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Enrichment of Wheat Flour Noodles with Oat Flour: Effect on Physical, Nutritional, Antioxidant and Sensory Properties

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ABSTRACT

The incorporation of oat flour in noodles preparation can improve its nutritional status and provide various health benefits to diabetic and cardiovascular patients. Present investigation was carried out with an aim to prepare nutrient rich noodles with supplementation of oat flour. The fortification was carried out by replacing wheat flour at 10, 20, 30, and 40% respectively with oat flour. The diameter of fortified noodles increased gradually with increasing level of oat flour. The brightness and whiteness index reduced, redness increased while yellowness decreased. The moisture content reduced gradually while no major changes were noticed in fat and ash content in the fortified noodles. The protein content improved significantly by 1.15 to 1.67 times while the fiber content from 1.73 to 3.41 folds respectively as compared to the control. The DPPH and ABTS radical scavenging activities had a steep increment with rising levels of oat flour. The sensory analysis revealed that maximum 20% oat flour can be incorporated in noodles to achieve considerably higher overall acceptability that was confirmed by t-test at significance level $p<0.05$.

Introduction

Noodles are highly popular in several (various) developed and developing countries including India because of less cooking time, and its good palatability (Aydin and Gocmen, 2011). During the past two decades, the consumption of noodles has increased considerably not only due to the changes in customer mindset and perspective but also the nutritional awareness amongst them (Mahmoud *et al.*, 2012). The noodles can also serve special dietary needs as their nutritional quality can be further increased by means of fortification of numerous components from buckwheat, hull less barley, rye flour, malted ragi flour, sweet potato flour (Hatcher *et al.*, 2005; Bilgicli *et al.*, 2009; Kulkarni *et al.*, 2012). The major ingredients required for noodles preparation are wheat flour, water, and salt while the addition of other minor ingredients like vegetable oil, glycerol monosterate, gums, gluten, etc. is required to meet the dough quality and also enhance cohesiveness, gumminess, springiness and chewiness properties (Day *et al.*, 2005; Kaur *et al.*, 2005; Prabhasankar *et al.*, 2007; Zawawi *et al.*, 2014). Commercially, wheat flour noodles are convenient and tasty food products that are rich in carbohydrates but are deficient in essential nutrients such as proteins/essential amino acid, dietary fibers, minerals and vitamins. The nutritional status of noodles however can be improved by incorporating nutritional components that are rich in protein and other nutrients (Chin *et al.*, 2012). Nowadays, high fiber components are becoming important constituent for fortification in processed and functional foods (Demirbas *et al.*, 2005). High fiber ingredients possess numerous properties which directly or indirectly influence the physiological and functional properties of foods. Fibers from different plant sources have been incorporated in food products to enhance the color, texture and aroma of the prepared product (Gupta *et al.*, 2010). Food and Drug Administration suggests the consumption of β-glucan soluble fiber (3 g/day) from several sources or products prepared from rolled oats. Oat bran is effective in reducing low density lipids and total cholesterol levels in serum. The cereal based food products are highly preferred and are consumed before and after meal by a wide range of consumers. Additionally, they possess a better shelf life and are also regarded as concentrated food because of their high nutrient content. Oat (*Avena sativa* L.) is a cereal that has finding ample applications in food fortification due to their high energy and nutritional value in particular high dietary fiber, vitamins and minerals content (Rasane *et al.*, 2015).

Oat, a cereal crop grown on about 500,000 hectares of land in India, is used for medicinal purposes and is a good source of fiber, protein and minerals. Oat grain is studied widely due to its particular chemical composition, nutritive and physiological values. They are a rich source of dietary fiber and specifically β-glucan which helps to minimize the blood cholesterol level by enhancing the excretion of bile in the body; decreases the risks of colon cancer and revel excellent antioxidant properties owing to presence of several phenolic compounds (Rasane *et al.*, 2015). Oat flour has good protein quality content and also shares a high score of essential amino acid as compared to wheat flour (Litwinek *et al.*, 2013). Therefore, several oat hydrocolloids are being developed to increase the β-glucan content of particular oat product. The oat hydrocolloid products with β-glucan possess numerous functional food applications in order to modify starch gelatinization and retrodegradation, maintain consistent rheology and texture of food products, reduce calories and fat content in food and also impart thawing/freezing stability (Inglett *et al.*, 2014).

