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ORIGINAL ARTICLE

Optimization of ingredients for noodle preparation using response surface methodology

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Abstract In the present investigation, the composite flour combinations using whole wheat flour (X1), tapioca flour (X2) and defatted soy flour (X3) for the noodle preparation were made through central composite rotatable design (CCRD). The analyzed responses were bulk density (BD), proximate composition, water uptake ratio (WUR), cooking volume expansion (VE), water absorption capacity (WAC), swelling capacity (SC), gruel solid loss (GSL), and sensory characteristics. A second order quadratic polynomial equation was fitted to the data of all responses for prediction. The maximum protein content of 16 g% was achieved by the combination of 75.54 g of whole wheat flour, 10 g of tapioca flour and 19.78 g of defatted soy flour. Since the inclusion of defatted soy flour >10 g resulted negative influence on good quality determining responses, the Chinese salted noodles of excellent quality with maximum WAC, WUR, VE, SC, protein, carbohydrate, ash and minimum GSL, BD, fat, moisture could be made from ratio of combination of three independent variables at 77.33 g (X1): 22.19 g (X2): 8.92 g (X3) respectively. The cost of production per kg of noodles with optimum level of ingredient was Rs.75.50/-.

Keywords Noodles · Whole wheat flour · Tapioca flour · Defatted soy flour · Responses · Central composite rotatable design (CCRD) · Numerical optimization · Cost of production

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Introduction

Noodles have been increasing as a result of their simple preparation requirement, desirable sensory attributes, long shelf- life, together with diversity and nutritive value. Noodle could serve as a suitable food for fortification and or enrichment purposes. As the world food market is being diversified, studying for the development and improvement of new and acceptable noodles satisfying consumer demands are imminent (Ge et al. 2001). Most of noodles are made from flours containing 8–10% protein and 0.36–0.4% ash. Noodles and other pasta types are rich in carbohydrate but they are deficient in terms of protein quantity and amino acid balance (Eyidemir and Hayta 2009). The consumption of foods enriched with proteins from plant sources has been increasing among vegetarian and health conscious people (Wu et al. 1998). Amongst the proteins of plant origin, cereals, beans and pulses are best sources. These proteins are considered to be partially incomplete because of deficiency of some of the essential amino acids. Therefore, for the vegetarian segment it is ideal to use different combinations of cereals and pulses to overcome this deficiency (Sharma et al. 2008). Use of wheat based pasta products often leads to imbalanced nutrients among consumers. In order to overcome imbalance in nutrients by the consumption of pasta products, balanced nutrient can be the provided by composite flour mixtures (Shanthi et al. 2005). Composite flour refers to mixtures in which cereal flours, predominantly wheat flour, are combined with other starch and protein sources including those derived from other cereals, roots, food legumes and oilseeds (Hulse 1974).

Soybean is an excellent source of dietary protein providing complete human requirement of almost all the amino acid. It is also an excellent source of minerals and vitamins

