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Optimisation of Physical Properties of Ready to Cook Fish Incorporated Noodles using Response Surface Methodology

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Abstract

Combination of fish mince and refined wheat flour was optimized for the development of fish incorporated noodles by using response surface methodology. Effect of different level of pink perch (*Nemipterus japonicus*) mince on physical properties like water absorption index, bulk density, colour values, cooking time, cooking loss, rehydration test, shearing strength and sensory score were evaluated. D-optimal mixture experimental design with 9 runs was formulated to optimize the different levels of fish mince and refined wheat flour. Linear, quadratic and cubic mixture polynomial regression was fitted to the experimental data and appropriate model was selected based on highest goodness of fit values (R^2). From the analysis, it was found that water absorption index decreased as the percentage of fish mince increased. Bulk density reduced and found to be maximum for fish incorporated noodles. Lightness reduced as fish concentration was increased, whereas a* and b* values were found to increase. Cooking time increased significantly as the percentage of fish mince increased; whereas, cooking loss was found to decrease on incorporation of fish mince to noodles. Rehydration test values were good for 10 and 15% fish mince incorporated samples. There was a decrease in shearing strength after 10% fish incorporated sample. Based on the desirability function calculation of multiple response samples, 15% fish mince incorporated samples were found most acceptable based on the physical properties and sensory score.

Keywords: Extrusion, fish mince, noodles, response surface methodology, desirability function

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Introduction

Noodles are a traditional ready to cook food product, originated in China and gradually spread into other Asian countries and became part of local cuisine, *Chicken Ramen* was the first instant noodle produced by Nissin Foods of Japan in 1958 (Fu, 2008). Nowadays, noodles have a special place in global food market due to various formulations for hand made noodles from China along with advanced processing techniques from Japan and other countries. Hatcher (2010) and Hou (2001) suggested that globalization of this food was mainly due the improvement of quality and processing of noodles. In Asia, major ingredients used for manufacturing of noodles are rice, buckwheat and starches derived from the mung bean and potato (Fu, 2008). Whereas, basic ingredients for wheat based noodles were flour, water and salt. Fish protein is considered as agood source of lysine with high biological value (Balachandran, 2001). Moreover cereal flours contain high amount of carbohydrate and lower protein content (Bent, 1986). Hence, a combination of fish meat and cereal was used for the preparation of noodles for enhancing its nutritional quality. Several studies have seen conducted for developing protein rich extrudates from various sources *viz.*, live-stocks, microbial cells and oil seeds (Gogoi et al., 1996; Suknark et al., 1998; Choudhury et al., 1998; Prabhasankar et al., 2009; Choo & Aziz, 2010; Kruger et al., 1998). Extrusion is a promising technology in food, feed and polymer industry. It is a multivariable unit operation in which a variety of raw materials undergo various operations like mixing, shearing, cooking, puffing and drying in one energy efficient rapid continuous process. Product characteristics of extrudates made from cereal flour depend on the physicochemical changes that take place due to the effect of extrusion variables (Pansawat et al. 2008). Banerjee & Chakraborty (1998) reported that the ingredients used for the production of extrudates strongly affected its physical properties. Effects of extrusion variables on structural changes and product properties of starchy materials have been reported (Kadan et al., 2003; Sacchetti et al., 2004; Titus & Glory, 2011). Research employing different combinations of ingredients for the preparation of noodles was conducted by several authors, like Panlasigui et al. (1992) who studied the effect of starch digestibility and glycemic response of extruded rice noodles. Development of nutrient rich noodles by supplementation with malted ragi flour was studied by Kulkarni et al. (2012). Texture of sweet potato starch noodles was studied by Seung-Young et al. (2005). Consumer acceptability of a novel extrusion-cooked salmon snack was reported by Kong et al. (2008).

