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ORIGINAL ARTICLE

Development of protein enriched noodles using texturized defatted meal from sunflower, flaxseed and soybean

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Abstract Texturized defatted meals from sunflower, soybean and flaxseed prepared using extrusion technology were incorporated in noodles to improve the protein content of noodles. Noodles were also evaluated for chemical composition, cooking quality, color, functional, textural and sensory properties. Sensory, color and cooking characteristics of noodles were negatively affected with increasing level as texturized flour compared with the control. Noodles with 10 % texturized sunflower and flaxseed flour received the highest sensory scores. Overall acceptability scores were maximum for control and noodles with 10 % texturized defatted meal of sunflower and flaxseed. Further incorporation of 20 % texturized defatted flour from soybean in noodle making gave satisfactory results in terms of overall acceptability. It was concluded that texturized defatted meal serve as good substitute to wheat flour with increased protein content in noodles production and utilization.

Keywords Defatted meal · Flaxseed · Sunflower · Soybean · Texturization

Introduction

Soybean, rapeseed, cottonseed, sunflower seeds and pea nuts are the most abundant protein meals and these represents a 69, 12.4, 6.9, 5.3 and 2.8 % of world protein meal production (Ash and Dohlman 2006). Vegetable proteins are deficient in sulfur amino acids when compared with animal proteins and contain antinutritive factors. These limitations are easily overcome by supplementation with other proteins and physicochemical treatments respectively. Oilseed protein makes a significant contribution to the human dietary protein intake. The purification of vegetable protein involves physicochemical and thermal processing, affecting the nutritional value of the final products, and also the functional properties, of interest when the proteomic product is destined for food or for non-food purposes. When added to foods, protein confers desirable functional properties, such as whipping capacity, viscosity, emulsification and water and oil holding capacities. Proteins play a decisive role in the nutritional, sensory, physicochemical and organoleptical properties. Protein content of defatted meals from dehulled oilseeds depends on the seed and ranges between 35 and 60 % (d.b.). As a general trend, meals contain antinutritional compounds, such as oligosaccharides, trypsin inhibitors, phytic acid, and tannins and present low protein solubility, which could limit its food applications. Texturization is considered as the effective method for removal of antinutritional factors from soybean and sunflower. Noodles were introduced as a part of the main diets in many Asian countries and also become popular in other countries outside of Asia. Noodles can be made from various cereal flours such as wheat, rice, buckwheat, and so on. Noodles, specifically wheat-based noodles were prepared by mixing raw materials, dough sheeting and cutting (Kruger et al. 1996). They are recognized as convenience of instant foods.

Due to their nutritional values and high protein content, sunflower, soybean and flaxseed plays a significant role in the manufacturing noodle. However, very little information is available on the incorporation of texturized defatted flour in making noodle. Therefore, the present study was planned with the objectives to optimize and to find out the best level on the basis of quality, to find the overall acceptability of the noodles on the basis of sensory evaluation by panelists and to study the cooking, textural, functional properties of noodle prepared

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after incorporation of texturized defatted flour of sunflower, soybean and flaxseed.

Materials and methods

Raw materials

Wheat, soybean, flaxseed and sunflower were procured from Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana.

Extrusion process for sunflower, soybean and flaxseed

The sunflower, soybean and flaxseed were cleaned and defatted using laboratory oil expeller. The meal was dried and milled into grits using Super Mill (Perten Instruments, Sweeden). After that, the sample was sieved using mesh screen to separate out the large particles of the seed coat. Texturization of sunflower, soybean and flaxseed defatted meal were carried out by using Clextral BC 21 twin screw extruder (Clextral, Firminy, France). The operating conditions were 16.36 % feed moisture, 300 rpm screw speed and 149.40 °C barrel temperature for sunflower defatted meal. The operating conditions were 19.84 % feed moisture, 300 rpm screw speed and 180 °C barrel temperature for soybean defatted meal. The operating conditions were 14 % feed moisture, 300 rpm screw speed and 120 °C barrel temperature for flaxseed defatted meal. Texturized proteins was milled into flour using cyclotec mill (Newport Scientific, Australia) and packed in suitable packaging material for further study.

Chemical characteristics

Chemical characteristics such as moisture, fat, protein and fiber of defatted meal and noodles were analyzed using standards procedures (AACC 2000).

