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

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Abstract–The flaked rice popularly called as poha is famous in cottage level for its nutritional value as well as snack food. Snack foods plays a major role in children's growth of vital parts and size and hence this snack food industry especially flaked rice has become common in day today life. The paddy hybrids of low cost if converted into snack food fetches a huge market value both in inland and in export and the selected variables for this processing of flaked rice includes, soaking time, roasting temperature, roasting time,drying temperature and flaking time. The hybrids selected are of different characteristics and the conditions of processing for making of flaked rice differs from each other. Hence the process is optimized for each and every variety separately. The optimized product is of good characteristics in appearance and taste is also tested for the commercialisation of the optimized process. The three different levels selected were in soaking time, 24 h, 36 h and 48 h, roasting temperature, 170 °C, 180 °C and 190 °C, roasting time, 2, 4 and 6 min, gap between rollers, 2, 3 and 4 mm and flaking time, 60, 90 and 120 sec. The optimizations of all these 5 parameters were made for a maximised yield of flaked rice and the hyrbids performing on par with IR-64, the ruling check variety is found out and has to be commercialized so that the cost involved in the check variety, IR-64 can be ruled out and hybrid can be replaced. The optimum conditions of PA-6444 for maximised yield of 0.42 g/kg of paddy hybrid were, 48.0h of soaking time, 190 °C of roasting temperature, 2.0min of roasting time, 2 mm of gap between rollers and 120sec of flaking time. The central composite design was performed with 27 runs in RSM in Minitab 17.0 sofware. The analysis of variance showed that, soaking time and gap between rollers had significant change in the output yield of flaked rice. Mean yield of PA-6444 is 380.75±9.68, minimum of yield is 305.00±9.68, maximum of yield is 447.00±9.68, cv is 13.21. Mean yield of IR-64, check variety is 309.48±1.11, minimum of yield is 301.00±1.11, maximum of yield is 317.67±1.11, cv is 1.86. The correlation coefficient between predicted and actual yield for the selected PA-6444 hybrid is 0.96 and that of the check variety, IR-64 is 0.94 in flaking of paddy hybrids.

INTRODUCTION

There are many value added products made from rice/paddy. As such paddy is consumed as staple food but when converted into value added products especially flaked rice gains money both in inland and foreign,since the world is fast moving with newer technologies day by day fast foods and value added foods are becoming common in households and one such product is chudduvva popularly called as flaked rice. This flaked rice when prepared using low cost hybrids becomes cost effective and even the broken rice during milling process when converted into snack food, flaked rice can be utilized into a value added product. Hence the optimization process was carried out for flaked rice of selected hybrids and cost economics was also worked out for commercialization.

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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 polyethylene buckets and then soaked in hot water. The variables selected were 24, 36 and 48 hours. Five operating parameters of soaking time, roasting temperature, roasting time, gap between rollers and flaking time were varied and optimization was done using Minitab 17.0 version software. The processing parameters were coded and then decoded for interpretation. Anova table was obtained with p-value for test of significance (Alireza Bazargan *et al.,* 2015). Central composite design method was used to obtain the ANOVA and opti- mization of the selected variables (Artit Kongaew *et al.,* 2012).

Different Methods of Flaking

Freshly harvested paddy is soaked in 24h in hot water, the excess water is drained and then roasted in a roaster at 180 °C for 1min if sprinkling is done with cold water, lengthy flakes are obtained and if sprinkled with hot water then short flakes are obtained. Thickness is most with water sprinkling due to imbibitions of water and light thick if no water sprinkling is done. Then pressed in edge runner. Soaking in cool water for thin flakes and paddy soaked in hot water at 70-80 °C for one day for thick flakes. The next method of making flaked rice is subjecting the cleaned paddy to soaking in cold water for 12h with wetness roasting and pressing in edge runner and the output of 1:1 as a part of flaked rice.

RESULTS AND DISCUSSION

The factors selected for flaking process includes, soaking time, roasting temperature, roasting time, gap between rollers and flaking time. The minimum observed yield value is 305 ±2.89 kg/t and maximum is 442±1.45 kg/t, the predicted minimum yield is 318.30 ±14.30 kg/t, the maximum predicted yield is 455.80±15.80 kg/t for PA-6444 hybrid. For IR-64 variety, the minimum observed yield is 301.00±0.33 kg/t and the maximum predicted yield is 317.00 ± 0.88 kg/t, the minimum predicted yield is 302.54 ± 2.37 kg/t and the maximum predicted yield is 317.80 ± 2.03 kg/t. The percentage increase in predicted value than that of observed value in the hybrid, PA-6444 is 2-4% and in IR-64 the predicted and observed are more or less same.

