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Technology for optimization of Process Technology for Puffing of Groundnut

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Abstract

High temperature, short time puffing technique was used for the development of puffed groundnuts. Process factors, including marinating time, surface drying time, and puffing temperature were considered for their influence on product quality, using the Box-Behnken Design of Experimentation. Replication surface methodology was used in the development of linear and quadratic models to investigate the synergism between process factors and replications in terms of puffing yield, expansion ratio, crispness, hardness, and colour L* value. At the optimal process condition, the best possible product quality was achieved: puffing temperature 250 °C, sousing time 45 min, and surface drying time 4 h, it can yield a puffing yield of 97.23%, expansion ratio 1.29, crispness with 22+ peaks, hardness of 69 N, and color L* of 50.23.

Key words: Groundnut, Hardness, Yield, Quadratic model

Introduction

Ready-To-Eat (RTE) food is one of the most important sectors of the food industry. The importance of RTE puffed and popped snacks is an undisputed fact in the era of fast life, fast urbanization shelter, and all health-conscious society. RTE snacks prepared by puffing and popping of cereals, pulses, and millets may offer a plethora of choices for meeting today's guidelines to increase the whole grain oil-free consumption for people of all age groups. Peanuts may be consumed and exported as raw, roasted, and salted or processed for further use in desserts, candies, and frozen water creams. Proximate analysis of peanut exhibiting rich source of oil (43%) with a high content of unsaturated fatty acids (87%). Peanut is further a good source of protein (22%). Epidemiological studies have reported that consumption of nuts, compared to other foods rich in fat, reduces oxidative stress, improves total cholesterol and high-density lipoprotein levels, thus reducing risk of coronary diseases and helps to control body weight. Except for the production of oil, peanuts are processed into snack foods due to its unique flavor and rich nutrients. Dried salted peanuts is one of the most popular snack foods, among which roasting is a key step in the process and directly impacts the quality and shelf-life of the final product. Puffed groundnut have availability of protein 23.63%, carbohydrates 14.89% and crude fibre 3.00%. However, puffing reduces moisture content and alters the internal microstructure of groundnut kernels to produce the characteristic crunchy and crispy texture, thus causes a reduction in the quality of aflatoxins-a toxin produced by fungus in groundnut kernels. Present study was undertaken to develop puffed product from groundnut and optimize the process parameters utilizing Marinating time, Surface drying time and Puffing temperature. For this purport, Box Behnken Design and replication surface methodology were habituated to fit a liner and second order polynomial by a least square technique.\nMaterials and Methods\nPreparation of puffed groundnut\n\tThe groundnut grain was purchased from local market. The marinating was carried out at 45 min, surface drying was carried out at 4 h and puffing was carried out by utilizing multi grain popping and puffing machine at 250 oC and 3 RPM. This machine has rotating drum and digital temperature controlled panel. The following quality characteristics are optimized by utilizing RSM.\nPuffing yield:\nPuffing yield = Number of puffed grain X 100\n Total number of grains in sample\nExpansion Ratio:\n\tThe expansion ratio for all the samples was tenacious in terms of ratio of average bulk volume of puffed product during puffing to the average initial bulk volume .\nExpansion ratio = Total popped/puffed volume\n \t Volume of raw kernels\nColor:

