Available online at www.sciencedirect.com
SCIENCE DIRECT®
Food Chemistry 90 (2005) 427–435
Food Chemistry
www.elsevier.com/locate/foodchem

Organoleptic and nutritional evaluation of wheat biscuits supplemented with untreated and treated fenugreek flour

Shalini Hooda, Sudesh Jood *

Department of Foods and Nutrition, CCS Haryana Agricultural University, Hisar 125 004, India

Received 23 May 2003; received in revised form 6 May 2004; accepted 6 May 2004

Abstract

Biscuits prepared from the blends containing different proportions (0%, 5%, 10%, 15% and 20%) of raw, soaked and germinated fenugreek seed flour were evaluated for width, thickness, spread ratio and sensory characteristics. The thickness of fenugreek supplemented biscuits increased, whereas width and spread ratio of biscuits decreased with the increasing level of fenugreek flour. The sensory results showed that a maximum of 10% fenugreek flour can be incorporated to prepare acceptable quality biscuits. Addition of raw, soaked and germinated fenugreek flour to wheat flour increased the contents of protein (10.5%, 10.4% and 11.0%), lysine (2.15, 2.20 and 2.25 g/100 g protein), dietary fibre (12.7%, 11.3% and 10.9%), total Ca (58.3, 57.1, 57.7 mg/100 g) and total iron (7.40, 7.26 and 7.36 mg/100 g), respectively, at 10% level of substitution. These biscuits can be safely stored in polypropylene bags upto 1 month without altering their organoleptic properties.

Keywords: Biscuit; Wheat; Fenugreek; Physical; Sensory; Nutritional

1. Introduction

Biscuits are convenient food products, becoming very popular among both rural and urban populations of India. Some of the reasons for such wide popularity are low cost among other processed foods, varied taste, easy availability and longer shelf life (Gandhi et al., 2001). The enrichment of protein may be achieved through incorporation of protein-rich non-wheat flours (Gandhi et al., 2001; Patel & Rao, 1996; Sharma & Chauhan, 2002; Singh, Singh, & Chauhan, 1996). Among them fenugreek seed flour has a great potential, due to its high and good quality protein (20–25%), lysine (5–6%), soluble (20%) and insoluble dietary fibre and, it also possesses hypocholesterolemic (Khosla, Gupta, & Nagpal, 1995; Sharma, 1986) and hypoglycemic (Neeraja & Rajyalakshmi, 1996) properties. Hence, development and consumption of such therapeutic bakery products would help to raise the nutritional status of the population. Information on incorporation of treated and untreated fenugreek seed flour in bakery products is scanty. Therefore, this study was designed to evaluate the effects of raw, soaked and germinated fenugreek seed flours on physical, chemical and sensory characteristics of wheat biscuits.

2. Materials and methods

2.1. Procurement of material

The bulk samples of commonly grown varieties of wheat, namely, WH-423 and fenugreek, Pusa early bunching, were obtained from the Department of Plant Breeding, CCS Haryana Agricultural University, Hisar, India. All the grains were cleaned, made free of dust and other foreign material. The grain samples of wheat and fenugreek were ground in a Junior Mill to pass through a 60 mesh sieve and stored in an air tight container until used.

* Corresponding author.
E-mail address: ramjood@rediffmail.com (S. Jood).

0308-8146/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2004.05.006

2.2. Processing methods

2.2.1. Soaking

Fenugreek seeds were first cleaned and freed of broken seeds, dust and other foreign materials and then soaked in tap water for 12 h at 37 °C. A seed to water ratio of 1:5 (w/v) was used. The unimbibed water was discarded. The soaked seeds were rinsed twice in distilled water and then dried at 55–60 °C.

2.2.2. Germination

The soaked seeds were germinated in sterile Petridishes lined with wet filter papers for 48 h at 37 °C, with frequent watering. The sprouts were rinsed in distilled water and dried at 55–60 °C. The dried samples of raw, soaked and germinated seeds were ground to fine powder in an electric grinder and then stored in plastic containers for further use.

2.3. Preparation of blends

Fenugreek raw seed powder was blended separately with wheat flour at different levels namely, 5%, 10%, 15% and 20%.

2.4. Preparation of biscuits

The sweet biscuits were prepared by using the AACC method (AACC, 1984) with slight modification. The ingredients included wheat flour or blends 100 g, sugar 10 g, fat 30 g, common salt 2 g, sodium bicarbonate 1.0 g, ammonia 50 g, vanilla 0.025 g and required amount of water. Preparation of biscuits was carried out using wheat flour samples replaced, separately, with 5%, 10%, 15% and 20% fenugreek seed flours. Shortening and creaming technique were used. The biscuits were baked at 160 °C for 20 min. After cooling for 30 min, the cookies were packed and used for evaluation of various physical and sensory characteristics.

2.5. Physical characteristics

Width of biscuits was measured by laying six biscuits edge to edge with the help of a scale rotating them 90° and re-measuring the width of six cookies in cm and then taking average value. Thickness (T) or height of biscuits was measured by stacking six biscuits on top of one another and taking average thickness (T) of six biscuits in cm. Spread ratio was calculated by dividing the average value of width (W) by average value of thickness (T) of biscuits. Per cent spread ratio was calculated according to AACC method (1984) by dividing the average value of width (W) by average value of thickness (T) of biscuits.

2.6. Sensory characteristics

The organoleptic characteristics of biscuits were determined, using a taste panel, consisting of 10 judges. The panellists were asked to evaluate the products for appearance, colour, texture, flavour and overall acceptability. The ratings were on a 9-point hedonic scale, ranging from 9 (like extremely) to 1 (dislike extremely), for each organoleptic characteristic (Austin & Ram, 1971). Results were subjected to analysis of variance.

