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β-carbonate rich noodles: Optimization and development using response surface methodology

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The objective of this work is to develop β-carotene rich noodles using response surface methodology. In this study the carrot pomace powder (10-30%), wheat flour (50-70%) and guar gum (0.1% to 0.3%) as independent variables were optimized using RSM. The β- carotene, Bulk density, Water absorption index, Water solubility index, and Sensory characteristics were measured as responses. In the experimental design, 20 different combinations were produced and were studied to know the effect of independent variables on responses. The optimized value of carrot pomace powder, wheat flour, and guar gum were obtained as 70 g, 30 g and 0.10 g, respectively. The beta carotene, bulk density, water absorption index, water solubility index, and sensory characteristics were found 4.609 mg, 0.5498 g/cm^3, 8.55 g/g, 81% and 6.3, respectively.

Key Words : β-carotene, noodles, carrot pomace powder, RSM, optimization

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INTRODUCTION

Noodles are strands cut from a sheet of dough made from flour, water and salts. The noodle market is growing fast in India. It has reached upto INR 2,500- 3,000 crore. The consumption of ready to eat food is increasing and among all, noodles has become an important part of Indian dietary because of their simple preparation process, low price and easy and fast cooking. India had 12th rank in production of Carrots and turnips in 2012 and the total production was estimated 0.56 million tones according to FAO, 2012. Carrot (*Daucus carota* L.) is a good source of β-carotene, vitamins and minerals (Walde *et al*., 1992). It also has therapeutical properties like cholesterol lowering properties, and reduces the risk of high blood pressure, heart disease and some type of cancer (Bakhru, 1993). 9.87 to 11.57mg of β-carotene and 13.53 to 22.95 mg of ascorbic acid content per 100 g was reported in carrot pomace powder (Upadhyay, 2008). Carrot pomace is a rich source of soluble fibre as investigated by various researchers (Chantaro *et al*., 2008; Nawirska and Uklañska, 2008).

The utilization of fruits and vegetable waste by product (pomace) may reduce the environmental issues as arises due to in appropriately disposed of these industrial byproducts (Niraj *et al*., 2014). The value added and functional products may also be prepared using these waste byproducts and cost of product can also be reduced.

Response surface methodology is used to reduce the large number of experiments to number practically possible and also maintains the reliability of results. When a large number of variables in two, three or four levels are to be considered in conducting experiments, response

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surface methodology is really remarkable. The effect of variable is analyzed independently after the experiments, which will indicate the ideal combination of variables which will yield maximum results.

The objective of this study was to incorporate carrot by-products (carrot pomace) as a source of dietary fibre and optimization of ingredients using response surface methodology to develop β-carotene rich noodles.

METHODOLOGY

The study was carried out in the Department of Food Processing and Technology, School of Vocational Studies and Applied Sciences, Gautam Buddha University, Greater Noida (U.P.), India in the academic year 2014-15.

Raw materials :

Wheat flour (Pillsbury Chakki Fresh Atta, General Mills India Pvt. Ltd.), Carrots and Salt were procured from local market Kasna, Greater Noida (U.P.), India. Guar gum and Starch was purchased from HiMedia laboratories, Mumbai.

Preparation of carrot pomace powder :

For the preparation of carrot pomace powder, mature and sound carrots were sorted and washed with running tap water to remove extraneous material and impurities. Carrots were sliced and crushed with philips juicer mixer grinder (Model No. : HL1631) for the extraction of juice. 51% of juice and 49% of carrot pomace was obtained. The pomace was spread uniformly in thin layer and dried in a tray drier (Make: Bajaj Process Pack Pvt. Ltd., Newdelhi, India) at 55°C till 7-8% moisture content. The grinding was done using the Philips mixer grinder (HL 7610/04). The pomace was ground to fine powder and sieved with an 80 sieve size through sieve shaker (Hightech Associate, New Delhi). The carrot pomace powder was then packed in air tight polyethylene bags and stored under refrigeration condition till further used.

