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Fortification of Wheat Flour With Ragi Flour: Effect on Physical, Nutritional, Antioxidant and Sensory Profile of Noodles

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Abstract

The utilization of ragi flour for noodles preparation can be ideal due to its higher dietary fiber and essential minerals content. Therefore, the current work was focused to prepare high nutrients noodles by supplementing ragi flour in wheat flour at 10, 20, 30, and 40% levels. The fortified uncooked noodles showed an increase in steady diameter from 1.23±0.03 mm to 2.33±0.06 mm with a gradual decrease in lightness and whiteness index from 45.46±1.23 to 32.38±1.27 and 43.07±1.06% to 31.09±1.14%, with respective increase of ragi flour. The moisture content of uncooked noodles decreased steadily, while minor changes were observed in fat and ash content. Significant increase in protein (1.06 to 1.25 folds) and crude fiber content (1.64 to 3.62 folds) was noticed in ragi flour noodles in correlation to the control, respectively. The ragi flour fortified noodles not only had a prominent DPPH and ABTS radical scavenging activity but also increased phenolics content. The sensory studies depicted that a maximum of 20% ragi flour can be integrated in the noodles to attain desired overall acceptability and that was further verified by t-test at significance level $p<0.05$.

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Introduction

Ragi (*Eleusine coracana*), commonly known as finger millet, is widely cultivated millet in the world. It is the sixth grown cereal in India and used as staple food across the country along with central and eastern Africa[1]. In recent decades, ragi has been in focus due to its nutritional strength and high amount of dietary fiber (e.g. Water soluble fibers like arabinoxylans while water insoluble fibers like lignin, cellulose, hemi-cellulose) and minerals (calcium,

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phosphorous and iron), essential amino acids and polyphenols content[1,2]. High fiber compounds have various characteristics which affect the foods functional and physiological properties. Fibers from a variety of plant sources have been previously incorporated in processed food products to enhance the color, texture and aroma with reduced calories of the prepared product[3]. Due to those properties, ragi is used in the development and preparation of infant, geriatric and health foods[4]. It is widely consumed in the various forms like puddings, porridges, flours and rotis[5].

Noodles are popular in India and other developing and developed nations, as the textural characteristics are pleasant and also requires less time for cooking. Since ancient times, noodles have been considered as staple food in Asian nations[6]. Due to globalization, food products have undergone noteworthy migration and evolution[7]. The modifications in processing and formulation are preliminarily required because of certain taste preferences, regional eating practices, technology advances and improved health advantages. Multi-cereal or multigrain composite flour products are primarily targeted as the vital carriers of the nutrition. Moreover, the blends and composites also support to reduce the amount of wheat flour needed and further widen the wheat flour availability and accessibility[3].

Traditionally noodles were formulated by using simple ingredients *viz.* wheat flour, salt, vegetable oil, minor ingredients (gums) and water. Wheat flour is the major indispensible ingredient of noodles as it provides necessary dough characteristics *viz*. plasticity, cohesiveness and elasticity[8,9]. Salt imparts taste, contributes to gluten structure development and prevents microbial growth[10]. Vegetable oils plays important role in lowering cooking losses, generating creamy yellow color and developing firm and non-sticky mouth feel[11,12].

The wheat flour noodles commercially available in market for ready use are convenient foods potentially rich in carbohydrates but lacking in crucial nutrients like dietary fibers, essential amino acids or proteins, minerals and vitamins. Hence, there is a requirement to increase the noodles nutritional qualities and promote health benefits to consumers. The nutritional profile of noodles can be enhanced by enriching with different fortificants which are potentially rich in dietary fiber, proteins and other nutrients and antioxidants[13].

Previously, various attempts have been made to supplement wheat flour with other flours like oat flour[14], sweet potato flour[15], malted ragi flour[7], rye flour[16], hull less barley[12], and buckwheat[17] to enhance and provide essential nutrients in various products. Noodles are a good option of utilizing the health benefits of ragi as it would be a better way to supply essential nutrients, and antioxidants. Hence, the present study was performed with a focus to enhance the nutritional profile of noodles formulated from wheat flour by incorporation of maximum possible level of ragi flour without considerably compromising the sensory attributes.