Colour (L* value) of the puffed products was determined using Hunter Lab colorimeter. Colour measurements were taken after 2 days of generation of products. Before testing the sample, the instrument was calibrated with standard black and white tiles supplied with the instrument. The colour readings were expressed in terms of L* value. The L* value is the spectrum of light-dark and it ranges from 0 to 100, i.e. 0 is black and 100 is white.\nTextural Measurement (Hardness and Crispness)\nThe texture attributes of puffed groundnut in terms of hardness and crispness were measured using a Stable Micro System TA-XT2 texture analyser (Texture Technologies Corp., UK) fitted with a 2.5 mm diameter circular punch. The measurements were made at a pre-test speed of 0.5 mm/s, test speed of 1 mm/s, distance of 50% strain and load cell of 5.0 kg. Hardness value was taken as mean peak compression force and was expressed in grams and crispness was measured in terms of number of major positive peaks (Cruzcelyis et al., 1996 and Anon et al., 1998) using the facility of Texture Analyser. For measurement of crispness a macro was developed which counts number of major peaks represented in the force-time deformation curve during compression (Nath and Chattopadhyay, 2007). The compression force at which product gives maximum resistance at the highest peak of graph was taken as the hardness value for that sample. Average of 10 replicates was taken for both the parameters in every individual experiment.

Experimental Design for puffed groundnut

In the present study, the process variables considered were sousing time (30 to 60 min), surface drying time (3 to 5 h) and puffing temperature (240 to 260 °C). The experimental design was applied after cull of the ranges. Seventeen experiments were performed according to a Box Behnken Design (BBD) with three variables and three levels of each parameter. Table 1 gives the calibers of variables in coded and authentic units, and Table 2 designates the treatment cumulations of variable levels utilized in the BBD. The central point in the design was reiterated five times to calculate the reproducibility of the method (Montgomery, 2001). In Table 1, the coded levels of process variables are fine-tuned as given below (Myers, 1971). The HTST puffing experiments were conducted according to the BBD design (Table 1) and RSM were applied to the experimental data utilizing a commercial statistical package, Design Expert - version 10.0 (Stat Ease, 2002). The relative effect of the process variables (Marinating time (ST), Surface drying time (SD), Puffing temperature (PT) on the replications was studied and the puffing process was optimized in order to get best quality puffed groundnut predicated yare-to-victual snacks. The replications studied were final puffing yield (PY) (%), Expansion ratio (ER), Hardness (HD), crispness (CSP, no. of +ve peaks) and colour L* value. A second order polynomial equation of the following form was surmised to relate the replication, Y and the factors, such as:

………. 1

Where, y = predicted replication, β0= a constant, βi= linear coefficient, βii= squared coefficient, βij= interaction coefficient, Xi and Xj= independent variables, =noise or error.

Table 1: Levels, codes and intervals of variation for puffing process

Sr. No.	Name of process variable	Range	Code (Xi)	LEVELS			Interval variation
				-1	0	+1	
1	Soaking time (min)	30 – 60	X_1	30	45	60	15
2	Surface drying time (h)	3– 5 h	X_2	3	4	5	1
3	Puffing temperature (°C)	240 – 260	X_3	240	250	260	10

Table 2: Experimental design (3 factors, 3 levels) and corresponding values of responses (quality parameters) obtained during puffing of groundnut

Treatments				Quality characteristics				
	X_1	X_2	X_3	Popping yield (%)	Expansion ratio	Hardness (N)	Crispiness (+ve peaks)	Color L*
1	-1	-1	0	85.67	1.19	79	13	50.59
2	1	-1	0	86.59	1.28	76	14	49.17
3	-1	1	0	81.42	1.21	81	16	50.42
4	1	1	0	91.62	1.27	76	15	49.54
5	-1	0	-1	56.74	1.12	140	14	32.73
6	1	0	-1	60.43	1.12	123	19	40.45
7	-1	0	1	77.52	1.15	49	21	41.52
8	1	0	1	79.75	1.13	54	13	42.57
9	0	-1	-1	61.38	1.12	127	14	43.78
10	0	1	-1	60.23	1.11	136	17	42.86
11	0	-1	1	82.53	1.12	60	19	47.24
12	0	1	1	81.65	1.16	53	18	48.65
13	0	0	0	96.52	1.27	68	23	50.85
14	0	0	0	96.29	1.28	70	22	50.43
15	0	0	0	96.37	1.31	68	23	48.56
16	0	0	0	97.23	1.28	70	23	50.76
17	0	0	0	97.63	1.29	69	22	50.23