Response Surface Methodology (RSM) is a statistical tool for modeling and optimization of multiple responses for predicting the best performance conditions with a minimum number of experiments (Giovanni, 1983). Thakur & Saxena (2000) used RSM for the optimization of ingredient levels for the formulation of extruded snack. Effect of extrusion conditions like barrel temperature, screw speed, moisture and fish flour on the physical properties of extruded ready-to-eat snacks were standardized using RSM (Singh et al., 2012). The present study was conducted to find a suitable combination of fish mince and refined wheat flour to optimize the process parameters and also to determine the changes in physical properties of ready to cook fish incorporated noodles by RSM.

Materials and Methods

Pink perch (*Nemipterus japonicus*) was used as a source of fish protein and was procured from fish landing centre at Thoppumpady, Cochin, Kerala, India. After dressing and washing of fish, the meat was separated by using a meat bone separator (Model SF-6, Safe World Enterprises (M), SDN,BDH, Malaysia). Fish mince (5, 10, 15 and 20%) was mixed with refined wheat flour (95, 90, 85 and 80%; Elite maida manufactured by M/s Yamuna Roller Flour Mills Pvt. Ltd., Kerala, India) 2% salt in a Bowl Chopper (MadoGarent, Type MTK 661, Maschinfabrik Dornhan, D-72175-Dorhan) and the final moisture was adjusted to 30%. The fish flour mix was kept in air conditioned room (24°C) for 30 min for conditioning. For extrusion, single screw extruder (G.L. Extrusion Systems Pvt. Ltd., KHSRA No. Rz172/12, Durga Park, New Delhi, India) with a noodle die of 1.5 mm diameter was used. The mixture containing fish mince and refined wheat flour was fed into the extruder manually at a feed rate of 200 g min^{-1}, extruded at a temperature ranging from 90-110°C and the extrudates collected in a tray and dried in electrical dryer at 60°C for 6 h. Noodles prepared without fish mince was kept as control. Products obtained were used for the analysis of physical and sensory properties.

Water absorption index (WAI) of the samples was determined by following the method described by Sosulusky (1962). Bulk density (BD) of the sample was measured by Sand Displacement Method (Anon, 1998). The Hunter Lab MiniScan® XP Plus spectro colorimeter, model No D/8-S (Hunter Associates Laboratory Inc., Reston, VA, USA) with geometry of diffuse 80 (Sphere-8 mm view) and an illuminant of D 65 optical sensor and 100 standard observer was used to measure instrumental colour. The colour values were expressed using the standard CIE L*, a*, b* system. Cooking time (CT) of the sample was estimated by the methodology of Kawaljit et al., (2010). For this, 10 g of noodles were boiled in 500 ml of water and the samples were examined after each minute of cooking for the disappearance of white core by squeezing a noodle thread between two transparent glass plates. The time taken for complete disappearance of white core was taken as the cooking time. Cooking loss (CL) was determined by the method described by Li & Chang (1981). Rehydration test was performed by the methodology of Von-Loesecke (1945). Shear strength of the product was measured using a Warner-Bratzler shear attachment (Gogoi et al., 1996). Sensory evaluation was carried out based on 10 point hedonic scale on characterization and differentiation of the various sensory characters such as appearance, texture, odour and flavour (IS:6273[II]-1971).

D-optimal mixture experimental design with 9 runs was formulated to optimize the different levels of fish mince (5, 10, 15 and 20%) and refined wheat flour (95, 90, 85 and 80%) (Table 1). The experimental data on water absorption index, bulk density, colour (L*, a* and b* values), cooking time, cooking loss, rehydration test, shear strength and sensory analysis were generated to fit linear, quadratic and cubic response surface mixture models of the form given in equation 1, 2 and 3 respectively. Desirability function score was computed for multiple responses and the level at which fish mince and wheat flour produced highest function score was considered as