Materials and Methods

Raw materials required for noodle preparation *viz.* wheat flour, ragi flour, salt and vegetable oil were purchased from local super market, Jalgaon, India. GMS (Glycerol monosterate), gluten, guar gum, and TBHQ (tert-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 plain wheat flour noodles (control noodles i.e. T_0) were formulated by few variations in trial and error method of noodles preparation[12]. A uniform dry mix was developed by blending wheat flour (100 g) and salt (2 g). The obtained dry mix was then thoroughly mixed with water (50 mL) and vegetable oil with added 200 ppm TBHQ (13 mL), further the mixing was continued for 5 min until dough of workable consistency was developed. The developed dough was further allowed to rest (10 min) and then passed from noodles making machine (Lab Scale Extruder Noodle Making Machine, Lab Line Instrument, Amravati, India) with 3 mm adjusted rollers gap and 15 rpm speed. The prepared sheet was refolded 3-4 times and further passed through noodles making machine with 1.5 mm adjusted rollers gap. The developed sheet was then rested (10 min) and further passed through rolling cutter operating at 25 rpm. The prepared noodles were collected, dried at 55±2 °C in hot air oven for 4h, packed in high density polyethylene bags and then stored at 25±2 °C for further analysis.

Preparation of Fortified Noodles

The preparation of fortified noodles was carried out by replacing wheat flour in the control noodles formulation with subsequent ragi flour at 10, 20, 30 and 40% levels. The formulation recipe used to prepare control and fortified noodles is as enlisted in Table 1.

Table 1: Formulation of ragi fortified noodles

Sample code	Wheat flour (g)	Ragi flour (g)	Salt (g)	Vegetable oil (g)	Gaur gum (g)	GMS (g)	Wheat gluten (g)
T_0	100	0	2	13	2	0.5	0
T_1	90	10	2	13	2	0.5	1
T_2	80	20	2	13	2	0.5	2
T_3	70	30	2	13	2	0.5	3
T_4	60	40	2	13	2	0.5	4

Proximate Composition

The proximate composition (%) of raw materials flours (both wheat and ragi) and prepared noodles was estimated by AACC methods[18]. Moisture was determined by gravimetric method by heating the samples at 100-105 °C for 4 h (AACC, method 44-15A). Fat content was analyzed by petroleum ether extraction and further followed by evaporation till a constant weight (AACC, method 30-25). Protein content (N (%) × 6.25) was measured by Kjeldahl method (AACC, method 46-13) using protein analyser. The crude fiber content was determined by acid and alkali digestion procedure (AACC, method 32-07). Ash content was estimated by dry combustion method (AACC, method 08-01).

Physical Parameters

The thickness of the prepared noodles was determined by measuring the diameter with vernier caliper (ISI). The L*, a* and b* were recorded on Hunter lab colorimeter (model DP-9000 D25 Hunter Associates Laboratory, Reston, VA, USA) and the whiteness index (WI)[19] and ΔE* were calculated as

$$\mathrm{WI} = 100 - \sqrt{(100 - \mathrm{L}^*)^2 + \mathrm{a}^{*2} + \mathrm{b}^{*2}} \quad ...(1)$$

$$\Delta E^* = \sqrt{(L_c^* - L_s^*)^2 + (a_c^* - a_s^*)^2 + (b_c^* - b_s^*)^2} \quad ...(2)$$

Where, L*, a*, b* indicates lightness/darkness, redness/greenness, and yellowness/blueness, respectively;c and s represents control and sample.

Antioxidant Activity

The respective flour and noodles samples (1 g) were dissolved in 80% methanol (10 mL) and agitated at room temperature 180 rpm for 2 h followed by centrifugation at 8,000 rpm for 5 min. The collected supernatant was measured (mL) and used to analyzethe ability to scavenge DPPH and ABTS free radicals andexpressed as % inhibition and antioxidant capacity (AOC) in terms of gallic acid equivalent i.e. GAE (mg/100g). The total phenolics content was also measured and expressed as GAE (mg/100g). Gallic acid (0.01mg/mL) was used as standard for estimating DPPH, ABTS and total phenolics content at 517, 734 and 735 nm, respectively[20,21].

$$\%\ \mathrm{Inhibition} = \frac{\mathrm{Abs_{Control}} - \mathrm{Abs_{sample}}}{\mathrm{Abs_{control}}} \times 100 \quad ...(3)$$

$$\Delta Abs = (\mathrm{Abs_{Control}} - \mathrm{Abs_{sample}}) \quad ...(4)$$

$$\mathrm{AOC} = \frac{\Delta Abs}{\text{Slope of standard graph}} \times \text{Gallic acid conc} \times \frac{\text{Supernatant yield}}{\text{Weight of sample}} \times 100 \quad ...(5)$$

Sensory Analysis

The sensory analysis of the prepared noodles was performed by a panel of 10 members. The prepared noodles were served to the panel members for sensory evaluation by developing a finished product (FP). The FP was prepared by boiling noodles (100 g) in milk (200 mL) and sugar (50 g) with 12 min cooking time. The panel members were asked to determine and estimate the FP for different sensory attributes *viz.* appearance, color, texture, flavor and overall acceptability. A 9 point Hedonic scale was utilized for the sensory analysis and the results achieved were evaluated statistically by using t-Test with significance level p<5% on Microsoft Excel, 2010.