Composite or multicereal/grain flour products are prominently focused as the primary carriers of nutrition. Additionally, these composites help to minimize the quantity of wheat flour required and also extend the accessibility and availability of wheat flour (*Gupta et al.*, 2010). There is huge opportunity to utilize the composite or multicereal/grain product development to meet customer needs and improve the diet. Hence the current work was carried out with a perspective to improve the nutritional quality of wheat flour formulated noodles by supplementing maximum level of oat flour to wheat flour without significantly affecting its sensory attributes.

Materials and Methods

Required raw material *viz.* oat flour (Brand: Quaker® Oats), wheat flour (*Triticum durum* L. variety *Lokwan*), table salt (Tata salt) and double filtered groundnut oil (Brand: Dhara) were purchased from local super market, Jalgaon, India. Glycerol monosterate (GMS), guar gum, gluten and TBHQ (t-butyl hydroquinone) were procured from Sigma-Aldrich, Mumbai, India. All the other chemicals and reagents used for analysis were of high purity and of analytical grade and procured from reliable sources.

Preparation of control noodles

The control noodles were prepared with slight modifications in trial and error method in noodles formulation as explained by Kulkarni *et al.,* (2012). The wheat flour (200 g) was mixed with salt (4 g) using a grinder to produce a uniform dry mix. This dry mix was further mixed with water (100 ml) and vegetable oil (26 ml containing 200 ppm TBHQ) and mixing was continued for 5 min till the dough developed a workable consistency. The dough was then allowed to rest for 10 min and further passed through a noodles making machine (Lab Scale Extruder Noodle Making Machine, Lab Line Instrument, Amravati, India) with rollers gap adjusted to 3 mm and speed 15 rpm. The obtained sheet was folded several times and again passed through noodles making machine with rollers gap adjusted to 1.5 mm. The prepared sheet was given a rest of 10 min and then passed through rolling cutter rotating at 25 rpm speed. The obtained noodles were collected and then dried in hot air oven at 55°C for 4 h. The dried noodles were packed in high density polyethylene bags and stored at room temperature for further analysis.

Preparation of fortified noodles

The fortified noodles were prepared by incorporating oat flour at 10, 20, 30 and 40% concentration of the wheat flour in the control noodles formulation. The recipe for control and fortified noodles formulation and coding given is as shown in Table 1.

Physical parameters

The diameter of the prepared noodles was measured by using Verniercalliper (ICI), while the color was determined by estimating L, a and b values using Hunter Lab (model DP-9000 D25 Hunter Associates Laboratory, Reston, VA, USA) as explained by Adsare *et al.,* (2016).

Proximate composition

The proximate composition of wheat flour, oat flour and prepared noodles was determined according to AACC (2000) methods. Moisture was analyzed by gravimetric method using hot air oven at 100-105°C for 4 h (AACC, method 44-15A). Fat content was determined by petroleum ether extraction further followed by evaporation till a constant weight was achieved (AACC, method 30-25). Protein content (N (%) × 5.7) was estimated by Kjeldahl method (AACC, method 46-13) using protein analyzer (Pelican Digetion-Kelplus KES 04LVA, Chennai, India). The crude fiber content was measured by acid and alkali digestion procedure (AACC, method 32-07) using Pelican Fibraplus FES04AS, Chennai, India instrument. Ash content was calculated by using dry combustion method (AACC, method 08-01).

Antioxidant activities

The respective flour and noodles samples (1 g) were dissolved in 95% ethanol (10 ml) and agitated at room temperature 120 rpm for 6 h followed by centrifugation at 8,000 rpm for 8 min. The supernatant was used to analyze the antioxidant capacity *viz.* the ability to scavenge DPPH and ABTS free radicals and which were estimated by the method explained by Kurhade *et al.,* (2016) and expressed as % inhibition and Trolox equivalent i.e. TE (µM/g).

