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Characterisation of tea fiber and its utilisation as a functional ingredient in the preparation of biscuits

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Abstract

Tea fiber (TF), a by-product of tea processing industry contained sugars (20%), total phenols (357 mg% as GAE) and dietary fiber (67.76%). The cellulose was present at 67.7% and lignin to an extent of 20%. Major phenolics identified were vanillic acid (58.67 mg/g) and procatechuic acid (36.42 mg/g). TF was blended with wheat flour at 0, 5, 7.5 and 10% and the blends were evaluated for rheological characteristics (farinograph, alveograph and amylograph) and biscuit making quality. Addition of increasing levels of TF made the dough stiff and weak. TF at 7.5% in the blend was found to give acceptable quality biscuits. Sugar (sucrose) in the formulation was replaced partially or completely with either sorbitol or maltitol, based on weight basis or sweetness basis. Biscuits prepared by replacing sucrose completely by maltitol were found to be highly acceptable. Nutritious biscuits can thus prepared by using TF as a source of fiber and maltitol as a sugar substitute.

Introduction

Dietary fiber mainly constitutes of polysaccharides, oligosaccharides, lignin, and associated plant substances which play an important role in many physiological processes. The most common sources of fiber used are bran from wheat, barley, corn, rice and oats; citrus fruits, grape, apple and sugar-beet fiber; soybean, peanut, pea and sunflower hull. On the other hand, the by-products generated during the processing of plant food constitute an economic and environmental problem and are now considered as a promising source of functional compounds (Carle *et al*., 2001).

Spent tea fiber (TF) is the by-product of the tea-brewing process. India's yearly tea production is approximately 857000 tonnes which is 27.4% of total world production. Amount of TF produced in India per year after processing is about 190400 tonnes *(www.teaboard.gov.in).* Finding a suitable alternative for the recovery or reuse of spent TFs would be environmentally beneficial. Spent TF contain lignin which functions as dietary fiber (Bunzel and Ralph, 2006) and also a good source of polyphenols having antioxidant, antibacterial and antitumor effects (Sakagami *et al*., 1991)

The demand for sugar free products without compromising on calories is increasing day by day (Diffy and Anderson, 1998). The main reason for alternative sweetening agents in foods today appears to be the people's desire to reduce their energy intake (Hyvonen, 1980). Many artificial and natural sweeteners have been developed which can replace sugar in bakery products. One such natural sweetener is polyols also referred as sugar alcohols consisting mainly of sorbitol, mannitol, isomalt, maltitol, lactitol, xylitol, erythritol and hydrogenated starch hydrolysates. Compared to sucrose, polyols are more advantageous because of their non-cariogenic property (Wennerholm *et al.*, 1991) and require lower insulin levels for their metabolism (Finer, 1991).

Use of polyols in place of sugar and polydextrose as a substitute for 35% of the fat content was studied (Zoulias *et al*. 2000). Sucrose replacement with fructose, sorbitol and mannitol improved the sweetness, flavor, crust color, spread, tenderness, keeping quality, nutrition and general appearance of cookies (Pasha *et al*., 2007). The effects of erythritol on the quality characteristics of Danish cookies and on the physical and sensory characteristics of chiffon cakes were also studied (Lin Hwang, and Yeh, 2003; Lin *et al*., 2010). The effect of total replacement of sucrose in sponge cakes with seven bulking agents - maltitol, mannitol, xylitol, sorbitol, isomaltose, oligofructose and polydextrose on cake quality was studied (Ronda *et al.*, 2004). The main objectives of the present study were to chemically characterize the tea fibre and efficiently utilize in biscuit formulation.

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Also investigate the effect of polyols on the chemical, rheological and baking quality of soft dough biscuits enriched with TFs.

Materials and Methods

Materials

Commercial wheat flour having 9.57% moisture, 10.45% protein and 0.57% ash was used in the study. Dried tea fiber (TF) collected from a commercial tea industry was ground into fine powder (throughs of 60 mesh sieve -250 micron). Liquid sorbitol 70%, a bulk sweetener and a humectant was procured from SD fine Chemical Limited, Mumbai. Maltitol (Maltisorb P 90) a white crystalline powder was procured from Roquette Signet Chemical Pvt Ltd. Mumbai.