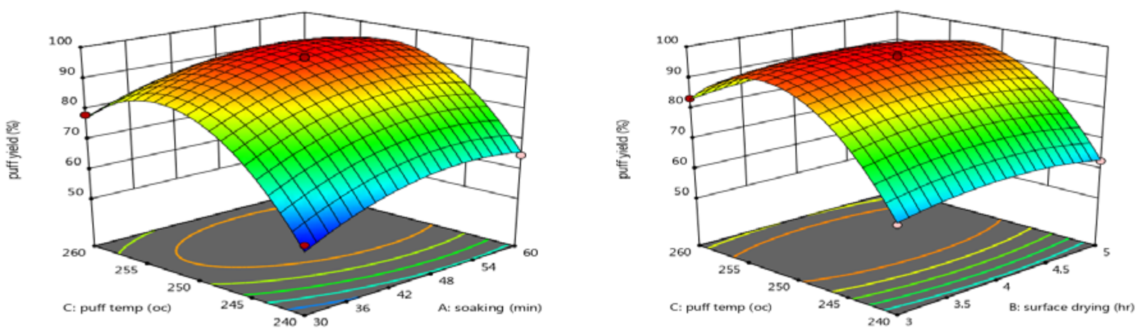
X_1 = soaking time, X_2 = Surface drying time and X_3 = puffing temperature

Data Analysis and Optimization

Regression analysis and analysis of variance (ANOVA) were performed to fit the models represented by Equation (1) and to evaluate the statistical significance of the model terms. Model adequacy was checked using model analysis, lack-of-fit tests, and R^2 (coefficient of determination) analysis according to Lee et al. (2000) and Weng et al. (2001). Lack of fit measures a model's failure to represent data within the experimental domain where points were not included in the regression or where variations cannot be explained by chance error (Montgomery, 2001). A significant lack of fit, indicated by a low probability value, leads to the rejection of the replication predictor. R^2 represents the ratio of explained variation to total variation, thus reflecting the goodness of fit (Haber and Runyon, 1977). The coefficient of variation (CV) represents the relative dispersion of experimental points from model predictions. Replication surfaces and contour plots were generated using Design Expertversion 10.0 (Stat Ease, 2002), which also facilitated numerical and graphical optimization.\nNumerical Optimization\nThe Design-Expert software's numerical optimization technique was used for the simultaneous optimization of multiple replications. Desired goals for each factor and replication were selected, with goals including maximize, minimize, target, within range, and none (for replications only). All independent factors were maintained within range, while replications were either maximized or minimized. To locate a solution optimizing multiple replications, goals were combined into an overall composite function D(x), known as the desirability function (Myers and Montgomery, 2002). Desirability ranges from zero (outside of limits) to one (at the goal), indicating the desirable range for each replication. Numerical optimization seeks to find a point that maximizes the desirability function, and goal characteristics can be modified by changing weight or importance (Stat Ease, 2002).\

Results and Discussion

Effect of Miscellaneous Process Parameters on Puffing Yield\nPuffing yield is the number of puffed grains divided by the sum total of grains in the sample. The calculated values for puffing yield of puffed groundnut with varying combinations of process parameters are provided in Table 2. Puffing yield values ranged between 56.74% and 97.63% across the variable coalescences studied. The quadratic equation model describing the effect of process parameters on puffing yield, in terms of actual levels of variables, is given as: ????????=96.80+3.13????1+1.15????2+12.33????3−0.8575????1????2−1.96????1????3−0.6050????2????3−6.39????12−3.45????22−20.60????32PY=96.80+3.13X1+1.15X2+12.33X3−0.8575X1X2−1.96X1X3−0.6050X2X3−6.39X12−3.45X22−20.60X32 (R^2 = 0.998)\nWhere ????1X1 is marinating time, ????2X2 is surface drying time, and ????3X3 is puffing temperature.\nThe comparative effect of each parameter on puffing yield was assessed using F-values in the ANOVA (Table 3) and the magnitude of coefficients of the actual variables. A model F-value of 386.77 insinuates implicitly the model is paramount at the 5% level. The lack of fit was non-significant, indicating a good model fit. Positive coefficients for the first-order terms of marinating time (????1X1), surface drying time (????2X2), and puffing temperature (????3X3) indicate that increases in such parameters result in increased puffing yields. Figure 1 shows that puffing yield increases with sousing time (????1X1) up to 45 minutes, surface drying time (????2X2) up to 4 hours, and puffing temperature at 250°C.