Table 1. Experimental design for the extrusion experiments and their results

Runs	Fish Mince (%)	Flour (%)	Water Adsorption Index	Bulk Density (%)	L* value	a* value	b* value	Cooking Time (min)	Cooking Loss (%)	Rehydration test(%)	Shearing Strength (N)	Sensory Analysis
1	5	95	1.78	3.7	81.54	1.19	13.87	7.1	1.56	3.65	5.66	8.6
2	10	90	1.53	3.69	80.36	1.32	14.59	7.3	0.98	4.39	8.88	8.7
3	15	85	1.36	3.62	79.98	1.38	16.25	7.2	1.21	3.53	8.03	8.8
4	20	80	1.01	2.88	77.39	2.38	18.77	7.4	1.11	3.12	3.88	8.3
5	0	100	1.92	3.72	82.19	1.03	12.88	7	1.47	3.59	3.19	8.6
6	0	100	1.91	3.72	82.16	1.05	12.59	7	1.45	3.51	3.2	8.6
7	20	80	1.03	2.89	77.36	2.35	18.66	7.4	1.1	3.11	3.81	8.3
8	0	100	1.93	3.73	82.19	1.03	12.69	7	1.47	3.55	3.21	8.6
9	10	90	1.49	3.66	80.36	1.33	14.63	7.3	0.99	4.33	8.55	8.7

optimum combination. The model was fitted using Design Expert 7.1.5.

Linear: $y = \Sigma_{i=1}^{q} \beta_i x_i + e$ ....(1)

Quadratic: $y = \Sigma_{i=1}^{q} \beta_i x_i + \Sigma_{i<j=2}^{q} \Sigma \beta_{ij} x_i x_j + e$ ......(2)

Quadratic: $y = \Sigma_{i=1}^{q} \beta_i x_i + \Sigma_{i<j=2}^{q} \Sigma_i \delta_{ij} x_i x_j +$

$\Sigma_{i<j=2}^{q} \Sigma \beta_{ij} x_i x_j (x_i - x_j) + e$ ....(3)

Where y is the response and $x_i = 0, \frac{1}{m}, \frac{2}{m}, \ldots \ldots, 1$, i, = 1, 2, ..., q (components x_1 and x_2), β_i is linear regression coefficient, β_{ij} is quadratic regression coefficient, δ_{ij} is cubic regression coefficient and e is error term.

Results and Discussion

Quadratic model was found suitable to explain the effect of percentage of fish mince on WAI with an R^2 value of 0.99 (Table 2). WAI indicates the part of starch that was not affected by the extrusion process and maintained its internal structure (Mason & Hoseney, 1986). Gomez & Aguilera (1983) suggested that WAI depends on the availability of hydrophilic groups and on the capacity of gel formation of the macromolecule. There was a significant reduction of WAI of noodles with percentage of fish mince (Fig. 1). This might be due to the decrease in starch content and denaturation of protein during extrusion and drying (Anon, 1998). Water absorption for noodles is affected by protein content, protein quality, damaged starch, and other physical properties of flour (Park & Baik, 2002). Park et al., (1993) reported an increased WAI of final extrudates because of the higher content of corn starch. Clayton & Miscorides (1992) found that starch molecules contribute towards water absorption index. However, dextrinised starch molecule may not contribute significantly towards the water absorption in the extruded products (Anon, 1998). WAI of control sample was 1.92; whereas 5, 10, 15

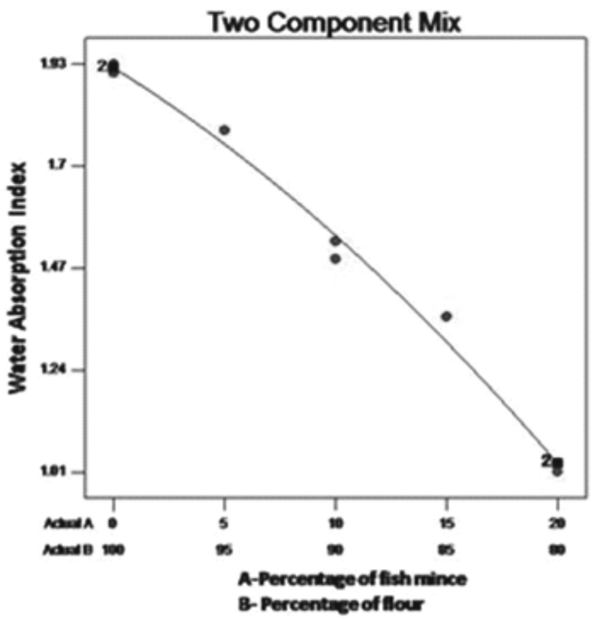

Fig. 1. Changes in WAI of extrudates as a function of fish-flour combination

and 20% fish mince incorporated noodles showed a value of 1.78, 1.53, 1.36 and 1.03 respectively.