Experimental design for noodles preparation :

The experiments were designed using the software Design Expert version 6.0.10. Same software was used for statistical analysis of experimental data. A three variables (five levels of all variable), Central Composite Rotatable Experimental Design (CCRD) was employed (Montgomery, 2001). Response surface methodology (RSM) was adopted in the design of experimental

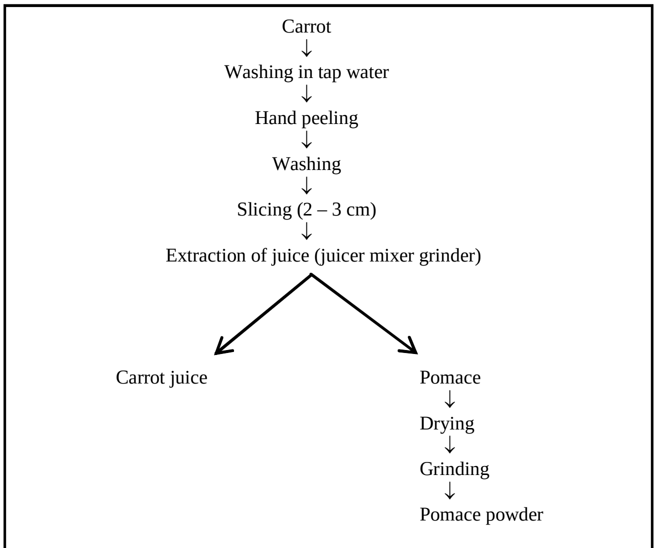

Fig. A : Outline of process for preparation of carrot pomace powder

combinations (Altan *et al.*, 2008; Yagci and Gogus, 2008; Ding *et al.*, 2005 and Montgomery, 2001). A three-variable (five levels of each variable) central composite rotatable experimental design was employed (Montgomery, 2001; Yagci and Gogus, 2008). The ingredients used for the noodles preparation wheat flour, carrot pomace powder and guar gum. The independent variables included the proportion of wheat flour (50-70%), carrot pomace powder (10-30%) and guar gum (0.1-0.3%). The five levels of the process variables were coded as -2, -1, 0, +1, +2 (Montgomery, 2001). The outline of experimental design with the coded and uncoded variable levels for experiment is presented in Table A.

Table A : The outline of experimental design with the coded and non coded variables levels

Independent variables	Non- coded value	Coded variable				
		-2	-1	0	+1	+2
Wheat flour	A	43.18	50	60	70	76.82
Carrot pomace powder	B	3.16	10	20	30	36.82
Guar gum	C	0.03	0.1	0.2	0.3	0.37

Preparation of noodles :

For preparation of noodles, the ingredients were optimized by RSM and twenty combinations of ingredients were found. According to these combinations, twenty samples of noodles were prepared. The method of preparation of noodle making was as follows:

Wheat flour + Carrot pomace powder —— Salt + Water
↓
Mixing
↓
Kneading
↓
Resting (20 minutes)
↓
Sheeting
↓
Rolling
↓
Cutting in sizes
↓
Drying (39^0C for 6-8 hrs)
↓
Dried noodles

Fig. B : Outline of process for production of noodles

Physico- chemical analysis :

Moisture, ash, crude fat, and bulk density of wheat flour and carrot pomace powder were determined. β-carotene of carrot pomace powder and noodles were determined. The hot air oven method was used to determine the moisture content of raw materials (AOAC, 1990). Ash content of the raw materials were determined by the standard procedure as given in (AOAC,1990) while crude fat was estimated using soxhlet apparatus as described in AOAC (1990). Bulk density was determined according to the method as described by (Okaka and Potter, 1977). β-carotene of carrot pomace powder was determined as the procedure described in Ranganna (1995). Water absorption index (WAI) and water solubility index (WSI) of noodles were measured using a technique developed by Ding *et al*. (2006).

Sensory score :

Sensory analysis was conducted for all the samples. Twenty panelists from Department of Food Processing and Technology were asked to assess the noodles. A rating test (hedonic rating test) was adopted for sensory evaluation. Different sensory characteristics like flavour, colour and overall acceptability were evaluated on the basis of 9-point hedonic scale. The scale range was like extremely to dislike extremely. Sensory evaluation was done room temperature.