(A) (B)

Figure 1 depicts the interaction between soaking time (????1X1) and puffing temperature (????3X3) at a fixed surface drying time (????2X2) (A) and between the surface drying time (????2X2) and puffing temperature (????3X3) at a fixed soaking time (????1X1) (B) on the puffing yield of puffed groundnut.\nEffect of Process Parameters on Expansion Ratio (ER)\nExpansion ratio (ER) is the ratio of volume of puffed grains to the volume of the initial sample of groundnuts. Computed values for the expansion ratio of puffed groundnut, prepared at different combinations of process parameters are given in Table 2. The expansion ratio values ranged from 1.11 to 1.31 for all the studied variable combinations. The quadratic model equation showing the effect of process parameters on the expansion ratio in terms of actual levels of variables is as follows:\nER=1.29+1.11????1+0.96????2 +2.16????3+0.02????1????2−0.05????1????3+0.05????2????3−0.03????12−0.03????22−0.13????32ER=1.29+1.11X1+0.96X2 +2.16X3+0.02X1X2−0.05X1X3+0.05X2X3−0.03X12−0.03X22−0.13X32 R^2=0.950 Where ????1X1 is soaking time, ????2X2 is surface drying time, and ????3X3 is puffing temperature.\nThe relative effects of each factor on the expansion ratio was also compared by the

Source	F-value				
	PY	ER	CRP	HDS	L*
Model	386.77*	14.81*	29.29*	192.58*	15.93*
X1-soaking time	38.93	2.54	2.32	18.92	1.91
X2-conditioning time	6.2095	1.3047	5.29	6.7568	5.218
X3-popping temp	716.27	5.22	9.21	445.27	18.57
X1X2	23.09	0.3428	1.18	0.3784	0.0267
X1X3	0.5716	0.1523	49.71	45.78	4.07
X2X3	0.0195	0.9521	4.71	24.22	0.4962
X1	200.32	3.39	86.34	16.83	16.52
X2	65.99	4.17*	76.31	52.67	14.22
X3	2094.86	113.46	13.90	590.37	88.28
Lack of Fit	4.90NS	5.33NS	5.28NS	4.83NS	6.02NS

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F-value in the ANOVA and the magnitude of the coefficients of the actual variable, as given in Table 3. The model F-value of 14.81 implies that the model is significant at the 5% level.\nPositive coefficients of the first-order terms of soaking time 1X1), surface drying time 2X2), and puffing temperature 3X3) showed that increasing these parameters increased the expansion ratio. The negative coefficients of the quadratic terms indicated that excess increase in the parameters leads to a decrease in the expansion ratio. It was also observed that the puffing temperature 3X3) had the most significant effect on the puffing yield and followed by the soaking time (1X1) and surface drying time (2X2).

Figure 1

Figure 2 demonstrates that the expansion ratio of puffed groundnut increases with soaking time ($X1X1$) up to 45 minutes, surface drying time ($X2X2$) up to 4 hours, and puffing temperature ($X3X3$) at 250°C. Beyond these levels, further increases in these process parameters lead to a decrease in the expansion ratio.