2.7. Nutritional characteristics

2.7.1. Proximate composition

Proximate composition was estimated by employing standard methods of analysis (AOAC, 1995).

2.7.2. Sugars, dietary fibre and total lysine

Total soluble sugars were extracted by refluxing in 80% ethanol (Cerning & Guilbot, 1973). Quantitative determination of total soluble sugars was carried out according to a colorimetric method (Yemm & Willis, 1954). Reducing sugars were estimated by Somogyi's modified method (Somogyi, 1945). Non-reducing sugars were determined by calculating the difference between total soluble sugars and reducing sugars.

Total soluble and insoluble dietary fibre contents were determined by following the enzymatic method (Furda, 1981). The sum of insoluble dietary fibre and soluble dietary fibre contents were calculated as total dietary fibre.

Total lysine was estimated according to the method described by Miyahara and Jikoo (1967).

2.7.3. Total and available minerals

The samples were wet acid-digested, using a nitric acid and perchloric acid mixture (HNO_3:$HClO_4$, 5:1 w/v). The total amounts of Ca, Fe and Zn in the digested samples were determined by atomic absorption spectrophotometry (Lindsey & Norwell, 1969). Ionizable Fe in the samples was extracted according to the procedure of Rao and Prabhavathi (1978) and Ca and Zn were extracted by the method of Kim and Zemel (1986). Available Ca, Fe and Zn were determined by atomic absorption spectrophotometry (Lindsey & Norwell, 1969).

2.7.4. In vitro starch and protein digestibility

In vitro starch digestibility was assessed by employing pancreatic amylase and incubating at 37° for 2 h. Liberated maltose was measured colorimetrically by using dinitro-salicylic acid reagent (Singh, Khedekar, & Jambunathan, 1982). Protein digestibility (in vitro) was assessed by employing pepsin and pancreatin (Akeson & Stahmann, 1964). The nitrogen contents of the sample and the undigested residue were determined by the mi-

cro-Kjeldahl method (AOAC, 1995). The digested protein of the sample was calculated by subtracting residual protein from total protein of the sample.

$$\text{Protein digestibility} = \frac{\text{Digested protein}}{\text{Total protein}} \times 100.$$

2.7.5. Antinutritional factors

Phytic acid was determined by the method of Haug and Lantzsch (1983). Total polyphenols were extracted by the method of Singh and Jambunathan (1981) and estimated as tannic acid equivalents, according to the Folin–Denis procedure (Swain & Hills, 1959).

2.8. Statistical analysis

The data were statistically analysed in a completely randomized factorial design according to the standard method (Panse & Sukhatme, 1961).

3. Results and discussion

3.1. Physical characteristics

Physical characteristics of biscuits, such as thickness, width and spread ratio, were affected significantly ($P < 0.05$) with the increase in the level of fenugreek flour (Table 1). The average width of control (wheat flour) biscuit was 3.01 cm whereas that of supplemented biscuits varied from 2.90 to 2.38 cm (raw), 2.66–2.36 cm (soaked) and 2.96–2.53 (germinated) at 5–20% levels. The average thickness of control biscuit was 0.78 cm and for other supplemented levels, it varied from 0.82 to 0.92 cm (raw), 0.81–0.89 (soaked) and, 0.84–0.97 cm germinated at 5–20% levels. The changes in width and thickness are reflected in spread ratio which was calculated by dividing the width (W) by thickness (T) of the biscuit. Spread ratio of control biscuit was 3.85, which decreased significantly ($P < 0.05$) and consistently from 3.54 to 2.59 in raw fenugreek and 3.28–2.65 in soaked fenugreek at 5–20% levels. These results indicated that the addition of raw, soaked and germinated fenugreek flour adversely affected the thickness and diameter and thus, spread ratio of the supplemented biscuits. Cookies having higher spread ratios are considered most desirable (Kirssel & Prentice, 1979). Other research workers also reported reduction in spread ratio when oat bran, soy flour and black gram flour were substituted for wheat flour (Chen, Tubenthaler, Leung, & Baranowski, 1998; Patel & Rao, 1996; Sharma & Chauhan, 2002; Singh et al., 1996). Reduced spread ratios of fenugreek-fortified biscuits were attributed to the fact that composite flours apparently form aggregates with increased numbers of hydrophilic sites available for competing for the limited free water in cookie dough (McWatters,

Table 1
Physical characteristics of fenugreek supplemented biscuits[a]

Supplementation level (%)	Width, W (cm)	Thickness, T (cm)	Spread ratio (W/T)
Control (wheat)	3.01 ± 0.04	0.78 ± 0.01	3.85
W:RF			
95:5	2.90 ± 0.02	0.82 ± 0.02	3.54 ± 0.02
90:10	2.68 ± 0.01	0.85 ± 0.03	3.15 ± 0.02
85:15	2.58 ± 0.01	0.89 ± 0.01	2.90 ± 0.01
80:20	2.38 ± 0.01	0.92 ± 0.00	2.59 ± 0.01
Mean	2.64 ± 0.01	0.87 ± 0.01	3.05 ± 0.01
CD ($P < 0.05$)	0.08	0.04	0.02
W:SF			
95:5	2.66 ± 0.02	0.81 ± 0.01	3.28 ± 0.03
90:10	2.57 ± 0.01	0.84 ± 0.02	3.17 ± 0.01
85:15	2.47 ± 0.03	0.87 ± 0.01	2.84 ± 0.03
80:20	2.36 ± 0.02	0.89 ± 0.01	2.65 ± 0.02
Mean	2.32 ± 0.02	0.85 ± 0.01	2.99 ± 0.02
CD ($P < 0.05$)	0.06	0.03	
W:RF			
95:5	2.96 ± 0.01	0.84 0.02	3.52 ± 0.02
90:10	2.75 ± 0.02	0.91 ± 0.03	3.02 ± 0.02
85:15	2.64 ± 0.03	0.93 ± 0.01	2.84 ± 0.05
80:20	2.53 ± 0.01	0.97 ± 0.01	2.61 ± 0.03
Mean	2.72 ± 0.02	0.91 ± 0.02	3.00 ± 0.03
CD ($P < 0.05$)	0.06	0.09	0.08
CD ($P < 0.05$) of all treatments	0.14	0.05	0.26

