Mangaraj S, et al., J Food Sci Nutr 2018, 4: 028
DOI: 10.24966/FSN-1076/100028

HSOA Journal of
Food Science and Nutrition

Research Article

Development of Nutritious Healthy Noodles Incorporating Soy Based Functional Food Ingredients

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Abstract

Noodles are ready to eat product that are popular among several group of consumer. However, the presently available noodles provided low protein quality. With the constituents of good quality protein and phytochemicals (isoflavonon), soybean has been accepted as the functional foods that have a potentially positive effect on health beyond basic nutrition. Proponents of functional foods say that they promote optimal health and help to reduce the risk of disease. Thus the study aimed to develop protein enriched soy noodles with Full Fat Soy Flour (FFSF), Defatted Soy Flour (DFSF), and Soy Protein Isolate (SPI) that has acceptable characteristics and contained soy protein 47.0%, 43.2% and 90% respectively of the amount recommended by ICMR/NIN per serving. The DFSF, FFSF and SPI were substituted in wheat flour using 5%, 10%, 15% and 20%, where SPI was also substitute at 8%. It was observed that the level of DFSF, FFSF and SPI substitution was acceptable from the panelist at 10%, 10% and 8% containing 16.91%, 16.69% and 16.87% protein respectively. The noodles packaged in PET-MET/LDPE and MET-MET/LDPE was not affected by moisture and the product was highly acceptable in comparison to LDPE and PP. To lead a nutritious and healthy life, consumer should take soy fortified noodles into their daily diet.

Introduction

A great interest has raised in the development of functional foods products that may provide a health benefit beyond the traditional nutrients [1]. Noodles are widely consumed throughout the world and a fast growing sector of the noodle industry, second to bread [2,3]. Study indicated that dried noodles or instant noodles contain about 9 g protein per 100 g of product [4]. This is due to low protein content cereals (rice and wheat flour) [5]. Several studies reported that malnutrition at early age causes impaired physical as well as mental development in children [6]. Also, researches carried out in India have confirmed that protein, energy and iron deficiency among school children has increased [7]. It is worthy to note that consumers worldwide are increasingly at risk of premature death from both cardiovascular disease and diabetes due to overweight, elevated cholesterol, high blood pressure and abnormal blood sugar. These risk factors are partially influenced by a diet low in fiber and high in refined grains, sugars and saturated fats. So, for gaining popularity as well as rendering noodles having high in protein and low in fat content in view of curbing varieties of ailment on our body with respect to changing lifestyle, research for alternative raw materials are still in continuing. Today soybeans are one of the most economicalcereal-based diets [8] and valuable agricultural commodities because of its unique chemical composition and multiple uses as food, feed and industrial materials. Soy bean (Glycine max) is an important source of oil (17-25%) and protein (35-45%) [9-11]. Soybeans have the highest protein content (40%) among cereal and other legume species, and the second highest oil content among all food legumes. Soy protein contains most the essential amino acids, most of which are present in amounts that closely match those required for humans or animals [12,13]. Furthermore, soybeans also contain many biological active components, including isoflavones, lecithin, saponins, oligosaccharides, and phytosterols [14]. Mangaraj et al., [15] stated that soybeans are good source of B6, foliate and vitamin E, whole soybeans have the highest levels of phytic acid, an organic acid and mineral cheater present in many plant tissues, especially bran and seed, which binds to certain ingested minerals; calcium, magnesium, iron and especially zinc-in intestinal tract and reduces the amount the body assimilates. It has been suggested that the high intakes of soy may explain, in part, the lower incidence of certain cancers in Asian countries, where soy consumption is high, when compared to Europe or America [16,17]. Nagarajan [18] suggested that soy isoflavonon may inhibit the effect of endothelial cell activation associated to chronicle diseases such as atherosclerosis by blocking the activation of inflammatory cells and the adhesion to the vascular endothelium. On 1999, the US Food and Drug Administration announced that food containing soy protein may reduce the risk of Coronary Heart Disease (CHD). The health claim is based on the US FDA's determination that 25 grams of soy protein per day, as part of a diet low in saturated fat and cholesterol may reduce the risk of heart disease by reducing blood cholesterol levels. Apart from noodles, enabling fast food items to be more nutritious is to fortify them with protein, vitamins and minerals etc., to compete with other non-nutritional, yet popular, fast food items. Singh et al., [19] prepared noodles from semolina of durum and aestivum wheat and flour of aestivum with or without 10% of different types of full fat soy flour (i.e., enzyme active, conventional and roasted soy flour) and defatted soy flour and reported the product made from durum semolina containing 10% of defatted soy flour was as good as that from durum semolina alone. Osorio [20] studied the quality parameters of noodles

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Citation: Mangaraj S, Swain S, Deshpande SS (2018) Development of Nutritious Healthy Noodles Incorporating Soy Based Functional Food Ingredients. J Food Sci Nut 4: 028.

Received: August 03, 2017; **Accepted:** January 31, 2018; **Published:** February 14, 2018

made with various supplements (extruded maize, maize, defatted soy flour and maize/soy flour blends, lecithin and wheat straw). The noodles made with extruded maize flour, maize flour, and wheat straw supplements had the highest total sensory score. Young Soo Kim [21] prepared wet noodles from wheat flour with 3, 5 and 7% oyster mushroom and oak mushroom with improved protein and fiber contents having better acceptability.