Table 1. Experimental results for Flaking of PA-6444

S No.	Factors designation	Parameters
1	A	Soaking time
2	B	Roasting temperature
3	C	Roasting time
4	D	Gap between rollers
5	E	Flaking time

Validation of the difference between predicted and observed showed no significance and was similar to the earlier findings of Andrew *et al.,* 2014. This indicates that the predicted and observed are significant statistically. In the ANOVA for PA-6444 hybrid the contribution of linear, squared and interaction terms are 6.26%, 34.83% and 5.73% respectively, 8.18% is under error contribution and is unexplained by the model. R^2 is 91.82%, R^2 (adj.) is 84.82% and R^2 (pred.) is 64.87%, hence the model is significant. Among the linear terms, highest contribution is by gap between rollers and is 3.24% and soaking time contribution 0.09%, roasting temperature contribution is 0.62%, roasting time is 0.11% and flaking temperature is 2.21%. The minimum contribution is by soaking time is 0.09%, A<C<B <E<D. In squared terms, A^2 is 14.91% and E^2 is 19.98%, flaking time contributes more than that of soaking time. The other factors are correlated with each other and are eliminated. In 2 way interactions, AD contributes 13.25%, BD is 10.44%, BE is 10.56%, CD is 12.55% and CE is 3.93%. CE<BD < BE < CD <AD. (Table 3) In the Anova for IR-64 variety, the contribution of linear, squared and interaction terms are 19.69%, 23.98% and 45.32% respectively. The model explains 88.98% of the information and 11.01% is explained by error term. The maximum contributors among linear terms are roasting time and minimum is roasting temperature(B). The contributions of factors are C<E<D<A<B. In squared terms, the maximum contribution is gap between rollers, 17.76% then soaking time, 5.61% followed by roasting temperature, 0.61% and then roasting time, 0.01%. The linear terms of soaking time is 1.33%, roasting temperature is 0.12%, roasting time is 13.60%, gap between rollers is 1.50% and flaking temperature is 3.14%, in squared terms, the soaking time contributes, 5.61% roasting temperature is 0.61%, roasting time is 0.01% and gap between rollers is 17.76%, the 2 way interactions, soaking

Table 2. Process Parameters for Flaking of PA-6444

E N	A	B	C	D	E	Obs. Y	Pred.Y
1	24	170	2	2	60	431.00±0.58	455.80±15.80
2	24	170	2	3	90	442.00±1.45	421.20±15.82
3	24	170	2	4	120	361.00±0.58	350.70±10.60
4	24	180	4	2	60	442.00±1.45	441.10±15.80
5	24	180	4	3	90	317.00±1.45	325.90±10.60
6	24	180	4	4	120	382.00±1.15	355.90±10.60
7	24	190	6	2	60	317.00±1.45	342.90±10.60
8	24	190	6	3	90	442.00±1.45	447.90±15.80
9	24	190	6	4	120	382.00±1.15	367.70±10.60
10	36	170	2	2	90	327.00±1.45	337.70±10.60
11	36	170	2	3	120	382.00±1.15	368.60±14.30
12	36	170	2	4	60	447.00±0.58	458.50±14.30
13	36	180	4	2	90	327.00±1.45	337.10±14.30
14	36	180	4	3	120	398.00±1.15	390.30±14.30
15	36	180	4	4	60	305.00±2.89	316.60±14.30
16	36	190	6	2	90	327.00±1.45	318.30±14.30
17	36	190	6	3	120	382.00±1.15	360.00±14.30
18	36	190	6	4	60	442.00±1.45	444.40±14.30
19	48	170	2	2	120	398.00±1.15	384.50±14.30
20	48	170	2	3	60	447.00±0.58	442.00±14.30
21	48	170	2	4	90	431.00±0.58	435.70±14.30
22	48	180	4	2	120	382.00±1.15	387.40±14.30
23	48	180	4	3	60	431.00±0.58	425.70±14.30
24	48	180	4	4	90	305.00±2.89	327.40±14.30
25	48	190	6	2	120	363.00±2.03	369.50±14.30
26	48	190	6	3	60	336.00±2.31	324.20±14.30
27	48	190	6	4	90	327.00±1.45	346.80±5.80