W, wheat flour; RF, raw fenugreek; SF, soaked fenugreek; GF, germinated fenugreek.
[a] Values are means ± SD.

1978). Rapid partitioning of free water of these hydrophilic sites occurs during dough mixing and increases dough viscosity, thereby limiting cookie spread and top grain formation during baking.

3.2. Sensory characteristics

The effects of fenugreek supplementation on the sensory characteristics of biscuits are presented in Table 2. With the increase in the level of fenugreek flour (raw, soaked and germinated) in formulation, the sensory scores for colour, texture and flavour of biscuits decreased sharply. Replacement of flour with 15% and 20% fenugreek flour (treated and untreated) significantly ($P < 0.05$) impaired the taste of biscuits (control samples had 7.25 score), which decreased significantly from 6.10 to 2.78 (raw), 6.50–3.00 (soaked) and 6.86–3.25 (germinated) up to 20% levels, respectively, which might be due to the bitter taste of fenugreek.

The control samples had maximum overall acceptability, whereas biscuits containing 15% and 20% raw and processed fenugreek flours were found to be unacceptable to the panellists. The overall acceptability score for control was 7.08 on a 9-point hedonic scale. Biscuits made from blends containing 10% level of all fenugreek flours did not differ significantly ($P < 0.05$) from the control. At 15% and 20% levels of substitution, the overall acceptability was rated as poor. The germinated fenugreek flour-supplemented biscuits performed better than the other fenugreek-supplemented biscuits. Similar observations with supplementation of soy flour (Dhingra & Jood, 2001; Singh et al., 1996), bengal gram flour (Patel & Rao, 1996) and wheat bran (Sharma & Chauhan, 2002) with wheat flour were also reported.

From the overall acceptability rating, it was concluded that fenugreek flour could be incorporated up to 10% level in the formulation of biscuits without affecting their sensory quality.

3.3. Nutritional evaluation

3.3.1. Proximate composition

Table 3 shows that the moisture, protein, fat, crude fibre and ash contents increased with increasing fenugreek (raw, soaked and germinated) flour in wheat flour, whereas total carbohydrate contents decreased from 62.7% (control biscuits) to 60.0% (germinated fenugreek-supplemented biscuits). Control biscuits had 9.21% protein content. In the case of supplemented biscuits, it ranged from 9.84% to 10.5%, 9.77–10.4% and 10.1–11.0% in raw, soaked and germinated fenugreek based biscuits. The increase in protein content of fenugreek supplemented biscuits might be the result of the appreciably higher protein content of fenugreek. Shar-

Table 2
Organoleptic acceptability of fenugreek supplemented biscuits[a]

Supplementation level (%)	Colour	Appearance	Texture	Flavour	Taste	Overall acceptability
Control (wheat)	7.00 ± 0.00	7.15 ± 0.16	7.00 0.00	7.00 ± 0.00	7.25 ± 0.20	7.08 ± 0.09
W:RF						
95:5	6.92 ± 0.07	6.45 ± 0.23	6.74 0.18	6.32 ± 0.07	6.10 ± 0.37	6.50 ± 0.13
90:10	5.62 ± 0.11	5.62 ± 0.13	5.94 ± 0.08	5.45 ± 0.10	5.00 ± 0.16	5.52 ± 0.15
85:15	4.70 ± 0.10	4.96 ± 0.16	5.38 ± 0.24	4.42 ± 0.13	3.58 ± 0.18	4.64 ± 0.06
80:20	3.87 ± 0.12	4.31 ± 0.23	4.42 ± 0.14	3.59 ± 0.15	2.78 ± 0.21	3.85 ± 0.20
Mean	5.27 ± 0.34	5.43 ± 0.22	5.63 ± 0.26	4.94 ± 0.31	4.37 ± 0.40	5.12 ± 0.30
CD ($P < 0.05$)	0.35	0.65	0.56	0.38	0.80	0.46
W:SF						
95:5	6.85 ± 0.15	6.38 ± 0.17	6.60 ± 0.11	6.50 ± 0.18	6.50 ± 0.17	6.56 ± 0.17
90:10	5.50 ± 0.17	5.50 ± 0.25	5.80 ± 0.24	5.60 ± 0.15	5.35 ± 0.16	5.55 ± 0.23
85:15	4.58 ± 0.16	4.85 ± 0.21	5.24 ± 0.17	4.58 ± 0.16	4.00 ± 0.27	4.67 ± 0.25
80:20	3.70 ± 0.06	4.20 ± 0.12	4.56 ± 0.14	3.65 ± 0.75	3.00 ± 0.11	3.87 ± 0.08
Mean	5.15 ± 0.35	5.30 ± 0.23	5.57 ± 0.23	5.08 ± 0.32	4.71 ± 0.41	5.16 ± 0.31
CD ($P < 0.05$)	0.48	0.65	0.56	0.48	0.62	0.63
W:GF						
95:5	6.78 ± 0.10	6.25 ± 0.22	6.48 ± 0.25	6.68 ± 0.15	6.86 ± 0.33	6.61 ± 0.10
90:10	5.38 ± 0.13	5.42 ± 0.30	5.67 ± 0.16	5.78 ± 0.11	5.89 ± 0.36	5.63 ± 0.18
85:15	4.44 ± 0.27	4.70 ± 0.19	5.02 ± 0.20	4.76 ± 0.09	4.45 ± 0.22	4.71 ± 0.11
80:20	3.62 ± 0.21	4.08 ± 0.10	4.38 ± 0.14	3.87 ± 0.11	3.25 ± 0.24	3.88 ± 0.46
Mean	5.05 ± 0.36	5.17 ± 0.24	5.42 ± 0.24	5.27 ± 0.32	5.11 ± 0.43	5.20 ± 0.33
CD ($P < 0.05$)	0.63	0.71	0.62	0.38	0.97	0.85
CD ($P < 0.05$) of all treatments	1.31	0.87	0.91	1.19	1.53	1.16

