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RESPONSE SURFACE METHODOLOGY FOR OPTIMIZATION OF PUFFING PROCESS FROM PROCESSING SELECTED PADDY HYBRID

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Abstract– The puffed rice comes under the category of snack foods and is very popular in southern parts of India. This puffed rice if made out of low cost hybrids fetches a huge revenue to Indian Economy. The processing operations performed during the process is same as that of the traditional method of making puffed rice only the processing conditions of time and temperature are altered to get a good quality puffed rice at a low cost. This study is performed for optimization of the processing parameters of puffed rice. The puffed rice is got from processing of different varieties/hybrids of paddy and the selected Paddy hybrids were KRH-2, and the traditional ruling variety, IR-64. The hybrid and the variety were grown in DRR field and then processed for making puffed rice. The processing parameters for the process, soaking time, roasting temperature, roasting time, drying temperature and puffing temperature. The three different levels were selected for each processing parameter and they were varied in different combination for obtaining processed puffed rice. The soaking time levels were 24, 36 and 48 h, roasting temperature, 180 °C, 185 °C and 190 °C, roasting time, 2, 3 and 4 min, drying temperature, 110°C, 115 °C and 120 °C and puffing temperature, 210°C, 215 °C and 220 °C. The response surface methodology was used to optimize the yield parameter of puffed rice for the selected processing parameters. The yield has to be maximized for the optimized processing parameters of soaking time, roasting temperature, roasting time, drying temperature and puffing temperature. The optimized conditions were analysed using Analysis of variance and the optimized value for the maximized yield was found to be at 24h of soaking time, 180 °C of roasting temperature, 2 min of roasting time, 110°C of drying temperature and puffing temperature of 220 °C for a maximized yield of 0.59 g/kg in KRH-2 hybrid. From the analysis of variance(ANOVA) technique, the central composite design method, drying temperature significantly affects the yield of the puffed rice.

INTRODUCTION

The puffed rice is a more of snack food than of main food and even the brokens and the low cost variety can be converted into healthy food by way of processing into puffed rice. The puffed rice production is made in 6 different methods. The puffed rice is of 2 types, one is serrated murmura and the other is polished murmura. The traditional cottage level processing steps on the preparation of serrated murmura in the first method is cleaning the paddy by spreading in the ground, then sprinkling water (cold water) on the ground over the grain is done, then kept in overnight under gunny bags in 24h, then roasting at 180°C for 1min, then puffing at 220°C for 1min and the serrated full paddy murmura is called as gilli. In the second method of preparation of serrated murmura, processing steps include, cleaned paddy soaked in hot water for 24h, draining the water and spreading on floor for 15 minutes, roasted at 180 ^{o}C-200 ^{o}C in roaster for 1minute, again puffed in roaster a 220 °C for 1min with sand (1 paddy:10 sand) or without sand and 0.5 serrated paddy murmura were prepared and packing was done. In third method, Chuduva polished murmura was prepared by selecting the cleaned paddy of 1kg then soaking in hot water, 2h at 280 ^{o}C, roasting at 180 ^{o}C for 1min, sprinkling water and then roasted in roaster for 1min and pressed in edge runner and then 0.5 h drying in shade was done. The end point is cutting the grain when held in between the teeth, roasted in roaster at