Statistical Analysis

All the experiments were performed in triplicates and the results are expressed in mean ± standard error. The data was analyzed by using Microsoft Excel, 2010 and SPSS Version[16]. One way ANOVA was used to test the mean differences and the statistical significance differences between mean values was established at P <0.05 and Duncan's New Multiple Range test.

Results and Discussion

Proximate Composition of Flours

The proximate chemical constituents of thewheat and ragi flours used for noodles are enlisted in Table 2 and the obtained results were similar to previous reports of Kulkarni *et al.,*12, Shukla and Srivastava[4] and Dissanayake and Jayawardena[23]. Herein, ragi flour was found to be potential source of crude fiber (3.79±0.09%) and minerals (2.22±0.13%).

Table 2: Proximate composition of flours used for noodle preparation

Constituents	Wheat flour	Ragi flour
Moisture (%)	9.69±0.11	10.34±0.17
Fat (%)	1.17±0.14	1.22±0.09
Protein (%)	10.68±0.25	8.17±0.12
Ash (%)	1.49±0.13	2.22±0.13
Crude fibre (%)	0.51±0.08	3.79±0.09
Carbohydrate (%)	76.46±0.45	74.26±0.25

The results are expressed in mean ± standard error

Effect of Ragi Flour Fortification on Physical Parameters of Noodles

The dough prepared from supplementation of ragi and wheat flour was highly viscous, much softer and less elastic thus not of desirable consistency and could not be used for noodles preparation[23]. Hence to make dough of desirable consistency guar gum, wheat gluten and GMS were incorporated in the mixture with some excess addition of water (15-20 mL) (Table 1). Processing conditions for making both control as well as ragi flour fortified noodles were kept constant.The water binding ability during dough development might have been affected by the action of available carbohydrates and non-polar chains[24,25]. The incorporated guar gum not only acts as dough thickener but also supports to strengthen the gluten development and structure formation thus contributing to the final texture of the noodles[10]. Guar gum has been also proven to enhance the Water binding capacity (WBC) of the noodles during cooking[12,26]. The additions of GMS in specific concentrations in dough results in slight decrease the hardness and moderately improve the gumminess, cohesiveness, springiness and chewiness[27]. Salt if added in specified amounts provides a pliable mouth feel, helps in development of protein network; acts as preservative and also restricts various enzyme activities[14].

The incorporation of the ragi flour in wheat flour in the prepared noodles resulted in steady increase in the diameter (Table 3). The diameter of the control noodles was 1.23±0.03 mm while the diameter of the noodles fortified with ragi flour by 10, 20, 30 and 40% was 1.33±0.03, 1.36±0.12, 1.83±0.03 and 2.33±0.06 mm respectively. The decrease of carbohydrate content with increasing content of ragi flour might have resulted in developing strong protein network and steady diameter[28].

The total color difference (ΔE^*) indicates the magnitude of the color difference between the fortified and control noodle samples and is one of the important quality parameter from consumer acceptance point of view. While L*, a* and b* values represents brightness/darkness, greenness/redness and blueness/yellowness of noodles, respectively. The control noodles illustrated highest L* values which reduced steadily with increasing ragi flour content (Table 3). The a* value increased while the b* value decreased with increasing incorporation of ragi flour in the wheat flour. A gradual decrease in the brightness of noodles with increasing ragi flour levels was noticed as evident from the steady decline in whiteness index of noodles. Similar trend in color pattern was recorded during noodles preparation by incorporation of Kenaf seeds yellow[6,14].