Sensory analysis

The sensory analysis of noodles was carried by a panel of 10 members. The developed noodles were offered to panelists for sensory evaluation by converting into a finished product. The finished product was made by boiling noodles (100 g) in single toned buffalo milk (200 ml) and sugar (50 g) with cooking time of 12 min. The panelists were asked to evaluate the finished product for appearance, color, texture, flavor and overall acceptability. A 9 point Hedonic scale was used for the sensory evaluation and the results obtained were analyzed statistically using t-Test with software (Microsoft Excel, 2010).

Statistical analysis

All the results were performed in triplicates and results are expressed as mean±SE. The mean, standard deviation and standard error were calculated by using Microsoft Excel, 2010.

Results and Discussion

Proximate composition of flours

The proximate composition (%) of wheat flour and oat flour is enlisted in Table 2. The obtained results for wheat flour were in correlation with earlier results reported by Kulkarni *et al.,* (2012), while the oat flour results were found to be in agreement with Johansson *et al.,* (2004); Virkki *et al.,* (2005); Majzoobi *et al.,* (2012). The results revealed that the proteins and minerals content of oat flour was 28.26% and 21.05% respectively higher than wheat flour indicating it to be their vital source. The crude fiber and fat content was 7.36 and 6.74 folds superior than the wheat flour revealing it to be their potential source. The antioxidant activity of wheat flour was 41.72±3.18 TE (µM/g) and 0.45±0.05 TE (µM/g) while that of oat flour was 97.41±0.35 TE (µM/g) and 2.53±0.03 TE (µM/g) as estimated by ABTS and DPPH assays, respectively. The presence of phenolic compounds and some polypeptides in wheat flour are responsible for its antioxidant properties (Kurhade *et al.,* 2016). The oats are reported to contain numerous polyphenolic compounds like avenanthramides, anthranilic acids, and ester coupled alkyl conjugates, ether and ester coupled glycerides which contribute to antioxidant activities (Rasane *et al.,* 2015).

Effect of oat flour fortification in physical and chemical parameters of noodles

The dough obtained by fortification of oat flour was not of workable/desirable consistency as it was much softer, more viscous and less elastic. Soft and viscous dough is not suitable for preparation of noodles (Majzoobi *et al.,* 2012). In order to achieve oat flour fortified dough of workable consistency, the recipe was modified by introducing guar gum, wheat gluten and GMS (Table 1). Excess water (15-20 ml) was required for the development of proper dough. The processing conditions and preparation method were kept same for control and fortified noodles. The presence of several carbohydrates and numerous non-polar side chains components in flours may impair the water holding and affect the dough development (Kinsella, 1976; Sathe *et al.,* 1982). The guar gum added plays a significant role as a thickener and also supports in enhancing the gluten structure which further contribute to the texture of the noodles (Li *et al.,* 2014). The addition of GMS at defined concentration in noodles helps to slightly reduce the hardness and moderately increase in cohesiveness, gumminess, springiness and chewiness (Kaur *et al.,* 2005). The supplementation of guar gum supports to augment the water binding capacity of the noodles during cooking (Sanchez *et al.,* 1995; Kulkarni *et al.,* 2012). The salt added facilitates the protein network development, imparts a pliable mouth feel to noodles and also helps to prevent the microbial growth by inhibiting numerous enzyme activities (Li *et al.*, 2014). The control and prepared noodles using supplementation of oat flour at different concentrations are shown in Figure 1.

Physical properties

The effect of fortification of oat flour stipulated a gradual increase in the diameter of noodles (Table 3). The diameter of noodles fortified with oat flour by 10, 20, 30 and 40% increased by 1.06, 1.28, 1.39 and 1.67 folds respectively. The enhancement in diameter might be due to reduction of carbohydrate content with increasing oat flour content and incorporation of increasing amount of gluten which might have contributed in development of strong protein network (Mahmoud *et al.*, 2012). The color determined by measuring *L**, *a** and *b** values represents brightness, redness and yellowness of noodles, respectively (Adsare *et al.*, 2016). The control noodles illustrated highest *L** values which reduced steadily with increasing oat flour content (Table 3). The *a** value rise while the *b** value decreased indicating increased redness and declined yellowness with increasing incorporation of oat flour in the wheat flour. A gradual decline in the brightness of noodles with increasing oat flour levels was noticed as evident from the steady decline in whiteness index of noodles. The decline in whiteness may be attributed to increase in fiber content which along with the polyphenols oxidase enzyme results in dark coloration (Han *et al.*, 2017). Similar trend in color pattern was recorded during noodles preparation by incorporation of Kenaf seeds yellow (Zawawi *et al.*, 2014).