Table 3:- Analysis of variance showing the effect of process parameters on puffing yield, expansion ratio, crispiness, hardness and colour L* value of puffed groundnut

PY- puffing yield, ER- expansion ratio, CRP- crispiness, HDS- hardness

L*- colour value * - significant, NS- Non-significant

constant (X1) (B) on expansion ratio of puffed groundnut

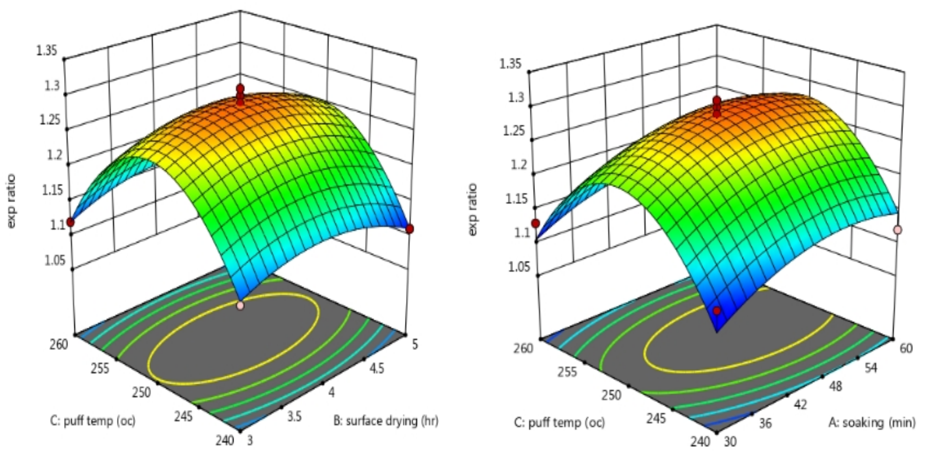
Effect of process parameter on crispiness (CR)

able 2 shows the predicted values of crispiness of puffed groundnut for different combinations of process parameters. According to optical scanning, the puffed groundnut crispiness values were ranged from 13 to 23 (no. of +ve peaks) for the combination of variables studied. Quadratic equation modeling of the effect of process parameters on the crispiness of puffed groundnut in terms of actual level of variables are given as:

CR = 22.60 - 1.37X1 + 2.75X2 + 4.88X3 - 0.50X1X2 – 3.25X1X3 – 1.00X2X3 – 4.18X12- 3.93X22 – 1.67X32 \t R2 = 0.974 …………… 4

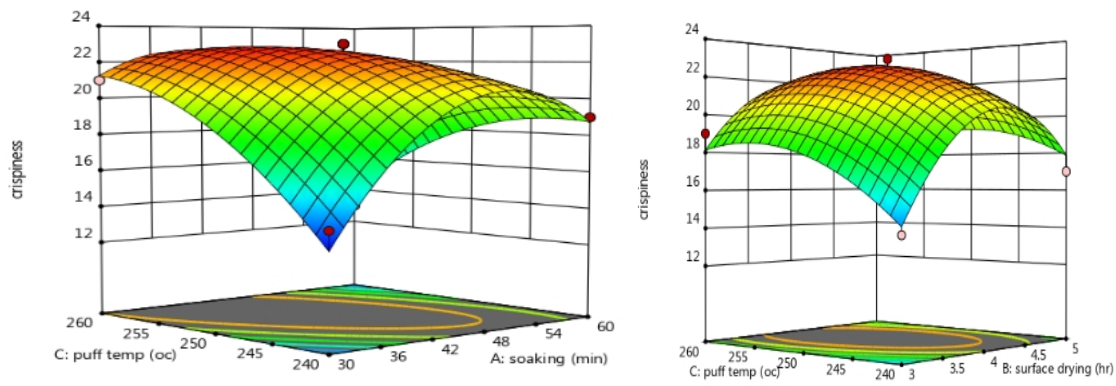
Where X1= sousing time, X2= surface drying time and X3= puffing temperature.