A number of research studies have been reported on baked products, extruded products and deep fat fried snacks, noodles made from rice, wheat, ragi and legume flours supplemented with soya flour, defatted corn germ meal, soybean meal etc. [Buiet; Rathi; Marques; Osorio; Nielsen; Sudha; Kaur; Hou and Kruk; Fu] [20,22-28]. The main object of the present study is to provide soy based low-fat and high protein nutritious food in accordance to ICME/NIN guidelines [29]. It is a particular object of the invention to provide novel fast food item in which the proteins are balanced to provide optimum nutrition (i.e., up to 13-17g/100g of product). This study will provide an additional source of utilization of soy flour in fast food formulation.

Material and Methods

Raw materials

Wheat flour, Refined wheat flour (Maida), soy flour (Defatted soy flour (DFSF)), Soy Protein Isolate (SPI)), oil, salt and packaging material (Low Density Polythelene (LDPE), Polypropylene (PP), Polyethylene Terephthalate (PET) films are laminated with metal foil (MET-PET)/LDPE,PET/MET-PET/LDPE) etc., were procured from local market of Bhopal. MET-PET films provide protective properties for food items requiring restricted visibility. Chemical composition of raw material used is shown in table 1.

Mixture design for development of noodles

The starting level of soy protein source were determined by reviewing the previous research which could substitute wheat flour for noodles with 5% soy protein source flour to noodles without adversely affecting color and flavor. Thus, substitution level started at 5% until 20% of soy flour because noodle dough could still be sheeted and cut into noodle strands. Then the optimum level of DFSF, FFSF and SPI substitution were selected by assessing noodles quality in terms of cooking time, stickiness, mouth feel color and sensory evaluation. Mixture design was employed to find out the effect of input parameters namely wheat flour, refined wheat flour, DFSF and SPI and their interaction on the quality parameters of noodles like protein, fat, carbohydrate and energy. Model on soy fortified noodles experimented at three parameter, in which both DFSF or SPI has been used along with wheat flour and refined wheat flour for making noodles.

Soy Protein Isolate based (SPI) mixture design

Optimization on the basis of blend of deferent type of flour in different ratio with wheat flour, refined wheat flour and SPI was analyzed using the predefined lower limit and higher limit (Wheat Flour-WF: 10-25%, Refined Wheat Flour-RWF: 60-80%, Soy Protein Isolate-SPI: 5-10%, Defatted Soy Flour (DFSF) 8-15%). The different combination with proportion of raw materials produced by RSM for experimental trials is given in table 2 and 3.

Noodle making machine

The noodle making machine (model KNME 2003, Figure 1) [30] having output capacity of 15 kg/h was procured from M/S Krishna Sales Company, New Delhi. The procedure involved in noodles making are mixing raw materials, resting the crumby dough, sheeting the dough into two dough sheets, compounding the two sheets into one, gradually sheeting the dough sheet into a specified thickness and slitting in to noodle strands (Figure 2). The machine parameters were feed moisture content: 30-50%, drying temperature: 45-60°C, steaming time: 7-12 min and drying time: 6-8 hrs.

Figure 1: Development of noodles using noodle making machine.

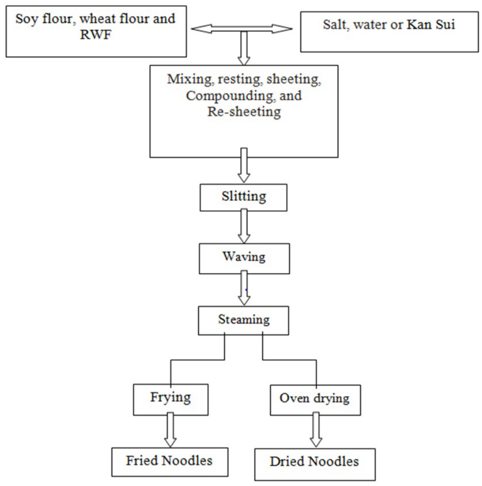

Figure 2: Flow chart of noodle making.

Raw Ingredient	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Carbohydrate (%)	Energy (k Cal)
Wheat	12.1	1.7	2.7	1.9	69.4	341.0
Refined Wheat Flour (RWF)	11.3	0.9	-	-	-	73.9
Defatted Soy Flour (DFSF)	47.0	1.2	-	4.3	38.4	329.0
Full Fat Soy Flour (FFSF)	43.2	19.5	4.6	3.7	20.9	432.0
Soy Protein Isolate (SPI)	90	0.1	0.1	0	-	-

Table 1: Chemical composition of raw material (per 100gm).

Input Parameters				Output Parameters		
Run	WF	RWF	SPI	Protein (%)	Fat (%)	Energy
1	19.90878	75.09122	5	14.15463	0.99876	340.765
2	24.33079	70.66921	5	13.94568	1.00034	338.675
3	12.33789	80	7.66211	15.13245	0.89743	343.321
4	21.22119	68.78556	9.993249	17.98453	0.94879	342.135
5	17.86295	72.28429	9.85276	17.54637	0.93654	341.875
6	10.60555	79.39445	10	17.87568	0.87436	343.256
7	14.24135	75.86167	9.896988	16.32452	0.90654	339.565
8	16.3651	78.6349	5	14.13002	0.95765	342.321
9	25	65.00111	9.998892	17.98734	0.99876	338.216
10	24.33079	70.66921	5	13.87523	1.00065	344.546
11	12.33789	80	7.66211	16.32765	0.96453	343.674
12	21.33811	71.6892	6.972685	14.94653	0.99564	339.165
13	16.3651	78.6349	5	13.54362	0.96345	347.321
14	10.60555	79.39445	10	17.13245	0.87965	345.34
15	25	65.00111	9.998892	16.98765	0.98765	341.321
16	25	67.76714	7.232864	14.56743	1.00324	339.1342

Table 2: Soy Protein Isolate (SPI) based mixture design.