Chemical analysis

Moisture content, total ash, crude protein and total fat were determined in the TF according to the standard methods (AACC, 2000). Bulk density of the TF was determined using a calibrated graduated cylinder (Borosil, India). Cylinder was filled with fiber with slight shaking and the contents of the cylinder was weighed and expressed as g/ml. The packed density was determined by pressing the sample in a graduated cylinder using a rubber stopper attached to a glass rod (Chen *et al*., 1988). Estimation of total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) was carried according to the standard AOAC methods (2005). TF as such, soluble and insoluble dietary fiber fractions of TF were analysed for sugar composition as described by Selvendran and Neil (1988). Samples were first hydrolyzed followed by neutralization with barium carbonate. The resultant monosaccharides were reduced with borohydride to obtain alditols, which were washed with methanol and acetylated using acetic anhydride and pyridine (1:1). The resultant alditol acetates were analysed by gas liquid chromatography (GLC - Shimadzu-CR4A) with a flame ionization detector OV-225. Peaks were identified by comparing with known standards of rhamnose, fructose, arabinose, xylose, mannose, galactose and glucose.

Tea fiber polysaccharides

Isolation of polysaccharides was estimated (Paramahams and Tharanathan, 1982). Powdered TF sample was subjected to 70% alcohol extraction to remove free sugars. The residue was further extracted twice with 10% alkali (1:10 w/v) under nitrogen for 4 h each. The extract was centrifuged and the alkali insoluble (AIR, lingo-cellulosic complex) was washed with water till the pH became neutral. The pH of the supernatant was adjusted to 4.5 by adding 50% acetic acid. The polysaccharides obtained at this pH were separated by centrifugation at 7000 rpm for 15 minutes and designated as hemi-A. To the supernatant, 3 volumes of ethanol were added in order to precipitate hemi-B polysaccharides. Alkali insoluble residue was further treated for estimation of cellulose in soluble and lignin in insoluble residues. Alkali insoluble (100 mg) was taken with 1ml of water and 5ml of 72% sulphuric acid solution, stirred occasionally with a glass rod and kept overnight at room temperature. It was diluted with 62 ml of water and refluxed over boiling water bath till the solution was clear. On filtration the filtrate was used for cellulose and insoluble residue for the lignin content.

Phenols and phenolics

Total phenols in TF were estimated using 80% acetone and expressed as gallic acid equivalents (GAE) according to Swain and Hillis (1959). Polyphenols were separated on a reverse phase C-18 column (4.6 x 250 mm) in a HPLC system (Agilent-Model 1200 series) using diode array detector (operating at 280 nm and 320 nm). A solvent system consisting of water:methanol:acetic acid (83:15:2) was used as mobile phase (isocratic) at a flow rate of 1ml/min (Glowniak *et al.*,1996). Known quantities of phenolic acid standards such as caffeic acid, P-coumaric acid, cinnamic acid, ferulic acid, gallic acid, gentasic acid, protocatechuic acid, syringic acid, vanillic acid were used for identification and quantification of phenolic acids present in the extract (Glowniak *et al*.,1996).

Dough characteristics

Blends of wheat flour and TF were prepared by substituting the wheat flour with spent TF at 0, 5, 7.5 and 10%. The effect of varying levels of TF on dough rheology and pasting characteristics was determined using farinograph (Brabender, Model No. 810108004, Duisburg, Germany) and micro visco-amylograph (Brabender, Model No. D-4 7055 OHG Duisburg, Germany) according to the standard AACC (2000) methods. Chopin alveograph was used to determine the extensible properties of the dough and parameters measured were - P, maximum overpressure; L, average abscissa at rupture; G, index of swelling; curve configuration ratio, P/L and deformation energy of dough, W (AACC, 2000).