The comparative effect of each factor on crispiness could be visually examined by the F-values in the analysis of variance (Table 3) and withal by the magnitude of coefficients of the coded variables. As evident from the ANOVA data, the model showed a high F value of 24.89 at 5 % level. The positive coefficients in case of first-order terms, i.e., surface drying time (X2) and puffing temperature (X3), denoted that increase in crispiness with an increase in these parameters, while negative coefficients of their interaction and quadratic term suggested that inordinate increase of these parameters resulted in a decrease of crispiness of puffed groundnut. Through Fig. 3, it was pellucid that crispiness of puffed groundnut incremented with an increase in marinating time (X1) of raw groundnut up to 45 min, surface drying of soused groundnut (X2) up to 4 hr, and puffing temperature (X3) at 250 oC respectively, further crispiness value of puffed groundnut decremented at higher calibers of surface drying of marinated groundnut (X2) up to 4 h and puffing temperature (X3) at 250 oC.



(A) **(B)**

Fig 2:- Effect of (X_1) and (X_3) at constant (X_2) (A) and effect of (X_2) and (X_3) at



(A) **(B)**

Fig 3: - Effect of (X_1) and (X_3) at constant (X_2) (A) and effect of (X_2) and (X_3) at constant (X_1) (B) on crispiness of puffed groundnut

Effect of Process Parameters on Hardness

The hardness of puffed groundnut was measured in a TA.XT-2 Texture Analyser, following the experimental design, and the results are shown in Table 4.16. The hardness value ranges between 49 to 140 N of the given cumulation of process parameters. The quadratic equation describing the effect of process parameters on the hardness of puffed groundnut in terms of actual levels of variables is:

HRD=69.00−4.501−1.50????2−38.753−0.5015.5013−4.00?23+3.2512+5.7522+19.2532HRD=69.00−4.50X1−1.50X2−38.75X3−0.50X1X2+5.50X1X3−4.00X2X3+3.25X12+5.75X22+19.25X32 (R^2 = 0.998)

Where ????1 is the marinating time, ????2 is the surface drying time, and ????3 is puffing temperature.

The comparative effect of each factor on hardness was estimated through the use of the F-values in the ANOVA and the magnitude of the coefficients of the coded variables. ANOVA data indicates a model F-value of 192.58, indicating significance at the 5% level. The negative coefficients of the first-order terms in the equation with actual variables indicate that the hardness