Functional properties of blends

Functional properties of blends containing semolina and defatted texturized protein from 0 to 40 % were done as follow.

Water absorption index (WAI), water solubility index (WSI) and fat absorption capacities (FAC)

Water absorption index (WAI) was measured according to the Stojceska et al. (2009) method. First, 1 g of blended flour was placed in a previously weighed 50 ml centrifuge tube. Then, 10 ml of distilled water was added and stirred homogeneously with a glass rod and centrifuged at 3,000 rpm for 10 min at room temperature (22 °C) using a Model T-8BL Laby™ centrifuge (Laby Laboratory Instruments, Ambala Cantt, India). The residue was weighed together with the centrifuge tube. The WAI values were expressed as gram of water absorbed/gram of flour. The supernatant was transferred to previously weighed dish which put in hot air oven for evaporation of water. The residue was weighed. A similar method was used to measure fat absorption capacity (FAC), although a 0.5 g sample was used in this case (Lin et al. 1974).

$$\mathrm{WAI}\ (g/g) = \frac{\text{Weight of residue}}{\text{sample taken}}$$

$$\mathrm{WSI}\ (\%) = \frac{\text{Weight of dry matter in supernatant} \times 100}{\text{Dry weight of sample}}$$

$$\mathrm{FAC}\ (\%) = \frac{\text{Weight of fat absorbed by sample} \times 100}{\text{Weight of sample}}$$

Foaming capacity

One gram of blended flour was dissolved in 100 ml of distilled water, until the desired pH was reached (2, 4, 6, 8 and 10). Then the suspensions were whipped at a low speed blender for 1 min at room temperature (22 °C). The resulting foam was poured into a 100 ml cylinder. Total foam volume was recorded and foam capacity was expressed as the percent increase in volume. To determine foam capacity (FC), foam volume was recorded after whipping and calculated according to the method proposed by Kabirullah and Wills (1982).

$$\mathrm{FC} = \frac{\text{Final foam volume} \times 100}{\text{Initial foam volume}}$$

Protein digestibility (PD)

Protein digestibility was estimated using method given by Elkhalil et al. (2001). One gram of flour sample was taken in a conical flask. To this, 50 ml of pepsin solution (5 g pepsin in 0.1 N hydrochloric acid) was added and incubated for 24 h at 37 °C. The solution was then neutralized by adding 30 ml of 0.2 N sodium hydroxide and then 50 ml of pancreatin solution (4 gm pancreatin in 1,000 ml of phosphate buffer of pH 8) was added and again incubated for 24 h at 37 °C. An enzyme blank was also run under the same prescribed conditions. Few drops of toluene were used to maintain aseptic environment in the system. The contents were centrifuged at a high speed and were filtered through Whatmann filter paper. The residue left was then analyzed for Nitrogen content by Micro-Kjeldhal method. The digestibility coefficient was determined by subtracting the residual protein from the initial protein on the basis of 100 gm of sample.

$$\%\ \text{Nitrogen} = \frac{\text{Volume of NaoH used} \times 0.0014 \times 100}{\text{Weight of sample}}$$

$$\text{Protein digestibility } (\%) = \frac{\text{N in Supernent}-\text{N in Pepsin}}{\text{N in sample}} \times 100$$

Noodle preparation

Noodles were prepared by Regol Vite Estrusione Technologie Agro Alimentarie Impianti (Gerampi, Rome, Italy) noodle making machine. To prepare noodle sample under laboratory conditions, semolina 600 g and water were used. For noodle preparation, texturized defatted meal of sunflower, soybean and flaxseed were used to replace wheat flour in the formulation at the level of 10, 20, 30 and 40 %. Noodles formulation was given in Table 1. The ingredients (semolina and water) were mixed in mixing chamber of noodle making machine for 5 min. Dough allowed to pass through sieves with rotating screw of noodle making machine. Desired length size noodles were cut by knife manually. Noodles were dried at 50 °C for 5 h in an air oven. The dried noodle samples were packed in polyethylene bags.