Baking test

Test baking of biscuits was carried out for blends containing different levels of TF by following the method described by Sudha *et al.*, (2007). The formula used was: 300 g flour, 90 g sugar powder, 60 g shortening (Marvo brand, M/s.Hindustan Lever Ltd., India), 3 g sodium chloride, 1.2 g sodium bicarbonate, 3 g ammonium bicarbonate, 6 g dextrose (Qualigens Glaxo India Ltd., Mumbai, India), 6 g skimmed milk powder (Sabarkantha District Co-operative Milk Producer's Union Ltd., Himantnagar, India) and water (variable). Sugar powder and fat were creamed in a Hobart mixer (Spar Mixer; Spar Food Machinery Mfg. Co., Ltd., Ta-Li City, Taichung, Taiwan) for 3 minutes. Milk powder, sodium bicarbonate, sodium chloride and ammonium bicarbonate were dissolved in water and added to the cream and mixed for 5–6 minutes to obtain a homogeneous cream. Flour was added to the above cream and mixed for 2-3 minutes. Dough was sheeted to 3.5mm thickness and cut into 51 mm diameter discs. The dough sheets were baked at 205°C for 9–10 minutes. Biscuits were cooled to room temperature, packed in polypropylene pouches and sealed. Sugar content in the formulation was replaced partially (50%) or completely (100%) with either of the polyols namely sorbitol or maltitol based on their respective sweetness. Food grade glycerol monostearate (GMS) and sodium stearoyl lactylate (SSL) were used as emulsifiers to improve the quality characteristics of biscuits.

Texture profile analysis (TPA) of dough

The biscuit dough texture was measured with two bite TPA using a texture analyser LR-5K (Lloyd Instruments Ltd, Hampshire, England) with 5K load cell. The maximum compression force required for compressing the sample (biscuit dough sheeted to 10 mm thickness and cut in to circular discs of 4 cm) was recorded by the texture analyser. The sample was placed on the platform of texture analyzer and compressed up to 80 % of its original height at a cross head speed of 50 mm/min using a 50 mm dia plunger.

Evaluation of biscuits

Diameter (W) and thickness (T) of biscuits were measured and spread ratio (W/T) was calculated. The objective evaluation of texture expressed as breaking strength (g, force) was measured using the triple beam (three point break) snap technique of Gains (1991) using a texture analyser (TAHDi, Stable Micro Systems, Godalming, UK).

Statistical analysis

Biscuit samples with different percentages of TF and sugar replacement coded with different numbers were given to panelists and were asked to rate for each sensory attribute by assigning a score on a 9 point hedonic scale for surface colour, surface characteristics, texture, taste and mouthfeel. All results reported are mean values of two experiments and the data were analyzed using analysis of variance (ANOVA); Duncan's multiple range test was used to separate the mean and statistical significance was determined at $P<0.05$ (Steel and Torrie. 1980).

Color measurement

The colour of biscuits were measured in terms of colour difference (ΔE), lightness (L^*) and colour (+ a: red, - a: green, + b: yellow, - b: blue) using Hunter Lab Colour Measuring system (Colour measuring Labscan XE system, USA).

Nutritional parameters of biscuits

The chemical parameters such as total ash, acid insoluble ash, crude protein and total fat in control biscuits and polyol incorporated biscuits were determined by BIS methods. Estimation of total dietary fibre (TDF), soluble dietary fibre (SDF), and Insoluble dietary fibre (IDF) was carried out according to the standard AOAC methods (2000). Phenolic acids were estimated as described in section 2.4.

Results and Discussions

Chemical characteristics of TF

TF used in the study had a moisture content of 6.9 %. The bulk density was 0.324 g/ml whereas the packed density was 0.366 g/ml indicating that the TF to be very light in nature. The protein content was 13.83 % and ash content was 4.54 %. Soluble dietary fiber content was 4.07% and insoluble dietary fiber content was 63.69 %. The total polyphenol content was 357 mg% as GAE (Gallic acid equivalent). These results indicate that TF is a good source of fibre as well as polyphenols.