2) PA-6444, Flaking

	Fit	SE Fit	95% CI	95% PI
1.	450.376	23.0361	(394.009, 506.743)	(360.732, 540.020)
2.	426.955	23.0361	(370.587, 483.322)	(337.311, 516.598)
3.	370.113	23.0361	(313.746, 426.480)	(280.469, 459.757)
4.	435.682	23.0361	(379.315, 492.050)	(346.038, 525.326)
5.	312.218	23.0361	(255.850, 368.585)	(222.574, 401.861)
6.	361.098	23.0361	(304.731, 417.465)	(271.454, 450.742)
7.	342.233	23.0361	(285.865, 398.600)	(252.589, 431.876)
8.	423.277	23.0361	(366.910, 479.645)	(333.634, 512.921)
9.	392.648	23.0361	(336.281, 449.016)	(303.005, 482.292)
10.	351.053	23.0361	(294.686, 407.420)	(261.409, 440.697)
11.	373.527	26.2006	(309.416, 437.638)	(278.823, 468.231)
12.	448.737	26.2006	(384.627, 512.848)	(354.033, 543.441)
13.	345.526	26.2006	(281.416, 409.637)	(250.822, 440.231)
14.	390.794	26.2006	(326.683, 454.905)	(296.090, 485.498)
15.	280.738	26.2006	(216.627, 344.848)	(186.033, 375.442)
16.	339.456	26.2006	(275.345, 403.567)	(244.752, 434.160)
17.	391.281	26.2006	(327.170, 455.391)	(296.577, 485.985)
18.	428.456	26.2006	(364.346, 492.567)	(333.752, 523.161)
19.	397.562	26.2006	(333.451, 461.673)	(302.858, 492.266)
20.	440.702	26.2006	(376.591, 504.813)	(345.998, 535.406)
21.	429.864	26.2006	(365.754, 493.975)	(335.160, 524.569)
22.	398.618	26.2006	(334.508, 462.729)	(303.914, 493.323)
23.	425.400	26.2006	(361.289, 489.510)	(330.695, 520.104)
24.	295.619	26.2006	(231.508, 359.729)	(200.915, 390.323)

Continued table ...

2) PA-6444, Flaking ..

	Fit	SE Fit	95% CI	95% PI
25.	372.583	26.2006	(308.473, 436.694)	(277.879, 467.288)
26.	329.492	26.2006	(265.381, 393.602)	(234.787, 424.196)
27.	329.992	27.4090	(262.924, 397.059)	(233.261, 426.722)

time and roasting temperature is 4.91%, soaking time and gap between rollers is 10.49%, soaking time and flaking time is 4.19%, roasting temperature and roasting time is 7.44%, roasting time and gap between rollers is 2.91% and roasting time and flaking time is 15.38%. The R^2 is 88.99%, R^2 (adj.) is 73.97% and R^2 (pred.) is 26.62%. Adding variables to the model increases the R^2 value and the model need not be adequate to fit the data,hence R^2 adj. and R^2 pred. must also be seen fro the adequacy of the model. In addition low PRESS is an indicator of adequacy of the model. This is similar to the earlier findings Alizera Bazargan *et al.,* 2015. In the regression equation for yield, the negative contribution is by soaking time and positive contribution is by roasting temperature, roasting time, gap between rollers flaking time and in the squared terms, negative contribution is by soaking time, roasting temperature, roasting time, gap between rollers, in the interaction terms, of soaking time and roasting temperature, roasting temperature and roasting time and roasting time and flaking time has negative contribution and soaking time and gap between rollers and soaking time and flaking time and roasting time and gap between rollers are positive contributors to the yield in the puffing process (Table 4). In the optimization plot for the PA-6444 hybrid, the optimum conditions for the factors, A,B,C,D and E for the maximised yield of 415.24kg/t, the composite desirability is 78% for yield and the other independent factors the desirability is 88%. The

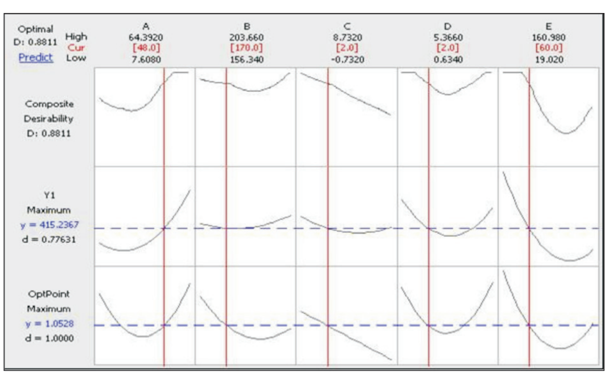

Fig. 1. Optimal processing conditions on the responses of yield of PA-6444, flaking