Statistical analysis :

The statistical analysis of the experimental data was performed to observe the effect of independent variables on measured responses. The second order polynomial equation was used to examine the statistical significance of the model as given in equ. 1. The responses (sensory score, β-carotene, bulk density, water absorption index, and water solubility index of the noodles) for different experimental conditions were performed and fitted in following equation as given below:

$$Y = {}_0 + {}_1x_1 + {}_2x_2 + {}_3x_3 + {}_{11}x_1^2 + {}_{22}x_2^2 + {}_{33}x_3^2 + {}_{12}x_1x_2 + {}_{13}x_1x_3 + {}_{23}x_2x_3 + £ \qquad (1)$$

where,

Y = Response variable

β_0 = Constant

$\beta_{1,}\ \beta_2,\ \beta_3$ = Linear effects of regression co-efficient

$\beta_{11,}\ \beta_{22,}\ \beta_{33}$ = Interaction effects of regression co-efficient

$\beta_{12,}\ \beta_{13,}\ \beta_{23}$ = Quadratic effects of regression co-efficient

ε= Random errors

x_1, x_2, x_3 = Independent variables

Design expert software was used for statistical analysis of experimental data. The adequacy of quadratic models for all responses was on the basis of R^2, F-value and p-value at 5 % level of significance.

OBSERVATIONS AND ASSESSMENT

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Physico-chemical analysis of raw materials :

The physico-chemial analysis of wheat flour and carrot pomace powder is presented in Table 1. Wheat flour contained 9.537 % moisture, 1.8 % crude fat, 0.85 % ash, and 0.721 % bulk density, respectively while carrot pomace powder contained 6.776 % moisture, 0.896 % crude fat, 1.698 % ash, 0.60 % bulk density and 9.97% β-carotene, respectively.

Table 1 : Physico- chemical analysis of wheat flour and carrot pomace powder

Sr. No.	Constituents	Wheat flour (%)	Carrot pomace powder (%)
1.	Moisture content	9.537	6.776
2.	Ash content	1.498	1.698
3.	Crude fat	1.8	0.896
4.	Bulk density (g/cm^3)	0.721	0.60
5.	Beta- carotene	–	9.97

Effect of independent variables on -carotene:

The measured β-carotene of the carrot pomace powder added noodles varied from 2.208 to 5.569 (Table 2). Table 3 shows the statistical attributes of β- carotene. Regression model fitted to experimental results for β-carotene shows that Model F-value of 9.85 is significant (P> 0.05). There is only a 0.07% chance that a Model F-Value this large could occur due to noise. Whereas the Lack of Fit F-value of 2.91 implies the Lack of Fit is not significant. There is a 13.15% chance that a Lack of Fit F-value this large could occur due to noise. The fit of model was also expressed by the co-efficient of determination R^2 *i.e.* 0.8987, which indicates that 89.87% of variability of the response could be explained by the model. The Adj R^2 was 0.8075. Adeq Precision was 11.434 which indicates an adequate signal. A ratio greater than 4 is desirable and hence, this model can be used to navigate the design space. Considering all the above criteria, the model (Eq. 2) was selected for represnting the variation of β- carotene. The quadratic model obtained from regression analysis for lateral expansion in term of coded levels of the variables was as follows:

$$\text{-carotene} = 4.33 - 0.38A + 0.85B + 0.073C - 0.048A^2 - 0.13B^2 - 0.035C^2 - 0.17A\ B + 0.045AC + 0.020BC \quad (2)$$

It is evident from the equation that the β-carotene of noodle had highly significant(P <0.0001) negative linear affect of wheat flour (A) and positive linear affet of carrot pomace powder (B). other linear term of guar gum (C) was not significant (P> 0.05). All the quadratic and interaction terms were not found significant (P> 0.05). Fig. 1 showed the effect of wheat flour and carrot pomace powder noodles on β- carotene. It was observed from the response surface plot between wheat flour and carrot pomace powder that both were affecting the β-carotene concentration. Response surface plot showed that β-carotene increased with increasing carrot pomace powder and decreased with increasing wheat flour content. The reason may be that carrot pomace powder which is itself a good source of β-carotene.