Sugar composition of TF

Carbohydrate composition of TF and of soluble and insoluble dietary fiber fractions of TF are given in Figure 1. Soluble dietary fiber fraction of TF composed mainly of arabinose (32.4%) and mannose (36.6%), with intermediate amounts of rhamnose (9.2%), xylose (12.2%) and glucose (9.6%). However insoluble fraction composed mainly of xylose (42.55%) and glucose (49.55%), with small quantities of arabinose, rhamnose and mannose. The carbohydrate composition of TF as such had no arabinose content, but had higher amounts of mannose (55.7%) and glucose (26.08%) and lesser amounts of rhamnose and xylose content. The variation in sugar

Table 1. Effect of tea fiber on biscuit dough and quality characteristics of biscuits

Tea fiber (%)	Biscuit dough: Hardness (N)	Springiness (mm)	Adhesiveness (Nmm)	Biscuit – Physical parameters: Spread ratio	Density (g/cm³)	Breaking strength (g force)	Surface Colour L*	a*	b*	ΔE	Sensory parameters: Surface character (9)	Crumb colour (9)	Texture (9)	Overall quality (9)
0	580	2.55	34.7	10.7	0.48	1192	64.32	10.75	35.16	41.15	8.35^{a}	8.3^{a}	8.5^{a}	8.5^{a}
5	633	1.87	17.72	10.4	0.51	1204	48.49	3.87	19.99	50.84	7.6^{b}	7.5^{b}	8.0^{ab}	7.7^{b}
7.5	675	0.93	16.15	10.2	0.52	1637	42.43	6.45	21.06	56.47	7.4^{b}	7.35^{b}	7.5^{b}	7.3^{b}
10	685	0.90	15.95	9.8	0.54	1872	41.34	7.00	20.34	57.38	6.75^{c}	6.5^{c}	7.0^{b}	6.7^{c}
SEM (±)	--	--	--	--	--	--	--	--	--	--	0.11	0.13	0.21	0.18

values for a particular column differ significantly when followed by different letters ($p<0.05$),
L: lightness/darkness; ±a: red/green; ±b: yellow/blue; ΔE: colour difference against standard white; S: subjective; O: objective; SEM: Standard error of mean at 20 degrees of freedom