optimum value desirability is 1 and this indicates the significance of the model for flaking process (Fig. 1). In 2 way interaction terms, the major contributor is CE, 15.38% followed by AD, 10.49%, BC, 7.44%, AB, 4.91%, AE, 4.19% and CD, 2.91%. In the regression equation, the terms soaking time A has negative contribution and other factors, B,C,D and E has positive contribution to the yield, the terms, squared soaking time, squared roasting temperature, squared roasting time, squared gap between rollers shows negative contribution and other terms, soaking time and roasting temperature, roasting temperature and roasting time and roasting time and flaking time has negative contribution and the terms, soaking time and gap between rollers, soaking time and flaking time and roasting time and gap between rollers has positive contribution. The optimum conditions of PA-6444 for maximised yield of 0.48g were, 48.0h of soaking time, 190 °C of roasting temperature, 2.0min of roasting time, 2 mm of gap between rollers and 120 sec of flaking time. This is similar to that of the Bakare *et al.,* (2009) in bread fruit lye peeling, Benkun Ql *et al.,* (2009); Dagnino *et al.,* (2013) in optimization of the acid pre treatments of rice hulls to obtain fermentable sugars for bio- ethanol production and Huzairy Hassan and Khairiah Abd. Karim, 2015 in optimization of alpha amylase production from rice straw using solid state fermentation. In the optimization plot of IR-64 in flaking the composite desirability is 92% for all the independent factors selected and the desirability for the yield is 84.17% and for optimum points it is 1 and hence the model is found to be significant since desirability is near to 100% the difference is error (Fig. 2). The optimum values found out for the yield of both the hybrid PA-6444 and the variety, IR-64 is similar to the earlier findings of Emmanuel kwas *et al.,* 2004. This optimization is mainly done to improve the independent variables performance for a said most desirable response. The graph showing the residual versus fitted line of hybrid, PA-6444 for flaking yield is shown in Fig. 3 and for IR-64 it is in Fig. 5. The response is found scattered both below and above the centre line and hence found to be significant. The normal probability plot of the

Table 3. Process Parameters for Flaking of IR-64 with their values at three levels

E N	A	B	C	D	E	Obs. Y	Pred. Y
1	-1	-1	-1	-1	-1	301.00±0.58	303.63±2.37
2	-1	-1	-1	0	0	311.00±0.58	306.70±2.37
3	-1	-1	-1	1	1	306.00±0.58	305.80±2.37
4	-1	0	0	-1	-1	316.00±0.88	317.80±2.03
5	-1	0	0	0	0	313.00±0.33	313.09±2.03
6	-1	0	0	1	1	303.00±0.33	302.54±2.37
7	-1	1	1	-1	-1	311.00±0.58	308.71±2.37
8	-1	1	1	0	0	317.00±0.88	316.07±2.37
9	-1	1	1	1	1	306.00±0.58	306.26±2.37
10	0	-1	-1	-1	-1	309.00±0.58	309.62±2.37
11	0	-1	-1	0	0	303.00±0.33	306.80±2.27
12	0	-1	-1	1	1	316.00±0.88	317.41±2.27
13	0	0	0	-1	-1	317.00±0.88	314.74±2.27
14	0	0	0	0	0	303.00±0.33	305.03±2.27
15	0	0	0	1	1	309.00±0.58	309.97±2.27
16	0	1	1	-1	-1	313.00±0.33	315.55±2.27
17	0	1	1	0	0	301.00±0.33	303.90±2.27
18	0	1	1	1	1	311.00±0.58	310.63±2.27
19	1	-1	-1	-1	-1	306.00±2.31	309.67±2.27
20	1	-1	-1	0	0	311.00±0.58	312.39±2.27
21	1	-1	-1	1	1	313.00±0.33	316.06±2.27
22	1	0	0	-1	-1	303.00±0.33	302.86±2.27
23	1	0	0	0	0	301.00±0.58	300.37±2.27
24	1	0	0	1	1	317.00±0.88	318.50±2.27
25	1	1	1	-1	-1	309.00±0.58	308.44±2.27
26	1	1	1	0	0	303.00±0.33	303.01±2.27
27	1	1	1	1	1	317.00±0.88	315.45±1.54