Fig.1 Prepared noodles by incorporation of different levels of oats flour in wheat flour

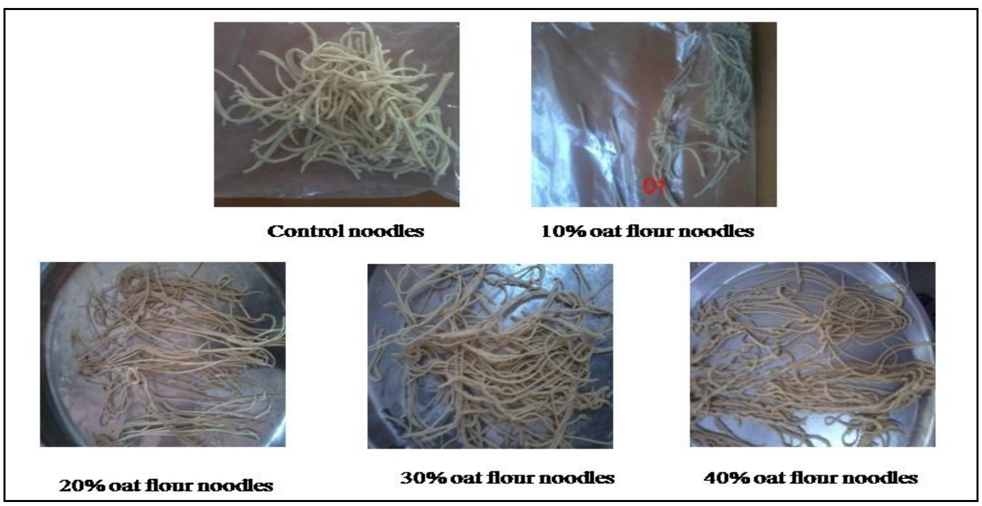

Table.1 Formulation used for preparation of control and oat flour fortified noodles

Sample code	Wheat flour (g)	Oat flour (g)	Salt (g)	Vegetable oil (g)	Guar gum (g)	GMS (g)	Wheat gluten (g)
C	200	-	4	26	-	-	-
O1	180	20	4	26	4	1	2
O2	160	40	4	26	4	1	4
O3	140	60	4	26	4	1	6
O4	120	80	4	26	4	1	8

Table.2 Proximate composition of wheat flour and oat flour

Sr. No.	Parameters	Wheat flour	Oat flour
1	Moisture (%)	9.72±0.09	8.64±0.21
2	Fat (%)	1.15±0.10	7.75±0.13
3	Protein (%)	10.73±0.23	13.57±0.18
4	Ash (%)	1.52±0.0.11	1.84±0.12
5	Crude fiber (%)	0.47±0.06	3.46±0.0.06
6	Carbohydrate (%)	76.44±0.43	64.71±0.37

Table.3 Effect of incorporation of different levels of oat flour in wheat flour on physical parameters of noodles

		C	O_1	O_2	O_3	O_4
Diameter (mm)		1.23±0.03	1.30±0.05	1.58±0.11	1.71±0.005	2.06±0.14
Color	L*	55.56±1.32	51.12±0.71	50.76±1.45	45.69±2.34	47.81±0.42
	a*	2.73±0.21	4.70±0.45	6.19±0.76	5.87±0.53	7.12±0.20
	b*	23.63±0.58	22.50±0.97	20.95±0.78	20.08±0.83	19.70±0.62
Whiteness Index		51.09±0.94	46.58±0.79	45.47±1.64	41.85±2.04	42.25±0.27

Table.4 Effect of incorporation of different levels of oat flour in wheat flour on chemical parameters of noodles