220 °C for 1min or 2 min and light puffed rice. The recovery rate is for 100 kg of paddy yields 60-70kg of puffed rice. The fourth method is ordinary polished murmura, cleaned paddy bold variety is soaked in hot water for 8h, 100 °C, 6h at 280°C draining the water, roasting at 180-200 °C, sprinkling of cold water, spreading one tumbler of water/kg, plastic nature of rice, dehulling in Atta Chakki/ordinary miller at hot condition, 0.5h paddy gets converted into rice, drying for 1h in hot sun. the end point of drying is cutting the grain between the teeth with kadak sound, sprinkling with salt water and puffing in roaster at 220 °C for 1min and puffed rice is then packed. The fifth method of producing polished murmura is selected fresh paddy, IR-64 and Jaya, soaked in hot water for 8h, draining the water and spreading in floor for 15 minutes, roasted in 180-200 °C roasting drum for 1min, sprinkling water and again roasting for 1min, then repeating the same process until plastic nature of rice is arrived, LSU drier drying/open yard sun drying is practised at 120 °C. The end point of drying is cutting the grain between the teeth with kadak sound in LSU drier it is subjected to 5 passes, then roasted at 220 °C (salt water sprinkled) for 1min without sand puffing at puffed rice then packaged stored and 100kg of paddy yields 62 kg of puffed rice. Milling is done in Atta Chakki costed around Rs. 12,000/. The sixth method is as per literature the production of polished murmura, the process parameters for various unit operations in rice puffing included hot water soaking of paddy for 8h, 92-98°C, 30-32% mc, heaping, 6-7h at ambient temperature a 27.70% mc then mechanical roasting was done a 85sec, 150-170 °C, 7- 8% mc, first roasting, 130 sec, 82-83 °C, 25.2% mc, second roasting, 20 sec, 148 °C, 18.10% mc, dipping in water, 12 sec, 85 °C, 2% mc, tempering of 24h, room temperature at 26% mc, drying for 6h, sun drying for final moisture content of 11% mc then milled in roasting temperaure, first salting of rice for 1h, sun drying for 29% mc, then shade drying was done at 4h, under sun, second salting, 1h, room temperature, 32-60% mc, drying for 4h, sun drying at 18% mc. First roasting, 20 min 80 °C, 15.80%mc, third salting and tempering, 40 min, room temperature a 12.40% mc, second roasting at 10 min, 130 °C, 8.08% mc and puffing was done in 7 sec, 260 °C at 1.5% mc. The seventh method of serrated murmura is subjecting the cleaned paddy soaked in hot water overnight, then fried with sand in pan, then paddy fried in hot iron pan with sand and then puffed rice, full serrated murmura. The eighth method of serrated murmura includes soaking the paddy on 4h in hot water, dried in shade, then roasted for puffing along with sand and the output is 1:4 parts of murmura in volume.

MATERIALS AND METHODS

The IIRR field was prepared with proper labeling for all the selected hybrids and the standard cultural practices were following using the mechanical devices. The harvested produce is cleaned thoroughly and graded uniformly. The samples were labeled in poly ethylene buckets and then soaked in hot water. The variables selected were 24,36 and 48 hours. Five operating parameters of soaking time,(A) roasting temperature,(B) roasting time,(C) drying temperature (D) and puffing temperature(E) were varied and optimization was done using Minitab 17.0 version software (Table 1) The processing parameters were coded and then decoded for interpretation. Anova table was obtained with p-value for test of significance.The actual and the predicted yield for all the selected variety were worked out (Table 2 & 3).

Table 1. Experimental results for Puffing of KRH-2

SN.	Factors Designation	Parameters
1	A	Soaking Time
2	B	Roasting Time
3	C	Roasting Time
4	D	Drying Temp
5	E	Puffing Temp

RESULTS AND DISCUSSION

The effect of variables, soaking time, roasting temperature, roasting time, drying temperature and puffing temperature are tested for all the hybrid, KRH-2 and the check variety, IR-64. The linear variables, soaking time has significant effect in the puffing of KRH-2 hybrid and the squared items of soaking time and puffing temperature has significant effect. In 2 way interaction, roasting temperature and drying temperature, roasting time and drying temperature has significant effect. ($p \leq 0.05$). The calculated R^2 is 75.23%, R^2(adj.) is 59.74% and R^2 (pred.) is 31.91%. The linear variables in IR-64 variety, roasting temperature and drying temperature has significant effect, in two way interaction, soaking time and roasting temperature

Table 2. Process Parameters for Puffing of KRH-2

Ex N	A	B	C	D	E	Obs.yield	Pred.yield
1	24	180	2	110	210	591.00±0.58	587.81±3.77
2	24	180	2	115	215	589.66±0.88	590.63±3.77
3	24	180	2	120	220	578.00±0.58	578.04±2.53
4	24	185	3	110	210	596.00±1.15	593.68±3.77
5	24	185	3	115	215	580.67±3.18	580.76±3.77
6	24	185	3	120	220	584.00±2.31	580.05±2.53
7	24	190	4	110	210	577.00±0.58	581.20±2.53
8	24	190	4	115	215	580.67±3.18	575.33±2.53
9	24	190	4	120	220	577.00±0.58	582.76±2.53
10	36	180	3	110	215	584.00±2.31	576.89±2.53
11	36	180	3	115	220	580.00±10.97	586.57±2.98
12	36	180	3	120	210	589.67±0.88	590.68±2.98
13	36	185	4	110	215	572.00±0.58	575.91±2.98
14	36	185	4	115	220	578.00±0.58	581.02±2.98
15	36	185	4	120	210	589.67±0.88	593.22±2.98
16	36	190	2	110	215	580.00±10.97	577.83±2.98
17	36	190	2	115	220	578.00±0.58	578.86±2.98
18	36	190	2	120	210	591.00±0.58	587.67±2.98
19	48	180	4	110	220	578.00±0.58	582.10±2.98
20	48	180	4	115	210	572.00±0.58	572.21±2.98
21	48	180	4	120	215	589.67±0.88	584.02±2.98
22	48	185	2	110	220	572.00±0.58	571.64±2.98
23	48	185	2	115	210	596.00±1.15	592.22±2.98
24	48	185	2	120	215	589.67±0.88	587.95±2.98
25	48	190	3	110	220	572.00±0.58	575.49±2.98
26	48	190	3	115	210	577.00±0.58	579.76±2.98
27	48	190	3	120	215	580.67±3.18	579.04±1.38

