Numerical optimization technique of the Design-Expert version 11.0 software was used for simultaneous optimization of the multiple responses. The desired goals for each factor and response were chosen. The possible goals are: maximize, minimize, target, within range, none (for responses only). All the independent factors were kept minimized from an economical point of view while the responses *viz*. Rehydration ratio, solubility, color and drying time were kept targeted.

2.4 Graphical optimization: Graphical optimization technique of design-expert software was carried out for obtaining the desired attributes in dried product. For graphical optimization, super- imposition of contour plots for all responses was done with respect to process variables using Box Behnken model of design expert version 11.0 software. The super imposed contours of all responses for drying temperature, drying thickness and whipping time and their intersection zone for maximum rehydration ratio, solubility and color and targeted drying time indicated the ranges of variables which were considered as the optimum range for best product in terms of responses.

2.5 Verification of optimum responses: The optimum responses were verified by conducting the Foam mat drying experiment under optimum conditions. The responses such as Rehydration ratio, solubility, color and drying time at optimum processing conditions were compared with the values which were predicted by the mathematical model.

3. Result and Discussions

3.1 Optimization of process parameter

The optimization of drying parameters such as drying temperature and foam thickness and whipping time are necessary so that minimum drying time could be achieved with the optimum drying temperature, foam thickness and whipping time. It is desired that the drying time should be minimum with optimum temperature of 60 °C and foam thickness of 3mm and whipping time 1.5 min. therefore keeping these factors in mind drying process was optimised.

As per three variables optimal model, 17 trials were performed as enumerated in Table 1 for obtaining the drying time, rehydration ratio, solubility and colour (L*, a* and b*) as responses for each condition. All these trials were replicated thrice and the average of the experimental data for moisture content, drying time, rehydration ratio, solubility and colour are reported. The egg liquid was converted into foamed with the help of electric blender at 1.5 and 2min whipping time and was spread on the trays by maintaining the thickness of foam 3 and 5mm at 60, 65 and 70 °C temperature.

3.1.1 Effect of variables on drying time

The variation in drying time by changing drying temperature, foam thickness and whipping time has been presented in Table 1.

Table 1: Observed drying time under varying processing parameters

A: Temperature	B: Foam thickness	C: Whipping time	Drying time
°C	mm	min	min
70	5	1.5	430
60	5	2	840
70	5	2	560
70	3	2	420
60	3	2	690
65	3	1.5	520
70	5	2	570
65	3	2	500
60	3	1.5	620
70	3	1.5	390
65	5	1.5	590
70	3	1.5	380
60	5	1.5	750
65	5	2	630
60	3	2	690
60	5	1.5	760
60	5	2	860

Applying the RSM method as per the proposed suggestion for the purpose of fitting experimental data quadratic model was used. The statistical significance for quadratic term was calculated for drying time. (Table 1)

The R^2 values was calculated by quadratic technique and found to 0.950662 showing good fit of model to the data. The model F value of 24.77372 implies that model is significant ($P<0.0001$). The linear terms (x_1 and x_2) are significant

($P<0.0001$). The lack of fit F value was non- significant which indicate that the developed model was adequate for predicting the response. Moreover the predicted R^2 of 0.797744was a reasonable agreement with adjusted R^2 of 0.912288. This revealed that the non significant terms have not been included in the model. Therefore this model could be used to navigate the design space.

Table 2: ANOVA for drying time during foam-mat tray drying of egg liquid

Source	Sum of	Df	Mean	F-value
Model	303786.9	7	43398.13	24.77372**
A-Temperature	207961.7	1	207961.7	118.7144**
B- Foam thickness	42000.3	1	42000.3	23.97577**
C-Whipping time	10397.85	1	10397.85	5.935589**
AB	51.53089	1	51.53089	0.029416*
AC	1036.472	1	1036.472	0.591667*
BC	1364.287	1	1364.287	0.7788*
A^2	2190.086	1	2190.086	1.250205*
B^2	0	0		
C^2	0	0		
Lack of Fit	5816.031	4	1454.008	0.730657^{NS}
Std. Dev.	41.85429			
Mean	592.9412			
C.V. %	7.058758			
R^2	0.950662			
Adjusted R^2	0.912288			
Predicted R^2	0.797744			

**Significant at 1% level, *significant at 5% level, NS- non significant

High value of coefficient of determination (R^2= 0. 950662) obtained for response variable indicated that the developed model for drying time adequately explained.

The regression equation describing the effects of process variables on drying time in terms of coded values of variable is given as:

$$\text{Drying time} = 560 - 131.617*A + 51.56656*B + 25.6574*C - 2.67183*AB + 9.291802*AC + 9.293831*BC + 26.85268*A^2 \quad .... (1)$$

(R^2=0.9506)

The linear negative terms equation 4.1 indicated that drying time decreased with increase in drying temperature. The linear positive terms indicated that drying time increased with increase in foam thickness. The linear positive terms indicated that drying time increased with increase in whipping time .The presence of negative interaction terms of drying temperature and foam thickness indicated that increase in their level decrease drying time. The presence of positive interaction terms of drying temperature and whipping time indicated that increase in their level increase drying time. The presence of positive interaction terms of foam thickness and whipping time indicated that increase in their level increase drying time. The positive values of quadratic terms of drying temperature indicated that higher values of these variables further increased drying time.