Sample code	Moisture (%)	Total fat (%)	Protein (%)	Crude fiber (%)	Ash (%)	Carbohydrate (%)
C	6.26±0.25	12.76±0.50	8.83±0.31	0.41±0.06	1.31±0.20	70.45±2.85
O_1	4.99±0.12	13.48±0.50	10.18±0.32	0.71±0.04	1.32±0.05	69.33±0.86
O_2	5.27±0.08	13.91±0.23	10.77±0.14	0.93±0.04	1.34±0.03	67.77±0.44
O_3	5.42±0.23	14.24±0.38	13.27±0.20	1.16±0.05	1.37±0.02	64.57±0.51
O_4	5.59±0.10	14.51±0.64	14.76±0.21	1.40±0.03	1.39±0.03	62.35±0.70

Results are mean ±SEM of three determinations

Table.5 Effect of incorporation of different levels of oat flour in wheat flour on antioxidant properties of noodles

Parameters		Control	O_1	O_2	O_3	O_4
DPPH	% inhibition	14.18±1.77^{e}	19.36±0.22^{d}	23.25±0.24^{c}	28.36±0.23^{b}	34.39±0.15^{a}
	TE (µM/g)	35.70±2.76^{e}	48.26±1.06^{d}	56.61±2.33^{c}	62.92±1.64^{b}	71.14±1.41^{a}
ABTS	% inhibition	20.66±1.72^{e}	28.49±0.66^{d}	33.70±1.45^{c}	37.64±1.02^{b}	42.76±0.88^{a}
	TE (µM/g)	0.41±0.11^{e}	0.62±0.01^{d}	0.77±0.02^{c}	0.97±0.01^{b}	1.19±0.01^{a}

Table.6 Effect of incorporation of different levels of oat flour in wheat flour on sensory characteristics of cooked noodles

Parameters	Control	O_1	O_2	O_3	O_4
Color	$7.8{\pm}0.08^{a}$	$7.02{\pm}0.07^{ab}$	$7.67{\pm}0.07^{ab}$	$6.55{\pm}0.09^{c}$	$5.98{\pm}0.08^{d}$
Appearance	$7.55{\pm}0.13^{a}$	$7.04{\pm}0.08^{b}$	$7.35{\pm}0.09^{ab}$	$6.67{\pm}0.08^{c}$	$6.36{\pm}0.09^{d}$
Texture	$7.68{\pm}.0.09^{a}$	$7.33{\pm}0.08^{b}$	$7.53{\pm}0.0.09^{ab}$	$6.87{\pm}0.06^{c}$	$6.52{\pm}0.06^{d}$
Flavor	$7.64{\pm}0.10^{a}$	$7.38{\pm}0.10^{ab}$	$7.53{\pm}0.09^{ab}$	$6.95{\pm}0.07^{c}$	$6.59{\pm}0.06^{d}$
Overall acceptability	$7.76{\pm}0.08^{a}$	$7.54{\pm}0.08^{ab}$	$7.58{\pm}0.08^{ab}$	$6.68{\pm}0.10^{c}$	$5.91{\pm}0.16^{d}$

Values are means±SE. Means not sharing a common superscript letter in a row are significantly different at $p<0.05$ as assessed by t-Test

Chemical parameters

The effect of various levels of oat flour incorporation on chemical parameters of noodles is highlighted in Table 4. The carbohydrate content in fortified noodles decreased gradually with increase in oat flour concentration with respect to the control. The considerable reduction may be due to supplementation of other nutrients by oat flour. The moisture content of the oat flour supplemented noodles gradually reduced from 6.24 to 5.6%. The resultant decrease in moisture could be due to low water retention capacity of oat flour and guar gum (Prabhashankar *et al.*, 2007). The fat content of noodles supplemented with oat flour did not increase considerably but there was a maximum increase of 13.79% in noodles supplemented with 40% oat flour. The possible reason could be the use of same recipe and very little or negligible contribution of fat by the oat flour. The results revealed a steep augmentation in protein content from 8.83 to 14.76% in noodles incorporated with oat flour. The protein content of the noodles supplemented with 10-40% oat flour was 1.15 to 1.67 folds significantly superior to the control noodles (8.83+0.31%). The increase in protein content might be mainly due to the addition of excess gluten in varying composition and contribution of some proteins from the oat flour. Choo and Aziz (2010) noticed a prominent increase in protein content due to gluten incorporation into the noodles formulated by fortification of banana flour. The presence of excess amount of gluten also enhances the dough formation and also strengthens the protein network which improves the chewiness of the noodles (Li *et al.*, 2014).