$$Y = 658.89-1.99A+4.32B+0.83C-5.64D- 0.31E-6.37A*B-5.00C*D-5.13D*E$$

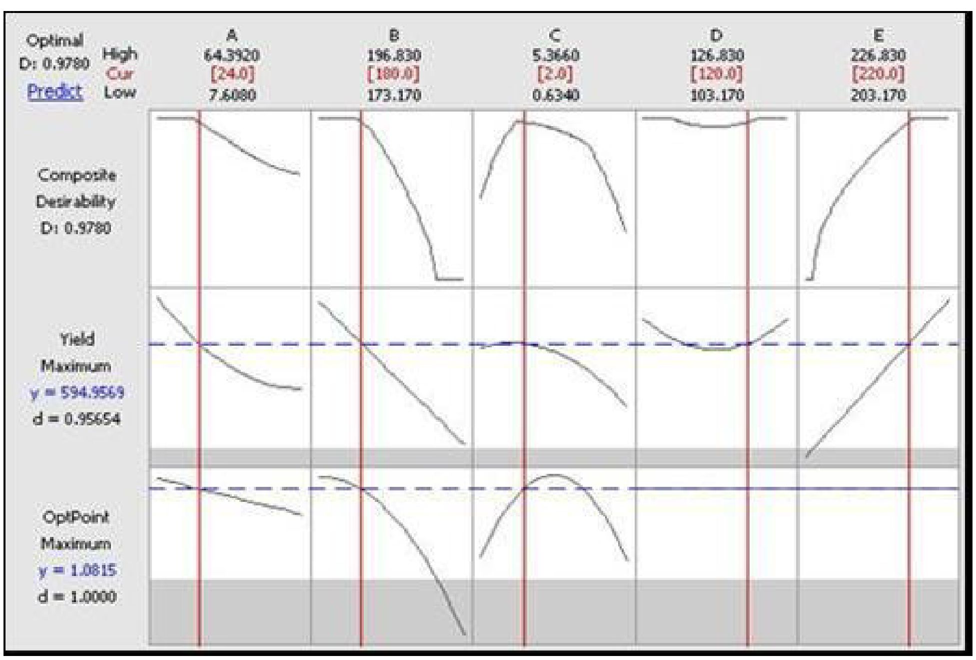

Fig. 1. Optimal processing conditions on the responses of yield of KRH-2,puffing

has significant, ($p \leq 0.05$). The R^2 is 57.90%, R^2 (adj.) is 39.19%, R^2(pred.) is 0.35%.

As 5 factors and three level of central composite design were chosen, there will be 27 runs. Table 1 illustrates the range of variables from low(-1) and high(+1). The experiment consisted of 27 runs. Statistical analysis of the process was performed to evaluate the analysis of variance (ANOVA) and p-test (Table 3). This paper also present the optimization using RSM to quantify the effect of main processing conditions and their interactions on yield and the optimum value of the soaking time, roasting temperature, roasting time, drying temperature and puffing temperature. Inorder to study the effect of processing conditions on the yield, a full quadratic model for each response was selected based on the best fit of the experimental data. The statistical significance of the developed models was evaluated using an analysis of variance (ANOVA) and the accuracy of the models was justified through a regression analysis and normal plot of residuals (Ahmad Rasyid *et al.,* 2016). The check variety IR-64 is compared with the selected hybrid of KRH-2 both for its yield as well as characteristics and contour plots and surface plots were plotted with the influencing processing parameters with that of the yield (Fig. 7-10). As a result estimated surface is an adequate approximation of the true response function, the results will be approximately equivalent to analysis of the actual system. A model fitting was done using Central Composite Design. The model parameters