Table 1 Estimated mean response levels of experimental variables

Runs	WAC%	WUR	GLS%	VE (ml/g)	SC (ml/g)	BD (g/ml)	Moisture (g%)	CHO (g%)	Protein (g%)	Fat (g%)	Ash (g%)	Mean sensory acceptability score
1	45.2	0.85	4.8	1.5	0.585	0.325	5.01	60.05	12.26	4.40	0.041	23.84
2	52.3	1.09	4.0	1.5	0.975	0.325	4.62	62.55	12.05	3.95	0.039	23.89
3	51.7	1.07	4.6	1.0	0.835	0.405	3.55	56.06	10.18	3.48	0.036	23.79
4	56.4	1.25	5.2	1.5	0.885	0.251	5.92	58.81	10.32	3.45	0.175	22.91
5	50.9	1.03	4.8	1.3	0.805	0.401	6.44	56.15	15.37	3.48	0.046	23.99
6	50.7	1.04	4.8	1.2	0.535	0.503	4.04	59.08	14.63	3.88	0.058	24.04
7	60.4	1.49	4.6	1.5	0.670	0.655	3.44	53.14	12.93	4.35	0.041	23.89
8	46.6	0.87	4.0	1.0	0.640	0.251	5.37	55.98	12.64	4.35	0.051	23.89
9	40.0	0.66	5.0	1.5	0.810	0.216	2.36	54.24	12.84	4.38	0.042	23.69
10	44.3	0.75	4.8	1.0	0.335	0.328	4.04	60.04	12.27	4.38	0.048	23.94
11	44.6	0.93	4.1	1.3	0.425	0.290	4.14	61.68	15.05	3.85	0.051	23.94
12	54.3	1.19	4.3	1.3	0.735	0.350	5.13	54.82	13.15	3.53	0.040	23.84
13	41.8	0.73	4.2	1.5	0.765	0.290	4.04	61.56	9.60	4.00	0.237	23.99
14	24.8	1.33	4.5	1.3	0.630	0.671	4.10	54.15	14.98	3.95	0.220	23.89
15	51.2	1.05	4.6	1.3	0.735	0.485	4.20	57.65	12.51	3.45	0.050	23.94
16	51.1	1.05	4.5	1.0	0.745	0.495	4.10	57.65	12.51	3.45	0.041	24.04
17	51.1	1.05	4.6	1.2	0.790	0.500	4.15	57.64	12.52	3.48	0.045	23.89
18	51.1	1.05	4.6	1.3	0.800	0.495	4.15	57.66	12.52	3.45	0.045	23.99
19	51.2	1.05	4.6	1.2	0.790	0.490	4.20	57.66	12.51	3.45	0.050	24.19
20	51.1	1.05	4.6	1.3	0.795	0.490	4.15	57.65	12.52	3.48	0.040	23.94

Values in table are the average of two determinants, *WAC* water absorption capacity, *WUR* water uptake ratio, *GSL* gruel solid loss, *VE* cooking volume expansion, *SC* swelling capacity, *BD* bulk density, *CHO* total carbohydrate

(Diwan et al. 2007). Looking to the nutritional and health benefits of soybean and its high production, there is a need to develop varieties of products. Efforts are being made to bring out delicious novel foods from soybean to promote its wide consumption and acceptance (Rachna et al. 2006).

Cassava flour is one of the major products from cassava roots traded in the world food market. Cassava flour has also continued to find wider applications in the food, feed and chemical industries. One of the most popular food uses of cassava flour worldwide is in the manufacture of baked product (Shittu et al. 2008). The ability of cassava to supply adequate calories at low cost encouraged the maximum use among low-income social groups. The native starches of cassava have been used extensively in traditional starchy foods such as noodles, snacks and desserts in the orient (Hongsprabhas et al. 2006). The sustainability of industrial growth of cassava depends to a large extent on diversification and value addition, for increasing internal demand as well as export markets. While considering the above mentioned facts, the present study was planned to enhance the utility of tapioca/cassava flour and defatted soy flour by its value addition and to optimize the level of wheat flour, tapioca flour and defatted soy flour in noodle preparation using response surface methodology.

Materials and methods

Whole wheat flour, tapioca flour and defatted soy flour were purchased from local market in Salem district, sifted through 60 mesh sieve and kept in an airtight container for further use.

Experimental design

The composite flour combinations were made through central composite rotatable design (CCRD) for three variables and five levels each with 6 centre point combination. The independent variables were whole wheat flour (X_1: 50–90 g), tapioca flour (X_2: 10–50 g) and defatted soy flour (X_3: 5–25 g).