Effect of independent variables on bulk density :

The measured bulk density of the carrot pomace powder added noodles varied from 0.5498 to 0.742 (Table 2). Table 3 shows the statistical attributes of bulk density. Regression model fitted to experimental results for bulk density shows that Model F-value of 12.27 is significant (P<0.001). There is only a 0.03% chance that a Model

Table 2 : Experimental central composite rotatable design (CCRD) runs and results of responses

Run	Wheat flour (g)	Carrot pomace powder (g)	Guar gum (g)	β- carotene (mg)	Bulk density (g/cm^3)	Water absorption index (g/g)	Water solubility index (%)	Sensory score
1	50.00	30.00	0.10	5.311	0.599	8.44	93	5.6
2	70.00	10.00	0.30	3.587	0.73	6.15	62	7.5
3	50.00	10.00	0.30	3.439	0.652	7.98	67	6.7
4	70.00	30.00	0.10	4.609	0.5498	8.55	81	6.3
5	60.00	3.18	0.20	2.208	0.672	5.26	51	7.6
6	60.00	20.00	0.20	4.452	0.651	7.22	73	6.9
7	43.18	20.00	0.20	5.027	0.682	7.07	83	6.2
8	70.00	10.00	0.10	3.229	0.742	5.85	60	7.6
9	60.00	20.00	0.03	3.911	0.624	7.02	75	7.3
10	60.00	20.00	0.20	4.616	0.674	7.31	69	7
11	60.00	20.00	0.37	4.136	0.701	7.6	69	6.4
12	60.00	36.82	0.20	5.311	0.561	8.34	92	5.9
13	60.00	20.00	0.20	4.206	0.695	8.34	71	6.6
14	50.00	30.00	0.30	5.569	0.605	8.69	95	5.8
15	50.00	10.00	0.10	3.571	0.723	6.22	64	6.45
16	60.00	20.00	0.20	3.873	0.664	7.94	67	7
17	76.82	20.00	0.20	2.946	0.702	6.98	57	7.3
18	60.00	20.00	0.20	4.526	0.68	8.15	68	6.7
19	60.00	20.00	0.20	4.352	0.687	7.92	72	7.3
20	70.00	30.00	0.30	4.737	0.66	8.84	78	6.6

F-Value this large could occur due to noise. Whereas the Lack of Fit F-value of 2.42 implies the Lack of Fit is not significant ($P > 0.05$). There is a 17.69% chance that a Lack of Fit F-value this large could occur due to noise. The fit of model was also expressed by the cofficient of determination R^2 *i.e.* 0.9170, which indicates that 91.70% of variability of the response could be explained by the model. The Adj R^2 was 0.8422. Adeq. precision was 12.904 which indicates an adequate signal. A ratio greater than 4 is desirable and hence this model can be used to navigate the design space. Considering all the above criteria, the model (Eq. 3) was selected for represnting the variation of bulk density. The quadratic model obtained from regression analysis for lateral expansion in term of coded levels of the variables was as follows:

$$\textbf{Bulk density} = 0.68 + 9.990\times10^{-3}A - 0.045B + 0.012C + 6.311\times10^{-3}A^2 - 0.020B^2 - 4.119\times10^{-3}C^2 - 0.011AB + 0.020AC + 0.025BC \quad (3)$$

It is evident from the equation that the bulk density of noodle had highly significant ($P < 0.0001$) negative linear affect of carrot pomace powder (B) and other linear terms of wheat flour (A) and guar gum (C) were not significant. The quadratic terms of carrot pomace powder (B^2) was significant having negative quadratic effect, indicating the convex shape variation on the bulk density. Other quadratic terms were not significant ($P > 0.05$). The interaction term of wheat flour and guar gum (AC) and carrot pomace powder and guar gum (BC) had positive significant effect, therefore we can assume that BD will show convex shape variation with the change in value of variables as shown in Fig. 2. The interaction term AB was found to be non significant ($P > 0.05$). Fig. 2 demonstrate that bulk density decreses with the incresae in carrot pomace powder. This result is an agreement