Prediction for Y, IR-64,flaking

Fit	SE Fit	95% CI	95% PI
1. 300.482	2.53920	(294.269, 306.695)	(290.601, 310.363)
2. 309.819	2.53920	(303.606, 316.032)	(299.938, 319.700)
3. 307.077	2.53920	(300.864, 313.290)	(297.196, 316.958)
4. 316.271	2.53920	(310.058, 322.484)	(306.390, 326.152)
5. 312.094	2.53920	(305.881, 318.307)	(302.213, 321.975)
6. 300.259	2.53920	(294.046, 306.472)	(290.378, 310.140)
7. 311.207	2.53920	(304.994, 317.420)	(301.326, 321.088)
8. 317.030	2.53920	(310.817, 323.244)	(307.149, 326.912)
9. 308.042	2.53920	(301.829, 314.255)	(298.161, 317.923)
10. 306.224	2.53920	(300.011, 312.437)	(296.343, 316.105)
11. 306.198	2.88802	(299.131, 313.265)	(295.759, 316.637)
12. 317.684	2.88802	(310.617, 324.751)	(307.245, 328.123)
13. 318.130	2.88802	(311.063, 325.197)	(307.691, 328.569)
14. 305.769	2.88802	(298.703, 312.836)	(295.330, 316.208)
15. 307.920	2.88802	(300.853, 314.986)	(297.481, 318.359)
16. 313.348	2.88802	(306.282, 320.415)	(302.909, 323.787)
17. 304.465	2.88802	(297.399, 311.532)	(294.026, 314.904)
18. 311.434	2.88802	(304.367, 318.500)	(300.995, 321.873)
19. 304.794	2.88802	(297.728, 311.861)	(294.355, 315.233)
20. 310.616	2.88802	(303.549, 317.682)	(300.177, 321.054)
21. 314.559	2.88802	(307.492, 321.626)	(304.120, 324.998)
22. 303.863	2.88802	(296.796, 310.930)	(293.424, 314.302)
23. 302.130	2.88802	(295.063, 309.196)	(291.691, 312.569)
24. 318.701	2.88802	(311.634, 325.768)	(308.262, 329.140)
25. 310.255	2.88802	(303.188, 317.322)	(299.816, 320.694)
26. 305.644	2.88802	(298.578, 312.711)	(295.205, 316.083)
27. 316.984	3.02121	(309.592, 324.377)	(306.322, 327.646)

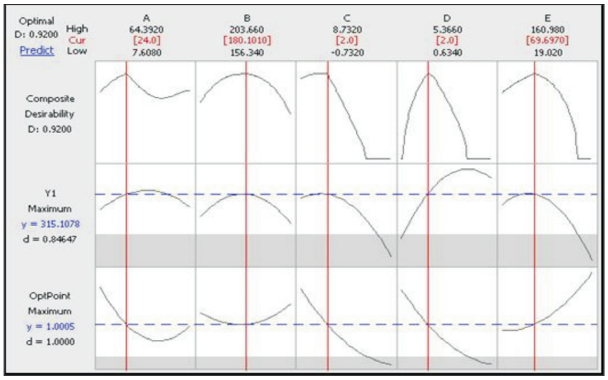

Fig. 2. Optimal processing conditions on the responses of yield of IR-64,flaking

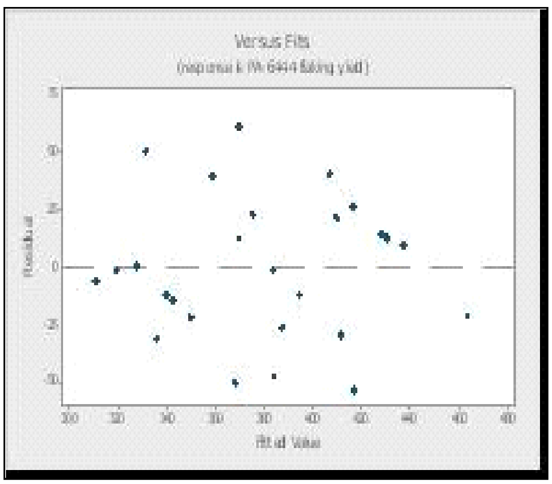

Fig. 3. Residual versus fitted line of hybrid PA-6444 for each response of flaking yield

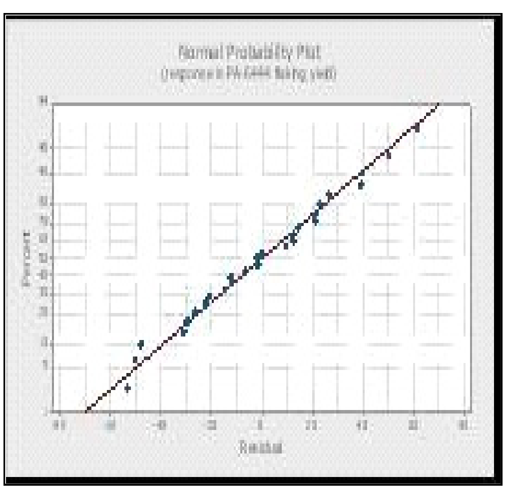

Fig. 4. Normal probability plot of the residual for the hybrid, PA-6444 for each flaking yield

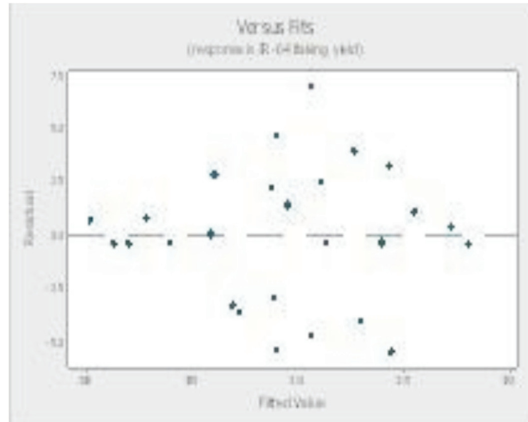

Fig. 5. Residual versus fitted line of variety IR-64 for each response of flaking yield