Noodle preparation

The noodle was prepared by mixing composite flour of 20 combinations with vegetable oil (50 ml/kg), whole beaten egg (60 g/5 kg), salt (5 g/kg) and water (1–1.25 L/5 kg). The ingredients were mixed in an electrical mixer to desired crumbly consistency similar to that of moist breads. The sheeting of dough was made by a process of folding and passing through the rollers of noodle making machine several times i.e. up to 5

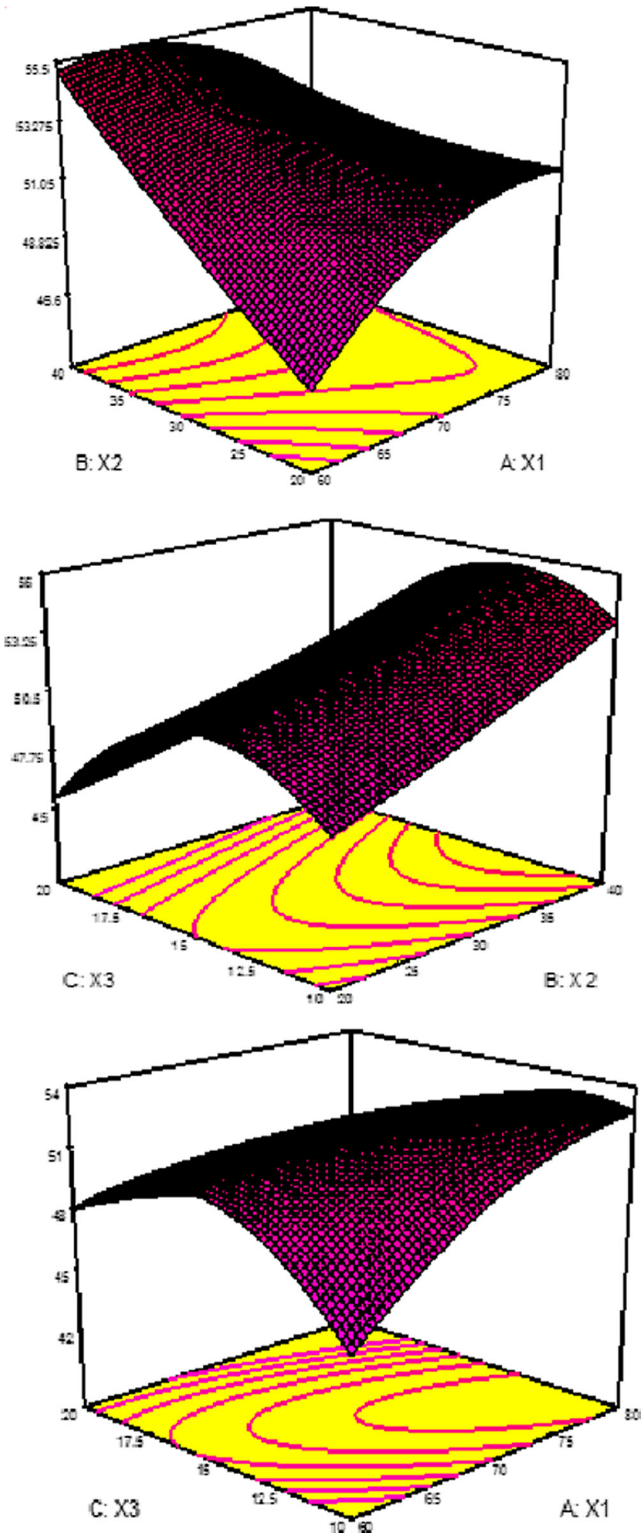