Note: (WF-Wheat Flour; RWF- Refined Wheat Flour; SPI- Soy Protein Isolate).

Input Parameters				Output Parameters		
Run	WF	RWF	DFSF	Protein (%)	Fat (%)	Energy (Kcal)
1	10.6244	74.3756	15	15.512	1.00232	387.345
2	10.26805	80	9.731949	14.101	0.978723	338.3712
3	25	66.51373	8.486266	13.341	1.00542	340.9536
4	25	66.51373	8.486266	13.654	0.999872	341.9564
5	17.73888	74.26112	8	14.122	0.986543	339.3452
6	24.99689	60.00311	15	15.325	0.985436	341.9456
7	21.88654	64.74022	13.37324	15	0.985342	343.1321
8	13.42041	75.85916	10.72043	14.12	0.97543	337.4231
9	17.73888	74.26112	8	13.342	0.96903	335.9876
10	24.99689	60.00311	15	15.342	1.00543	339.3215
11	14.35615	70.64385	15	15	0.98765	333.1432
12	18.62192	69.39567	11.9824	14.894	0.97654	332.9856
13	18.51129	66.48871	15	15.324	0.98765	338.1432
14	10.26805	80	9.731949	14.444	0.97987	336.2435
15	21.68259	70.31741	8	14.346	1.00834	341.4356
16	10.6244	74.3756	15	14.543	1.00765	332.8796

Table 3: DFSF based mixture design.

Note: (WF-Wheat Flour; RWF-Refined Wheat Flour; DFSF-Defatted Soy Flour (DFSF).

Sensory analysis

The products were evaluated for taste color, texture/mouth feel, flavor appearance and overall acceptability; by a panel of nine trained panelists using 9-point Hedonic scale (BIS, 1975). The mean score of 5 was considered as acceptable. Also the optimized samples of extruded were given to school children of different age group of nearby school (Brg. Trivedi Memorial Academy, Nabi Bagh, Bhopal) for knowing the acceptability level of the product. Total 300 no's. of children (10-18 years) and 15 teachers were provided the samples and collected the response.

Quality assessment of developed products

Textural properties: Textural properties of extruded snacks were measured using a TA-XT plus Texture Analyzer (Stable Micro Systems, London, England). Testing condition was 5.0 mm/s pre-test speed, 5.0 mm/s test speed, 10.0 mm/s post test speed. Each measurement was conducted on 50% strain of individual force-time curves of the TPA, hardness, cohesiveness, stickiness, springiness, chewiness, gumminess and adhesiveness values were determined according to the description.

Nutritional analysis: The moisture, fat, protein and ash were estimated using standard AOAC methods (2005). Carbohydrate and calories was calculated by subtracting the percentage of moisture, ash, crude protein and fat from 100 and by using factors 4.0, 4.0 and 9.0 to calculate the energy provided by protein, carbohydrates and fat, respectively.

Packaging and storage study of extruded snack foods and noodles: The final accepted noodles were filled in different type packaging material as described above and the sample was sealed using heat sealing machine and kept in the ambient temperatures to be studies. Then, quality parameters like moisture content, texture and sensory characteristics were measured in every month up to three month of storage.

Optimization of noodles

Response surface methodology was applied to the experimental data using a commercial statistical package, design-expert version 7.6 (Stat ease Inc, Minneapolis, USA, Trial version). The response surface and contour plots were generated for different interaction for any two independent variables, while holding the value of other two variables as constant (at the central value). Such three dimensional surfaces could give accurate geometrical representation and provide useful information about the effect of any two independent parameters on a particular dependent parameters [31]. Desirability, a mathematical method was used for selecting the optimum process values.

Results and Discussion

Soy Protein Isolate (SPI) based noodles

Protein: The protein content of the SPI and DFSF based noodles varied from13.94 to 17.98% and 13.54 to15.52% respectively with significant mean values ($p<0.05$). The model were adjusted for protein content in the mixture design are presented in ANOVA (Table 4) revealed that all model were significant ($P<0.001$) with high R^2 (>0.90) and low coefficient of variation (3.53%). The non-significant lack of fit (F-value=0.57) indicated the model is adequate for describing the independent parameters with better accuracy. A similar observation of high R^2 (0.75) and low CV (2.58%) was found for DFSF based noodles (Table 5). The linear model are maximum affected by SPI content in the model because the high amount of protein output of 17.987% in input complex ratio, wheat flour X^1=24.908 g, refined wheat flour X^2=65.259 g and soy protein isolate X^3=9.833 g and minimum output of protein in this model 13.5436 by wheat flour X^1=21.357, refined wheat flour X^2=73.789 and soy protein isolate 4.854. It was found that with the increased in refined wheat flour and wheat flour, protein content decreased, while increasing soy protein isolate increased protein content.

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*** Mixture Component Coding is U_Pseudo. ***						
Analysis of variance table [Partial sum of squares-Type III]						
Source	**Sum of Squares**	**Df**	**Mean Square**	**F Value**	**p-value Prob>F**	
Model	37.02865	2	18.51433	59.54066	<0.0001	Significant
Linear mixture	37.02865	2	18.51433	59.54066	<0.0001	
Residual	4.042385	13	0.310953			
Lack of fit	2.377834	8	0.297229	0.892821	0.5788	Not significant
Pure error	1.664551	5	0.33291			
Cor total	41.07104	15				
Std. dev.	0.557631		R-Squared	0.901576		
Mean	15.77886		Adj R-Squared	0.886434		
CV%	3.53404		Pred R-Squared	0.853106		
Press	6.033076		Adeq Precision	14.76095		

Table 4: ANOVA for linear mixture model for protein content of SPI based noodles.