Table 3: Effect of incorporation of varying levels of ragi flour on physical parameters of noodles

Samples	Diameter (mm)	Color				Whiteness index
		L*	a*	b*	∆E*	
T_0	1.23±0.03[a]	45.46±1.23[a]	5.28±0.71[b]	15.38±0.71[d]		43.07±1.06[a]
T_1	1.33±0.03[ab]	42.63±0.56[b]	5.87±1.20[a]	14.37±0.63[c]	3.64±0.79	40.52±0.70[b]
T_2	1.46±0.12[abc]	38.94±0.63[c]	5.83±0.63[ab]	11.81±0.63[b]	7.65±1.14	37.51±0.67[c]
T_3	1.83±0.03[cd]	35.14±1.73[c]	6.35±0.39[a]	9.80±0.34[b]	7.95±2.19	34.08±1.67[c]
T_4	2.32±0.06[d]	32.38±1.27[c]	6.64±0.67[a]	11.14±0.80[a]	9.47±1.33	31.09±1.14[c]

The results are expressed in mean ± standard error

Effect of Ragi Flour Fortification on Chemical Parameters of Noodles

The effect of varying levels of ragi flour incorporation on chemical parameters of noodles is shown in Table 4. The amount of carbohydrate in the ragi flour fortified noodles reduced steadily with increasing flour concentration in contrast to the control noodles, this could be due to incorporation of other nutrients associated with the ragi flour. The moisture content in the ragi flour fortified noodles showed consistent reduction from 12.86±0.1 to 11.42±0.09%. The resultant decline in moisture content could be attributed to low WBC of the flours used for noodle preparation and guar gum[11].

The fat content of ragi flour fortified noodles decreased steadily and the least fat content (12.07±0.23) was noticed at 40% replacement of wheat flour with ragi flour which was 9.67% less than the control noodles. The probable reason might be the use of same recipe and negligible or very little fat contributed by the ragi flour. There was a gentle increment in protein content from 9.11±0.27 to 11.35±0.29% in noodles subsequently prepared by supplementation of wheat flour with the ragi flour respectively. The protein content of the fortified noodles with 10-40% ragi flour was 6.26 to 24.59% considerably higher than the plain wheat flour noodles (9.68+0.29%). The steady rise in protein content could be possibly because of the extra gluten addition in increasing concentration and some proteins contributed by the ragi flour. There was a prominent increase in proteins levels due to gluten fortification into noodles prepared by incorporation of banana flour[29] and oats flour[14]. The availability of gluten in excess amount helps to enhance the dough development and also supports the formation of protein network which further enhances the noodles chewiness[10].

Table 4: Effect of incorporation of varying levels of ragi flour on chemical parameters of noodles

Samples	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Crude fiber (%)	Carbohydrate (%)
T_0	12.86±0.1[e]	12.5±0.20[e]	1.16±0.08[c]	9.11±0.27[e]	0.45±0.11[e]	63.92±0.76[e]
T_1	12.38±0.08[d]	12.39±0.25[cd]	1.30±0.09[b]	9.68±0.25[d]	0.74±0.09[d]	63.51±0.51[d]
T_2	11.95±0.11[c]	12.30±0.16[bc]	1.38±0.11[ab]	10.22±0.37[c]	1.02±0.08[c]	63.13±0.80[c]
T_3	11.66±0.12[b]	12.18±0.19[ab]	1.43±0.17[a]	10.83±0.42[b]	1.35±0.14[b]	62.55±0.62[b]
T_4	11.42±0.09[a]	12.07±0.23[a]	1.49±0.15[a]	11.35±0.29[a]	1.63±0.12[a]	62.03±0.39[a]

The results are expressed in mean ± standard error

The crude fiber of noodles incorporated with ragi flour was much greater than those prepared with the wheat flour alone. The crude fiber prominently increased by 1.64, 2.27, 3.0 and 3.62 folds by the substituting ragi flour by 10, 20, 30 and 40% respectively. The increment in the crude fiber content was solely due to supplementation of ragi flour at different levels. These enhanced levels of crude fiber could have also contributed in improvement of the textural properties of noodles[30]. The ash content ultimately signifies the presence of minerals in noodles was not influenced by adding specified amount of ragi flour for the wheat flour. There was a considerably higher amount of ash content noticed at 30 and 40% ragi supplementation and the enhancement was 23.28 and 28.49% in accordance to the control noodles (1.16±0.08%).

Effect of Ragi Flour Fortification on Antioxidant Properties

The antioxidant capacity provides the information regarding the ability to inhibit the oxidation process[19,31]. The total phenolics along with ABTS and DPPH were performed and the obtained results were represented as % inhibition and gallic acid equivalent (GAE mg/100g). The effect of fortifying wheat flour with ragi flour at different levels is indicated in Table 5 and an increasing trend was noticed.