Cubic model was fitted to the experimental data on changes of BD of noodles with respect to varying concentration of fish mince and wheat flour with a coefficient of determination of 0.99 (Table 2). Slight reduction of BD was noticed in control, 5, 10 and 15% fish mince incorporated noodles; whereas, drastic reduction of BD was observed at 20% fish mince noodles (Fig. 2). Bulk density is the ratio of mass of extrudates to the apparent volume of a specific container. Hence, it directly influences the storage space of manufacturing unit and shipping containers (Guy, 2001). Case et al. (1992) suggested that reduction of bulk density of the extrudates was due to the enhancement of gelatinisation. Suknark et al. (1998) found that BD in extrudates varied due to the screw speed, which produces smaller diameter extrudates with increased length and volume. Reduction of starch contentas the percentage of fish mince increased mainly accounts for the reduction of bulk density of the product. Clayton & Miscourides (1992) reported that protein content in fish encloses the available starch and causes limiting the expansion of product. Bulk density of control, 5, 10, 15 and 20% fish mince incorporated noodles were 3.73. 3.70, 3.66, 3.62 and 2.89 respectively.

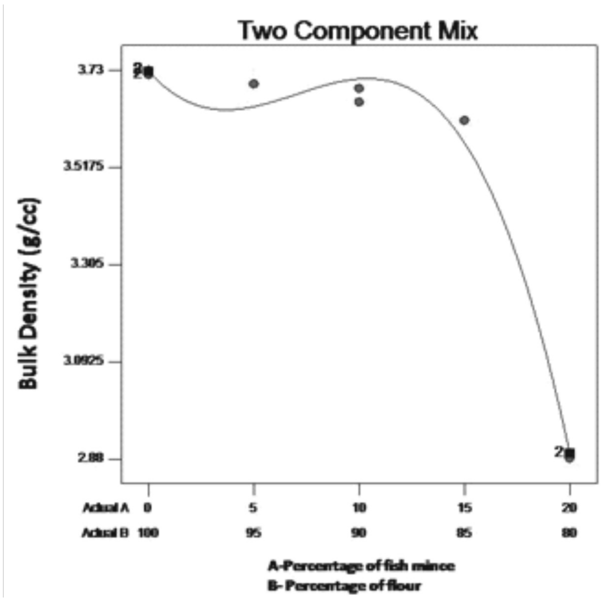

Fig. 2. Changes in BD of extrudates as a function of fish-flour combination

Colour is one of the most important quality parameters of the noodles determining the acceptability. Quadratic model (R^2 = 0.98) was fitted to explain the changes of lightness (L* value) of the noodles with respect to changes in the fish mince and wheat flour (Table 2). Fig. 3a clearly depicts that L* value of the samples was significantly reduced with respect to increase in the percentage of fish mince. Decrease in the lightness of extruded cereal based fish products may be due to the Maillard browning reaction. Lightness of control sample was 82.2, which reduced to 77.3 in 20% fish mince incorporated the noodles. Yun et al. (1997) suggested that protein and ash content causes significant changes in the colour of noodle. Cubic model was fitted with an R^2 value of 0.9898 and 0.9981 for the changes of redness (a* value) and yellowness (b* value) of the noodles with respect to changes in the concentration of fish mince and refined wheat flour (Table 2). It was found that yellowness and redness