W, wheat flour; RF, raw fenugreek; SF, soaked fenugreek; GF, germinated fenugreek.
[a] Values are means ± SD of 10 panellists.

Table 3
Proximate composition of fenugreek supplemented biscuits (g/100 g, on dry matter basis)[a]

Supplementation level (%)	Moisture	Fat	Protein	Crude fibre	Ash	Carbohydrate
Control (wheat)	3.15 ± 0.02	21.12 ± 0.05	9.21 ± 0.13	2.05 ± 0.02	1.80 ± 0.05	62.7 ± 0.30
W:RF						
95:5	3.18 ± 0.01	21.19 ± 0.03	9.84 ± 0.11	2.24 ± 0.03	1.83 ± 0.03	61.7 ± 0.47
90:10	3.25 ± 0.02	21.28 ± 0.06	10.5 ± 0.08	2.46 ± 0.01	1.88 ± 0.02	60.6 ± 0.13
Mean	3.21 ± 0.02	21.23 ± 0.04	10.2 ± 0.16	2.35 ± 0.05	1.85 ± 0.02	61.2 ± 0.33
CD ($P < 0.05$)	NS	NS	0.39	0.09	NS	1.07
W:SF						
95:5	3.17 ± 0.03	21.18 ± 0.10	9.77 ± 0.09	2.30 ± 0.03	1.80 ± 0.00	61.8 ± 0.26
90:10	3.23 ± 0.02	21.21 ± 0.07	10.4 ± 0.17	2.55 ± 0.01	1.83 0.02	60.8 ± 0.12
Mean	3.20 ± 0.02	21.19 ± 0.06	10.1 ± 0.16	2.42 ± 0.06	1.81 0.01	61.3 ± 0.25
CD ($P < 0.05$)	NS	NS	0.53	0.10	NS	0.80
W:GF						
95:5	3.19 ± 0.01	21.15 ± 0.06	10.1 ± 0.14	2.37 ± 0.02	1.86 ± 0.01	61.3 ± 0.46
90:10	3.27 ± 0.02	21.06 ± 0.05	11.0 ± 0.11	2.70 ± 0.03	1.91 ± 0.02	60.0 ± 0.24
Mean	3.27 ± 0.02	21.10 ± 0.04	10.6 ± 0.22	2.53 ± 0.07	1.88 ± 0.01	60.7 ± 0.37
CD ($P < 0.05$)	0.07	NS	0.49	0.10	NS	1.25
CD ($P < 0.05$) of all treatments	0.06	NS	0.58	0.20	NS	1.03

W, wheat flour; RF, raw fenugreek; SF, soaked fenugreek; GF, germinated fenugreek; NS, non-significant.
[a] Values are means ± SD of three independent determinations.

ma and Chauhan (2000) also reported significantly ($P < 0.05$) higher protein content of breads prepared from blends of wheat-fenugreek flours.

3.3.2. Sugars, dietary fibre and total lysine

Total, reducing and non-reducing sugar contents of control (wheat) biscuits were 13.3%, 5.07% and 8.27%, respectively, (Table 4). The biscuits supplemented with 5% and 10% levels of raw and soaked fenugreek flours showed a non-significant decrease in total, reducing and non-reducing sugar contents as compared to control biscuits. Among the supplemented biscuits, biscuits with soaked fenugreek-supplemented flour exhibited minimum values of total, reducing and non-reducing sugars namely 13.2%, 5.03% and 8.18%, respectively. Biscuits made from blends of wheat-germinated fenugreek (10%) exhibited maximum contents of total, reducing and non-reducing sugars. This increase might be due to hydrolysis of seed polysaccharides during germination of fenugreek, leading to more available sugars (Hooda & Jood, 2003).

The results regarding total, soluble and insoluble dietary fibre are given in Table 4. Wheat biscuits had 8.81%, 3.90% and 4.91% total, soluble and insoluble dietary fibre contents, respectively. All the dietary fibre constituents increased significantly ($P < 0.05$) on increasing the supplementation of wheat with raw and soaked fenugreek flour in biscuits. It was found that, at 10% level of supplementation, with raw fenugreek flour, there were increases of 44%, 38% and 49% in total, soluble and insoluble dietary fibre contents of biscuits as compared to control. This may be due to higher contents of dietary fibre constituents in raw fenugreek. However, biscuits made from wheat and germinated fenugreek blends contained lower amount of total 9.86–10.92 and 3.94–4.05 soluble dietary fibre at 5% and 10% levels than other supplemented biscuits. During germination, dietary fibre contents of fenugreek decreased, due to breakdown of galactomannan to galactose by α-galactosidase (Neeraja & Rajyalakshmi, 1996).