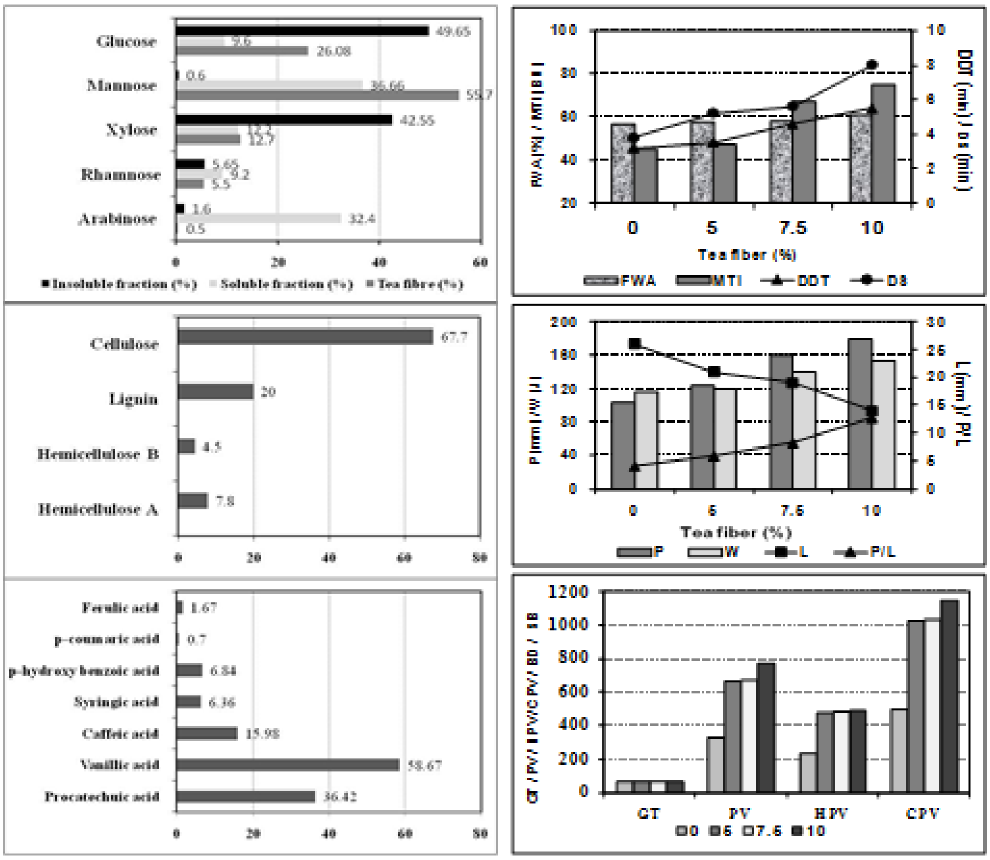

Figure 1. Sugars (%), fiber composition (%) and phenolics (mg/g) in tea fiber and effect of tea fiber on the rheological characteristics of wheat flour dough

composition in TF as such and after extraction of soluble and insoluble might be due to the extraction process.

Fiber composition and polyphenols in TF

Among the fiber components, cellulose in TF was maximum at 67.7 g/100g. The lignin was around 20.0 g/100g, whereas the hemicelluloses A and hemicelluloses B content in TF was in the range of 4.5-7.2 g/100g. These results indicate that the TF is rich in fiber components compared to wheat flour. Estimation of phenolics showed that the main tea catechins epicatechin (EC), epigallocatechin (EGC) and epigallocatechin gallate (EGCG); epicatechin gallate (ECG) were not present in the TF. Rather higher levels of vanillic acid (58.76 mg/g) and procatechuic acid (36.42 mg/g) were present in TF (Figure 1). Caffeic acid was present at 15.98 mg/g and other phenols were in the range of 0.7-6.84 mg/g of TF.

Effect of TF on the rheological characteristics

The effect of different levels of TF on the rheological characteristics of wheat flour is shown in Figure 1. With the addition of increasing levels of TF in the blend the water absorption increased

Table 2. Effect of additives on the quality characteristics of biscuits with 7.5% tea fiber

Additives	Water required (ml)	Spread (cm)	Thick-ness (cm)	Spread ratio	Density (g/cm^3)	Color (9)	Surface character (9)	Crumb color (9)	Crumb texture S (9)	Crumb texture O (g force)	Overall quality (9)
0	24.0	5.50	0.54	10.2	0.52	7.4^c	7.4^c	7.0^b	7.0^b	1637	7.3^c
GMS**	22.3	5.59	0.57	9.8	0.49	7.65^b	7.6^b	7.5^a	7.0^b	1407	7.5^b
SSL**	22.6	5.60	0.58	9.6	0.46	7.4^c	7.4^c	7.5^a	7.0^b	1366	7.3^c
GMS+SSL***	22.5	5.65	0.57	9.9	0.48	7.87^a	8.0^a	7.5^a	7.5^a	1343	8.0^a
SEM (±)	--	--	--	--	--	0.15	0.13	0.14	0.23	--	0.19

** added at the level of 0.5%, *** added at the level of 0.25% each; GMS: Glycerol mono stearate; SSL: Sodium steroyl lactylate; values for a particular column differ significantly when followed by different letters ($p<0.05$); S: subjective; O: objective; SEM: Standard error of mean at 20 degrees of freedom

marginally from 56.9% to 58.0%. Similar effects on water absorption were observed when wheat bran or rice bran was added, respectively (Barber *et al.*, 1981; Pomeranz *et al.*, 1977 and Sudha *et al.*, 2007). The differences in water absorption is mainly caused by the greater number of hydroxyl group which exist in the fiber structure and allow more water by interacting through hydrogen bonding (Rosell *et al.*, 2001). Incorporation of increasing levels of TF reduced the dough development time at lower levels of incorporation and at 10% fiber level both the dough development time and dough stability was more than the control. The mixing tolerance increased as the incorporation level of TF increased. The above results indicate that on increasing the levels of fibre addition, weakening of the dough increased.

The data on the effect of different levels of TF on alveograph characteristics of wheat flour dough are shown in the Figure 1. The maximum pressure values (P) increased from 104 to 179 mm whereas the extensibility values (L) decreased from 26 to 14 mm. The influence of these fiber sources on dough characteristics may be due to the presence of pectins, hemicelluloses, including pentosans tea fibre (Aykroyd and Doughty, 1964).