*** Mixture Component Coding is U_Pseudo. ***						
Analysis of variance table [Partial sum of squares-Type III]						
Source	**Sum of Squares**	**Df**	**Mean Square**	**F Value**	**p-value Prob>F**	
Model	5.774653	2	2.887327	20.42253	<0.0001	Significant
Linear mixture	5.774653	2	2.887327	20.42253	<0.0001	
Residual	1.837933	13	0.141379			
Lack of fit	0.956299	8	0.119537	0.677931	0.7027	Not significant
Pure error	0.881634	5	0.176327			
Cor total	7.612586	15				
Std. dev.	0.376005		R-Squared	0.758567		
Mean	14.52563		Adj R-Squared	0.721423		
CV%	2.58856		Pred R-Squared	0.623935		
Press	2.86283		Adeq Precision	8.937561		

Table 5: ANOVA for linear mixture model for protein of DFSF based noodles.

The regression equation describing the effect of the process variables on the fat content of product in terms of actual level of the variables are given as:

Protein=0.10275*WF+0.10239*RWF+0.81480*SPI …… (1) for SPI based noodles

Protein=0.12396*WF+0.12084*RWF+0.32549*DFSF…...(2) for DFSF based noodles

The contour response surface (Figure 3) for protein content showed increasing consistency value of response due to the increasing defatted soy flour concentration. A mixture design surface consistency decreased by the increasing refined wheat flour. The result is in agreement with the report by Sudha et al., [32] who revealed that inclusion of soy flour and whey protein concentrate in instant vermicelli not only enhanced their protein content and *in vitro* protein digestibility but also reduced the fat uptake in noodles. As SPI and DFSF are the main source of protein in the product, described above, high protein content of the products is also reflected in respective regression coefficients [SPI (>0.80) and DFSF (>0.30)]. This may be because the soy proteins compete strongly for water with the other proteins present in the formulation, which coincides with some stipulations [33], who pointed out that soy proteins have a high hydrophilicity, competing for the water not only with the proteins present in the formulation, but also with starch.

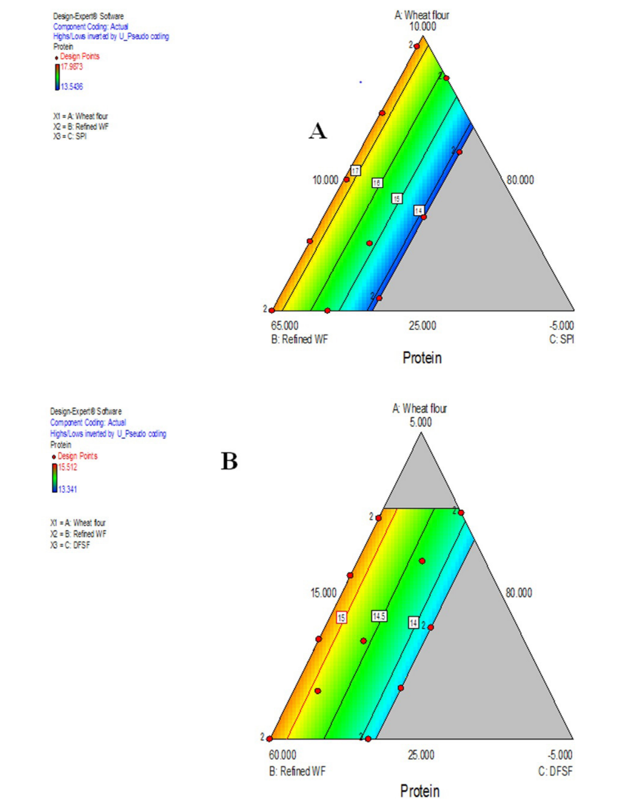

Figure 3: Effect of WF, RWF and DFSF on protein content of noodles. a) SPI based; b) DFSF based.

Fat content: Fat content varied from 0.87 to 1.0% for SPI based and 0.97 to 1.0% for DFSF based noodles with CV of 1.87 and 0.831% respectively with non significant (P>0.05) mean values. There were little variations in fat content because the entire ingredient had lower amount of fat. The model were adjusted for fat content are presented in ANOVA (Table 6 and 7) revealed that all model were significant (P<0.01) with high R^2 (>0.72) for both products. The non-significant lack fit (P>0.82) indicated the model is adequate for the independent parameters for fat content for SPI based products. A similar behavior was also found for DFSF based products. The regression equation describing the effect of the process variables on the fat content of product in terms of actual level of the variables are given as:

Fat: 0.0155*WF+8.89525E-003*RWF+1.67046E-003*SPI….. (3) for SPI based noodles

Fat=0.030966*WF+0.075855*RFW+0.0758*DFSF-2.5396E-4*WF2-1.37816E-3*RWF2-7.4859E-*DFSF2………… (4) for DFSF based noodles

*** Mixture Component Coding is U_Pseudo. ***						
Analysis of variance table [Partial sum of squares-Type III]						
Source	**Sum of Squares**	**Df**	**Mean Square**	**F Value**	**p-value Prob>F**	
Model	0.027184	2	0.013592	42.58544	<0.0001	Significant
Linear mixture	0.027184	2	0.013592	42.58544	<0.0001	
Residual	0.004149	13	0.000319			
Lack of fit	0.001806	8	0.000226	0.481461	0.829	Not significant
Pure error	0.002344	5	0.000469			
Cor total	0.031334	15				
Std. dev.	0.017865		R-Squared	0.867578		
Mean	0.957124		Adj R-Squared	0.847205		
CV%	1.866581		Pred R-Squared	0.805794		

Table 6: ANOVA for Linear Mixture Model for fat content of SPI based noodles.