Table 2. Regression coefficients of fitted model with R^2 values

Response	Fitted Model	A=Fish mince	B=Flour	A*B	AB(A-B)A^2B-AB^2	R^2
WAI	Quadratic	-0.079703	0.019215	6.78545E-004	-	0.9927
BD	Cubic	-3.57270	0.037274	0.058128	2.25432E-004	0.9920
L* value	Quadratic	-0.039776	0.821450	7.86964E-003	-	0.9764
a* value	Cubic	4.95591	0.010296	-0.079889	-3.14940E-004	0.9898
b* value	Cubic	7.20676	0.12729	-0.10953	-4.13180E-004	0.9981
CT	Linear	0.089454	0.070175	-	-	0.8750
CL	Linear	-5.91340E-003	0.014406	-	-	0.5346
RT	Quadratic	-0.63966	0.035152	8.16719E-003	-	0.7905
SS	Cubic	-23.63280	0.031700	0.37840	1.37000E-003	0.9903
Sensory	Cubic	-3.50134	0.086033	0.058623	2.32787E-004	0.9791

of noodles enhanced with percentage of fish mince (Fig. 3b and 3c). Increase in the redness may be due to the presence of caroteniod pigment in fish mince (Skrede & Storebakken, 1986). Factors affecting the colour of fish incorporated food were fish carotenoid pigments (astaxanthin and canthaxanthin), water content, raw ingredients and processing conditions. (Hutchings, 1999). Redness of control and 20% fish mince incorporated noodles was 1.03 and 2.38, respectively; whereas, yellowness showed a value of 12.88, 13.87, 14.63, 16.25 and 18.77 for control and increasing fish mince incorporated noodles respectively.

Linear model was found to be most suitable for explaining the changes in cooking time of the noodles as a function of different levels of fish mince and refined wheat flour (R^2 value of 0.87). The coefficients of the fitted model are given in Table 2 and the predicted and observed values of cooking time of noodles were presented in Fig. 4. Cooking time is considered as the important parameter in commercial point of view, which depends on the ingredients of the extrudates. Kawaljit et al. (2010) found that lowest cooking time in potato starch incorporated noodles than rice starch noodles. Cooking time of the extrudates increased with the concentration of fish mince. Control sample showed 7 min to attain the optimum cooking time; whereas, 20% fish mince incorporated noodles required 7.4 min. This could be due to the increased fish protein content, which might take longer time for cooking.

Cooking loss was mainly influenced by dissolving and releasing of gelatinized starches from the noodle surface during cooking (Chang & Wu, 2008). Fig. 7 clearly depicts the cooking loss of the samples as a function of fish-flour combination. Linear model was used to explain the changes of cooking loss with respect to changes of fish mince and wheat flour with an R^2 value of 0.53. The model (Fig. 5) implies a significant decrease in cooking loss from 1.47 for 5% fish meat incorporated noodles to a value of 1.1 for 20% noodles. Cooking loss of the noodles was mainly dependent on the combination of ingredients. Young et al. (1996) found that highest cooking loss in mung bean starch based noodles than those made from potato starch. Cooking loss of the noodles was mainly due to the solubilisation of loosely bound gelatinized starch on the surface of the noodles (Chansri et al., 2005). Hence, reduced cooking loss in fish incorporated noodles might be due to the low content of starch. However, cooking time directly influences the cooking loss of the noodles (Young et al., 1996).

Quadratic model with an R^2 value of 0.79 was fitted to predict the trend of rehydration test (RT) of noodles in terms of different levels of fish mince and wheat flour. The fitted values of rehydration ratio are given in Fig. 6 and the parameters of the fitted model showed in Table 2. During cooking of noodles, initially the surface gets cooked, then it proceeds towards the centre. If it overcooked, the outer surface of the noodles gains too much water which causes significant reduction of firmness and stickiness. Rehydration ratio of the noodles could be used as a parameter to predict the cooking quality of the noodles because the less the degree of rehydration, the stronger the noodles texture (Chansri et al., 2005). Control 5, 10 and 15% fish