Color analysis

Color of noodle samples was evaluated by measuring the L (100=white; 0=black), a (+, red; −, green), and b (+, yellow; −, blue) value. Sample size of noodle was 100 g. Noodle arranged according to lengthwise and the surface color was measured at three different positions along length of noodles using a Minolta Spectrophotometer CM-508d (Minolta Co., Ltd Japan) (Kimura et al. 1993). Mean value is mean of three readings.

Texture analysis

Texture of the noodles was evaluated on texture analyzer (TA-XT2i) (Bourne 1982). Noodles subjected to compression test to measure hardness (N) and area (Nmm). The dimension of extruded noodles is 2.5 mm in diameter and 12 in. in length. The settings used for test were pretest speed (1 mm/s), test speed (1 mm/s), post test speed (1 mm/s), distance (15 mm) and force (60 g).

Table 1 Formulation for noodles

Formulation	Level (%)	Semolina (g)	Texturized flour (g)	Water added (ml)
Control	0	600	0	230
Sunflower	10	540	60	245
	20	480	120	260
	30	420	180	275
	40	360	240	290
Soybean	10	540	60	250
	20	480	120	260
	30	420	180	280
	40	360	240	300
Flaxseed	10	540	60	260
	20	480	120	280
	30	420	180	300
	40	360	240	325

Each value is a mean of three observations (*n*=3)

Cooking quality

Cooking loss

Cooking loss of noodles samples was determined according to AACC (2000). The optimum cooking time for noodles, which was the time required to the white core in noodles strand to disappear, was determined by squeezing the noodles between two fingers. For cooking loss determination, 25 g noodle sample was cooked in 250 ml boiling water for 20 min in pan. The cooking water was collected in a tared beaker, dried to constant weight in a dry air oven at 100±1 °C. The residue was weighed and the cooking loss during cooking was calculated as a percentage of the starting material (Chakraborty et al. 2003).

Water uptake ratio

Water uptake ratio was calculated as the percentage difference in weight of noodle before and after cooking divided by the weight of noodle before cooking.

$$\text{Water uptake ratio} = \frac{(\text{Weight of noodles after cooking} - \text{Weight of noodles before cooking}) \times 100}{\text{Weight of noodles before cooking}}$$

Swelling volume

Swelling volume was determined as the percentage difference in volume was determined as the percentage difference in volume of cooked and uncooked noodles. Twenty five gram of cooked and uncooked noodle was put into 250 ml of water. Swelling volume was expressed as the percentage difference in volume of the cooked and uncooked noodle samples divided by the volume of uncooked noodle.

$$\text{Swelling volume (\%)} = \frac{(\text{Volume of noodles after cooking} - \text{Volume of noodles before cooking}) \times 100}{\text{Volume of noodles before cooking}}$$

Sensory evaluation

Noodles samples (100 g) were cooked for 18 min in 1 L unsalted water and drained. The cooking time for sensory evaluation and for losses calculations is same. Noodles were evaluated for color, appearance, taste, texture and overall acceptability by panel of semi trained judges (Larmond 1970).

Statistical analysis

Factorial CRD with multiple replications was carried out and difference between means was obtained using CPCS-1 software developed by the Department of Mathematics and Statistics, PAU, Ludhiana, India. All the statistical procedures were performed at a significance level of 95 % (Singh et al. 1991).

Results and discussion

Chemical composition

Defatted meal characteristics

The defatted sunflower meal had 2.56 % moisture, 2.54 % fat, 43.38 % protein, 13.07 % fiber and 32.54 % protein digestibility. The defatted soybean meal had 2.70 % moisture, 2.26 % fat, 52.86 % protein, 3.29 % fiber and 56.33 % protein digestibility. The defatted flaxseed meal had 2.61 % moisture, 2.71 % fat, 38.24 % protein, 12.24 % fiber and 43.77 % protein digestibility (Table 2).

Functional properties

All functional properties excluding fat absorption capacity increased significantly with increase in level of texturized defatted flour of sunflower, soybean and flaxseed (Table 3). Functional properties improved because of protein content increased with increased level of texturized defatted flour of sunflower, soybean and flaxseed as these were rich in proteins. Sudha et al. (1998) showed functional properties were lowered with increase in level of finger millet flour as protein content decreased in blend but reverse was case in present study. But in cases since texturized protein was added. So functional properties improved expect for fat absorption.