3.1.2 Effect of variables on rehydration ratio

The observed data for rehydration ratio under varying processing parameters has been given in Table 3. The rehydration ratio during the drying was found to be dependent on the drying temperature, foam thickness and whipping time.

Table 3: Observed rehydration ratio under varying processing parameters

A:Temperature	B: Foam thickness	C:Whipping time	Rehydration ratio
°C	mm	min	
70	5	1.5	3.26
60	5	2	3.56
70	5	2	3.25
70	3	2	3.31
60	3	2	3.68
65	3	1.5	3.54
70	5	2	3.26
65	3	2	3.51
60	3	1.5	3.7
70	3	1.5	3.34
65	5	1.5	3.38
70	3	1.5	3.35
60	5	1.5	3.61
65	5	2	3.32
60	3	2	3.68
60	5	1.5	3.61
60	5	2	3.57

Equation 2 gives the predicted rehydration ratio as a function of temperature, foam thickness and whipping time expressed in coded form. This equation was obtained using step-down regression method where factors with F- values less than 1 were rejected as described by Snedecor and Cochran (1967). The data for rehydration ratio were analysed stepwise regression analysis as shown in table 4. The quadratic model was fitted with the experimental data and statistical significance for linear and quadratic terms was calculated for ascorbic acid as shown in table 4. The R^2 value was calculated by least square technique and found to be 0.93474 showing good fit of model to the data. The Model F-value of 18.41776 implies the model is significant ($P<0.0001$).The linear terms (A and B) are significant ($P<0.0001$). The lack of fit F value was non- significant which indicates that the developed model was adequate for predicting the response. Moreover the predicted R^2 of was 0.758434 in reasonable agreement with adjusted R^2 of 0.883994. This reveals that the non significant terms have not been included in the model. Therefore this model could be used to navigate the design space.

Table 4: ANOVA for rehydration ratio during foam-mat tray drying of egg liquid

Source	Sum of	Df	Mean	F-value
Model	0.348749	7	0.049821	18.41776**
A-Temperature	0.309942	1	0.309942	114.5783**
B- Foam thickness	0.035503	1	0.035503	13.12477**
C-Whipping time	0.000977	1	0.000977	0.361214**
AB	0.003871	1	0.003871	1.430958*
AC	0.003127	1	0.003127	1.155848*
BC	0.001022	1	0.001022	0.377802*
A^2	0.004195	1	0.004195	1.55089*
B^2	0	0		
C^2	0	0		
Lack of Fit	0.012146	4	0.003036	1.244424^{NS}
Std. Dev.	0.05201			
Mean	3.470588			
C.V. %	1.4986			
R^2	0.93474			
Adjusted R^2	0.883994			
Predicted R^2	0.758434			

**Significant at 1% level, *significant at 5% level, NS- non significant

High value of coefficient of determination ($R^2 = 0.93474$) obtained for response variable indicated that the developed model for rehydration ratio accounted for and adequately explained 1.96% of the total variation. The result of analysis of variance indicated that the linear terms of temperature, foam thickness and whipping time were highly significant at 1% level (Table 4).

The comparative effect of each factor on rehydration ratio could be observed by F values in the ANOVA (Table 4) and also by the magnitudes of the coded variables. The F values indicated that drying temperature was the most influencing factor followed by drying thickness and whipping time.

The regression equation describing the effects of process variables on rehydration ratio in terms of coded values of variables is given as:

$$\text{Rehydration ratio} = 3.4375 - 0.26068*A - 0.04741*B - 0.00787*C + 0.017957*AB + 0.016138*AC + 0.008044*BC + 0.037165\,A^2 \qquad \text{.......}\ (2)$$

($R^2 = 0.93474$)

The linear negative terms [Eqn. 2] indicated that rehydration ratio decreased with decrease temperature, foam thickness and whipping time. The linear positive term indicated that increased with increase in temperature, foam thickness and whipping time. The positive values of quadratic terms of interaction of temperature indicated that higher values of these variables further increase with rehydration ratio.