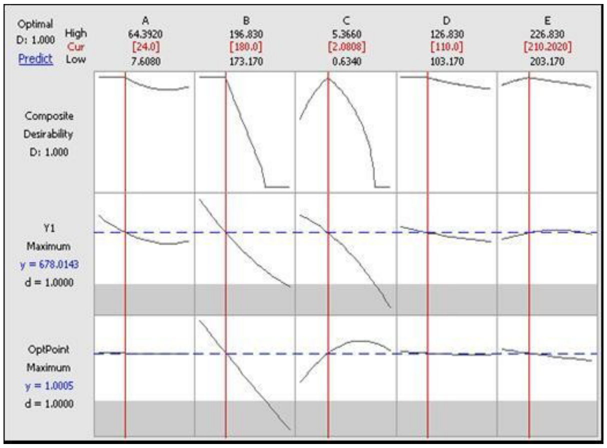

Fig. 2. Optimal processing conditions on the responses of yield of IR-64, puffing

Table 3. Process Parameters for Puffing of IR-64

E N	A	B	C	D	E	Obs Y	Pre Y
1	-1	-1	-1	-1	-1	672.67±4.33	654.19±5.40
2	-1	-1	-1	0	0	672.67±1.45	663.59±5.40
3	-1	-1	-1	1	1	678.00±0.58	672.23±5.40
4	-1	0	0	-1	-1	672.67±1.45	669.11±5.40
5	-1	0	0	0	0	655.00±0.58	658.16±5.40
6	-1	0	0	1	1	647.00±0.58	648.67±5.40
7	-1	1	1	-1	-1	678.00±0.58	659.62±5.40
8	-1	1	1	0	0	664.00±3.46	656.91±5.40
9	-1	1	1	1	1	647.00±0.58	645.55±5.40
10	0	-1	-1	-1	-1	655.00±0.58	660.86±5.40
11	0	-1	-1	0	0	641.00±0.58	645.81±7.00
12	0	-1	-1	1	1	672.67±4.33	666.47±7.00
13	0	0	0	-1	-1	651.00±0.58	663.58±7.00
14	0	0	0	0	0	642.00±1.15	650.48±7.00
15	0	0	0	1	1	678.00±0.58	676.19±7.00
16	0	1	1	-1	-1	664.00±3.46	643.72±7.00
17	0	1	1	0	0	641.00±0.58	645.17±7.00
18	0	1	1	1	1	672.67±4.33	678.23±7.00
19	1	-1	-1	-1	-1	642.00±1.15	649.84±7.00
20	1	-1	-1	0	0	678.00±0.58	675.53±7.00
21	1	-1	-1	1	1	655.00±0.58	665.62±7.00
22	1	0	0	-1	-1	641.00±0.58	647.94±7.00
23	1	0	0	0	0	672.67±1.45	671.14±7.00
24	1	0	0	1	1	651.00±0.58	662.92±7.00
25	1	1	1	-1	-1	647.00±0.58	656.33±7.00
26	1	1	1	0	0	642.00±1.15	643.27±7.00
27	1	1	1	1	1	655.00±0.58	658.89±2.11

can be approximated as proper experimental designs are used to collect the data. The composite desirability optimisation for the IR-64 was also plotted as graph in the Fig. 2. Table 3 shows the process parameters for IR-64 with the observed and the predicted values. Analysis of variance for the variety IR-64 is as shown in Table 5.

The optimum yield of the puffed rice is affected by the operating/ processing parameters of soaking time, roasting temperature, roasting time, drying temperature and puffing temperature. This is similar to the earlier findings of the optimum conditions, Kim and Ahuc, 2000, purification and molecular characterisation of a bacteriocin from pedi- ococcus sp. Isolated from fermented flatfish, Muhammad Wasee Mumtaz *et al*., 2012, an emphatic tool for optimised biodiesel production using rice bran and sunflower oils, Vahid Mosayebi and Farideh Tabatabari Yazdi, 2015, optimisation of microwave assisted extraction of pectin from black mulberry pomace and Sridevi and Genitha, 2012, optimization of osmotic dehydration process of pine apple by response surface methodology. The control of the processing parameters in the production of puffed rice results in the better quality characteristics of the puffed rice and better market value, hence there has been a continuous need to define the most appropriate conditions for puffed

Table 4. Analysis of variance(ANOVA) for response surface quadratic models on the yield of the hybrid, KRH-2 in puffing process