Water absorption index, water solubility index, foaming capacity and protein digestibility increased with increased level of incorporation of texturized defatted flour of sunflower, soybean and flaxseed in semolina for noodle making. Fat absorption capacity decreased with increased level of incorporation of texturized defatted flour of sunflower, soybean and flaxseed flour in semolina for noodle making. Decrease in fat absorption with increased protein content is desirable because low fat consumption keeps human healthy. It has been reported that protein content had an inverse correlation with free lipid level of instant noodles (Moss et al. 1987; Park and Baik 2004). Therefore noodle made from protein rich texturized defatted flour of sunflower, soybean and flaxseed absorb less fat as compared to controls.

Table 2 Chemical composition of defatted meal

Defatted meal	Moisture content (%) ± SD	Fat (%) ± SD	Protein (%) ± SD	Fibre (%) ± SD	PD (%) ± SD
Sunflower	2.56±0.33	2.54±0.08	43.38±0.39	13.07±0.02	32.54±0.06
Soybean	2.70±0.27	2.26±0.04	52.86±0.68	3.29±0.29	56.33±0.05
Flaxseed	2.61±0.12	2.71±0.07	38.24±0.58	12.24±0.93	43.77±0.09

Each value is a mean of three observations (n=3)

SD Standard deviation; *PD* Protein Digestibility

Table 3 Effect of incorporation of texturized defatted meal on functional properties of blends

Sample	Percent	Functional properties				
		Water absorption index (g/g) ± SD	Water solubility index (%) ± SD	Fat absorption capacity (%) ± SD	Foaming capacity (%) ± SD	Protein digestibility (%) ± SD
Control	0	5.51±0.025	7.84±0.053	104.79±0.616	8.12±0.031	38.75±1.700
Sunflower	10	6.11±0.032	6.52±0.025	96.15±1.031	7.58±0.042	49.37±1.057
	20	6.24±0.015	7.24±0.040	91.88±0.729	10.40±0.036	54.83±1.380
	30	7.45±0.036	8.10±0.040	77.80±0.300	12.82±0.025	57.99±0.498
	40	7.65±0.055	8.233±0.042	75.99±0.325	15.62±0.031	61.12±0.562
Soybean	10	6.16±0.035	7.14±0.036	92.80±0.300	23.18±0.025	74.56±0.967
	20	6.67±0.031	7.51±0.026	90.63±0.666	24.72±0.025	79.40±0.946
	30	7.38±0.015	8.23±0.026	89.06±0.153	25.14±0.040	81.53±1.011
	40	7.85±0.036	8.39±0.031	87.53±0.104	25.82±0.035	81.23±1.021
Flaxseed	10	6.22±0.025	6.91±0.046	98.68±0.257	14.72±0.026	56.14±1.446
	20	6.90±0.015	7.30±0.031	97.54±0.406	15.43±0.031	59.61±1.432
	30	7.62±0.026	8.13±0.036	84.28±0.193	15.87±0.031	61.64±0.798
	40	7.95±0.044	8.45±0.040	83.35±0.175	16.13±0.057	63.87±0.478
LSD ($p<0.05$)		0.05	0.06	0.80	0.056	1.82

Each value is a mean of three observations ($n=3$)

SD Standard deviation

Noodles characteristics

Moisture content of noodles incorporated with defatted sunflower meal at 10, 20, 30 and 40 % level ranges from 2.44, 2.55, 2.7 and 2.76 %, respectively. Protein, fat, fiber ash and protein digestibility of noodles incorporated with defatted sunflower meal increased as compared to control (Table 4). Noodles incorporated with defatted soybean (10, 20, 30 and 40 %) and flaxseed (10, 20, 30 and 40 %) meal showed increased water absorption and improved protein digestibility with increasing levels of incorporation. The proper water absorbance was determined by appearance and handling properties of dough. Similarly for noodle incorporated with defatted soybean (10, 20, 30 and 40 %) and flaxseed (10, 20, 30 and 40 %) meal showed increased protein, fat, fiber ash and protein digestibility as compared to control (Table 4).