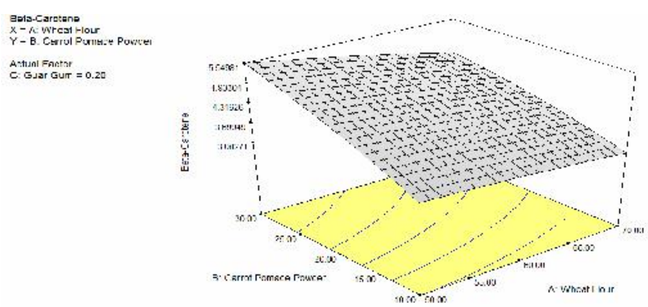

Fig. 1 : Effect of wheat flour and carrot pomace powder on beta- carotene

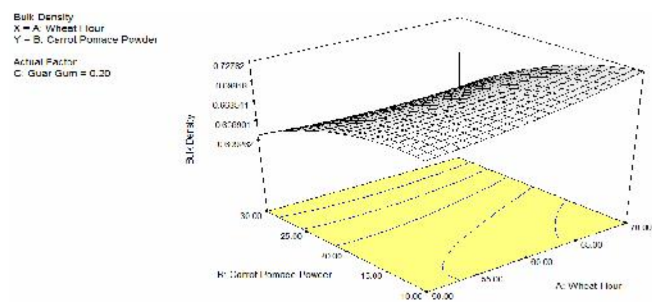

Fig. 2 : Effect of wheat flour and carrot pomace powder on bulk density

Table 3 : ANOVA results of responses as a linear, quadratic and interaction terms on each response variable

Source	β- carotene		BD		WAI		WSI		Sensory score	
	F-Value	p- Value	F-Value	p- Value	F-Value	p- Value	F-Value	p- Value	F-Value	p- Value
Model	9.85	0.0007	12.27	0.0003	6.96	0.0028	23.14	< 0.0001	7.17	0.0025
A	14.24	0.0036	3.14	0.1066	1.18	0.3021	39.90	< 0.0001	22.62	0.0008
B	70.34	< 0.0001	64.89	< 0.0001	49.33	< 0.0001	158.64	< 0.0001	37.33	0.0001
C	0.51	0.4910	4.47	0.0606	3.46	0.0925	0.22	0.6479	0.60	0.4563
A^2	0.24	0.6343	1.32	0.2767	1.26	0.2876	0.74	0.4094	1.66	0.2260
B^2	1.70	0.2216	13.81	0.0040	2.90	0.1193	2.06	0.1815	1.66	0.2260
C^2	0.13	0.7276	0.56	0.4700	0.15	0.7064	2.65	0.1346	0.71	0.4177
AB	1.60	0.2350	2.40	0.1525	2.80	0.1254	4.08	0.0710	0.28	0.6093
AC	0.12	0.7412	7.68	0.0198	0.93	0.3572	0.37	0.5581	0.086	0.7754
BC	0.023	0.8831	11.44	0.0070	1.07	0.3258	0.37	0.5581	0.17	0.6902
Lack of fit	2.91	0.1330	2.42	0.1769	1.64	0.2996	3.38	0.1039	1.95	0.2407
R^2	0.8987		0.9170		0.8623		0.9542		0.8657	
Adj R^2	0.8075		0.8422		0.7383		0.9129		0.7449	
Adeq precision	11.434		12.904		9.041		16.483		9.085	

with the result of Kumar *et al*. (2010), who stated that bulk density decreased with the CPPP proportion, which may be attributed to lighter mass of the fibrous pomace in comparison to other constituents.

Effect of independent variables on water absorption index :

The measured WAI of the carrot pomace powder added noodles varied from 5.2 to 8.84 (Table 2). The similar results have been obtained by Niraj *et al.* (2014) in pineapple pomace powder added extruded products. Table 3 shows the statistical attributes of WAI. Regression model fitted to experimental results for WAI shows that Model F-value of 6.96 is significant. There is only a 0.28% chance that a Model F-Value this large could occur due to noise. Whereas the Lack of Fit F-value of 1.64 implies the Lack of Fit is not significant. There is a 29.96% chance that a Lack of Fit F-value this large could occur due to noise. The fit of model was also expressed by the co-efficient of determination R^2 *i.e.* 0.8623, which indicates that 86.23% of variability of the response could be explained by the model. The Adj R^2 was 0.7383. Adeq precision was 9.041 which indicates an adequate signal. A ratio greater than 4 is desirable and hence this model can be used to navigate the design space. Considering all the above criteria, the model (Eq. 4) was selected for represnting the variation of WAI. The quadratic model obtained from regression analysis for lateral expansion in term of coded levels of the variables was as follows:

$$\mathbf{WAI = 7.79 - 0.15A + 0.99B + 0.26C - 0.15A^2 - 0.23B^2 - 0.053C^2 + 0.31AB - 0.18AC - 0.19BC} \quad (4)$$

It is evident from the equation that the water absorption index of noodle had highly significant (P <0.0001) positive linear affect of carrot pomace powder (B). Other linear terms of wheat flour (A) and guar gum (C) were not significant. All the quadratic terms and interaction terms were not found significant (P> 0.05). The variation in water absorption index with wheat flour and carrot pomace powder was shown in 3D surface plot (Fig. 3).