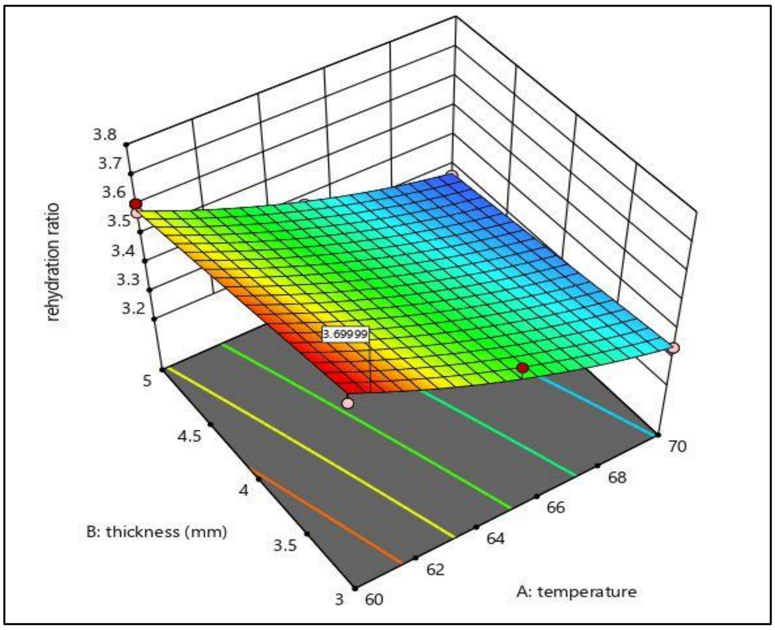

Fig 1: Variation in rehydration ratio with foam thickness and temperature

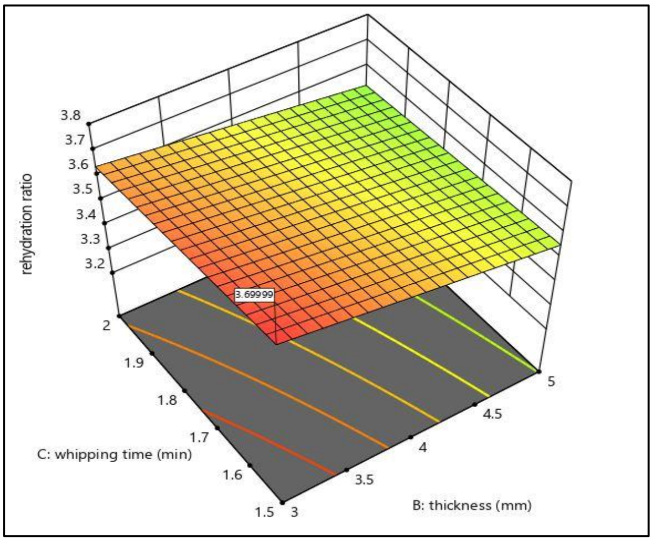

Fig 2: Variation in rehydration ratio with foam thickness and whipping time

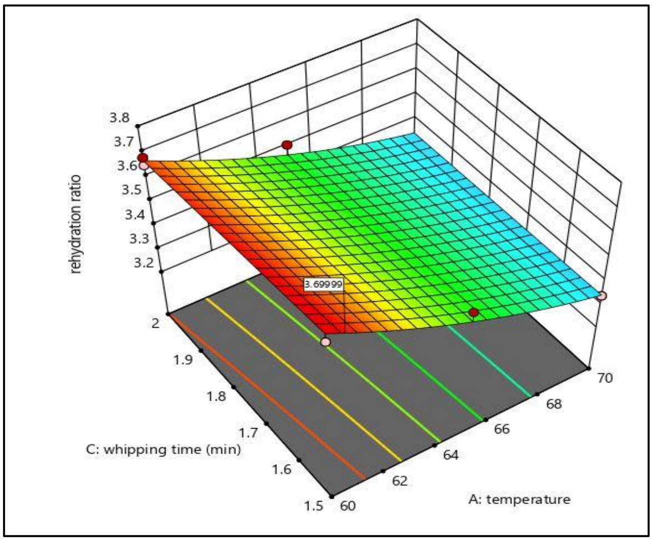

Fig 3: Variation in rehydration ratio with whipping time and temperature

3.1.3 Effect of variables on solubility

The observed data for solubility under varying processing parameters has been given in Table 5. The solubility during the drying was found to be dependent on the temperature, foam thickness and whipping time.

Table 5: Observed solubility under varying processing parameters

A: Temperature	B: Foam thickness	C: Whipping time	Solubility
°C	mm	min	%
70	5	1.5	73.42
60	5	2	90.10
70	5	2	72.91
70	3	2	76.22
60	3	2	93.54
65	3	1.5	87.69
70	5	2	72.16
65	3	2	86.31
60	3	1.5	94.76
70	3	1.5	78.16
65	5	1.5	87.68
70	3	1.5	78.15
60	5	1.5	92.14
65	5	2	84.48
60	3	2	93.6
60	5	1.5	92.14
60	5	2	92.1

Equation 3 gives the predicted solubility as a function of temperature, foam thickness and whipping time expressed in coded form. This equation was obtained using step-down regression method where factors with F- values less than 1 were rejected. The data for solubility were analysed stepwise regression analysis as shown in Table 5. The quadratic model was fitted with the experimental data and statistical significance for linear and quadratic terms was calculated for water activity as shown in Table 5. The R^2 value was calculated by least square technique and found to be 0. 987601 showing good fit of model to the data. The Model F-value of 102.4052 implies the model is significant (*P*<0.0001). The linear terms (A, B and C) are significant (*P*<0.0001). The lack of fit F value was non- significant which indicates that the developed model was adequate for predicting the response. Moreover the predicted R^2 of 0.94794 was in reasonable agreement with adjusted R^2 of 0.977956. This reveals that the non significant terms have not been included in the model. Therefore this model could be used to navigate the design space.

Table 6: ANOVA for solubility during foam-mat drying of egg liquid

Source	Sum of	Df	Mean	F-value
Model	1103.878	7	157.6969	102.4052**
A-Temperature	986.6739	1	986.6739	640.7261**
B- Foam thickness	38.70366	1	38.70366	25.13337**
C-Whipping time	7.677509	1	7.677509	4.98562**
AB	3.505621	1	3.505621	2.27648*
AC	0.072399	1	0.072399	0.047015*
BC	0.013442	1	0.013442	0.008729*
A^2	22.24666	1	22.24666	14.44653*
B^2	0	0		
C^2	0	0		
Lack of Fit	9.958777	4	2.489694	3.191425^{NS}
Std. Dev.	1.240939			
Mean	84.91118			
C.V. %	1.461456			
R^2	0.987601			
Adjusted R^2	0.977956			
Predicted R^2	0.947949			

**Significant at 1% level, *significant at 5% level, NS- non significant

High value of coefficient of determination (R^2 = 0. 987601) obtained for response variable indicated that the developed model for ascorbic acid accounted for and adequately explained 1.96% of the total variation. The result of analysis of variance indicated that the linear terms of drying temperature and foam thickness were highly significant at 1% level (Table 6). The presence of quadratic terms of drying temperature and foam thickness indicated curvilinear nature of response surface. The quadratic terms of drying temperature and foam thickness were also highly significant at 1% level.