Fig. 1 Effect of independent variables on water absorption capacity

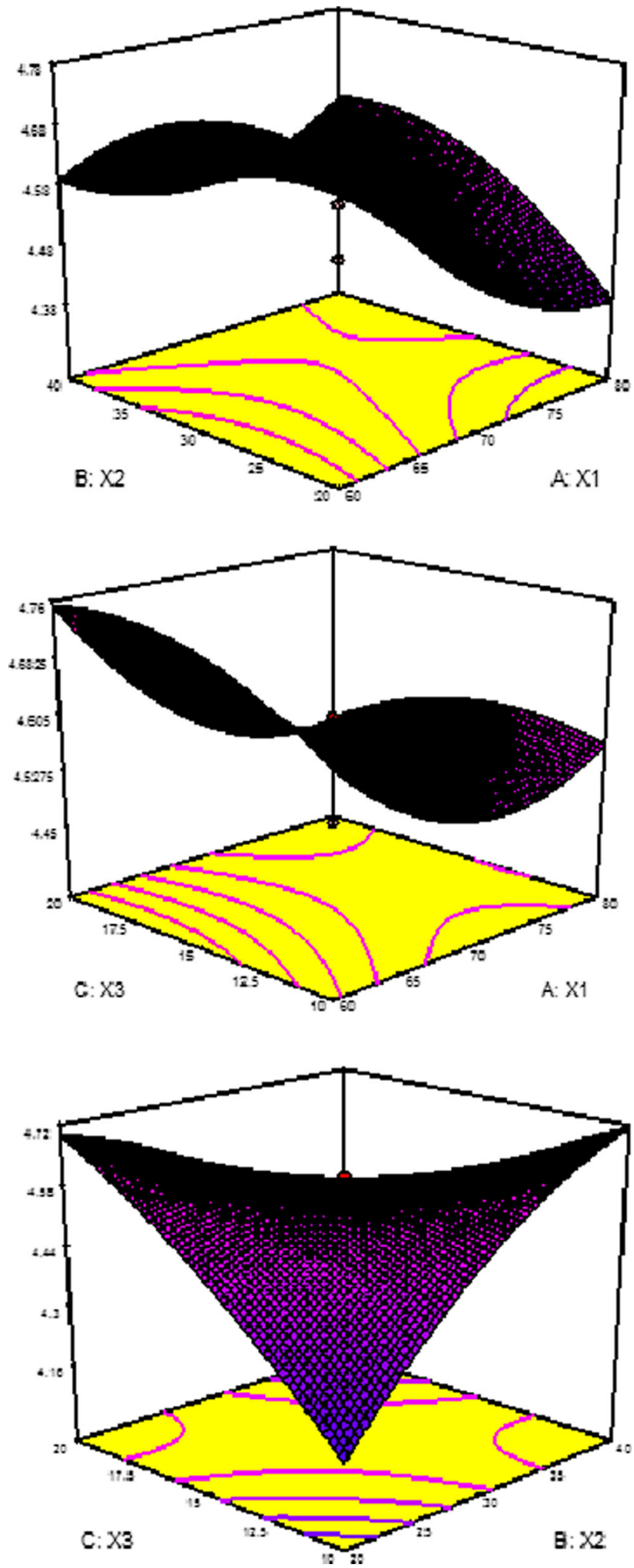

Fig. 2 Effect of independent variables on gruel solid loss

passes. The sheeted dough was extruded through a suitable die (1.6 mm width and 1.8 mm height) and cut to have the desired size of extrudates. The extruded noodle was steamed for 10 min at 102–105 °C and distributed over the wire mesh tray for solar drying (40–45 °C; 25–30% RH). The dried noodle was packed in LDPE pack.