Table 4 Chemical composition of noodles prepared from texturized defatted meal of sunflower, soybean and flaxseed

Sample	%	Moisture (%) ± SD	Protein (%) ± SD	Fat (%) ± SD	Fiber (%) ± SD	Ash (%) ± SD
Control	0	2.38±0.02	9.29±0.015	1.57±0.026	2.19±0.031	0.68±0.026
Sunflower	10	2.44±0.04	13.75±0.025	2.90±0.015	14.84±0.017	1.29±0.021
	20	2.55±0.02	15.92±0.026	3.19±0.020	15.12±0.015	1.77±0.062
	30	2.70±0.01	18.19±0.015	3.34±0.050	18.55±0.045	2.26±0.021
	40	2.76±0.02	20.40±0.020	5.31±0.051	19.09±0.056	2.50±0.025
Soybean	10	2.60±0.06	14.59±0.021	4.91±0.026	10.39±0.015	1.20±0.015
	20	2.66±0.03	17.64±0.015	5.01±0.074	12.22±0.026	1.72±0.020
	30	2.80±0.02	20.74±0.026	5.11±0.040	14.18±0.219	2.21±0.036
	40	2.85±0.02	23.77±0.021	6.27±0.025	15.63±0.036	2.45±0.025
Flaxseed	10	2.49±0.12	13.12±0.025	3.06±0.040	9.58±0.015	1.14±0.015
	20	2.56±0.22	14.74±0.015	3.88±0.026	10.25±0.026	1.24±0.021
	30	2.64±0.01	16.35±0.031	4.49±0.067	12.39±0.021	1.76±0.012
	40	2.70±0.17	17.99±0.101	4.90±0.025	13.49±0.031	2.21±0.021

Each value is a mean of three observations ($n=3$)

SD Standard deviation

Color measurements of noodles

Color is one of the most important features in quality of noodles. Results from color evaluation showed that there was slight variations in the a and b value of the noodle samples which were marginally affected by addition of texturized defatted flour of sunflower, soybean and flaxseed for noodle making (Table 5). The result showed that the amount of texturized defatted flour of sunflower, soybean and flaxseed for noodle making significantly affect L, a, and b value. Visually noodles become darker with increased level of texturized defatted flour of sunflower, soybean and flaxseed. The lightness (L) for noodle incorporated with texturized defatted sunflower flour (10–40 %) ranged from 53.21 to 48.35. Similar finding were reported by Rayas Durate et al. (1966) and Chillo et al. (2008) where lightness (L) value for spaghetti containing buckwheat flour decreased significantly as compared to control.

Textural properties of noodles

Instrumental measurement of cooked noodle texture can be a reliable and convenient alternative evaluation to the sensory method (Lee et al. 1987). Due to the above reasons, instrumental method is widely used for the measurement of noodle texture (Hatcher et al. 1999). Textural properties of noodle prepared from texturized defatted flour of sunflower, soybean and flaxseed were affected by the composition of flour blends as shown in Table 5. The incorporation of texturized defatted sunflower flour at the level of 10, 20, 30 and 40 % in flour for noodle making caused decrease in hardness (firmness) of noodle from 2.85 to 2.16 N as compared to control (7.09 N). Similarly, the hardness for noodles incorporated with texturized defatted flour of soybean and flaxseed at the level of 10, 20, 30 and 40 % in flour for noodle making ranged from 5.13 to 2.44 N and 4.94 to 3.50 N, respectively. However, flour protein content was not correlated with surface firmness. Surface firmness might vary with the degree of gluten development in the dried salt noodle (Oh et al. 1985). Rupture energy decreased significantly for noodle prepared from texturized defatted flour of sunflower, soybean and flaxseed. Texture is a critical characteristic of noodles and many ingredients such as starch, water and protein, and additives like gum play important roles in defining the textural properties. Water absorption level has a major impact on textural properties of oriental noodles (Hatcher et al. 1999). As shown in Table 3 water absorption of texturized protein was more. So addition of texturized defatted meal resulted in better texture in noodles.