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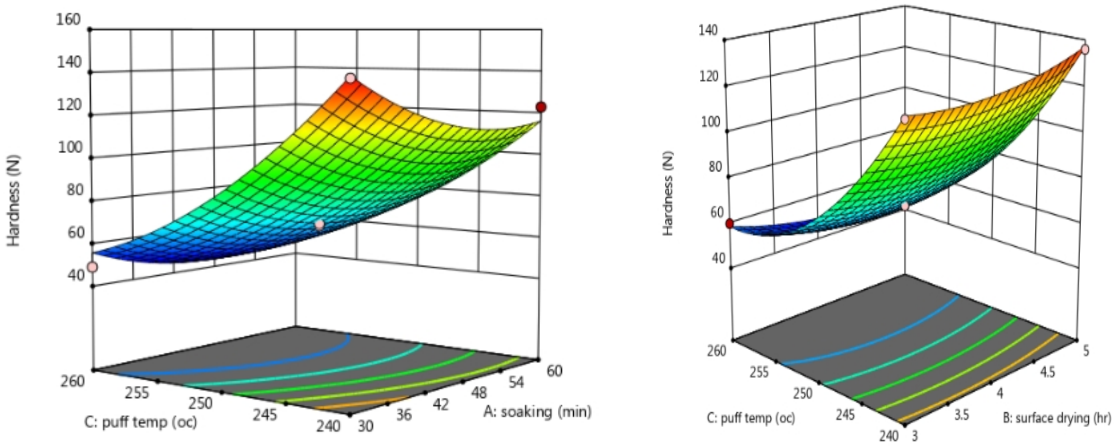
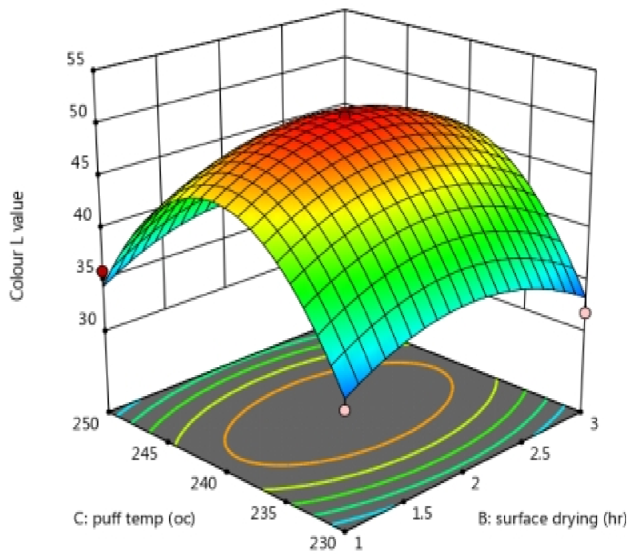
of puffed groundnut decreases with increases in sousing time (1X1), surface drying time (2X2), and puffing temperature (3X3). It was visually inspected that puffing temperature (3X3) had the most significant influence on hardness, followed by sousing time (1X1) and surface drying time (2X2). Figure 4 shows that the hardness of puffed groundnut decreases with an increase in marinating time to 45 minutes, surface drying time to 4 hours, and puffing temperature, with further increases in these parameters leading to reduced hardness.



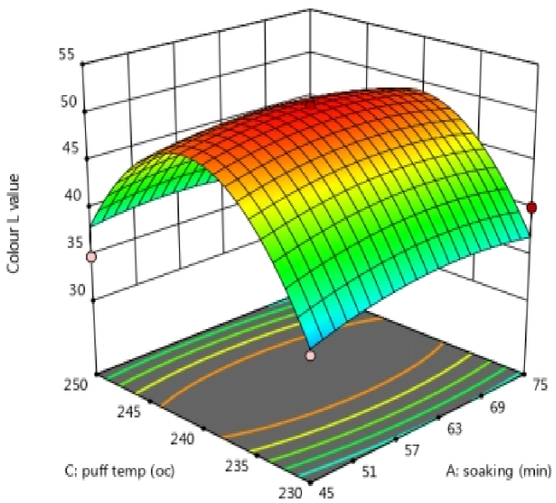
(A) (B)

Fig 4:- Effect of (X_1) and (X_3) at constant (X_2) (A) and effect of (X_2) and (X_3) at constant (X_1) (B) on hardness of puffed groundnut

Effect of Process Parameters on Color (L* Value) of Puffed Groundnut\nColor of puffed groundnut, measured as L* value using a Color Flex Hunter Lab Colorimeter, represents the lightness of the product. The L* values ranged from 32.73 to 50.85 for the various process parameter cumulations as presented in Table 2. The quadratic equation which describes the effect of process parameters on the L* value of puffed groundnut in terms of actual levels of variables is as follows:\nCLR=50.17+1.611+2.872+6.523 +0.13112−1.67????13+0.5823−3.28?12+3.0422−7.5732CLR=50.17+1.61X1+2.87X2 +6.52X3+0.131X1X2−1.67X1X3+0.58X2 X3−3.28X12+3.04X22−7.57X32 (R^2 = 0.953)\nWhere ????1X1 is marinating time, ????2X2 is surface drying time, and ????3X3 is puffing temperature.\nThe comparative effect of each factor on the L* value was assessed using F-values in the ANOVA and the magnitude of the coefficients of the coded variables as presented in Table 3. The ANOVA data records a model F-value of 15.93, significant at the 5% level, with a non-significant lack of fit F-value, indicating a good model fit.\nPositive coefficients for the linear terms indicate that the L* value increases with sousing time (????1X1), surface drying time (????2X2), and puffing temperature (????3X3). However, the negative coefficients for the quadratic terms indicate that excessive increases in these parameters result in a decrease in the L* value. Figure 5 shows that the L* value of puffed groundnut increases with sousing time up to 45 minutes, surface drying time up to 4 hours, and puffing temperature at 250°C, but decreases at higher calibers of these parameters.