Effect of independent variables on water solubility index :

The measured water solubility index of carrot pomace powder added noodles varied from 51 to 95 (Table 2). Table 3 shows the statistical attributes of water

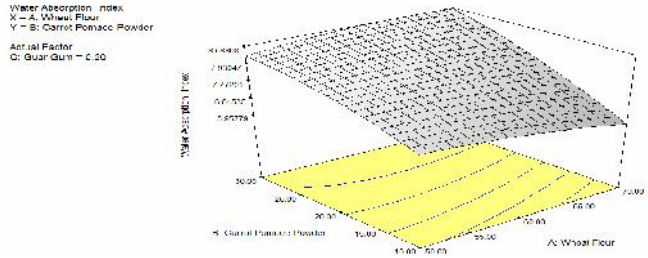

Fig. 3 : Effect of wheat flour and carrot pomace powder on water absorption index

solubility index. Regression model fitted to experimental results for water solubility index shows that Model F-value of 23.14 is significant. There is only a 0.01% chance that a Model F-Value this large could occur due to noise. Whereas the Lack of Fit F-value of 3.38 implies the Lack of Fit is not significant. There is a 10.39% chance that a Lack of Fit F-value this large could occur due to noise. The fit of model was also expressed by the co-efficient of determination R^2 *i.e.* 0.9542, which indicates that 95.42% of variability of the response could be explained by the model. The Adj R^2 was 0.9129. Adeq. precision was 16.483 which indicates an adequate signal. A ratio greater than 4 is desirable and hence this model can be used to navigate the design space. Considering all the above criteria, the model (Eq. 5) was selected for represnting the variation of water solubility index. The quadratic model obtained from regression analysis for lateral expansion in term of coded levels of the variables was as follows:

$$\mathbf{WSI = 69.88 - 5.98A + 11.93B - 0.45C + 0.79A^2 + 1.32B^2 + 1.50C^2 - 2.50AB - 0.75AC - 0.75BC} \quad (5)$$

It is evident from the equation that the water solubility index of noodle had highly significant (P <0.0001) negative linear affect of wheat flour (A) and positive linear affect of carrot pomace powder (B). other linear term of guar gum (C) was not significant (P> 0.05). All the quadratic terms and interaction terms were not found significant (P> 0.05). The variation in water solubility index with wheat flour and carrot pomace powder was shown in 3D surface plot (Fig. 4).

Effect of independent variables on sensory score:

The measured sensory score of carrot pomace powder added noodles varied from 5.6 to 7.6 (Table 2). Table 3 shows the co-efficient of model and other statistical attributes of sensory score. Regression model fitted to experimental results for sensory score shows

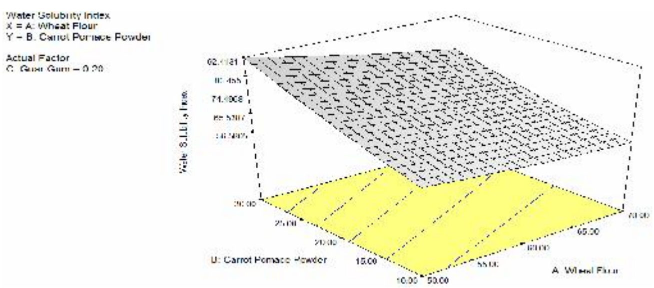

Fig. 4 : Effect of wheat flour and carrot pomace powder on water solubility index