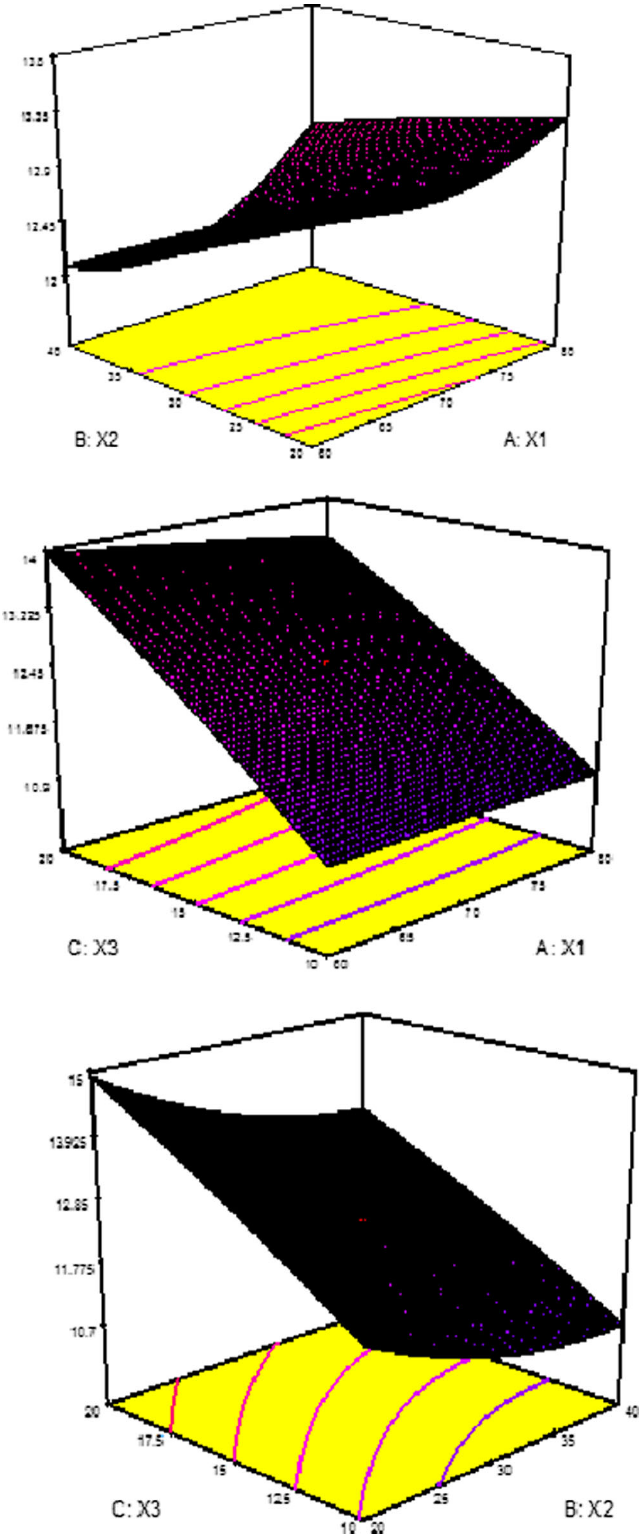

Fig. 3 Effect of independent variables on protein content

Response for optimization

The noodles prepared as per the combination prescribed by CCRD of 20 runs were analyzed for its properties such as bulk density (Devaraju et al. 2006), moisture (Ranganna 2006), total carbohydrate (Sadasivam and Manickam 2005), protein (Sadasivam and Manickam 2005), fat (Sadasivam and Manickam 2005), ash (Ranganna 2006), water uptake ratio (Hundal et al. 2007), cooking volume expansion (Hundal et al. 2007), swelling capacity (Williams et al. 1983), gruel solid loss (AACC 2000), water absorption capacity (Williams et al. 1983) and sensory analysis (Urooj et al. 2006) done by 25 semi trained panel members using 5 point hedonic scale for optimization.

Numerical optimization and point prediction

The levels of each independent variable were predicted into current model by calculating the expected responses and associated confidence intervals (95%) based on prediction equation. A second order Quadratic polynomial equation of the following form was fitted to the data of all responses for prediction. The proposed model was

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{11} X_1 X_1 + \beta_{22} X_2 X_2 + \beta_{33} X_3 X_3$$

Where β_0, β_1, β_2, β_3, β_{11}, β_{22}, β_{33}, β_{12}, β_{13}, β_{23} where the regression coefficients**,** X_1, X_2, X_3, were the independent variables and Y was the dependent variable. The optimum noodle formulation was obtained by combining set goals of all quality parameters with maximum importance of 3.

Economics of production of optimized noodle

The total cost of the product was calculated by assessing fixed cost, variable cost and net profit ratio as 10% of sum of fixed and variable cost. TCP (total cost of the product) = FC (fixed cost) + VC (variable cost) + net profit ratio.