Total lysine content of control biscuit was 1.82 g/100 g protein whereas, in all fenugreek supplemented biscuits at 5% and 10% levels, it ranged from 1.97 to 2.15 (raw), 1.99–2.20 (soaked) and 2.02–2.25 g/100 g protein (germinated). Among the supplemented biscuits, germinated fenugreek-supplemented biscuits had higher lysine contents than others. This could be contributed to higher lysine contents of germinated fenugreek flour (Hooda & Jood, 2003), a lysine content improved on germination due to bioconversion.

3.3.3. Starch and protein digestibility (in vitro)

It was observed that in vitro starch digestibility of substituted biscuits increased with increase in the level of supplementation of fenugreek flours in wheat flours (Table 5). Control biscuits had 36.9 mg maltose released/g meal starch digestibility which significantly ($P < 0.05$) improved up on substitution of processed (soaked and germinated) fenugreek flour in wheat flour. Maximum (41.3 mg maltose released/g meal) starch digestibility was found in germinated fenugreek-supplemented biscuits and minimum (34.9 mg maltose released/g meal) in control (wheat) biscuits. As wheat had higher contents of phytic acid and polyphenols,

Table 4
Sugars, dietary fibre and total lysine contents of fenugreek-supplemented biscuits (%, on dry matter basis)[a]

Supplementation level (%)	Sugars (%)			Dietary fibre (%)			Total lysine (g/100 g protein)
	Total	Reducing	Non-reducing	Total	Soluble	Insoluble	
Control (wheat)	13.3 ± 0.18	5.07 ± 0.02	8.27 ± 0.18	8.81 ± 0.44	3.90 ± 0.13	4.91 ± 0.33	1.82 ± 0.11
W:RF							
95:5	13.3 ± 0.22	5.05 ± 0.02	8.26 ± 0.21	10.8 ± 0.46	4.65 ± 0.24	6.10 ± 0.37	1.97 ± 0.07
90:10	13.3 ± 0.17	5.03 ± 0.03	8.25 ± 0.33	12.7 ± 0.39	5.41 ± 0.22	7.31 ± 0.46	2.15 ± 0.12
Mean	13.3 ± 0.12	5.04 ± 0.02	8.25 ± 0.18	11.7 ± 0.52	5.03 ± 0.22	6.70 ± 0.38	2.06 ± 0.07
CD ($P < 0.05$)	NS	NS	NS	1.68	0.71	1.20	NS
W:SF							
95:5	13.3 ± 0.27	5.05 ± 0.01	8.22 ± 0.27	10.1 ± 0.54	4.20 ± 0.15	5.92 ± 0.50	1.99 ± 0.15
90:10	13.2 ± 0.18	5.03 ± 0.03	8.18 ± 0.47	11.4 ± 0.47	4.51 ± 0.29	6.87 ± 0.32	2.20 ± 0.18
Mean	13.2 ± 0.14	5.04 ± 0.01	8.20 ± 0.24	10.8 ± 0.43	4.35 ± 0.16	6.39 ± 0.34	2.09 ± 0.11
CD ($P < 0.05$)	NS	NS	NS	1.18	NS	0.93	NS
W:GF							
95:5	15.3 ± 0.14	5.80 ± 0.04	9.50 ± 0.225	9.79 ± 0.42	3.94 ± 0.10	5.85 ± 0.43	2.02 ± 0.11
90:10	16.0 ± 0.35	6.25 ± 0.02	9.70 ± 0.29	10.8 ± 0.51	4.05 ± 0.19	6.79 ± 0.40	2.25 ± 0.06
Mean	15.6 ± 0.17	6.02 ± 0.02	9.60 ± 0.16	10.3 ± 0.38	3.99 ± 0.10	6.32 ± 0.36	2.13 ± 0.08
CD ($P < 0.05$)	0.36	0.42	0.20	1.01	NS	NS	NS
CD ($P < 0.05$) of all treatments	0.48	0.06	0.64	1.43	0.54	1.15	0.30

W, wheat flour; RF, raw fenugreek; SF, soaked fenugreek; GF, germinated fenugreek.
[a] Values are means ± SD of three independent determinations.

poor starch digestibility might be due to the binding property of inhibitors with amylase (Kalra, 1996).

Control biscuits had 69.4% protein digestibility which did not change significantly ($P < 0.05$) when biscuits were prepared from raw and soaked fenugreek-supplemented blends. However, biscuits made from wheat-germinated fenugreek flour blends had significantly ($P < 0.05$) higher protein digestibility. This improvement of in vitro starch and protein digestibility might be due to reduction in phytic acid and polyphenols by hydrolytic enzymes up on germination and during baking. Phytic acid and polyphenols are known to associate with

Table 5
Total and per cent availability of minerals of fenugreek-supplemented biscuits (on dry matter basis)[a]