The crude fiber content of oat flour supplemented noodles was much higher than those prepared from plain wheat flour. There was a prominent increment in crude fiber by 1.73, 2.27, 2.83 and 3.41 times with replacement of wheat flour by oat flour by 10, 20, 30 and 40% respectively. The rise in crude fiber levels was due to addition of oat flours at varying concentration and also guar gum. These increased levels of crude fiber might have helped to improve the textural properties of noodles (Chongtham *et al.*, 2011). The ash content which indirectly indicates the mineral content was not greatly affected by replacing specified amount of wheat flour with the oat flour. The obtained results were in similar trend observed by Aydin and Gocmen (2011).

Antioxidant properties

The antioxidant property indicates the capability to inhibit oxidation process. The antioxidant capacity was determined by DPPH and ABTS inhibition assay as these are simple, rapid and inexpensive and the results are expressed in % inhibition and trolox equivalent i.e. TE (μM/g). The basis for these assays is that antioxidant molecules react with the free radicals of DPPH and ABTS and convert them to 2,2-diphenyl-1-picrylhydrazine and stable ABTS molecules respectively. The influence of incorporation of oat flour to wheat flour at different levels on antioxidant properties of noodles is depicted in Table 5. The radical scavenging activity of the wheat flour noodles increased steadily with continuous increase in oat flour supplementation. The DPPH radical stabilizing activity of the oats incorporated noodles at 10, 20, 30 and 40% augmented by 1.37, 1.64, 2.00 and 2.43 folds as compared to the control while the ABTS radical quenching activity increased by 1.51, 1.88, 2.37 and 2.90 times, respectively. The possible reason for the increase in antioxidant activity might be contribution of antioxidant compounds by oat flour and some polypeptides from gluten incorporated during noodles preparation (Kurhade *et al.,* 2016; Han *et al.,* 2017; Rasane *et al.,* 2015).

Sensory properties

The influence of addition of oat flour at varying concentrations to wheat flour on sensory characteristics of noodles is shown in Table 6. There was a significant difference in color after incorporation of oat flour at 30% and above. More reddish color noodles were formed as compared to the control noodles and similar findings were reported by Reungmaneepaitoon *et al.,* (2006) during preparation of fried noodles with oat bran. Noticeable difference was observed in the appearance of prepared noodles at 20% and higher incorporation level as the color was a bit dark and roughness was higher in correlation to the control. The roughness might be due to high fiber content and the non-uniformities caused during noodles making. There was a considerable difference in texture score at incorporation level of 20% and above due to hardness. The hard texture could be due to strong protein network formed because of high protein and fiber content in fortified noodles. Substantial increments in scores for flavor (taste and smell) were observed for incorporation at 30% and above. The slight difference in characteristic aromatic flavor of oat flour than wheat flour could have been the reason for the same. Considering the overall acceptability score the noodles supplemented with 20% oat flour were revealing higher acceptance than others as well as the control. Yadav *et al.,* (2011) reported the mixing of rice starch and pigeon starch substantially influences cooking and sensory attribute of the noodles. Choo and Aziz (2010) noticed that replacement of 20% wheat flour with banana flour possess higher sensory acceptance due to superior characteristic flavor and textural properties. The higher sensory acceptance is also depended on the color and appearance of the noodles and Mahmoud *et al.*, (2012) found that the fortification of 5-20% of proteins from lupine affects the acceptability of noodles.

Oat flour can be successfully incorporated to enhance the nutritional properties of noodles as they contribute to proteins and crude fiber content. The optimum level of oat flour addition was 20% as the physical and sensory properties are dependent upon the level of oat flour incorporation. Nutritional noodles with high fiber and protein content and prominent antioxidant properties can be prepared by supplementing maximum 20% oat flour in the formulation of noodles without influencing the overall quality.

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