*** Mixture Component Coding is U_Pseudo. ***						
Analysis of variance table [Partial sum of squares-Type III]						
Source	**Sum of Squares**	**Df**	**Mean Square**	**F Value**	**p-value Prob>F**	
Model	0.001822	5	0.000364	5.359067	0.0118	Significant
Linear mixture	0.000321	2	0.00016	2.358509	0.1448	
WF*RWF	0.000471	1	0.000471	6.927213	0.0251	
WF*DFSF	0.000537	1	0.000537	7.905854	0.0184	
WF*DFSF	0.000144	1	0.000144	2.112546	0.1767	
Residual	0.00068	10	6.80E-05			
Lack of fit	0.000296	5	5.93E-05	0.77272	0.6079	Not significant
Pure error	0.000383	5	7.67E-05			
Cor total	0.002501	15				
Std. dev.	0.008245		R-Squared	0.728226		
Mean	0.990078		Adj R-Squared	0.59234		
CV%	0.83277		Pred R-Squared	0.305582		

Table 7: ANOVA for Linear Mixture Model for fat content of DFSF based noodles.

It is found that the interaction terms WF*RWF, RWF*DFSF and WF*DFSF are significant (P<0.05). From the regression coefficient, it is seen that RWF have high regression coefficient (8.89) indicating its better impact on fat contents on SPI based products. Fat is generally affected by DFSF but the role was meager as evident from regression equation for DFSF based noodles where all three ingredients have similar impact on fat content. For DFSF based noodles, the quadratic model showed two angle effects on the fat response, first effect under increasing consistency of fat response by the increasing refined wheat flour and other hand increasing fat by the increasing wheat flour consistency. From figure 4, lowest fat value are observed corresponding to the increasing of soy protein isolates in the composition but increased in fat percentage is due to the increasing quantity of both component wheat flour and refined wheat flour.

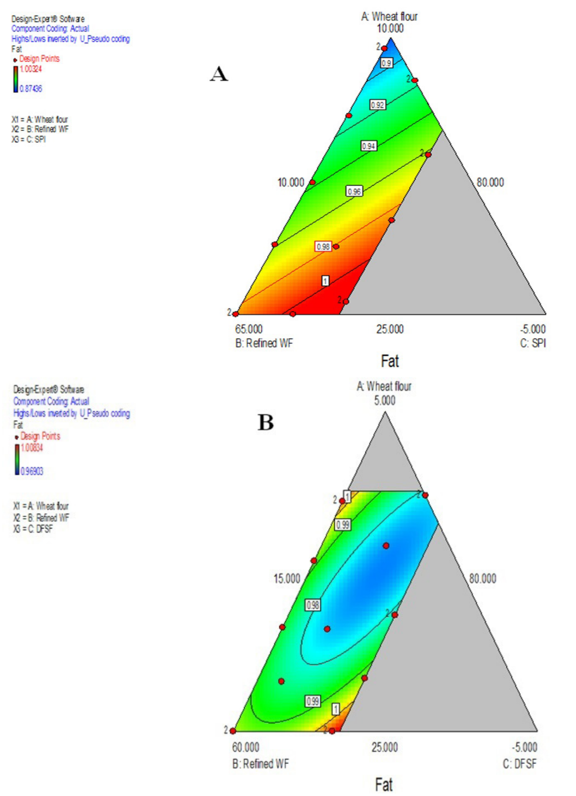

Figure 4: Effect of WF, RWF and DFSF on fat content of noodles. a) SPI based; b) DFSF based.

Generally, the protein content is believed to play a role in oil absorption in extruded product. Defeating increases the protein solubility and water absorption capacity by uncovering of hydrophilic groups in extruded starch-protein material [34] and oil absorption capacities of the extruded products [35]. Again, increase in temperature leads to starch gelatinization where depolymerisation of amylose and amylopectin resulted into the high water and fat absorption capacity of the product [36]. In contrary, Moss et al., [37] reported that noodles made from high-protein wheat flour absorbed less oil than noodles made from low-protein flour. They proposed that the high oil absorption in low-protein flour noodle was due to the formation of coarse globules during steaming, allowing oil to penetrate easily through the noodle. In our study, products having high protein contents were due to protein rich SPI which showed less oil absorption than the low protein samples. Protein content is not the sole factor influencing oil uptake, protein quality also significantly affects free oil absorption in instant noodles [38]. During moisture removal process, the spaces of water vapors may filled by fat globules causing more fat content in extruded products.

Energy content: Energy content was ranged from 338.675 to 347.321 for SPI based, and 332.87 to 387.34 Kcal for DFSF based noodle products with the CV of 0.64 and 0.29% respectively. Using t-test, it was found that mean value for both the products are statistically non significant (P<0.84, tcritical=2.11). The model were adjusted for calorie content in this mixture design, are presented in table 8 and 9. The model were significant (P<0.05; P<0.001) with non significant lack of fit (P>0.85; P>0.37) for both products.