Supplementation level (%)	Total Ca (mg/100 g)	Available Ca (%)	Total Fe (mg/100 g)	Available Fe (%)	Total Zn (mg/100 g)	Available Zn (%)
Control (wheat)	56.9 ± 0.22	52.1 ± 0.26	7.15 ± 0.16	50.3 ± 0.32	3.75 ± 0.22	56.1 ± 0.35
W:RF						
95:5	57.6 ± 0.29	51.9 ± 0.34	7.26 ± 0.20	49.8 ± 0.39	3.90 ± 0.26	55.9 ± 0.31
90:10	58.3 ± 0.11	51.7 ± 0.23	7.40 ± 0.18	49.3 ± 0.18	4.06 ± 0.25	55.6 ± 0.26
Mean	57.9 ± 0.21	51.8 ± 0.26	7.33 ± 0.13	49.6 ± 0.26	3.98 ± 0.17	55.7 ± 0.45
CD ($P < 0.05$)	0.65	NS	NS	NS	NS	NS
W:SF						
95:5	57.0 ± 0.26	52.3 ± 0.16	7.19 ± 0.28	50.1 ± 0.36	3.86 ± 0.35	56.2 ± 0.40
90:10	57.1 ± 0.17	52.5 ± 0.31	7.26 ± 0.13	50.6 ± 0.26	3.97 ± 0.20	56.2 ± 0.30
Mean	57.1 ± 0.14	52.4 ± 0.22	7.22 ± 0.14	50.4 ± 0.24	3.91 ± 0.18	56.2 ± 0.45
CD ($P < 0.05$)	NS	NS	NS	0.54	NS	NS
W:GF						
95:5	57.4 ± 0.18	53.0 ± 0.19	7.25 ± 0.31	51.9 ± 0.28	3.89 ± 0.37	56.9 ± 0.22
90:10	57.9 ± 0.14	53.9 ± 0.21	7.36 ± 0.24	52.5 ± 0.24	4.03 ± 0.30	57.7 ± 0.21
Mean	57.6 ± 0.33	53.4 ± 0.17	7.30 ± 0.18	52.2 ± 0.38	3.96 0.22	57.3 ± 0.36
CD ($P < 0.05$)	NS	0.78	NS	0.62	NS	0.71
CD ($P < 0.05$) of all treatments	0.77	0.72	0.48	0.98	0.21	1.11

W, wheat flour; RF, raw fenugreek; SF, soaked fenugreek; GF, germinated fenugreek; NS, non-significant.
[a] Values are means ± SD of three independent determinations.

Table 6
Phytic acid, polyphenol, in vitro starch digestibility and in vitro protein digestibility of fenugreek-supplemented biscuits (on dry matter basis)[a]

Supplementation level (%)	Phytic acid (mg/100 g)	Polyphenols (mg/100 g)	In vitro Starch digestibility (mg maltose released/g meal)	In vitro protein digestibility (%)
Control (wheat)	219 ± 1.67	288 ± 1.33	34.9 ± 2.82	69.4 ± 0.20
W:RF				
95:5	226 ± 1.33	275.88 ± 2.08	36.7 ± 0.44	69.4 ± 0.30
90:10	244 ± 1.13	270 ± 1.47	38.4 ± 0.48	68.9 ± 0.16
Mean	235 ± 4.11	273 ± 3.86	37.5 ± 0.49	69.1 ± 0.19
CD ($P < 0.05$)	4.86	7.11	1.82	NS
W:SF				
	95:5	218 ± 1.00	273 ± 1.78	37.2 ± 0.37
69.8 ± 0.21	90:10	229 ± 1.21	256 ± 1.69	39.4 ± 0.52
69.7 ± 0.24	Mean	224 ± 2.57	265 ± 4.01	38.3 ± 0.58
69.7 ± 0.14	CD ($P < 0.05$)	4.37	6.83	1.80
0.89	*W:GF*			
95:5	213 ± 0.66	271 ± 1.58	38.1 ± 0.50	70.2 ± 0.22
90:10	221 ± 1.06	254 ± 1.25	41.3 ± 0.44	70.8 ± 0.30
Mean	212 1.96	262 ± 4.39	39.7 ± 0.78	70.5 ± 0.18
CD ($P < 0.05$)	3.48	5.62	1.85	0.59
CD ($P < 0.05$) of all treatments	9.55	12.86	1.97	1.04

W, wheat flour; RF, raw fenugreek; SF, soaked fenugreek; GF, Germinated fenugreek; NS, Non-significant.
[a] Values are means ± SD of three independent determinations.

protein to form insoluble complexes, thus affecting the in vitro digestibility of proteins (Feng, Chen, Kramer, & Reeck, 1991; Kataria, Chauhan, & Punia, 1989).

3.3.4. Total and available minerals

Total and available minerals in control as well as supplemented biscuits are presented in Table 6. Control biscuits had low total Ca (56.9 mg/100 g), Zn (3.75 mg/100 g) and Fe (7.15 mg/100 g) contents. Mineral contents increased on increasing the substitution of raw and processed fenugreek flour in wheat flour. Raw fenugreek supplemented biscuits manifested higher contents of total Ca, Fe and Zn, followed by soaked and germinated fenugreek-supplemented biscuits. Availabilities of Ca (53.9%), Fe (52.5%) and Zn (57.7%) were significantly ($P < 0.05$) higher in germinated fenugreek (10%)-supplemented biscuits. This might be attributed to higher mineral contents of germinated fenugreek flour. As phytate hydrolyzed upon germination, the major phosphorus-bearing compounds in cereals, chelate divalent and trivalent cations, such as Ca, Fe and Zn, form insoluble complexes and thereby reduce the in vitro availability of minerals (Haug & Lantzsch, 1983).