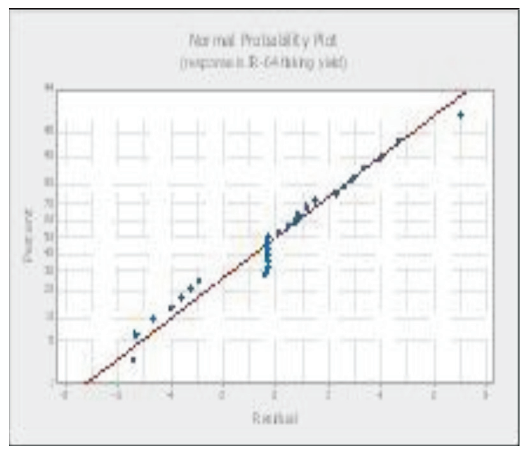

Fig. 6. Normal probability plot of the residual for the variety, IR-64 for each flaking response of yield

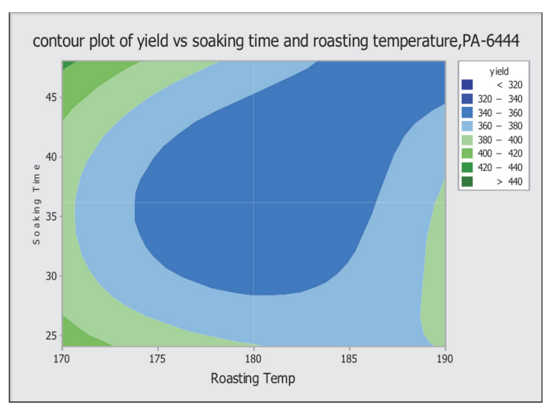

Fig. 7. Contour plot of yields vs soaking time and roasting temperature, of flaking in PA-6444 hybrid

residual for the hybrid, PA-6444 and for IR-64 for flaking yield is as shown in Fig. 4 & 6. The points are scattered around the straight line and hence found to be statistically significant and hence the model can be accepted. In the normal probability plot if the data are not linear, then the error is not evenly distributed. The residuals are scattered randomly with the response hence the data fits the model well.

In Fig. 7, contour plot of yield vs soaking time and roasting temperature of flaking in KRH-2 hybrid. The yield is maximum at a lower roasting temperature and higher soaking time. In Fig. 9 from the contour plot of yield vs soaking time and roasting temperature in flaking of IR-64 variety, the maximum yield is with increased soaking time ad roasting temperature in flaking of IR-64 variety, the

Table 3. Analysis of variance (ANOVA) for response surface quadratic models on the yield of the hybrid, PA-6444 in flaking process

Analysis of Variance, PA-6444, flaking

Source	DF	Seq SS	Contribution	Adj SS Adj	MS	F-Val	P-Val
Model	12	60246.80	91.82%	60246.80	5020.60	13.10	0.00 s
Linear	5	4109.00	6.26%	4109.00	821.80	2.14	0.12
A	1	55.90	0.09%	55.90	55.90	0.15	0.70
B	1	403.60	0.62%	403.60	403.60	1.05	0.32
C	1	73.60	0.11%	73.60	73.60	0.19	0.66
D	1	2125.50	3.24%	2125.50	2125.50	5.55	0.03 s
E	1	1450.40	2.21%	1450.40	1450.40	3.79	0.07 s
Square	2	22853.00	34.83%	22853.00	11426.50	29.82	0.00 s
A*A	1	9779.50	14.91%	14840.80	14840.80	38.74	0.00 s
E*E	1	13073.50	19.93%	13073.50	13073.50	34.12	0.00 s
2-Way Interaction	5	33284.80	50.73%	33284.80	6657.00	17.37	0.00 s
A*D	1	8695.60	13.25%	8695.60	8695.60	22.70	0.00 s
B*D	1	6847.60	10.44%	6847.60	6847.60	17.87	0.00 s
B*E	1	6930.60	10.56%	6930.60	6930.60	18.09	0.00 s
C*D	1	8235.60	12.55%	8235.60	8235.60	21.50	0.00 s
C*E	1	2575.60	3.93%	2575.60	2575.60	6.72	0.02 s
Error	14	5363.90	8.18%	5363.90	383.10		
Total Model	26	65610.70	100.00%				

Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
19.57	91.82%	84.82%	23049.30	64.87%