Results and discussion

Estimated response levels of variables

The estimated response levels of experimental variables were indicated in Table 1. A wide variation in all the responses was observed for different experimental combinations i.e. 24.76 to 60.445% for WAC; 0.665 to1.325 for water uptake ratio; 3.98 to 5.15% for gruel solid loss; 1 to 1.5 ml/g for volume expansion; 0.335 to 0.975 ml for swelling capacity; 2.16 to 6.71 g/ml for bulk density; 2.355 to 6.435 g% for moisture; 53.14 to 62.545 g% for total carbohydrate; 9.595 to 15.365 g% for protein; 3.45 to 4.4 g% for fat; 0.02 to 0.175 g% for ash; and 23.69 to 24.04 for mean sensory acceptability score. Protein content in noodles was similar to those quoted by Nagao (1996) for alkaline noodle flours

Table 2 Regression coefficients of second order quadratic polynomial model for the responses

Coefficients	WAC	WUR	GSL	VE	SC	BD	Moisture	CHO	Protein	Fat	Ash	Mean sensory acceptability score
β_0	52.54	1.07	4.58	1.22	0.79	0.492	4.30	57.65	12.46	3.47	0.040	23.97
β_1	0.41	0.000	−0.081	−0.069	−0.051	−0.15	0.31	1.41**	−0.14	−0.00046	0.011	−0.017
β_2	2.22	0.074	0.021	−0.031	0.047	0.080	0.001	−1.72**	−0.75**	−0.045	0.0006	−0.092
β_3	−1.94	0.084*	0.012	−0.056	−0.056	0.79**	0.021	−1.75**	1.34**	0.042	−0.0008	0.074
β_{12}	−2.01	−0.081	0.096	0.012	−0.013	−0.83**	0.89**	0.019	0.10	0.0003	0.017	−0.12
β_{13}	−3.22	−0.13*	−0.044	−0.14*	−0.092	−0.18	−0.31	0.066	−0.12	0.11*	−0.014	0.11
β_{23}	−0.63	−0.012	−0.25*	0.062	−0.024	0.000	−0.91	0.20**	−0.077	0.35**	−0.018	0.097
β_{11}	−1.53	−.075*	0.085	0.010	−0.043	−0.55**	−0.17	−0.13**	−0.020	0.23**	−0.00028	−0.058
β_{22}	0.29	0.014	−0.078	0.023	−0.041	−0.43**	0.19	0.15**	0.37**	0.061**	−0.00028	−0.039
β_{33}	−3.75**	0.0006	−0.047	0.048	−0.021	−0.032	0.048	0.052	−0.086	0.13**	0.043**	−0.026
R^2%	64.22	75.17	65.98	61.89	61.14	84.54	72.66	99.82	96.22	94.26	86.9	52.81
F	1.99	3.36	2.15	1.80	1.75	6.07	2.95	631.45	28.28	18.25	7.43	1.24
P	0.1486^{NS}	0.036*	0.1238	0.1854	0.1982	0.0047**	0.0534	0.0001**	0.0001**	0.0001**	0.0021**	0.3675

The signs of regression coefficient within each equation reveal the direction of the effect of each independent variable, the squares and interactions. Values in table are the average of two determinants, *WAC* water absorption capacity, *WUR* water uptake ratio, *GSL* gruel solid loss, *VE* cooking volume expansion, *SC* swelling capacity, *BD* bulk density, *CHO* total carbohydrate.

Table 3 Optimum level and predicted value

Solutions	Optimum level			Predicted value												
	X1	*X2*	X3	WAC	WUR	GSL	VE	SC	BD	CHO	Protein	Ash	Moisture	Fat	MSC	Desirability
1	77.33	22.19	8.92	49.40	1.03	4.16	1.52	0.85	0.345	62.21	11.36	0.09	4.17	4.03	23.91	0.60
2	60.47	26.29	21.28	46.41	1.21	4.85	1.45	0.87	0.471	54.80	14.66	0.11	4.74	3.67	23.79	0.53
3	75.54	10	19.78	43.31	1.03	4.52	1.12	0.60	0.315	60.26	16.52	0.06	4.43	3.4	24.03	0.52