*** Mixture Component Coding is U_Pseudo. ***						
Analysis of variance table [Partial sum of squares-Type III]						
Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob>F	
Model	38.47702	2	19.23851	3.95992	0.0454	Significant
Linear mixture	38.47702	2	19.23851	3.95992	0.0454	
Residual	63.15801	13	4.858309			
Lack of fit	26.36935	8	3.296168	0.447987	0.8504	Not significant
Pure error	36.78867	5	7.357733			
Cor total	101.635	15				
Std. dev.	2.204157		R-Squared	0.37858		
Mean	341.9144		Adj R-Squared	0.282977		
CV%	0.644652		Pred R-Squared	0.041856		

Table 8: ANOVA for Linear Mixture Model for energy content of SPI based noodles.

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob>F	
Model	31.81132	5	6.362263	6.532988	0.006	Significant
Linear mixture	14.95817	2	7.479085	7.679778	0.0095	
AB	15.47507	1	15.47507	15.89033	0.0026	
AC	0.354093	1	0.354093	0.363594	0.5599	
BC	0.171868	1	0.171868	0.17648	0.6833	
Residual	9.738673	10	0.973867			
Lack of fit	5.605641	5	1.121128	1.356302	0.3731	Not significant
Pure error	4.133032	5	0.826606			
Cor total	41.54999	15				
Std. dev.	0.986847		R-Squared	0.765616		
Mean	337.9824		Adj R-Squared	0.648423		
CV%	0.291982		Pred R-Squared	0.427936		

Table 9: ANOVA for linear mixture model for energy content of DFSF based noodles.

The regression equation describing the effect of the process variables on the fat content of product in terms of actual level of the variables are given as:

Energy: 3.20271*Wheat flour+3.49858*Refined wheat flour+3.18264*SPI……. (5) for SPI based noodles

Energy= =6.55271*Wheat flour+3.42727*Refined wheat flour+1.56198*Defatted soy flour-0.042774*wheat flour*refined wheat flour-0.035375*wheat flour*defatted soy flour-0.025897*refined wheat flour*defatted soy flour……… (6) for DFSF based noodles

From the regression coefficients, energy content is affected by the refined wheat flour (3.49858) and followed by wheat flour (3.20271), soy protein isolate (3.18264). Refined wheat flour was shown more effect compare to other both component.

However, quadratic model followed for DFSF based noodles where all the interaction terms are negative showing their negative impact on energy content. From figure 5a, with the increased in WF and RWF the energy content increased for SPI based noodles but in figure 5b, it is seen that quadratic effect of responses showed relative effect of all components but some plot area more effected by wheat flour and refined wheat flour because high consistency energy response plot area in increasing wheat flour consistency and decreasing defatted soy flour consistency.

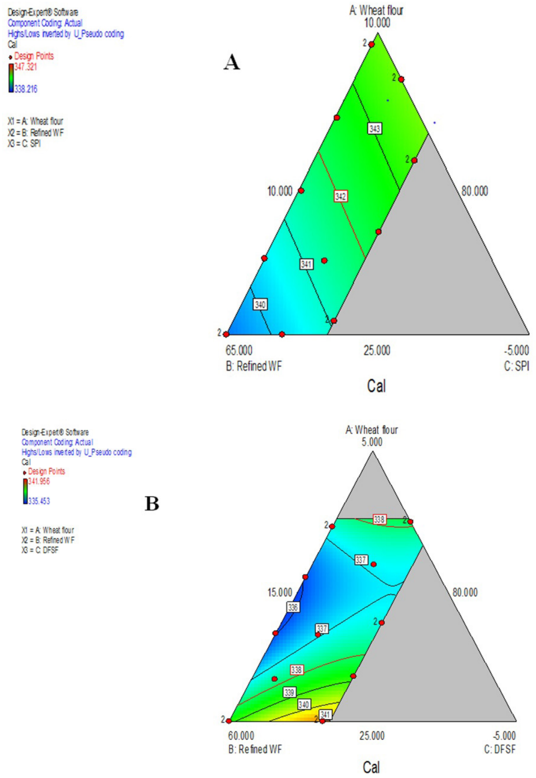

Figure 5: Effect of WF, RWF and DFSF on energy content of noodles. a) SPI based; b) DFSF based.

Optimization of process parameters

Based on the objective requirement enabling noodles having high in protein, carbohydrate and energy content, and low in fat, moisture and ash content, three combinations of products were found as mentioned in table 10.

Formulations	Protein Content (%)	Fat Content (%)	Moisture Content (%)	Ash Content (%)	Carbohydrate Content (%)	Energy Contents (kcal.)
Control	8.27	4.78	6.2	1.96	79.59	394.46
S-1	16.91	6.85	6.9	2.26	67.08	397.61
S-2	16.69	8.80	6.1	2.72	66.14	410.52
S-3	16.87	5.59	5.9	2.23	68.71	392.63

Table 10: Initial quality of most accepted soy fortified and control noodles.

Quality assessment of optimized noodles

Protein contents: Results revealed that all three samples of soy protein enriched noodles provided more protein than control sample. The protein content of soy fortified noodles were two times that of control sample. Adding of soy flour (DFSF, FFSF and SPI) to mixed flour markedly increased protein content than control sample. From the above data it is revealed that soy fortified noodles with 10% FFSF, 10% DFSF, 8% SPI and control formula contained 16.69%, 16.91%, 16.87% and 8.27% of protein contents respectively. Soy flour blended noodles recorded maximum protein 16.91 per cent in sample 1 (10% DFSF) and minimum protein 8.27% in control sample.