The comparative effect of each factor on solubility could be observed by F values in the ANOVA (Table 6) and also by the magnitudes of the coded variables. The F values indicated that drying temperature was the most influencing factor followed by foam thickness and whipping time.

The regression equation describing the effects of process variables on solubility terms of coded values of variables is given as:

$$\text{Solubility} = 86.5425 - 0.16068*A - 0.04741*B - 0.00787*C + 0.017957*AC + 0.016138*AC + 0.008044*BC + 0.037165*A^2 \quad \text{....... (3)}$$

($R^2 = 0.987601$)

The linear negative terms [Eqn. 3] indicated that solubility decreased with increase temperature, foam thickness and whipping time. The positive values of quadratic terms of interaction of temperature, foam thickness and whipping time indicated that higher values of these variables further increase solubility. The linear positive value indicated that solubility increase with increase temperature.

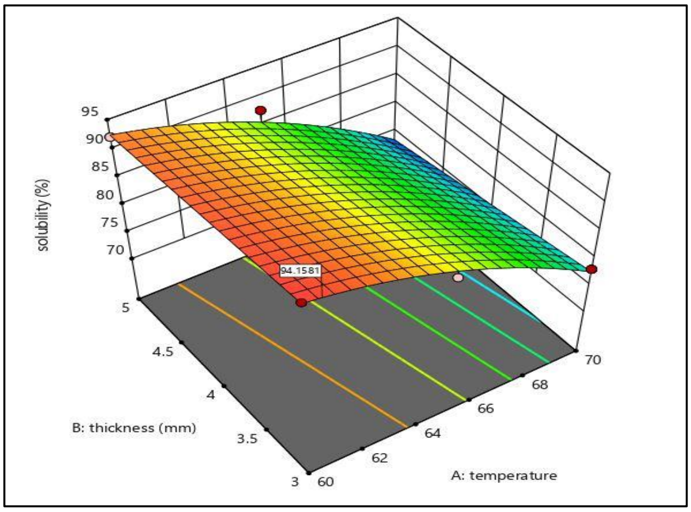

Fig 4: Variation in solubility with foam thickness and temperature

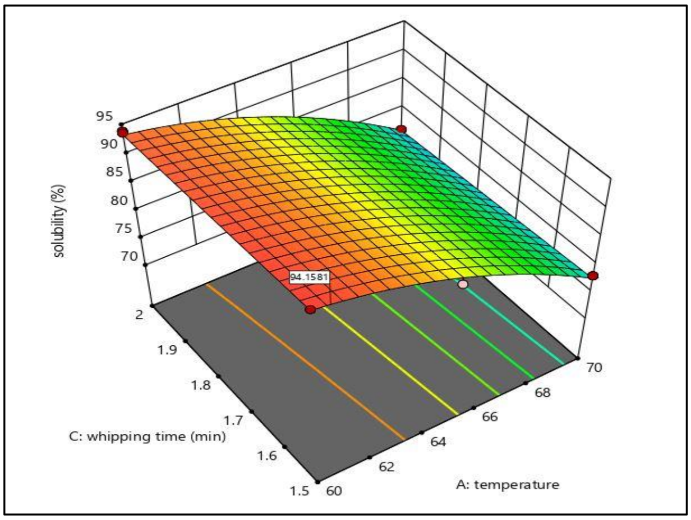

Fig 5: Variation in solubility with whipping time and temperature

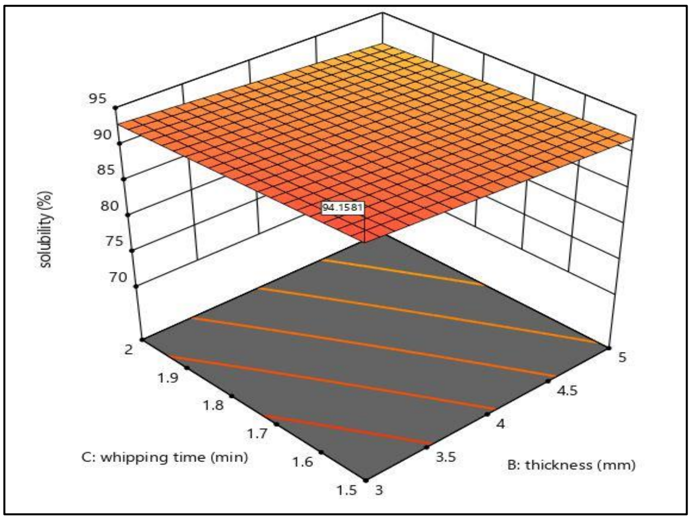

Fig 6: Variation in solubility with foam thickness and whipping time

3.1.4 Effect of variables on L*, a* and b*

The observed data for L*, a* and b* under varying processing parameters has been given in table 7. The value of L*, a* and b* during the drying was found to be dependent on the drying temperature, foam thickness and whipping time.