WAC water absorption capacity, *WUR* water uptake ratio, *GSL* gruel solid loss, *VE* cooking volume expansion, *SC* swelling capacity, *BD* bulk density, *CHO* total carbohydrate, *MSC* mean sensory score

Table 4 Comparison of determined quality parameters of optimized noodle with branded noodle

Quality parameters	Branded noodle (Maggie)	Optimized noodle	p value (two tail)
Bulk density (g/ml)	0.395±0.02	0.351±0.01	0.105
Water absorption capacity (%)	46.2±0.07	48.6±0.57	0.034
Water uptake ratio	2.87±0.36	1.4±0.17	0.036
Swelling capacity (ml/g)	0.83±0.02	0.86±0.01	0.168
Cooking volume expansion (ml/g)	1.62±0.17	1.47±0.04	0.333
Gruel solid loss (g%)	8.68±0.08	4.32±0.13	0.001
Total carbohydrate (g%)	67.5±1.85	64.4±0.85	0.161
Protein (g%)	9.9±0.42	11.7±0.14	0.030
Fat (g%)	8.1±0.28	3.9±0.28	0.005
Ash (g%)	2.2±0.16	0.89±0.08	0.017
Moisture (g%)	8.6±0.02	5.6±0.57	0.009
Mean sensory score	21.6±1.3	22.2±0.92	0.647

n=Two tail means the region of rejection would consist of a range of numbers located on both sides of sampling distribution

(10.5–12%). Crosbie et al. (1999) recorded protein contents ranging between 10 and 12.2% in 21 experimental noodle samples, while the commercial Top Raman noodle contained 11% protein. Baik and Lee (2003) and Wang et al. (2004) reported that the protein values were between 10.5–16.4 and 10.1–19.3% respectively for cooked white salted noodles.

Dick and Youngs (1988) considered that gruel solid loss of 7% was found to be acceptable for dried pasta. The gruel solid loss for all 20 runs of noodles were <6%.

Influence of independent variables on response

The effect of each independent variable on determined responses at single, interactive (Figs. 1, 2 and 3) and quadratic level studied through second order polynomial quadratic equation was presented as regression coefficient of that model in Table 2. R^2 was above 80% in responses such as bulk density (84.54%), carbohydrate (99.82%), protein (96.22%), fat (94.22%), and ash (86.9%) content of noodles (significant at $p<0.01$). The sign and magnitude of the coefficients indicated the effect of variables on the responses. The addition of tapioca flour and defatted soy flour had significant contribution in raising water absorption capacity and water uptake ratio of noodles respectively. Good water absorption is a required factor in determining quality of pasta products. Hummel (1966) mentioned that good quality macaroni products should absorb at least twice their weight after boiling in water. The interactive effect of tapioca flour and defatted soy flour had significant negative contribution to gruel solid loss.

The swelling capacity of noodles was not significantly influenced by the independent variables. Among the linear terms, defatted soy flour had positive significant effect on bulk density at $p<0.05$. But the incorporation of tapioca flour and whole wheat flour had significant negative influence on bulk density. Among the interaction terms, the whole wheat flour and tapioca flour mixed at 60 g and 20 g respectively showed the maximum moisture content and the effect was found to be significant at $p<0.05$. The moisture content of noodle was quite important parameter from quality point of view. In the final product it should be in the range of 6–7% (Oberoi et al. 2007).

The tapioca flour and defatted soy flour incorporation into the whole wheat flour had significant negative influence on total carbohydrate content at $p<0.05$. The protein content of noodles was positively (significant at $p<0.05$) influenced by the incorporation defatted soy flour and negatively (significant at $p<0.05$) influenced by incorporation of tapioca flour. The mixing of wheat flour up to 70 g and defatted soy flour up to 15 g had negative influence on fat content, above that level indicated the positive effect. The whole wheat flour and tapioca flour had positive contribution to ash content whereas defatted soy flour provided the negative effect up to the level of 15 to 16 g incorporation at linear terms. Though incorporation of tapioca flour had negative influence on mean total sensory score, the effect was not significant at linear level.