The data on the effect of different levels of TF on amylograph characteristics of wheat flour are shown in Figure 1. The data showed that the gelatinisation temperatures of the blends were comparable to the control except for 10% blend where the gelatinization temperature slightly increased. The peak viscosity which refers to the ability of starch granules to swell before breaking increased from 325 to 771 BU. Hot paste viscosity and cold paste viscosity also increased on addition of tea fibre compared to control. The breakdown and setback values also increased. The breakdown values, which are related to the starch, increased from 89 to 282 BU with increase in the fiber content. The higher BD values at higher concentration of fiber content indicate that the fiber fraction interacted with the starch and made the swollen granules more fragile. Similar results were reported by Sudha *et al.*, (2007).

Texture profile analysis (TPA) of biscuit dough

The control biscuit dough (wheat flour) hardness was 580 N and gradually increased to 685 N upon incorporation of increasing amounts of TF from 0 to 10% (Table 1). The springiness value, which describes the recovery behaviour of the dough between the two strokes, decreased with increase in the fiber addition from 2.55 to 0.9 mm. Sangeetha *et al.*, (2011) reported similar results while studying the influence of sugarcane bagasse. This indicates that the dough with TF can also withstand the second deformation relative to their behaviour under first deformation. The adhesive property which enables the substances / surfaces to adhere to one another greatly decreased from 34.7 Nmm to 15.95 Nmm with increase in the fibre levels.

Effect of different levels of TF on the quality characteristics of biscuits

Biscuits prepared from wheat flour – TF blends (0, 5, 7.5 and 10%) were evaluated for various physical characteristics. The water required to form the biscuit dough increased from 18 to 25%. The spread ratio of the biscuits decreased from 10.7 to 9.8. The biscuits were slightly denser as seen in the marginal increase in the density values. The force required to break the biscuits increased from 1192 to 1872 g with increase in the fiber content in the formulation indicating the biscuits became harder with increase in fiber content (Table 1).

The surface colour of the biscuits were analyzed and the results are presented in Table 1. Addition of increasing levels of TF from 0 to 10%, decreased the lightness value from 64.32 (control) to 41.34

Table 3. Effect of polyols on the physical characteristics of biscuits**

Polyol	Water required (ml)	Density (g/cc^3)	Spread ratio	Parameters L*	a*	b*	ΔE	Surface character (9)	Crumb color (9)	Crumb texture S (9)	O (g force)	Overall quality (9)
NIL	22.5	0.48	9.9	46.21	4.4	19.65	52.88	7.8^a	7.5^a	7.5^a	1343	7.5^a
Sorbitol (PR-WB)	19.3	0.49	10.0	45.85	2.91	19.05	49.43	7.0^b	7.3^{ab}	7.1^{ab}	1270	7.0^b
Sorbitol (CR-WB)	17.3	0.57	10.3	42.75	5.43	21.8	56.59	6.5^c	7.0^b	6.5^c	1217	6.5^c
Sorbitol (PR- SB)	17.3	0.52	9.8	36.64	4.66	21.11	58.66	6.1^d	7.0^b	6.5^c	1453	6.5^c
Sorbitol (CR- SB)	10.0	0.61	9.9	37.05	5.28	15.88	60.58	6.5^c	6.5^c	6.0^d	1419	6.0^d
Maltitol (PR), SB/WB	22.8	0.50	10.8	49.03	5.29	21.35	52.41	7.0^b	7.0^b	7.0^b	1328	7.0^b
Maltitol (CR), SB/WB	26.1	0.51	10.65	50.71	5.19	19.01	48.81	7.1^b	7.0^b	6.5^c	1375	7.0^b
SEM (±)	--	--	--	--	--	--	--	0.16	0.19	0.11	--	0.22

**7.5% fiber+ GMS (0.25%) +SSL (0.25%); WB – weight basis; SB – sweetness basis; PR – partial replacement; CR – complete replacement L^*: lightness/darkness; $\pm a^*$: red/green; $\pm b^*$: yellow/blue; ΔE: colour difference against standard white; values for a particular column differ significantly when followed by different letters ($p<0.05$); S: subjective; O: objective; SEM: Standard error of mean at 36 degrees of freedom

(10% TF) along with the increase in the redness and yellowness values. The ΔE which is the total colour diffrence between standard white sample value also showed an increasing trend from 41.15 to 56.47. This indicate that the colour of the biscuits which was golden brown for control changed to brown and dark brown colour with increasing levels of TF. The increase in the brown colour was due to the increase in the addition of brown coloured TF.