Fat contents: Addition of soy flour (DFSF, FFSF and SPI) to mixed flour markedly increased fat content than control sample. It is revealed that soy fortified noodles with 10% FFSF, 10% DFSF, 8% SPI and control formula contained 6.80%, 8.8%, 5.59% and 4.78% of fat contents respectively. Soy flour blended noodles recorded maximum fat of 8.80% in sample 2 (10% FFSF) and minimum fat 4.78% in control sample.

Moisture content: Incorporation of soy flour (DFSF, FFSF and SPI) to mixed flour slightly increased moisture content than control sample. From the table 10 it is revealed that soy fortified noodles with 10% FFSF 10% DFSF, 8% SPI and control formula contained 6.9%, 6.1%, 5.9% and 6.24% of moisture contents respectively. Soy flour blended noodles recorded maximum moisture of 6.9% in sample 1 and minimum moisture of 6.2% in control sample.

Ash contents: Addition of soy flour to mixed flour slightly increased ash content than control sample. It is revealed that (Table 10) soy fortified noodles with 10% FFSF 10% DFSF, 8% SPI and control formula contained 2.26%, 2.72%, 2.23% and 1.96% of ash contents respectively. Soy flour blended noodles recorded maximum ash content of 2.72% in sample 2 (10% FFSF) and minimum ash content of 1.96% in control sample.

Carbohydrates contents: Addition of soy flour (DFSF, FFSF and SPI) to mixed flour slightly decreased carbohydrate content than control sample. It is found that soy fortified noodles with 10% FFSF, 10% DFSF, 8% SPI and control formula contained 67.08%, 66.14%, 68.71% and 79.59% of carbohydrate contents respectively. Control sample recorded maximum of CHO 79.78%. Minimum carbohydrate content of 66.14% was observed in sample 2 (10% FFSF).

Energy contents: Fortification of soy flour (DFSF, FFSF and SPI) to mixed flour increased energy contents than control sample. Soy fortified noodles with 10% FFSF, 10% DFSF, 8% SPI and control formula contained 397.61 Kcal, 410.52 Kcal, 392.63 Kcal, and 394.46 Kcal of energy respectively. Soy flour blended noodles recorded maximum energy contents 410.52 Kcal in sample 2 (10% FFSF) and minimum energy contents of 394.46 Kcal in control sample.

Textural Properties Analysis (TPA) of soy fortified and control noodles

The textural quality results obtained for S-1, S-2, S-3 and control noodles are presented in figure 6. In control sample, there was slightly higher in hardness and less in gumminess as compared to all three substitutions (10% DFSF, 10% FFSF, and 8% SPI). The texture of extruded product depends mainly on the processing parameters, but chemical composition of the ingredients is also important [39]. The high content of protein might have affected characteristics of the starch matrix (i.e., the viscoelastic properties of molten extrudate) so that it no longer holds water vapor, resulting in higher break strength.

Significant ($P<0.05$) change in hardness of control samples was found than rest samples may be due to low protein content (8.27%) which is in agreement with the report by Leonel et al. and Singh et al. [40,41] reported that addition of fatty acids alters the physical and chemical properties of starchy foods. The springiness in S1-S3 is more elastic to control noodle, which means, these noodle easy to bounce back to its original position. Gumminess is the energy required to disintegrate a semisolid food to a state ready for swallowing and is a combination of hardness and cohesiveness [15]. The gumminess in S1-S3 noodle is pastier than control noodle as there was significant difference ($P<0.05$) between them. Chewiness is a combination of hardness, cohesiveness, and elasticity. In this study, control noodle is tougher than S1-S3 due to the significant existence between them. The higher value of chewiness, gumminess, cohesiveness and springiness of samples (1-3) may be due to low fat and high carbohydrate content which caused to form inclusion compounds with amylose, with the hydrocarbon portion of the lipid located within the helical cavity of amylose. This is in agreement with the report by Kaur & Singh [19].

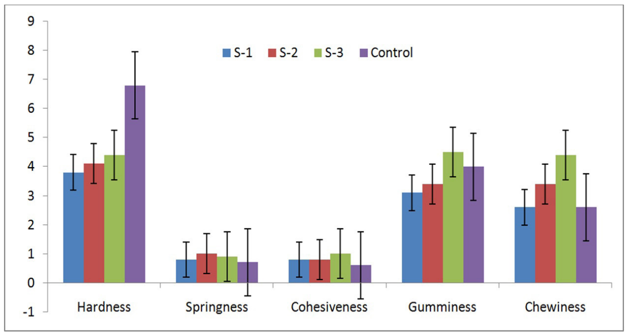

Figure 6: Textural properties of optimized noodles.

Packaging and storage of noodles

The biochemical analysis of soy fortified and control noodles packed using different packaging materials and kept for storage was done at regular intervals and the results are depicted in figure 7-9. During the packaging study of SPI fortified noodles moisture content slightly increased in LDPE and PP package. It is revealed that moisture content with LDPE, PP, PET MET/LDPE and PET/PET MET/LDPE after third month of storage were 7.8%, 6.8%, 6.25% and 5.9%, respectively. The moisture content of DFSF based noodles (Figure 9) was slightly increased (8.2, 7.2, 6.9 and 6.4%) in third month of storage as compared to SPI based products LDPE and PP packaging material and was contributed to the role in carbohydrate and energy content. From the results (Figure 10), it is revealed that moisture content of control noodles with LDPE, PP, PET MET/LDPE and PET/PET MET/LDPE after third month was 7.8%, 6.4%, 5.7% and 5.5%, respectively. The moisture content slightly increased in LDPE and PP packages during storage.