Table 7: Observed L*, a* and b* under varying processing parameters

A:Temperature	B: Foam thickness	C:Whipping time	L*	a*	b*
°C	mm	min			
70	5	1.5	49.36	17.45	36.02
60	5	2	49.99	10.14	38.92
70	5	2	47.03	18.13	37.36
70	3	2	52.42	17.07	35.45
60	3	2	62.92	8.92	39.90
65	3	1.5	61.34	9.88	38.52
70	5	2	47.03	18.13	37.36
65	3	2	59.11	11.62	37.96
60	3	1.5	64.25	7.91	41
70	3	1.5	57.1	13.66	37.82
65	5	1.5	56.86	11.73	37.51
70	3	1.5	57.1	13.66	37.82
60	5	1.5	58.11	9.73	38.67
65	5	2	47.98	12.37	37.98
60	3	2	62.92	8.92	39.93
60	5	1.5	64.25	7.91	37.9
60	5	2	49.99	10.14	38.92

A second order polynomial equation 4 was used to fit the experimental data presented in table 7. Equation 4 gives the predicted L*, a* and b* as a function of drying temperature, foam thickness and whipping time expressed in coded form. This equation was obtained using step-down regression method where factors with F- values less than 1 were rejected as described by Snedecor and Cochran (1967). The data for L*, a* and b* were analysed stepwise regression analysis as shown in Table 7. The quadratic model was fitted with the experimental data and statistical significance for linear and quadratic terms was calculated for L*, a* and b* as shown in Table 8 to 10. The R^2 value was calculated by least square technique and found to be 0.939587 (L*), 0.981836 (a*) and 0.939069 (b*) showing good fit of model to the data. The Model F-value of 19.99 (L*), 69.49628 (a*) and 19.8154 (b*) implies the model is significant (*P*<0.0001). The linear terms (A and B) are significant (*P*<0.0001). The lack of fit F value was non -significant which indicates that the developed model was adequate for predicting the response. Moreover the predicted R^2 of 0.701734 (L*), 0.918201 (a*) and 0.694786 (b*) was in reasonable agreement with adjusted R^2 of 0.892599 (L*), 0.967708 (a*) and 0.891678 (b*). This reveals that the non significant terms have not been included in the model. Therefore this model could be used to navigate the design space.

Table 8: ANOVA for L* during foam-mat drying of egg liquid

Source	Sum of	Df	Mean	F-value
Model	567.3652	7	81.05218	19.99633**
A-Temperature	156.0402	1	156.0402	38.49658**
B- Foam thickness	197.7826	1	197.7826	48.79481**
C-Whipping time	127.3136	1	127.3136	31.40945**
AB	7.154501	1	7.154501	1.765083*
AC	2.94352	1	2.94352	0.726194*
BC	32.85571	1	32.85571	8.105813*
A^2	0.046045	1	0.046045	0.01136*
B^2	0	0		
C^2	0	0		
Lack of Fit	17.63037	4	4.407592	1.169135^{NS}
Std. Dev.	2.013294			
Mean	55.90588			
C.V. %	3.60122			
R^2	0.939587			
Adjusted R^2	0.892599			
Predicted R^2	0.701734			

**Significant at 1% level, *significant at 5% level, NS- non significant

Table 9: ANOVA for a* during foam-mat drying of egg liquid

Source	Sum of	Df	Mean	F-value
Model	201.0348	7	28.71926	69.49628^{**}
A-Temperature	170.5128	1	170.5128	412.6152^{**}
B- Foam thickness	11.32608	1	11.32608	27.40742^{**}
C-Whipping time	9.631613	1	9.631613	23.30705^{**}
AB	1.192197	1	1.192197	2.884936^{*}
AC	0.463524	1	0.463524	1.121657^{*}
BC	1.067867	1	1.067867	2.584077^{*}
A²	4.882668	1	4.882668	11.81532^{*}
B²	0	0		
C²	0	0		
Lack of Fit	2.063039	4	0.51576	1.557058^{NS}
Std. Dev.	0.642844			
Mean	12.19824			
C.V. %	5.269978			
R²	0.981836			
Adjusted R²	0.967708			
Predicted R²	0.918201			

**Significant at 1% level, *significant at 5% level, NS- non significant

Table 10: ANOVA for b* during foam-mat drying of egg liquid

Source	Sum of	Df	Mean	F-value
Model	26.79729	7	3.828185	19.8154^{**}
A-Temperature	21.8848	1	21.8848	113.2798^{**}
B- Foam thickness	2.414615	1	2.414615	12.4985^{**}
C-Whipping time	0.474163	1	0.474163	2.454357^{**}
AB	2.468445	1	2.468445	12.77713^{*}
AC	0.025003	1	0.025003	0.129421^{*}
BC	5.089457	1	5.089457	26.34398^{*}
A²	0.059645	1	0.059645	0.308733^{*}
B²	0	0		
C²	0	0		
Lack of Fit	1.349832	4	0.337458	4.338621^{NS}
Std. Dev.	0.439537			
Mean	38.15529			
C.V. %	1.151967			
R²	0.939069			
Adjusted R²	0.891678			
Predicted R²	0.694786			

**Significant at 1% level, *significant at 5% level, NS- non significant

High value of coefficient of determination R^2 obtained for response variable indicated that the developed model for L*, a* and b* accounted for and adequately explained optimum variation.