3.3.5. Phytic acid and polyphenols

The control (wheat) biscuits had 219 mg/100 g phytic acid and this increased significantly ($P < 0.05$) with rise in the levels of fenugreek flours (Table 6). The maximum increase of 12% in phytic acid over the control was found in biscuits containing raw fenugreek flour at 10% level (244 mg/100 g) while minimum increase (2%) was found in germinated fenugreek flour (221 mg/100 g), over the control. The increased phytate content of the biscuits seems to be the direct effect of replacement of wheat flour with fenugreek flour, which has of high content of phytic acid (Hooda & Jood, 2003). Contrary to this, polyphenolic contents decreased progressively with increasing level of fenugreek flour. Among the supplemented biscuits, germinated fenugreek flour-supplemented biscuits had contained significantly lower contents of polyphenols at 5% and 10% levels. This might be due to oxidation and decarboxylation of the phenolic acids up on germination (Jood, Chauhan, & Kapoor, 1987; Tressel, Bahri, Molzen, & Khossa, 1977).

3.4. Sensory evaluation of stored biscuits

Overall acceptabilities of control and supplemented biscuits did not differ significantly ($P < 0.05$) up to 30 days of storage (Table 7). Control biscuits had 7.08, 7.08, 7.08 and 7.06 overall acceptability scores at 0, 10, 20 and 30 days of storage. Among supplemented biscuits, germinated fenugreek-supplemented biscuits, at 10% level, had higher overall acceptability scores (5.63, 5.63, 5.59 and 5.50), followed by soaked supplemented biscuits (5.55, 5.55, 5.52 and 5.45) and raw supplemented biscuits (5.52, 5.52, 5.50 and 5.46) at 0, 10, 20 and 30 days of storage, respectively. It is therefore, concluded that overall acceptability scores of supplemented biscuits were still in the category of 'like

Table 7
Effect of storage on overall acceptability of fenugreek supplemented biscuits[a]

Supplementation level (%)	Storage period (days)				Mean	CD ($P < 0.05$)
	0	10	20	30		
Control (wheat)	7.08 ± 0.25	7.08 ± 0.38	7.08 ± 0.24	7.06 ± 0.16	7.07 ± 0.11	NS
W:RF						
95:5	6.50 ± 0.33	6.50 ± 0.28	6.49 ± 0.31	6.46 ± 0.20	6.48 ± 0.12	NS
90:10	5.52 ± 0.15	5.52 ± 0.46	5.50 ± 0.22	5.46 ± 0.11	5.50 ± 0.11	NS
Mean	6.01 ± 0.27	6.01 ± 0.32	5.99 ± 0.28	5.96 ± 0.25	5.99 ± 0.13	
CD ($P < 0.05$)					0.64	
W:SF						
95:5	6.56 ± 0.30	6.56 ± 0.20	6.54 ± 0.36	6.49 ± 0.33	6.53 ± 0.11	NS
90:10	5.55 ± 0.20	5.55 ± 0.26	5.52 ± 0.14	5.45 ± 0.18	5.51 ± 0.87	NS
Mean	6.05 ± 0.28	6.05 ± 0.27	6.03 ± 0.29	5.97 ± 0.29	6.02 ± 0.13	
CD ($P < 0.05$)					0.98	
W:GF						
95:5	6.61 ± 0.22	6.61 ± 0.17	6.58 ± 0.11	6.51 ± 0.26	6.57 ± 0.08	NS
90:10	5.63 ± 0.18	5.63 ± 0.25	5.59 ± 0.43	5.50 ± 0.35	5.58 ± 0.13	NS
Mean	6.12 ± 0.25	6.12 ± 0.25	6.08 ± 0.30	6.00 ± 0.30	6.08 ± 0.13	
CD ($P < 0.05$)					0.72	
CD ($P < 0.05$) of all treatments					1.02	

W, wheat flour; RF, raw fenugreek; SF, soaked fenugreek; GF, Germinated fenugreek; NS, Non-significant.
[a] Values are means ± SD of three independent determinations.

moderately' up to 30 days of storage. Hence, supplemented biscuits can be stored safely in polyethylene bags at room temperature for 30 days without any adverse changes in the organoleptic traits.

4. Conclusion

It may be inferred from the present study that fenugreek flour could be incorporated up to a 10% level in the formulation of biscuits without affecting their overall quality. The physical, sensory and nutritional characteristics, in general, revealed that biscuits containing 10% germinated fenugreek flour were the best among all the composite fenugreek flour biscuits. Hence, development and utilization of such functional foods will not only improve the nutritional status of the general population but also helps those suffering from degenerative diseases.

References

AACC. (1984). *Approved methods of analysis*. St. Paul, Minnesota: The American Association of Cereal Chemists.

Akeson, W. E., & Stahmann, M. A. (1964). A pepsin pancreatin digestibility index of protein quality evaluation. *Journal of Nutrition, 83*, 257–259.

AOAC. (1995). *Official methods of analysis*. Washington, DC: Association of Official Analytical Chemists.

Austin, A., & Ram, A. (1971). Studies on chapati making quality of wheat, Indian Council of Agricultural Research, New Delhi. *Technical Bulletin, 31*, 96–101.

Cerning, J., & Guilbot, J. (1973). Changes in carbohydrate composition during maturation of wheat and barley kernel. *Cereal Chemistry, 50*, 220–222.

Chen, H., Tubenthaler, G. K., Leung, H. K., & Baranowski, J. D. (1998). Chemical, physical and baking properties of apple fibre compared with oat and wheat bran. *Cereal Chemistry, 65*, 244–250.

Dhingra, S., & Jood, S. (2001). Organoleptic and nutritional evaluation of wheat breads supplemented with soybean and barley flour. *Food Chemistry, 77*, 479–488.

Feng, G. H., Chen, M., Kramer, K. J., & Reeck, G. R. (1991). Alpha-amylase inhibitors from rice: Fractionation and selectivity towards insect, mammalian and bacterial alpha-amylases. *Cereal Chemistry, 68*, 516–521.