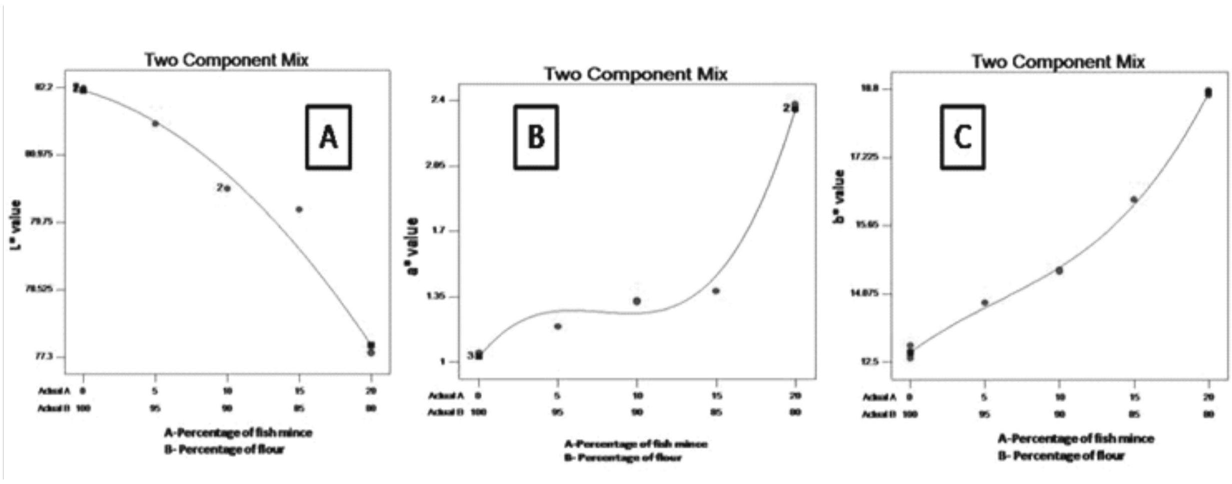

Fig. 3. Changes in L*, a*, b* value of extrudates as a function of fish-flour combination

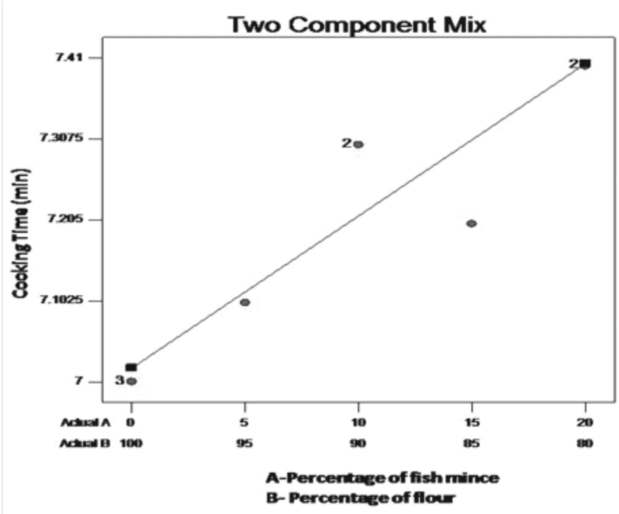

Fig. 4. Changes in cooking time of extrudates as a function fish-flour combination

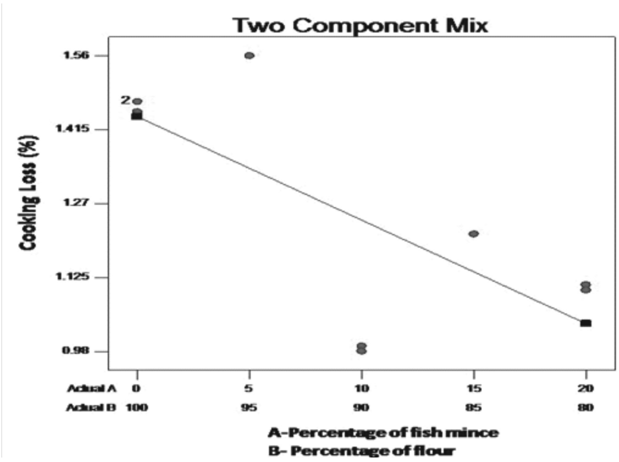

Fig. 5. Changes in cooking loss of extrudates as a function of fish-flour combination

mince incorporated samples revealed rehydration ratio of 3.59, 3.65, 4.39 and 3.53%, respectively. Least rehydration value (3.11%) was observed in 20% fish mince incorporated noodles.