The regression equation describing the effects of L*, a* and b* for process variables on in terms of coded values of variables is given as:

$$L^* = 56.3225-3.60528*A-3.53864*B-2.83909*C+0.771989*AB+0.49517*AC-1.44227*BC-0.12313*A^2 \quad ...... (4)$$

$(R^{2=}0.\ 939587)$

$$a^*= 11.4+3.76877*A+0.846802*B+0.780893*C+0.315134*AB+0.196498*AC0.26002*BC+1.267902*A^2 \quad .... (5)$$

$(R^{2=}0.\ 981836)$

$$b^* = 37.9925 - 1.35018*A - 0.39099*B - 0.17326*C + 0.453454*AB -0.04564*AC+0.567646*BC+0.140134*A^2 \quad .... (6)$$

$(R^{2=}0.\ 939069)$

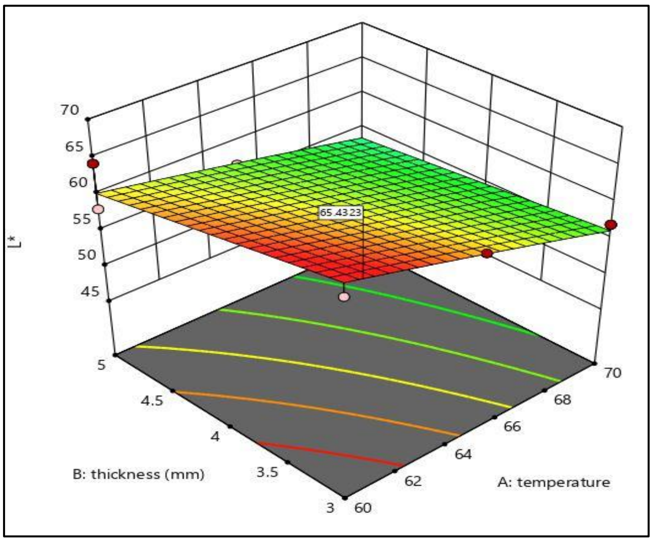

Fig 7: Variation in L* with foam thickness and temperature

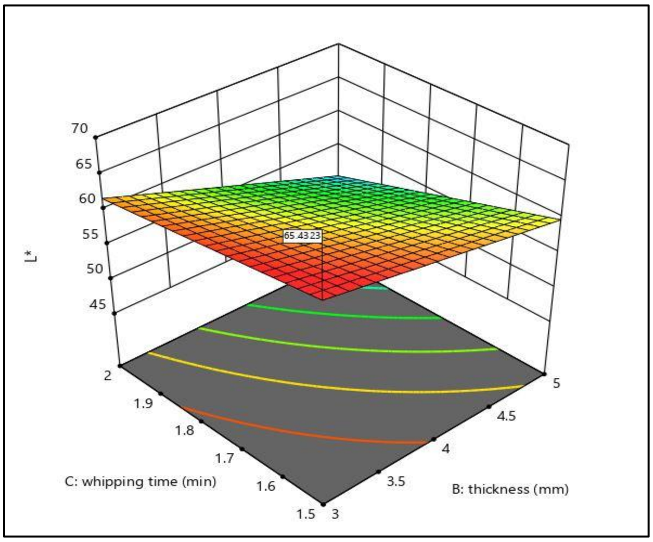

Fig 8: Variation in L* with foam thickness and whipping time

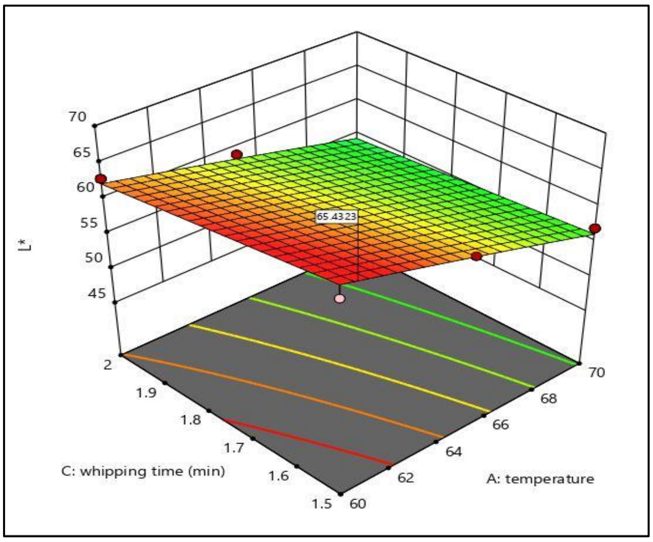

Fig 9: Variation in L* with whipping time and temperature

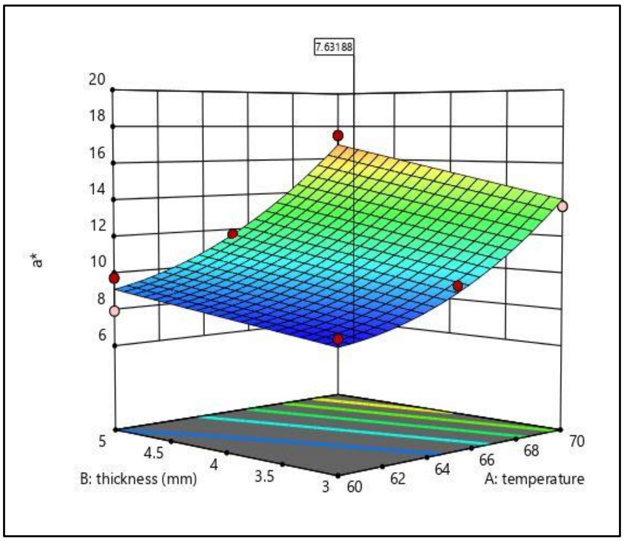

Fig 10: Variation in a* with foam thickness and temperature

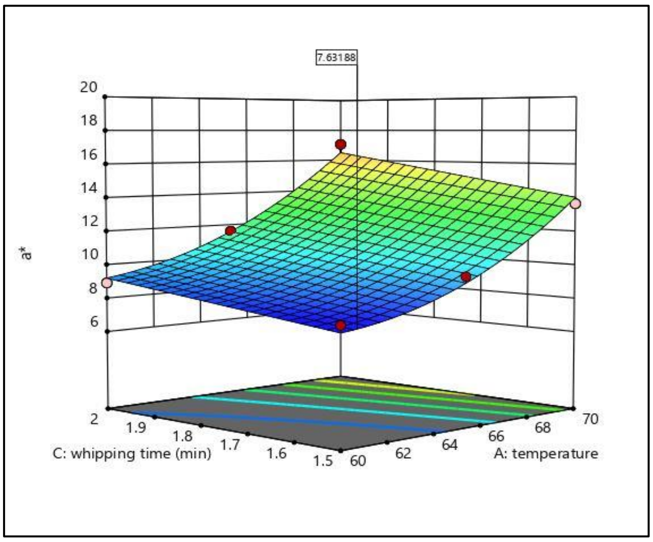

Fig 11: Variation in a* with whipping time and temperature

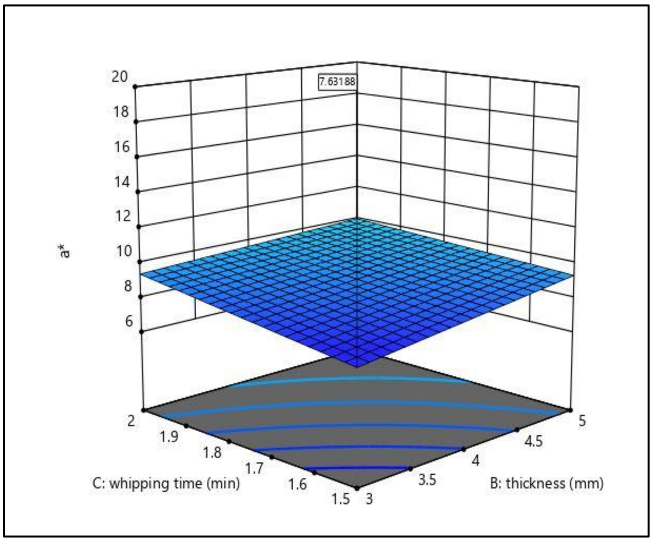

Fig 12: Variation in a* with foam thickness and whipping time

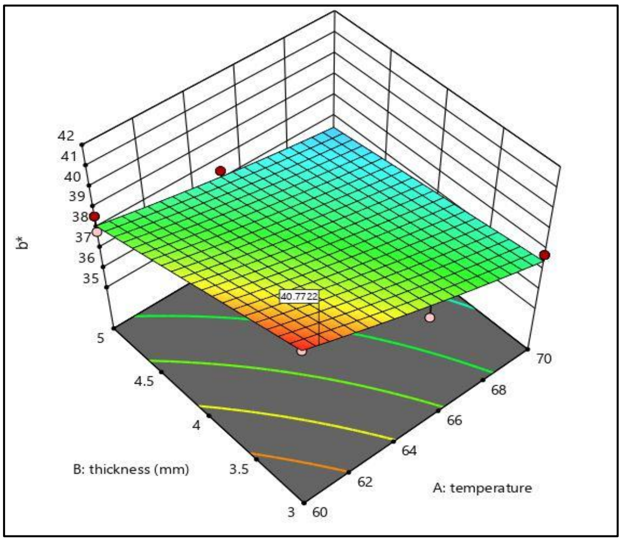

Fig 13: Variation in b* with foam thickness and temperature

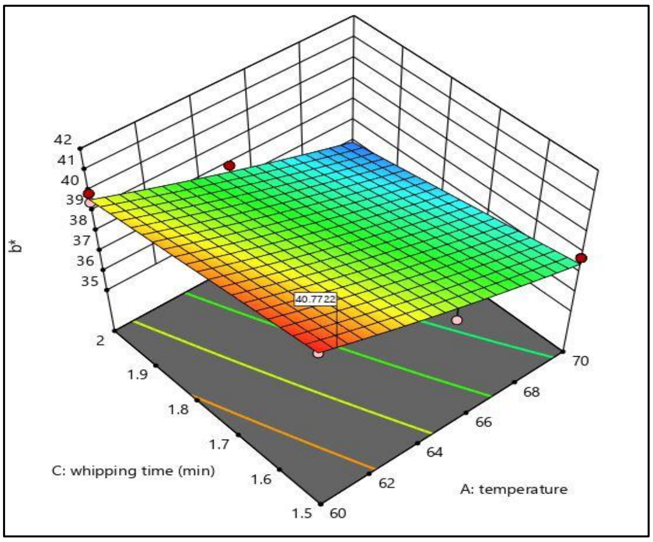

Fig 14: Variation in b* with whipping time and temperature

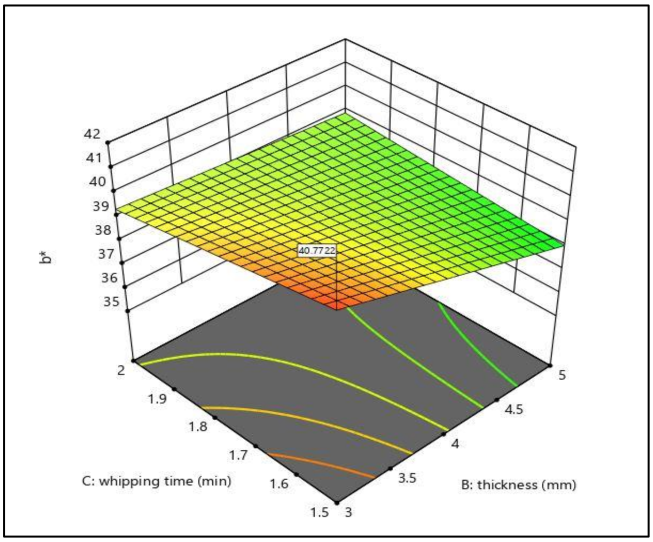

Fig 15: Variation in b* with foam thickness and whipping time

3.2 Numerical optimization of Foam-Mat Tray Dried Egg: I- optimal optimization technique was carried out for the process parameters of the drying of egg liquid. To perform this operation, Design expert version 11.0.5.0 of the STATEASE software (Stat ease Inc, Minneapolis, USA, Trial version). The constraints were set such that the selected variables (A, B and C) would be minimize from economical point of view for the most important product attribute and close to the optimum for the others (Jain *et al.*, 2011). The main criteria for constraints optimization were minimize possible drying time, maximize possible rehydration ratio, maximize possible solubility, maximize values of L*and b* and minimize value of a*.