The sensory scores for colour of the biscuits decreased on increase in the TF as biscuit colour changed from golden brown to dark brown (Table 1). Surface characteristic scores of fibre incorporated biscuits slightly decreased with increasing levels of TF. The biscuit texture was comparable to control at 5% and became harder beyond 5% level, which may be due to increase in the amount of dietary fiber contributed by the TF. The taste values decreased significantly at 10% level and the mouthfeel values decreased gradually. Based on these results, it was found that 7.5% incorporation of TF was acceptable so as to have beneficial effects of the fiber.

To improve the quality characteristics of biscuits incorporated with 7.5% tea fibre, Glycerol Mono Stearate (GMS) and Sodium Steroyl Lactylate (SSL) were used as additives (Table 2) either individually or in combination. The water requirement for the preparation of biscuits upon addition of additives GMS or SSL and their combination did not vary to a greater extent. There was no significant difference in the spread of the biscuits but the thickness of the biscuits increased from 0.54 to 0.58 mm. The density of biscuits decreased and addition of additives in combination made the biscuits more porous. The breaking strength values which were 1637 g at 7.5% incorporation of TF reduced on addition of additives, and further reduced when additives were added in combination (1343 g). These results indicate that the combination of GMS and SSL improved the quality characteristics of biscuits in all respects. Combination of additives made the biscuits less dense. The breaking strength values reduced as compared with the biscuits without additives when added in combination (1637 to 1343 g). These results indicate that addition of GMS and SSL in combination improved the textural quality of biscuits to a greater extent. The surface smoothness improved, biscuits were crispier, had better mouthfeel, taste and overall quality scores. Similar results were obtained when these additives were added in combination to bagasse incorporated biscuits (Sangeetha *et al.*, 2011). Emulsifiers are known to enhance the incorporation of air, creating great numbers of air bubbles, aid in dispersing the shortening in sufficiently small particles and produce the maximum number of effective nucleating sites (Kamel and Ponte, 1993).

Addition of GMS, SSL or combination of both GMS and SSL did not have further change in the color and was similar to biscuit without additives. The surface smoothness improved on addition of either of the emulsifiers and in case of GMS and GMS+SSL, the scores were still better. The crumb texture improved and the biscuits were crispier when the emulsifiers were added in combination. The mouth feel, taste and the overall quality scores were thus slightly higher in biscuits where GMS and SSL

Table 4. Chemical composition of biscuits

Parameters	Control	Sugar substitute (CR)	
		Sorbitol	Maltitol
Total ash* (%)	1.05	1.33	1.45
Insoluble ash* (%)	0.017	0.021	0.023
Crude protein* (%)	7.83	7.13	7.13
Total fat* (%)	14.35	14.49	14.53
Soluble dietary fiber* (%)	0.05	1.68	1.74
Insoluble dietary fiber* (%)	1.96	7.73	7.93
Total dietary fiber* (%)	2.01	9.41	9.67
Plenolic Acids (mg %)			
Procatechuic acid	--	5.86	5.46
Vanillic acid	--	14.3	16.5
Caffeic acid	--	6.27	5.31
Syringic acid	--	1.02	0.98
p-Hydroxy benzoic acid	--	1.16	1.23
p-Coumaric acid	0.09	0.38	0.87
Ferulic acid	0.17	0.36	0.75

* values expressed on dry weight basis, CR – complete replacement

were used in combination (Table 3).