Cubic model was found to be most suitable model to explain the changes in shear strength of noodles in terms of different levels of fish mince and wheat flour. The model was fitted with an R^2 of 0.99 and parameters of the fitted model are presented in Table 2. The observed and predicted values of shear strength of the noodles are given in Fig. 7. The force required to break the noodles was 8.88 and 8.03 N in 10 and 15% fish mince incorporated noodles, respectively. Whereas, there was a decrease in shear

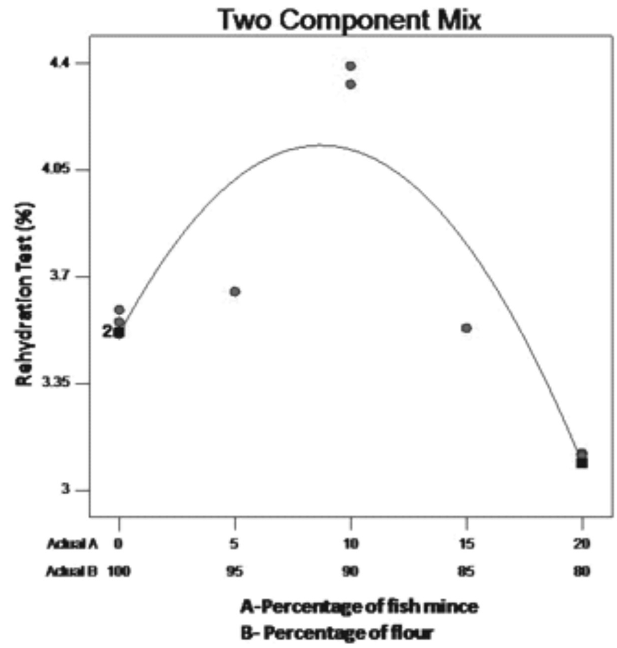

Fig. 6. Changes in Rehydration test of extrudates as a function of fish-flour combination

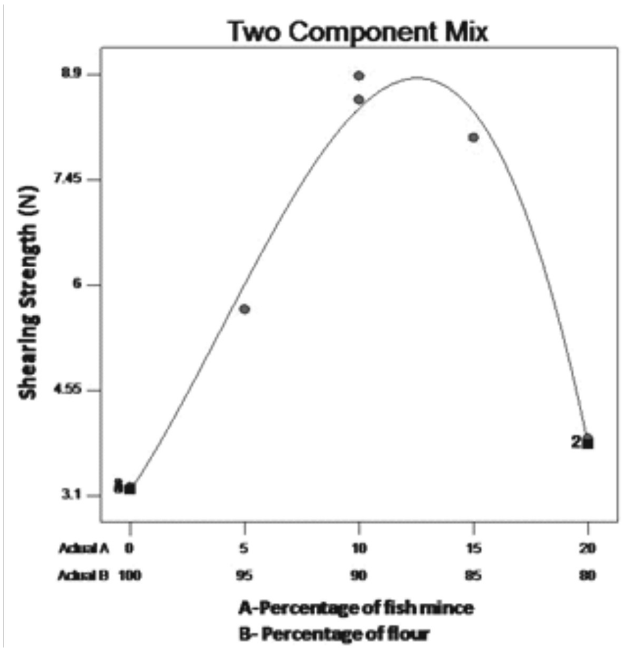

Fig. 7. Changes in shearing strength of extrudates as a function of fish-flour combination

strength for 20% fish mince incorporated noodles as the amount of starch molecule decreases and facilitates easy breaking of the product. Decreased breaking strength was reported for hydrolyzed arrow tooth flounder muscle by Choudhury & Gautam (2003).