The desired goals for each factor and response are shown in Table 11. In order to optimize the process parameters for drying of egg liquid by numerical optimization which finds a point that maximizes the desirability function. The goal setting begins at a random starting point and proceeds up the steepest slope on the response surface for a minimize possible drying time, maximize possible rehydration ratio, maximize possible solubility possible maximize values of L*and b* and minimize value of a*.

Table 11: Optimization criteria for different process variables and responses for drying of egg liquid

Name	Goal	Lower	Upper	Lower	Upper	Importance
A:Temperature	is in range	60	70	1	1	3
B: Foam thickness	is in range	3	5	1	1	3
C:Whipping time	is in range	1.5	2	1	1	3
Drying time	minimize	380	860	1	1	3
Rehydration ratio	maximize	3.25	3.7	1	1	3
Solubility	maximize	71.16	94.76	1	1	3
L*	Maximize	47.03	64.25	1	1	3
a*	Minimize	7.91	18.13	1	1	3
b*	maximize	35.45	41	1	1	3

3.3 Graphical optimization: A graphical multi-responses optimization technique was adapted to determine the workable optimum conditions for the foam-mat tray dried egg. The contour plots for all responses were superimposed and regions (yellow regions) that best satisfy all the constraints were selected as optimum conditions. The criteria for constraint optimization are already given in Table 12.

Superimposed contour plots having common superimposed area for all responses for the foam-mat tray dried egg are shown in Fig. 1. Table 12 shows the software generated optimum conditions of independent variables with the predicted values of responses.

Table 12: Solution generated by the software for drying of egg liquid

Temperature, °C	Foam thickness, mm	Whipping time, min	Drying time, min	Rehydration ratio	Solubility, %	L*	a*	b*