Optimized level of ingredients

Numerical multi-response optimization was adopted to determine the optimum level of each independent variable and the respective predictive value of responses as per the set goals with maximum desirability function was reported in Table 3. The optimum level of independent variables for formulation of the noodles with maximum protein content of 16.52% as predicted value were 75.54 g whole wheat flour, 10 g of tapioca flour and 19.78 g of defatted soy flour with desirability of 0.52. Alpaslan and Hayta (2006) reported that flaxseed, soy and corn flours added to a typical snack formulation up to levels of 10% with a reasonable acceptance offering promising nutritious and healthy alternative to consumers. Since the incorporation of defatted soy flour

Table 5 Production cost of optimized noodle/kg

S.No.	Expenses/kg	Cost of production (Rs.)		
		1	2	3
1	Personnel (A)	5.00	5.00	5.00
2	Raw materials			
	a) Wheat flour	25.50	20.10	25.80
	b) Tapioca flour	5.10	6.00	2.40
	c) Soy flour	12.30	29.50	28.20
	d) Salt and/oil	2.00	2.00	2.00
	e) Egg	1.00	1.00	1.00
	Total (B)	45.90	58.60	59.40
3	Utilities			
	a) Power	1.00	1.00	1.00
	b) Water	2.00	2.00	2.00
	c) Fuel	2.00	2.00	2.00
	Total (C)	5.00	5.00	5.00
4	Contingency expenses			
	a) Transport	0.50	0.50	0.50
	b) Publicity, postage, telephone, stationary	0.50	0.50	0.50
	c) Packaging material cost	2.50	2.50	2.50
	Total (D)	3.50	3.50	3.50
5	Depreciation on building (@5%)	0.25	0.25	0.25
6	Depreciation on machine (@10%)	1.00	1.00	1.00
7	Interest on capital investment (@12%)	2.00	2.00	2.00
	Total (E)	3.25	3.25	3.25
8	Total cost of production (A+B+C+D+E)	62.65	75.35	76.15
9	Average yield loss cost at 10%	6.25	7.50	7.60
10	Net profit ratio @10%	6.25	7.50	7.60
11	Cost of Developed product per kg (8+9+10)	75.15	90.35	91.35
12	Valid cost of production per kg	75.50	90.50	91.50

1,2,3 indicates the three best solution for composite flour combinations on numerical optimization

>10% showed negative influence on quality index of noodles, a well acceptable noodles with maximum WAC, Swelling capacity, volume expansion and minimum gruel solid loss which were considered to be the quality index of noodles was formulated with the optimum level of three independent variables at 77.33 g of whole wheat flour, 22.19 g of tapioca flour and 8.9 g of defatted soy flour with the maximum desirability of 0.60.

The quality index of noodle prepared with optimum level of ingredients (77.33 g of whole wheat flour, 22.19 g of tapioca flour and 8.9 g of defatted soy flour) was compared with branded noodle (Maggie) which revealed that (Table 4) the water absorption capacity and protein content of optimized noodle was significantly ($p<0.05$) higher; water uptake ratio, gruel solid loss, fat, moisture and ash content were significantly lower than the branded noodle.

Production cost of optimized noodle

The cost calculation for the production of 1 kg of developed noodle with optimum level of ingredients (Table 5) revealed the total cost of production was minimum (Rs.75.50/-) for noodles prepared by mixing the wheat flour, tapioca flour and defatted soy flour at the level of 77.33 g, 22.19 g and 8.9 g respectively.

Conclusion

Optimization processes provide ample opportunities for scientific investigation on food product development. The highly acceptable Chinese salted noodles with an excellent quality of maximum WAC, WUR, VE, SC, protein, CHO, ash and minimum GSL, BD, fat, moisture can be made from ratio of combination of three independent variables at 77.33 (X_1): 22.19 (X_2): 8.92 (X_3) respectively. The predicted response values under the identified optimum levels were experimentally verified to be in general agreement with the model.

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