Coded Coefficients

Term	Effect	Coef SE Coef	95% CI	T-Value	P-Value	VIF	
Constant	346.82	5.80	(334.37,359.27)	59.76	0.00		
A	-6.79	-3.39	8.88	(-22.44,15.65)	-0.38	0.70	1.00
B	18.23	9.11	8.88	(-9.93,28.16)	1.03	0.32	1.00
C	7.78	3.89	8.88	(-15.15,22.94)	0.44	0.66	1.00
D	-41.83	-20.92	8.88	(-39.96,-1.87)	-2.36	0.03	1.00 s
E	34.56	17.28	8.88	(-1.77,36.33)	1.95	0.07	1.00
A*A	195.3	97.70	15.70	(64.00,131.30)	6.22	0.00	1.05 s
E*E	183.3	91.70	15.70	(58.00,125.30)	5.84	0.00	1.05 s
A*D	261.0	130.5	27.40	(71.70,189.3)	4.76	0.00	1.00 s
B*D	-231.6	-115.8	27.40	(-174.60,-57.10)	-4.23	0.00	1.00 s
B*E	233.0	116.5	27.40	(57.80,175.30)	4.25	0.00	1.00 s
C*D	254.0	127.0	27.40	(68.30,185.80)	4.64	0.00	1.00 s
C*E	142.0	71.0	27.40	(12.30,129.80)	2.59	0.02	1.00 s

Regression Equation in Uncoded Units

Y=346.82-1.43A+3.85B+1.65C-8.84D+7.30E+17.45A*A+16.38E*E+23.31A*D-20.69B*D
+ 20.81B*E+22.69C*D+12.69C*E

Table 4. Analysis of variance (ANOVA) for response surface quadratic models on the yield of the hybrid, IR-64 in flaking process

3) Analysis of Variance, IR-64, flaking

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Val	P-Val
Model	15	765.28	88.99%	765.28	51.01	5.93	0.00 s
Linear	5	169.32	19.69%	169.32	33.86	3.93	0.02 s
A	1	11.46	1.33%	11.46	11.46	1.33	0.27
B	1	1.02	0.12%	1.02	1.02	0.12	0.73
C	1	116.93	13.60%	116.93	116.93	13.58	0.00 s
D	1	12.90	1.50%	12.90	12.90	1.50	0.24
E	1	27.00	3.14%	27.00	27.00	3.14	0.10
Square	4	206.21	23.98%	206.21	51.55	5.99	0.00 s
A*A	1	48.20	5.61%	126.82	126.82	14.73	0.00 s
B*B	1	5.23	0.61%	47.32	47.32	5.50	0.03 s
C*C	1	0.07	0.01%	21.97	21.97	2.55	0.13
D*D	1	152.69	17.76%	152.69	152.69	17.73	0.00 s
2-Way	6	389.75	45.32%	389.75	64.95	7.54	0.00 s
A*B	1	42.25	4.91%	42.25	42.25	4.91	0.04 s
A*D	1	90.25	10.49%	90.25	90.25	10.48	0.00 s
A*E	1	36.00	4.19%	36.00	36.00	4.18	0.06 s
B*C	1	64.00	7.44%	64.00	64.00	7.43	0.02 s
C*D	1	25.00	2.91%	25.00	25.00	2.90	0.11
C*E	1	132.25	15.38%	132.25	132.25	15.36	0.00 s
Error	11	94.71	11.01%	94.71	8.61		
Total Model Summary	26	860.000	100.00%				

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
2.93	88.99%	73.97%	631.070	26.62%

Coded Coefficients

Term	Effect	Coef SE Coef	95% CI	T-Val	P-Val	VIF
Constant	315.45	1.54	(312.06, 318.83)	205.24	0.00 s	
A	-3.07	-1.54	1.33	(-4.47, 1.39)	-1.15	0.27 1.00
B	0.92	0.46	1.33	(-2.47,3.39)	0.34	0.73 1.00
C	9.81	4.91	1.33	(1.98,7.84)	3.69	0.00 1.00s
D	3.26	1.63	1.33	(-1.30,4.56)	1.22	0.24 1.00
E	4.71	2.36	1.33	(-0.57, 5.29)	1.77	0.10 1.00
A*A	-20.56	-10.28	2.68 (-16.17, -4.38)	-3.84	0.00 1.36s	
B*B	-12.56	-6.28	2.68 (-12.17, -0.38)	-2.34	0.03 1.36s	
C*C	-8.56	-4.28	2.68 (-10.17,1.62)	-1.60	0.13 1.36	
D*D	-22.56	-11.28	2.68 (-17.17,-5.38)	-4.21	0.00 1.36s	
A*B	-18.19	-9.10	4.11 (-18.14,-0.06)	-2.22	0.04 1.00s	
A*D	26.59	13.30	4.11 (4.26,22.33)	3.24	0.00 1.00s	
A*E	16.79	8.40	4.11 (-0.64,17.44)	2.04	0.06 1.00	
B*C	-22.39	-11.20	4.11 (-20.23,-2.16)	-2.73	0.02 1.00s	
C*D	13.99	7.00	4.11 (-2.04,16.04)	1.70	0.11 1.00	
C*E	-32.19	-16.09	4.11 (-25.13,-7.06)	-3.92	0.00 1.00s	