Effect of polyols on the quality characteristics of biscuits

Polyols namely sorbitol (sweetness compared with sucrose-0.6) and maltitol (sweetness compared with sucrose-0.9) were used to replace the sugar (sucrose) either partially or completely based on either weight basis or sweetness basis. The water requirement upon addition of sorbitol decreased as sorbitol used was in liquid form, whereas on addition of maltitol, the water requirement increased with either partial substitution or complete substitution (Table 3). The weight of the biscuits was found to be highest when sorbitol was used to replace sugar completely on sweetness basis. The increase in the weight is due to the slight retention of moisture as sorbitol is usually used as humectants in many products. The sorbitol biscuits were slightly denser compared to biscuits with sugar (sucrose). The spread ratio of sorbitol based biscuits increased when sugar was partially replaced, whereas on complete replacement, the spread ratio marginally decreased. Replacement of sugar on weight basis reduced the breaking strength values, however when used on sweetness basis, the breaking strength values increased (Table 3). Biscuits containing maltitol, used to replace sugar either partially or completely had slightly higher spread ratio. Addition of maltitol either partially or completely did not affect the breaking strength values (Table 3).

The biscuits prepared from 7.5% blend of wheat flour-TF, where sugar was substituted with sorbitol and maltitol on weight basis or sweetness basis were analyzed for color measurement (Table 3). Partial replacement of sugar with sorbitol either on weight basis or sweetness basis did not change the L^* values, whereas on complete replacement, the L^* value decreased to a greater extent. Addition of maltitol either on weight basis or sweetness basis increased the lightness value to a greater extent. The biscuits were slightly less brownish compared to biscuits with sorbitol. This is clearly reflected in ΔE values. The ΔE values were highest in sorbitol biscuits, whereas the ΔE values were comparable to biscuits containing sucrose when maltitol was used as sugar replacer.

The sensory evaluation of biscuits prepared from 7.5% blend of wheat flour-TF, and sugar replaced with either sorbitol or maltitol either on weight basis or sweetness basis are presented in Table 3. Sorbitol when used on sweetness basis, had better taste than when used on weight basis. Maltitol having sweetness equivalent to sucrose, hence replacement of sugar either on weight basis or sweetness basis was same. The colour of the biscuits were less brownish than biscuits containing either sugar (sucrose) or sorbitol. The texture of the biscuits was crispy compared to biscuits containing sorbitol. Partial replacement of sugar with maltitol gave biscuits with comparable sweetness, whereas on complete replacement, the biscuits were less sweet but acceptable. Among the two polyols used, biscuits prepared with maltitol were more acceptable than biscuits with sorbitol.

Nutritional parameters of biscuits

The chemical composition of biscuits prepared from 100% wheat flour (control) and biscuits prepared from 7.5% TF–wheat flour blend, wherein sugar was substituted with different polyols are shown in Table 4. The moisture content of control biscuit and sorbitol incorporated TF biscuits had similar moisture content, whereas maltitol incorporated TF biscuits had slightly low moisture content. The ash content, which was 1.05% for control increased to 1.33-1.45% in TF incorporated biscuits. The percentage of acid insoluble ash was in the range of 0.17-0.23%. There was no significant difference in either protein or fat content of either control or fiber enriched biscuits. The total dietary fiber content of TF incorporated biscuits was significantly higher than control biscuits. Since the percentage of insoluble fiber in TF was more, the content of insoluble fiber was also higher in fiber incorporated biscuits. The phenolics which were identified in TF were also observed in TF incorporated biscuits. Among the phenolics identified, vanillic acid was found to the maximum and ferulic acid was found to be minimum.

These results indicate that just replacing the wheat flour with 7.5% TF, biscuits rich in either soluble or insoluble fiber or rich in phenolics can be made.

Conclusions

The results indicate that the tea fibre; a by-product produced in the tea industry is a good source of dietary fiber and also rich in polyphenols. The studies also indicate that the by product can be efficiently utilized as a fiber fortificant in the preparation of bakery products. Highly nutritious biscuits can be prepared by replacing wheat flour with TF at 7.5% level, with increased dietary fiber content. Among the polyols used, maltitol based biscuits had better sensory and textural characteristics. Biscuits with either of the polyols had perceptible sweetness. Thus fiber enriched sugar substituted biscuits could be nutritional supplement to people suffering from constipation, obesity, colon cancer, diabetes, hyperlipidemia, hypertension coronary heart disease, intestinal disorders and various other diseases / disorders and would thus catch the market potentially.

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