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Model	10	1056.94	75.23%	1056.94	105.69	4.86	0.00 s
Linear	5	306.86	21.84%	306.86	61.37	2.82	0.05 s
A	1	202.87	14.44%	202.87	202.86	9.33	0.00 s
B	1	22.56	1.61%	22.56	22.56	1.04	0.32
C	1	4.89	0.35%	4.89	4.88	0.22	0.64
D	1	66.91	4.76%	66.91	66.91	3.08	0.09
E	1	9.63	0.69%	9.63	9.62	0.44	0.51
Square	2	218.26	15.53%	218.26	109.13	5.02	0.02 s
A*A	1	57.23	4.07%	103.94	103.94	4.78	0.04 s
E*E	1	161.03	11.46%	161.03	161.03	7.40	0.01 s
2-Way	Interaction	3 531.82	37.85%	531.82	177.27	8.15	0.00 s
A*E	1	61.36	4.37%	61.36	61.36	2.82	0.11
B*D	1	245.45	17.47%	245.45	245.45	11.28	0.00 s
C*D	1	225.00	16.01%	225.00	225.00	10.34	0.00 s
Error	16	348.08	24.77%	348.08	21.75		
Total	26	1405.02	100.00%				

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
4.66	75.23%	59.74%	956.67	31.91%

Coded Coefficients

Term	Effect	Coef	SE Coef	95% CI	T-Value	P-Value	VIF
Constant		579.04	1.38	(576.11, 581.98)	418.71	0.00 s	
A	12.92	6.46	2.12	(1.98, 10.95)	3.05	0.00	1.00 s
B	4.31	2.16	2.12	(-2.33, 6.64)	1.02	0.32	1.00
C	-2.01	-1.00	2.12	(-5.49, 3.48)	-0.47	0.64	1.00
D	7.42	3.71	2.12	(-0.77, 8.20)	1.75	0.09	1.00
E	-2.82	-1.41	2.12	(-5.89, 3.08)	-0.67	0.51	1.00
A*A	16.35	8.17	3.74	(0.25, 16.10)	2.19	0.04	1.05 s
E*E	20.35	10.17	3.74	(2.25, 18.10)	2.72	0.01	1.05 s
A*E	-21.93	-10.96	6.53	(-24.80, 2.87)	-1.68	0.11	1.00
B*D	43.85	21.93	6.53	(8.09, 35.76)	3.36	0.00	1.00 s
C*D	41.98	20.99	6.53	(7.15, 34.83)	3.22	0.00	1.00 s

Regression Equation in Uncoded Units

Y =579.04+2.73A+0.91B-0.42C+1.56D-0.59E+1.46A*A+1.81E*E- 1.96A*E+3.92B*D+3.75C*D rice production in snack food items (Arokiyamary and Sivakumar, 2011). The good correlation between these observed values and predicted values indicated the reliability of Central composite Design incorporate desirability function method and it could be effectively used to optimize the process parameters.(Arulmathi *et al.,* 2015). In RSM, natural variables are transformed into coded variables which are dimensionless and having a mean zero and the same spread of standard deviation. (Meyers and Montgomery, 2002) RSM/Ridge analysis was perfomed to determine the critical levels of the design variables that produce the maximum response (Bakare *et al.,* 2009).

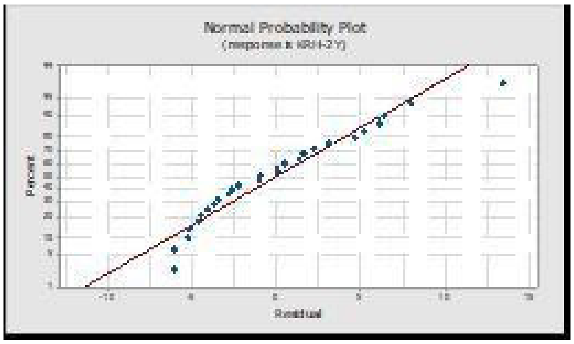

Fig. 3. Residual versus fitted line of hybrid KRH-2 for each response of puffing yield

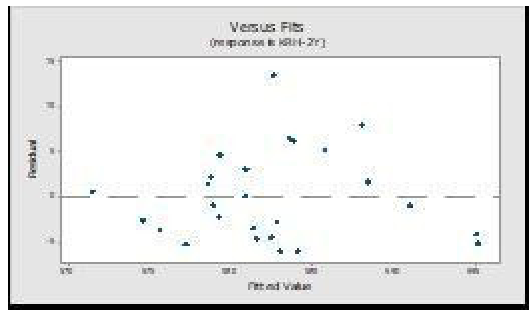

Fig. 4. Normal probability plot of the residual for the hybrid,KRH-2 for each puffing yield