(A)



(B)

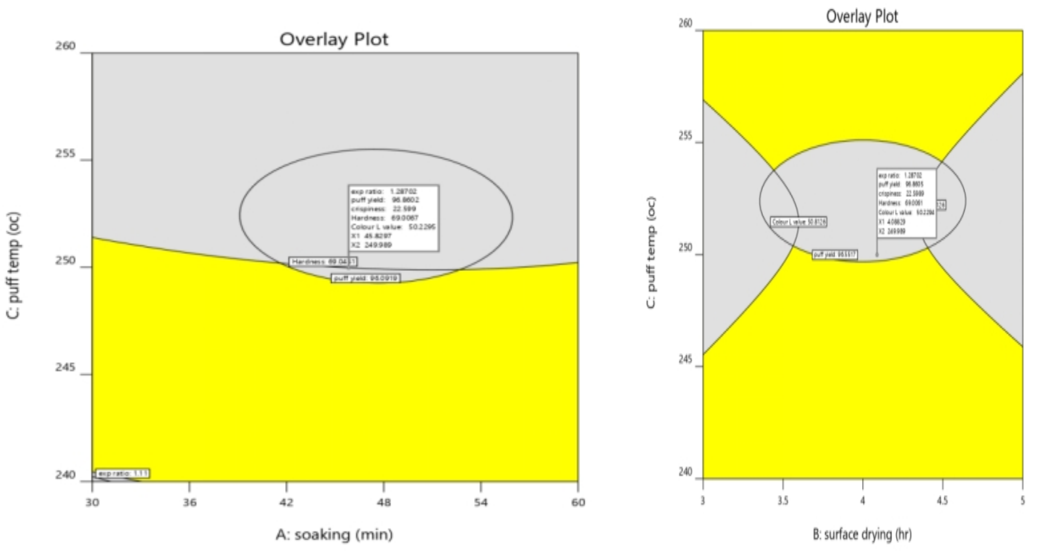
Optimization:

For the optimization of process parameters, the simultaneous optimization of responses was done using the Design-Expert program, Version 10.0, from STAT-EASE software. The optimal conditions of the independent variables were generated with the predicted values of the responses. Superimposed contours of the responses, namely puffing yield, expansion ratio, hardness, crispiness, and color depicted by L* value, against soaking time, surface drying time, and puffing temperature are shown in Figure 6.\n\n\tThe optimum conditions for the process variables from numerical optimization are as follows:

Soaking time (min)	:	45
Surface drying time (h)	:	4
puffing temperature (^{o}C)	:	250

The optimum values of process variables obtained by graphical optimization as follows:

Puffing yield (%)	:	96.85
Expansion ratio	:	1.29
Crispiness	:	22
Hardness (N)	:	69.08
Colour L* value	:	50.22



(a) **(b)**

Fig. 6 (a and b) Overlay plot showing predicted values of quality characteristics of puffed groundnut

CONCLUSION:

The technique of BBD in design of experiments and RSM was used for optimization and successfully demonstrated the impact of process parameters on the replications of the puffed groundnut. Optimum puffing of groundnut grains at 250 °C followed by marinating time 45 min and surface drying time 4 h. At optimal process condition, the puffed groundnut product had puffing yield of 97.63%, expansion ratio of 1.29, crispness of 22 +ve peaks, hardness of 69 N, and L* value of color of 50.23.

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