Furda, I. (1981). Simultaneous analysis of soluble and insoluble dietary fibre. In W. P. T. James & O. Theander (Eds.), *The analysis of dietary fibre in food* (pp. 163–172). New York: Marcel Dekker.

Gandhi, A. P., Kotwaliwale, N., Kawalkar, J., Srivastava, D. C., Parihar, V. S., & Raghu Nadh, P. (2001). Effect of incorporation of defatted soy flour on the quality of sweet biscuits. *Journal of Food Science and Technollgy, 38*, 502–503.

Haug, W., & Lantzsch, H. J. (1983). Sensitive method for the rapid determination of phytate in cereals and cereal products. *Journal of Science and Food Agriculture, 34*, 1423–1426.

Hooda, S., & Jood, S. (2003). Effect of soaking and germination on nutrient and antinutrient content of fenugreek (*Trigonella foenum graecum* L.). *Journal of Food Biochemistry*.

Jood, S., Chauhan, B. M., & Kapoor, A. C. (1987). Polyphenol of chickpea and black gram as affected by domestic processing and cooking. *Journal of Science and Food Agriculture, 38*, 145–149.

Kalra, S. (1996). *Studies on the nutritional and anticholesterolemic properties of barley*. M.Sc. Thesis, CCSHAU, Hisar, India.

Kataria, A., Chauhan, B. M., & Punia, D. (1989). Antinutrients and protein digestibility (in vitro) of mungbean as affected by domestic processing and cooking. *Food Chemistry, 32*, 9–17.

Khosla, P., Gupta, D. D., & Nagpal, R. K. (1995). Effect of *Trigonella faecum Graecum* (fenugreek) on serum lipids in normal and diabetic rats. *Indian Journal of Pharmacology, 27*, 89–93.

Kim, H., & Zemel, M. R. (1986). In vitro estimation of the potential bio-availability of calcium from sea mustard, milk and spinach under stimulated, normal and reduced gastric acid conditions. *Journal of Food Science, 51*, 957–963.

Kirssel, L., & Prentice, M. (1979). Protein and fibre enrichment of cookie flour with brewer's spent grains. *Cereal Chemistry, 50*, 261–265.

Lindsey, W. L., & Norwell, M. A. (1969). A new DPTA-TEA soil test for zinc and iron. *Agronomy Abstracts, 61*, 84.

McWatters, K. H. (1978). Cookie baking properties of defatted peanut, soybean and field pea flours in baking powder biscuits. *Cereal Chemistry, 55*, 853–863.

Miyahara, S., & Jikoo, K. (1967). Examination of the method of calorimetric determination of lysine. *Journal of Japanese Society of Food Science and Technology, 14*, 512–513.

Neeraja, A., & Rajyalakshmi, P. (1996). Hypoglycemic effect of processed fenugreek seeds in humans. *Journal of Food Science and Technology, 33*, 427–430.

Panse, V. G., & Sukhatme, P. V. (1961). *Statistical methods for agricultural workers* (2nd ed.). New Delhi: Indian Council of Agricultural Research.

Patel, M. M., & Rao, V. (1996). Influence of untreated, heat treated and germinated blackgram flours on biscuit making quality of wheat flour. *Journal of Food Science and Technology, 33*, 53–56.

Rao, B. S. N., & Prabhavathi, T. (1978). An in vitro method for predicting the bioavailability of iron from foods. *American Journal of Clinical Nutrition, 31*, 169–173.

Sharma, H. R., & Chauhan, G. S. (2000). Physicochemical and rheological quality characteristics of fenugreek (*Trigonella foenum graecum* L.) supplemented wheat flour. *Journal of Food Science and Technology, 37*, 87–90.

Sharma, H. R., & Chauhan, G. S. (2002). Effects of stabilized rice bran-fenugreek blends on the quality of breads and cookies. *Journal of Food Science and Technology, 39*, 225–233.

Sharma, R. D. (1986). An evaluation of hypocholestrolemic factors of fenugreek seeds in rats. *Nutrition Reports International, 34*, 669–671.

Singh, R., Singh, G., & Chauhan, G. S. (1996). Effect of incorporation of defatted soy flour on the quality of biscuits. *Journal of Food Science and Technology, 33*, 355–357.

Singh, U., & Jambunathan, R. (1981). Studies on desi and kabuli chickpea (*Cicer arietinum*) cultivars. Level of protease inhibitors, levels of polyphenolic compounds and in vitro protein digestibility. *Journal of Food Science, 46*, 1364–1367.

Singh, U., Khedekar, M. S., & Jambunathan, R. (1982). Studies on desi and kabuli chickpea cultivars. The level of amylase inhibitors, level of oligosaccharides and in vitro starch digestibility. *Journal of Food Science and Technology, 47*, 510.

Somogyi, M. (1945). A new reagent for the determination of sugars. *Journal of Biological Chemistry, 160*, 61–62.

Swain, J., & Hills, W. E. (1959). The phenolic constituents *Pramus domesiicai.* The qualitative analysis of phenolic constituents. *Journal of Science and Food Agriculture, 10*, 63–68.

Tressel, R., Bahri, D., Molzen, M., & Khossa, T. (1977). Formation of flavour components in asparagus 2. Formation of flavour components in cooked asparagus. *Journal of Agricultural and Food Chemistry, 25*, 459–463.

Yemm, E. W., & Willis, A. J. (1954). The estimation of carbohydrates in plant extracts by anthrone. *Biochemical Journal, 54*, 508–509.