Table 5. Analysis of variance(ANOVA) for response surface quadratic models on the yield of the hybrid, IR-64 in puffing process

Analysis of Variance, IR-64,puffing

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Val	P-Val
Model	8	2971.73	57.90%	2971.73	371.46	3.09	0.02 s
Linear	5	1501.23	29.25%	1501.23	300.24	2.50	0.06 s
A	1	107.22	2.09%	107.22	107.22	0.89	0.35
B	1	507.80	9.89%	507.80	507.79	4.23	0.05 s
C	1	18.96	0.37%	18.96	18.95	0.16	0.69
D	1	864.65	16.85%	864.65	864.65	7.20	0.01 s
E	1	2.61	0.05%	2.61	2.60	0.02	0.88
2-Way Interaction	3	1470.50	28.65%	1470.50	490.16	4.08	0.02 s
A*B	1	650.25	12.67%	650.25	650.25	5.42	0.03 s
C*D	1	400.00	7.79%	400.00	400.00	3.33	0.08
D*E	1	420.25	8.19%	420.25	420.25	3.50	0.07
Error	18	2160.93	42.10%	2160.93	120.05		
Total	26	5132.67	100.00%				

Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
10.95	57.90%	39.19%	5114.56	0.35%

Coded Coefficients

Term	Effect	Coef SE Coef	95% CI	T-Val	P-Val VIF		
Constant	658.89	2.11	(654.46, 663.32)	312.47	0.00 s		
A	-9.40	-4.70	4.97	(-15.14,5.75)	-0.95	0.35	1.00
B	20.45	10.22	4.97	(-0.22,20.67)	2.06	0.05	1.00 s
C	3.95	1.98	4.97	(-8.47,12.42)	0.40	0.69	1.00
D	-26.68	-13.34	4.97	(-23.78,-2.90)	-2.68	0.01	1.00 s
E	-1.46	-0.73	4.97	(-11.18,9.71)	-0.15	0.88	1.00
A*B	-71.40	-35.70	15.30	(-67.90,-3.50)	-2.33	0.03	1.00 s
C*D	-56.00	-28.00	15.30	(-60.20, 4.20)	-1.83	0.08	1.00
D*E	-57.40	-28.70	15.30	(-60.90, 3.50)	-1.87	0.07	1.00

Regression Equation in Uncoded Units

From the contour plot of yield vs soaking time and roasting temperature in KRH-2 hybrid is the maximum yield is obtained as the soaking time is 34h and roasting temperature is 186°c as the roasting time alone increases the puffing yield decreases and the soaking time beyond 45 h the yield tremendously decreases (Fig. 8) In the contour plot of yield vs soaking time and roasting temperature in IR-64 variety, the yield is maximum as the soaking time is 46-48h and roasting temperature is 190°C. As the soaking time and roasting temperature decreases the yield decreases (Fig. 10) for a yield of 640-645kg/t. From the surface plot it is clearly evident that the yield is maximum at a drying temperature of 110 °C and roasting time of 3 min for an yield of 585 kg/t (Fig. 7) and in IR-64 variety, the yield is 648kg/t for a drying temperature of 115°C and a roasting time of 3min (Fig. 9). The minimum observed yield is 572kg/t±0.58 and the maximum is 596kg/t±1.15, the minimum predicted yield is 571kg/t±2.98 and the maximum is 593 kg/t ± 3.77 in KRH-2 hybrid (Table 2). In IR-64 variety the minimum observed yield is 641kg/t±0.58 and the maximum is 678kg/t ±0.58 in observed yield and in the predicted yield the minimum is 643 kg/t±7.00 and the maximum is 678kg/t±7.00 (Table 3). The difference in predicted and observed is only 0.5% and this indicates the significance in the yield parameter in both hybrid and IR-64 variety tested for puffing. From the regression equation in uncoded units in KRH-2 hybrid it is clearly seen that the linear terms, roasting time and puffing temperature are negatively correlated to that of yield and the squared items are positively correlated to yield and the interaction terms of soaking time and puffing temperature are negatively correlated (Table 4). In IR-64 variety, in the regression equation, the linear terms of soaking time, drying temperature and puffing temperature are negatively correlated and the interaction terms are also negatively correlated. (Table 5).