Cooking quality of noodles

Cooking quality is the characteristics of most importance to consumer and therefore of great importance to noodle processors. The result indicated that the cooking loss increased from 6.55 to 7.94 for texturized defatted flour of sunflower (10 to 40 %), 5.60 to 7.59 % for soybean (10 to 40 %) and 6.18 to 8.61 % for flaxseed (10 to 40 %) incorporation in noodles (Table 6). The differences in cooking quality were attributed primarily to gluten fraction. This is because by increasing the amount of texturized defatted flour of sunflower, soybean and flaxseed in noodle making, the gluten fraction was diluted,

Table 5 Effect of incorporation of texturized defatted meal on the color (L, a, b values) and textural properties of noodles

Sample	Percent	L ± SD	a ± SD	b ± SD	Hardness (N) ± SD	Area (Nmm) ± SD
Control	0	73.01±0.76	1.41±0.09	10.14±0.43	7.09±0.15	0.12±0.02
Sunflower	10	51.28±0.12	0.61±0.19	4.23±0.21	2.86±0.47	0.07±0.02
	20	46.89±1.52	0.68±0.10	4.53±0.21	2.60±0.40	0.04±0.03
	30	43.89±0.82	0.78±0.02	5.50±0.35	4.73±0.56	0.07±0.02
	40	38.77±0.88	0.94±0.04	5.92±0.03	2.66±0.25	0.03±0.01
Soybean	10	63.41±1.70	1.18±0.15	11.03±0.13	5.14±0.71	0.08±0.01
	20	60.61±1.13	1.16±0.10	11.37±0.34	2.07±0.34	0.02±0.02
	30	59.38±0.22	2.20±0.01	12.79±0.32	3.25±0.21	0.03±0.01
	40	58.64±0.45	2.54±0.05	12.51±0.14	0.44±0.05	0.02±0.01
Flaxseed	10	53.21±2.70	2.36±0.38	5.62±0.61	3.51±0.18	0.05±0.04
	20	53.41±1.22	2.39±0.04	5.96±0.67	4.94±0.44	0.06±0.01
	30	50.64±1.77	2.61±0.03	6.21±0.36	5.38±0.36	0.07±0.01
	40	48.35±0.30	2.91±0.04	6.82±0.30	3.87±0.29	0.05±0.01
LSD (p<0.05)		2.121	0.233	NS	0.55	0.047

Each value is a mean of three observations (n=3)

SD Standard deviation; *LSD* Least significant difference; *NS* non significant

Table 6 Effect of incorporation of texturized defatted meal on cooking quality of noodles

Sample	Percent	Cooking time (minutes)	Cooking loss (d.b. g%) ± SD	Water uptake ratio ± SD	Swelling volume (ml/g) ± SD
Control	0	18	6.55±0.076	2.88±0.015	1.64±0.025
Sunflower	10	14	6.55±0.214	3.27±0.026	1.91±0.026
	20	13	6.64±0.026	3.53±0.031	2.47±0.015
	30	13	7.37±0.030	3.88±0.026	2.63±0.021
	40	12	7.94±0.038	4.07±0.025	2.75±0.026
Soybean	10	13	5.60±0.030	3.20±0.031	1.96±0.015
	20	12	6.26±0.046	3.64±0.025	2.39±0.025
	30	11	7.49±0.015	3.80±0.025	2.83±0.036
	40	10	7.59±0.036	3.91±0.025	2.93±0.015
Flaxseed	10	14	6.18±0.032	3.18±0.026	1.70±0.057
	20	13	6.95±0.094	3.40±0.053	2.38±0.031
	30	12	7.10±0.031	3.60±0.021	2.60±0.031
	40	11	8.61±0.057	3.78±0.032	2.74±0.036
LSD ($p<0.05$)			3.44	0.04	0.04

$n=3$

SD Standard deviation; *LSD* Least significant difference

leading to less water retention for noodle. Therefore, increasing amount of texturized defatted flour increase the functional dough properties and decrease the cooking quality of noodle. The amount of residue in cooking water is commonly used as an indicator of cooked pasta quality. Low amount of residue indicate high pasta cooking quality (DelNobile et al. 2005). Dick and Young (1988) considered that cooking loss of 7 to 8 % to be acceptable for dried pasta. In present study, cooking loss for noodle from blends less that 9 %. The cooking loss on dry basis decreased significantly with increased level of texturized defatted flour in semolina for noodle making as compared to control. The cooking time of noodles developed from texturized defatted flour of sunflower, soybean and flaxseed varied from 11 to 14 min. The influence of flour protein on the quality characteristics of dry noodles was investigated by Oh et al. (1985) who found that the optimum cooking time of dried salt noodles increased linearly with flour protein content.