60.619	3.00	1.5	634.322	3.7	94.15	65.43	7.6	40.7

3.4 Validation of the model for foam-mat tray dried egg: Foam-mat tray dried egg experiments were conducted at the optimum process conditions (Temperature = 60.61 ºC, Foam thickness = 3mm and whipping time 1.5 min) for testing the adequacy of model equations for predicting the response values. The observed experimental values (mean of three values) and values predicted by the equations of the model are presented in Table 12. The experimental values were found to be very close to the predicted values.

4. Conclusion

The effect of drying temperature, foam thickness and whipping time of drying process was investigated and these were optimized. The regression equations of second order polynomial were found to predict the behavior of foam-mat tray drying process of egg. The effect of different drying temperature, foam thickness and whipping time on rehydration ratio (RR) of results are presented as 3.70, 3.54 and 3.34 dried at 60, 65 and 70 ºC of foam thickness 3mm and whipping time 1.5 min respectively. Hunter lab colorimeter was used to measure the colour of the dried product. Colour (L*-value) were recorded as for the foam-mat tray dried egg powder were 64.24, 61.34 and 57.10 1.5 for 3mm foam thickness min whipping time and drying temperature 60, 65 and 70 °C respectively. The effect of different drying temperature, foam thickness and whipping time on solubility of results are presented as The solubility of egg powder for drying temperatures 60, 65 and 70 °C, foam thickness 3mm and whipping time 1.5 min were ranged from 78.16 to 94.76.

1. Rehydration ratio (RR) was highest for lowest temperature and thickness.
2. The foam-mat tray dried egg powder at 65 ºC drying temperature and 3mm foam thickness and 1.5 min whipping time shown best values of L*, a* and b* than the other drying temperature, drying thickness and whipping time.

5. References

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