The variance inflation factor is 1.00 and hence multicollinearity does not exist and the factors are not correlated. The analysis of variance table summarizes the linear terms, squared terms and the interactions. The contribution of the linear, squared and the interaction are 21.84%, 15.53% and 37.85% respectively. 24.77% of the information is unexplained in the model and this is under error contribution. In KRH-2 puffing the model is significant and contributes 75.23% and error contribution is 24.77%. Among the linear variables, the maximum contribution is by soaking time, 14.44% followed by drying temperature, 4.76%, roasting temperature, 1.61%, puffing temperature, 0.69% and roasting time 0.35%. A<D<B<E<C. Among the squared terms, puffing temperature is the major contributor is 11.46% and then by soaking time, 4.07%, among the 2 way interaction terms, BD, 17.47%, CD, 16.01% and AE, 14.37%. BD <CD<AE. In the regression equation, the yield factor is influenced by soaking time, roasting temperature and drying temperature positively and the other factors, roasting time and puffing temperature influences the yield negatively in squared terms, both soaking time and puffing temperature have positively influence, the terms, soaking time and puffing temperature have negative influence, roasting temperature and drying temperature and roasting time and drying temperature have positive influence on yield. In IR-64 variety among the linear terms the maximum contribution is drying temperature, 16.85% followed by roasting temperature, 9.89%, soaking time 2.09%, roasting time, 0.37% and puffing temperature, 0.05% among the interaction terms, the major contributor is AB,12.67% followed by DE, 8.19% and then CD,

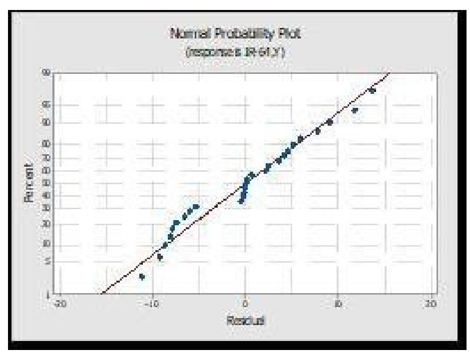

Fig. 5. Residual versus fitted line of hybrid IR-64 for each response of puffing yield

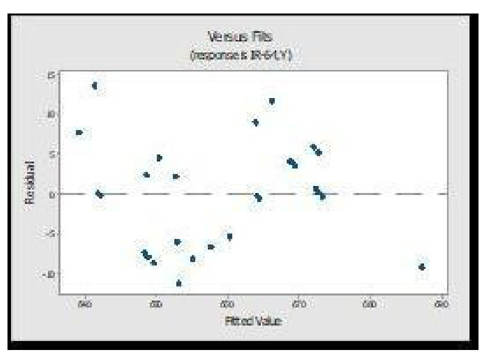

Fig. 6. Normal probability plot of the residual for the hybrid, IR-64 for each response of puffing yield

7.79%. The linear terms contribution is 29.25% 2 way interaction terms is 28.65, error is 42.10%. The total contribution by the model is 57.90% and that of error is 42.60% and significant is the model with p≤0.05 in total linear, squared and interaction terms. The R^2 is 57.90%, R^2(adj.) is 39.19% and R^2(pred.) is 0.35%. From the regression equation, the positive influencing variables to yield are roasting temperature, roasting time the other variables of soaking time,drying temperature and puffing temperature have negative influence on yield. All the interaction terms, AB, CD and DE have negative influence on yield of puffing. The intensity of negative influence is more in AB followed by DE and CD. The small p value for all the variables, p≤0.05 indicate that these effects are statistically significant. The coefficient Table gives the coefficient for all the terms in the model because we used an orthogonal design, each effect is estimated independently therefore the coefficients for the linear terms are the same as the linear model is just fitted. Residual values are the difference between the observed value and its corresponding fitted value. Residual values are especially useful in regression and ANOVA procedures because they indicate the extent to which a model accounts for the variation in the observed data. The results can be obtained visually from the residual versus fits probability plot of effects method (Bangphan *et al.*, 2016). Probability plot for the hybrid, KRH-2 and IR-64 variety plots (Fig. 3-6) each value vs the percentage of values in the sample that are less than or equal to it, along a fitted distribution line. The scales are transformed as necessary to that of the fitted distribution forms a straight line. This plot is used to evaluate the fit of a distribution to the data and compare the different sample distribution (Fig.5, 6). Standard Residuals equals the value of the residual divided by an estimate of its standard deviation. This is useful because raw residuals can be poor indicates of outliers due to their non constant variance (Fig. 3). The check of the normality assumptions of the data is then conducted, it can be seen in Fig. 4&6, that all the points on the normal plot come close to forming a straight line. This implies that the data are fairly normal and there is no deviation from the normality. The straight line in the optimisation graph represents the desirability for the response increases linearly (Fig.1&2) The desirability must be near to one for the optimized