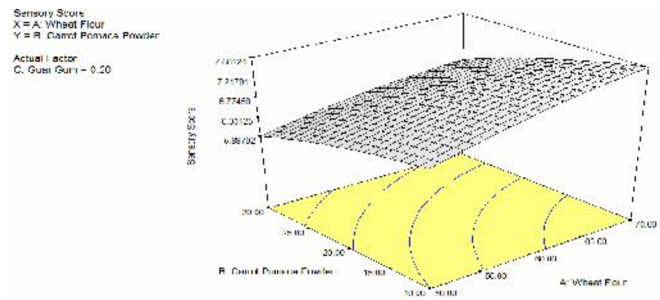

Fig. 5 : Effect of wheat flour and carrot pomace powder on sensory score

that Model F-value of 7.17 is significant. There is only a 0.25% chance that a Model F-Value this large could occur due to noise. Whereas the Lack of Fit F-value of 1.95 implies the Lack of Fit is not significant. There is a 24.07% chance that a Lack of Fit F-value this large could occur due to noise. The fit of model was also expressed by the co-efficient of determination R^2 *i.e.* 0.8657, which indicates that 86.57% of variability of the response could be explained by the model. The Adj R^2 was 0.7449. Adeq. precision was 9.085 which indicates an adequate signal. A ratio greater than 4 is desirable and hence this model can be used to navigate the design space. Considering all the above criteria, the model (Eq. 6) was selected for represnting the variation of sensory score. The quadratic model obtained from regression analysis for lateral expansion in term of coded levels of the variables was as follows:

$$\text{Sensory score} = 6.92 + 0.39A - 0.50B - 0.063C - 0.10A^2 - 0.10B^2 - 0.067C^2 - 0.056AB - 0.031AC + 0.044BC \quad (6)$$

It is evident from the equation that the sensory score of noodle had highly significant ($P < 0.0001$) positive linear affect of wheat flour (A) and negative linear affect of carrot pomace powder (B). Other linear term of guar gum (C) was not significant ($P > 0.05$). All the quadratic terms and interaction terms were not found significant ($P > 0.05$). The variation in sensory score with wheat flour and carrot pomace powder was shown in 3D surface plot (Fig. 5). Figure indicates that increase in the concentration of carrot pomace powder caused slightly decrease in sensory score while increase in the concentration of wheat flour shows the linear increase in sensory score. This result is an agreement with the result of Kumar and Kumar (2012), who stated that overall acceptability of buns increased initially and decreased further with the increase in pomace proportion.

Optimization :

A numerical multi-response optimization technique was applied to determine the optimum condition of wheat flour, carrot pomace powder and guar gum (Table 4). The optimum ingredients for development of β-carotene rich noodles were 70g of wheat flour, 30g of carrot pomace powder and 0.10 g of guar gum. The predicted values of responses obtained by design expert software resulted 4.283 mg of β-carotene, 0.553 g/cm^3 bulk density, 8.60 of water absorption index, 78.89 % water solubility index, 6.5 of sensory score (Table 5) and the actual values of these response were 4.609 mg, 0.5498 g/cm^3, 8.55, 81%, and 6.3 for β-carotene, bulk density, water absorption index, water solubility index, and sensory score, respectively (Table 5).

Table 4 : Selection of levels of constraints for optimized condition of noodles

Constraints	Goal
Wheat flour	Maximize
Carrot pomace powder	Maximize
Guar gum	In range
Beta-carotene	Maximize
Bulk density	Minimize
Water absorption index	Maximize
Water solubility index	Maximize
Sensory Score	Maximize

Table 5 : Predicted and actual values of responses

Responses	Predicted value	Actual value
Beta- carotene (mg)	4.283	4.609
Bulk density(g/cm^3)	0.553	0.5498
Water absorption index (g/g)	8.60	8.55
Water solubility index (%)	78.89	81
Sensory score	6.5	6.3

Conclusion :

From the proceeding discussions and analysis of results, it could be summed up that ingredients namely moisture content, carrot pomace powder, and gum content level caused significant effects on noodles. The outcome of the present research can be used as valuable information for the development of β-carotene rich noodles. Noodle samples were formulated from different combination of wheat flour, carrot pomace powder and guar gum. The colour of the noodles varied due to variation in level of carrot pomace powder incorporation and chemical changes. The overall results reveal that the flavour of noodles was acceptable when level of incorporation carrot pomace powder was increased upto 20%. It was observed that the expansion, water solubility index and absorption index increased with the increase in carrot pomace powder proportion, whereas bulk density decrease with the increase in carrot pomace powder proportion.

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