Cubic model was fitted to predict the changes of sensory score of the noodles with respect to fish mince and wheat flour. Fig. 8 clearly depicted that there was no significant difference for the sensory score of control and 5% fish mince incorporated sample. Whereas 10 and 15% fish mince incorporated samples revealed better sensory acceptability than 20% fish mince incorporated sample. However, among the samples, 15% fish incorporated noodle was found to be most acceptable by considering physical properties and sensory score. It was observed that the level of fish mince content was responsible for the significant changes in cooking, colour and textural properties of the noodles. Textural properties of noodles are mainly affected by the structural network of starches, glutens, proteins, fibers and other additional ingredients. These may either weaken or strengthen formation of hydrogen bonds within the noodle structure network (Kong et al., 2012).

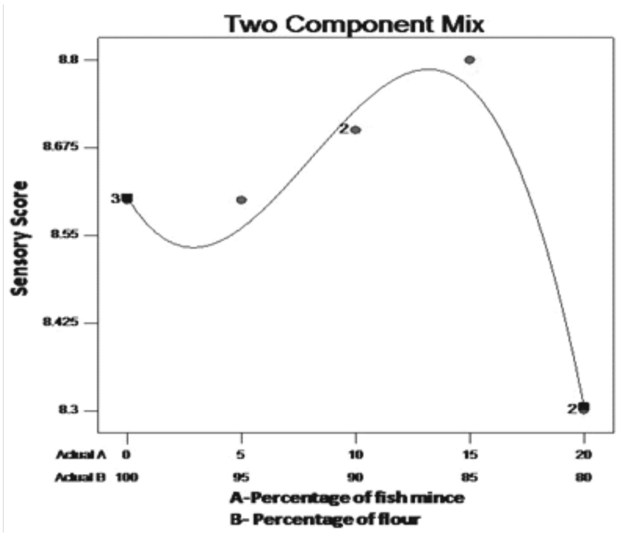

Fig. 8. Changes in sensory score of extrudates as a function of fish-flour combination

Desirability function score was computed by simultaneous evaluation of multiple responses to optimize the combination of different concentrations of fish-flour incorporated noodles. The desirability function graph is given in Fig. 9. The maximum desirability function score was 0.522 at 15 % of fish mince and 85% of refined wheat flour.

Result obtained in the present study revealed the combination of fish mince and refined wheat flour significantly altered the physical properties of fish noodles. Water Absorption Index reduced when the fish mince concentration increased. Noodle cooking

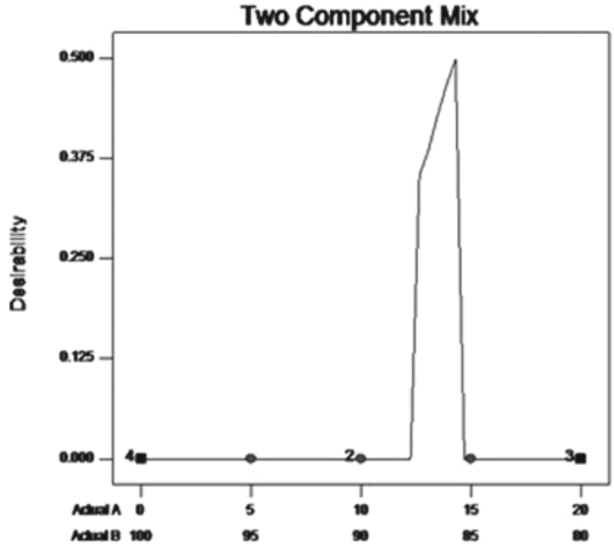

Fig. 9. Desirability function score of fish mince and flour

quality was affected by the difference in protein content in fish noodles. Significant colour changes were found to affect the appearance of the noodles. Linear model was found to be most suitable for explaining the changes in cooking time and cooking loss of the noodles as a function of different levels of fish mince and refined wheat flour (R^2 value of 0.87 and 0.53, respectively). Quadratic model was found suitable to explain the effect of percentage of fish mince on WAI, L* value and rehydration test with an R^2 value of 0.99, 0.97 and 0.79, respectively. Cubic model showed an R^2 value of 0.99, 0.99 and 0.97, respectively for BD, a* value, shearing strength and sensory. From the physical properties and sensory evaluation point of view, 15% fish incorporated noodles was found to be superior among the samples.

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