The cooking characteristics of noodles prepared from texturized defatted flour of sunflower, soybean and flaxseed revealed that water uptake ratio of cooked noodle increased significantly with increased level of above said ingredients in noodle making as compared to control (Table 6). Water uptake ratio for noodles increased with increased level of incorporation of texturized defatted flour of sunflower (10–40 %), soybean (10–40 %) and flaxseed (10–40 %) which ranged from 3.27 to 4.07, 3.20 to 3.91 and 3.18 to 3.78, respectively. Similarly Singh et al. (2006) reported a volumetric expansion index of 2.7 to 3.9 for extrudate made out of Soy-kodo blends.

Table 7 Effect of incorporation of texturized defatted meal on sensory property of noodles

Sample	Percent	Color	Appearance	Taste	Texture	Overall acceptability
Sunflower	0	7.90	8.00	8.00	7.90	8.03
	10	7.40	7.80	7.60	7.40	7.55
	20	7.00	7.00	7.00	6.80	6.90
	30	6.20	6.80	7.00	6.40	6.60
	40	5.40	5.40	6.20	5.80	5.70
LSD ($p<0.05$)		0.99	1.18	0.84	0.91	0.76
Soybean	0	7.90	7.90	8.00	8.10	8.20
	10	7.80	8.30	8.50	8.50	8.42
	20	8.20	8.10	8.30	8.00	8.46
	30	7.80	7.60	8.10	8.00	7.85
	40	7.10	7.10	7.60	8.00	7.35
LSD ($p<0.05$)		0.60	0.72	NS	NS	0.40
Flaxseed	0	7.90	8.00	8.00	7.90	8.03
	10	8.10	8.20	8.00	8.00	8.15
	20	7.10	7.40	7.10	6.90	7.05
	30	6.30	6.30	6.10	5.90	6.10
	40	5.20	5.60	5.50	5.25	5.58
LSD ($p<0.05$)		0.54	0.71	0.70	0.69	0.52

Each value is a mean of ten observations ($n=10$)

LSD Least significant difference; *NS* non significant

Sensory evaluation of noodles

The sensory evaluation is the nearest to consumer's estimation and still remains the most reliable test because it allows the overall characteristics of cooked noodle to be evaluated. The sensory evaluation of cooked noodles is shown in Table 7. Regarding color, appearance, taste, texture and overall acceptability of the noodles incorporated with texturized defatted flour of 10 % sunflower, 20 % soybean and 10 % flaxseed appeared to have acceptability nearest to control. These findings might conclude that using texturized defatted flour of 10 % sunflower, 20 % soybean and 10 % flaxseed received the overall acceptability scores closest to control. The result revealed that color of noodles becomes darker (from light brown to dark brown) while increasing the level of texturized defatted flour of sunflower and flaxseed while it become darker yellow in case of texturized defatted flour of soybean incorporated noodles. Sensory evaluation of noodle eating quality is a direct and ultimate method for evaluating the final product. Nevertheless, sensory evaluation is very subjective, laborious and expensive and, therefore, quicker and more accurate methods to identify wheat flour suitable for noodles are required (Hou 2001).

Conclusion

The incorporation of texturized defatted flour of sunflower, soybean and flaxseed improved the quality of noodle in terms of protein, fibres, taste and protein digestibility. As for increasing the amount of texturized defatted flour of sunflower, soybean and flaxseed flour for noodle processing, handling and cooking loss deteriorated proportionally while functional properties like water absorption index, water solubility index, foaming capacity and protein digestibility increased proportionally but fat absorption capacity decreased proportionally. Noodles supplemented with texturized defatted flour from 10 % sunflower, 20 % soybean and 10 % flaxseed were observed to have acceptable sensory properties. This has also resulted increase in protein 13.75 % for sunflower, 17.64 % soybean and 13.12 % for flaxseed and fiber 14.84 % for sunflower, 14.18 % soybean and 9.58 % for flaxseed content of noodles Hence the texturized defatted flour of sunflower, soybean and flaxseed incorporation had potential as ingredients in novel noodle products targeting health conscious consumers who associate with darker colored cereal based food having superior nutritional composition. This could in turn lead to an increase in food availability and helps to improve the nutrition of the rural population of India.

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