The moisture content was affected on the carbohydrate and energy which are related to nutrition value of noodles and quality of product. All types of soy fortifications for the development of noodles and control sample were more interactive to moisture in LDPE packaging material followed by PP, PET MET/LDPE, PET/PET MET/LDPE packages.

Sensory evaluation

The soy fortified noodles were served to 46 school children (age group: 7-12 years). The consumer responses were obtained in structured preformed for sensory evaluation and analyzed. The analysis suggests that soy fortified noodles was very much liked (85% of both adult and school children). Scores obtained for overall acceptability reveals that product containing 10% DFSF, 10% FFSF, 8% SPI and control are acceptable. Mean score for different characteristics of all type of packed noodles are summarized in figure 10. All types of soy fortified noodles give significant difference (P<0.05) in the term of general appearance, color and overall acceptability from control formula. On the other hand, there were no significant difference (F<0.05) among control sample and DFSF, FFSF and SPI formulas in term of stickiness and texture/mouth feel, respectively.

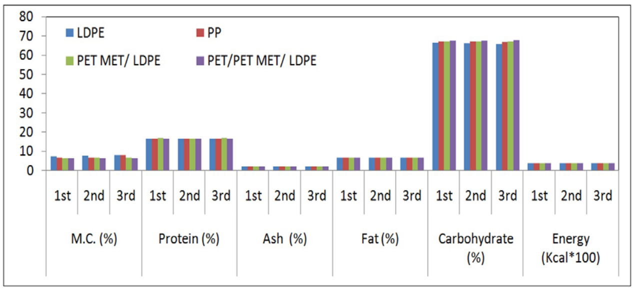

Figure 7: Variations in quality of SPI based noodles during packaging and storage for 3 months.

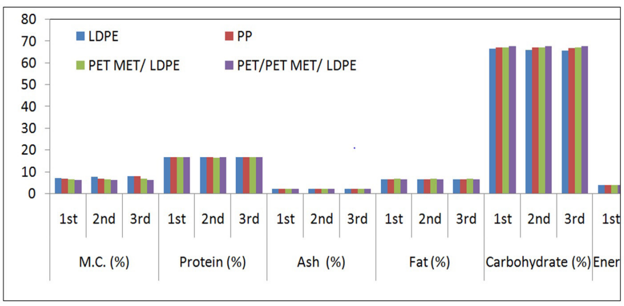

Figure 8: Variations in quality of DFSF based noodles during packaging and storage.

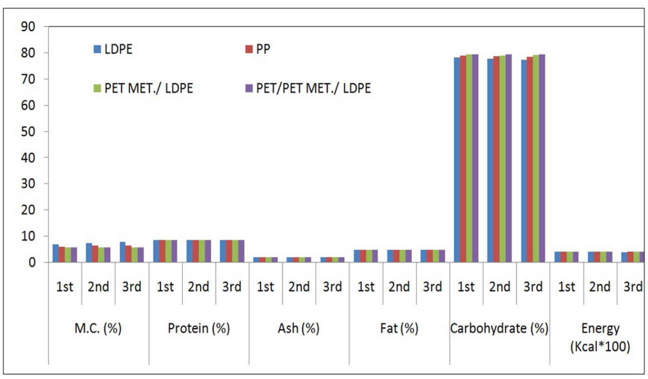

Figure 9: Variations in quality of control noodles during packaging and storage.

Conclusion

Efforts have been made to develop nutritious protein enriched healthy noodles by incorporating soy flour at 10% DFSF, 10% FFSF and 8% SPI as per ICMR/NIN requirement for soy health claim. All three (DFSF, FFSF and SPI) noodles contained more protein when compared with control noodles. The increased substitution of soy flour (FFSF, DFSF and SPI) caused brittle and hard cooked noodles strand which reduced the chewiness and increased the firmness respectively. All types of soy fortified noodles give significant difference (P<0.05) in the term of general appearance, color and overall acceptability from control formula. On the other hand, there were no significant difference (F<0.05) among control sample and DFSF, FFSF and SPI formulas in term of stickiness and texture/mouth feel, respectively. FFSF, DFSF and SPI were used as soy protein sources in soy protein enriched noodles because of their low cost and functional food characteristics. Even FFSF cost was lower than other soy protein source (DFSF and SPI). Defatted soy flour and SPI increased the protein, ash content of the noodles keeping the fat at optimum level. It is concluded that SPI and DFSF based noodles provides the best technological responses for getting high energy content and low fat content noodles products with more favourable sensory evaluation. This study focuses to develop the process for production of nutritionally balanced formulated and functional noodles in meeting the intended nutritional requirements and is also accessible to the young children at minimum possible cost. The new products were highly appreciated by the school children when it was given after mid-day-meal.

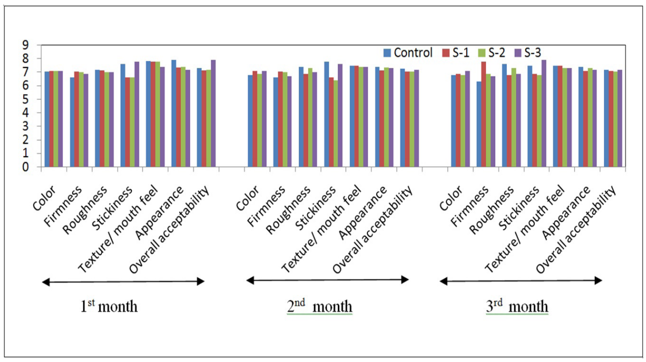

Figure 10: Mean score of soy fortified noodles obtained in sensory evaluations.

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