Table 5: Effect of fortification of varying levels of ragi flour on antioxidant properties of noodles

Antioxidant properties	DPPH		ABTS		PhenolicsGAE (mg/100g)
	% Inhibition	GAE (mg/100g)	% Inhibition	GAE (mg/100g)	
T_0	3.04±0.38[e]	7.83±0.98[e]	5.90±0.96[e]	2.20±0.16[e]	6.46±0.12[e]
T_1	9.22±0.35[d]	23.77±0.89[d]	10.28±1.11[d]	4.31±0.33[d]	9.46±0.18[d]
T_2	14.24±0.42[c]	36.75±1.09[c]	19.14±1.36[c]	7.61±0.33[c]	11.99±0.45[c]
T_3	18.82±0.25[b]	48.54±0.63[b]	24.59±0.60[b]	9.62±0.25[b]	13.43±0.18[b]
T_4	22.52±0.37[a]	58.09±0.94[a]	29.16±0.65[a]	11.32±0.34[a]	15.24±0.15[a]

The results are expressed in mean ± standard error

The DPPH and ABTS radical stabilizing activity of the ragi incorporated noodles at 10, 20, 30 and 40% augmented by 3.03, 4.68, 6.19 and 7.41 times, 1.74, 3.24, 4.17 and 4.94 times, respectively.Moreover, there was also an increment in the phenolics content after fortification of ragi flour by 1.46, 1.86, 2.08 and 2.36 folds, respectively. The plausible reason for the enhanced antioxidant capacity and phenolics content could be contribution of phenolics and other antioxidant compounds by ragi flour and some polypeptides from gluten incorporated during noodles preparation[1,2].

Effect of Ragi Flour Fortification on Sensory Characteristics of Noodles

The effect of incorporation of ragi flour in varying concentrations on sensory profile of noodles is depicted in Table 6. There was a considerable difference in color after ragi flour incorporation at 20% and above levels. Brown or dark cream color noodles were formed in contrast to the plain wheat flour noodles and inline reports were observed by Kulkarni *et al.,*[12] and Kudake *et al.,*[14] during preparation of malted ragi and oats flour supplemented noodles, respectively. Substantial difference was recorded for the appearance of fortified noodles above 20% incorporation level than the control due to a bit dark color and higher surface roughness. The increased roughness may be introduced because of increment in dietary fiber levels and the non-uniformities occurred at the noodles preparation time. There was a significant difference in texture score due to hardness in noodles generated by incorporation of 20% and above level of ragi flour. The hardness might have increased because of strong protein network developed due to high fiber and protein content in the fortified noodles. The reductions in scores for flavor (smell and taste) were noticed for addition of ragi flour at 20% and above level while the slight difference in specific aromatic flavor of ragi flour could have been one of the prominent reasons for the same. The added ingredients like guar gum, vegetable oil and gluten helped to overcome the sensory defects. If the overall acceptability score the noodles is taken into consideration, the supplementation of 20% ragi flour revealed higher acceptance in contrast to others. The blending of pigeon and rice starch prominently affected the cooking and sensory features of the developed noodles[32]. The addition of banana flour for wheat flour (20%) gained higher sensory score and acceptance due to the superior and characteristic flavor and textural properties[29]. The increased sensory acceptance is also associated with the color and appearance of the developed noodles and the supplementation of proteins (5-20%) from lupine influences the acceptability of noodles[28].

Table 6: Effect of fortification of varying levels of ragi flour on sensory characteristics of noodles

Sensory parameters	Color	Texture	Appearance	Flavor	Overall acceptability
T_0	7.80±0.08^{a}	7.68±0.09^{a}	7.55±0.13^{a}	7.64±0.10^{a}	7.76±0.08^{a}
T_1	7.70±0.07^{ab}	7.61±0.11^{ab}	7.47±0.13^{ab}	7.58±0.10^{ab}	7.59±0.08^{ab}
T_2	7.53±0.09^{ab}	7.44±0.11^{abc}	7.32±0.12^{abc}	7.38±0.11^{abc}	7.50±0.07^{ab}
T_3	7.24±.09^{b}	7.21±0.11^{bcd}	7.06±0.13^{bcd}	7.05±0.10^{cd}	7.18±0.07^{b}
T_4	6.82±0.05^{c}	6.91±0.12^{d}	6.62±0.11^{d}	6.67±0.11^{d}	6.79±0.07^{c}

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

Conclusion

Ragi flour can be effectively incorporated to augment the nutritional profile of noodles as they contribute to elevated crude fiber and minerals content antioxidant activities. The ambient level of ragi flour incorporation was 20% as the physical and sensory characteristics are dependent upon the level of ragi flour addition. The noodles with high nutrient content *viz.* crude fiber and minerals content can be prepared by fortifying a maximum of 20% ragi flour in the noodles recipe without affecting the overall acceptability and quality.

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