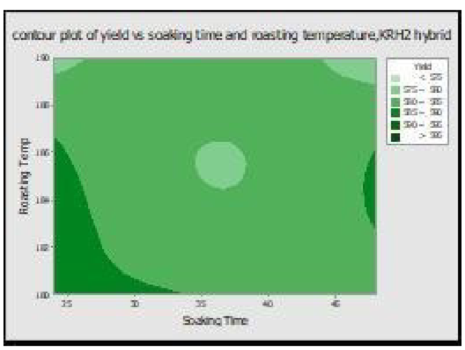

Fig. 7. Contour plot of yields vs soaking time and roasting temperature, of puffing in KRH-2 hybrid

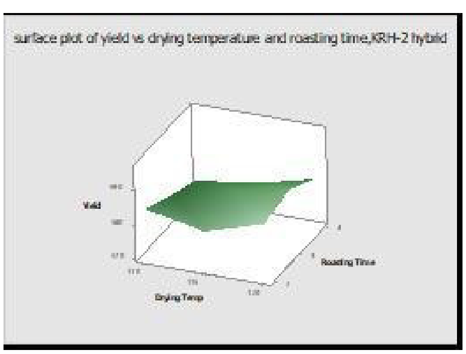

Fig. 8. Response surface plot of yields vs time and roasting temperature, soaking of puffing in KRH-2 hybrid

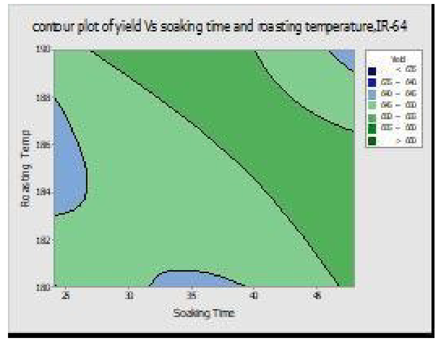

Fig. 9. Surface plot of yields vs roasting time and drying temperature, puffing in IR-64 hybrid

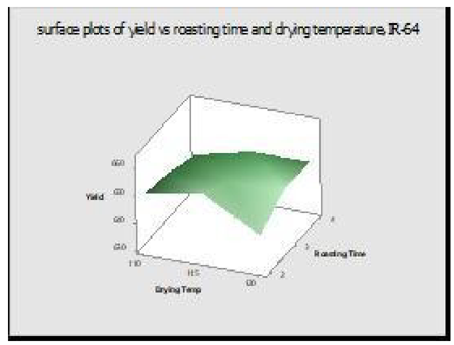

Fig. 10. Contour plot of yield vs soaking time and roasting temperature, puffing in IR-64 hybrid

solution, Minitab determines optimal settings for input variables by maximising the composite desirability. Composite desirability is the weighted geometric mean of the individual desirabilities for the response. Here the composite desirability (0.98), Fig.1 is fairly close to 1 which indicates the settings appear to achieve favourable results for all responses as a whole. The individual desirability indicates that the settings are more effective at maximising the yield. From the graphs, the curves show that the target is close to maximum yield for the selected KRH-2 hybrid.

CONCLUSION

Based on the response optimization analysis made for the selected hybrid,KRH-2, it is found out that the best optimum processing conditions are 24h of soaking time, 180 °C of roasting temperature, 2.0min of roasting time, 120 °C of drying temperature and 220 °C of puffing temperature among the selected three levels of processing conditions in the process of puffing for a maximised yield of 594.95 kg/t and in check variety and ruling variety of puffing in cottage level is IR-64, the optimized processing conditions were 24h of soaking time, 180 °C of roasting temperature, 2.08 min of roasting time, 110 °C of drying temperature and 210 °C of puffing temperature for a maximised yield of 678.01 kg/t. The composite desirability function of the response surface methodology in design of experiments is much useful in predicting the level of significance of all the independent parameters on the dependent parameter of yield in the puffing process for the selected KRH-2 hybrid as well as IR-64 variety.

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