Regression Equation in Uncoded Units

Y=315.45-0.64A+0.19B+2.07C+0.68D+0.99E-1.83A*A-1.12B*B-0.76C*C-2.01D*D-1.62A*B + 2.37A*D+1.50A*E-2.00B*C+1.25C*D-2.87C*E maximum yield is with increased soaking time as well as roasting temperature but within specified limits of 32 h to 48 h and 175-190 °C. In Fig. 8, the response surface plot of yield vs flaking time and roasting temperature of flaking in KRH-2 hybrid it is evident that the yield of flaked rice increases with decreasing the flaking time and increasing the roasting temperature. In Fig. 10 the surface plot of yield vs flaking time and roasting temperature in flaking of IR-64 variety, the yield is maximum at a medium flaking time of 90 sec and highest roasting temperature of 190 °C. The predicted interval value ranges are higher than the confidence interval values. The predicted values were also tabulated alongwith the standard error with the observed values and standared error terms. The 95% confidence intervals values and 95% prediction interval values were calculated and it was found to be the confident interval values were within the range of actual observed values. The observed values lies within the range of 95% confidence intervals and hence regression is significant.

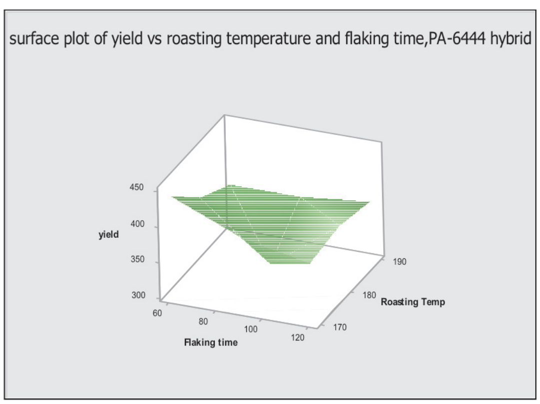

Fig. 8. Response surface plot of yield vs flaking time and roasting temperature, of flaking in PA-6444 hybrid

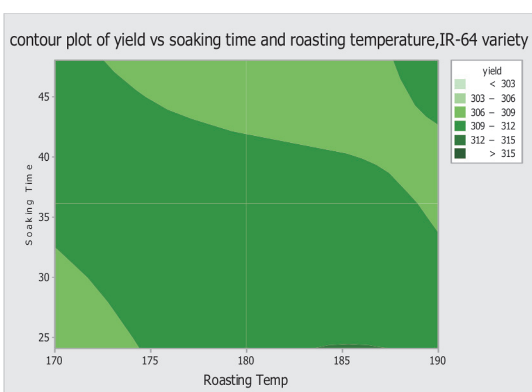

Fig. 9. Contour plot of yield vs soaking time and roasting temperature in flaking of IR-64 variety

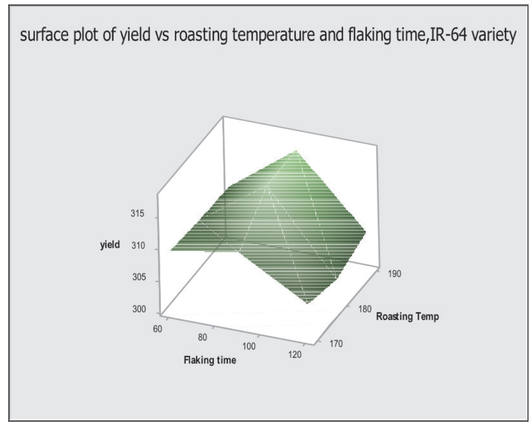

Fig. 10. Surface plot of yield vs flaking time and roasting temperature in flaking of IR-64 variety

Fig. 11. IR-64 flaked rice

Fig.12. PA-6444 flaked rice

CONCLUSION

Based on the optimization plot of Design of Experiments in Minitab 17.0 software, the optimized values of the selected independent variables of soaking time were 48 h of soaking time, 170 °C of roasting temperature, 2.0 min of roasting time, 2.0 mm of gap between the rollers and 60 sec of flaking time in the selected PA-6444 hybrid for a maximised yield of 415.24 kg/t and in the check variety, IR-64 the optimized independent variables of soaking time, 24h, roasting temperature, 180 °C, roasting time, 2 min gap between the rollers, 2.0 mm and flaking time, 69 sec for a maximum yeild of 315.11 kg/t, yield being the dependent variable.

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