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Development and Physico-Nutritional Evaluation of Sweet Potato Flour Based Gluten Free Cookies

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Abstract

Sweet potato flour based gluten free cookies suitable for coeliac patients were developed using sweet potato flour (40-60%), rice flour (20-25%), sorghum flour (15-20%) and cassava flour (5-15%). Cookies were developed using creamery method and evaluated for physical properties, textural analysis, proximate composition and sensory characteristics. Spread ratio of sweet potato flour based gluten free cookies varied from 3.95 to 5.49 as against 8.26 for the control maida-based cookie and it decreased with increasing level of sweet potato flour. Breaking hardness was the highest for 60% sweet potato flour incorporated cookies. Mineral content in sweet potato flour based gluten free cookies was higher than maida based cookie. Gluten free cookies prepared with sweet potato flour showed the maximum crude fiber content as compared to maida based cookie. Results indicated that sweet potato flour based gluten free cookies for coeliac patients with high overall acceptability scores could be prepared using the composite flour mix with sweet potato flour (60%), rice flour (20%), sorghum flour (15%) and cassava flour (05%).

Key words: Sweet potato flour, gluten free, cookies, nutrition, sensory evaluation

Introduction

Coeliac disease (CD) is a chronic autoimmune disorder, estimated to affect approximately 1-2% of the world population and results from the dietary intolerance to gluten (Green and Jabri, 2003; Reilly and Green, 2012). Ingestion of gluten by coeliac patients causes villous atrophy of the small intestine and leads to cramping, bloating, diarrhea, weight loss, vitamin and mineral deficiencies etc. (Green and Cellier, 2007). The disease has reached alarming proportions in Europe, USA and in India, it has been diagnosed in 26-49% of children, presenting with diarrhea in tertiary care hospitals (Bhatnagar et al., 2005; Yaccha et al., 1993). Consumption of gluten-free diet as a strict life-long strategy is the only known treatment for coeliac disease, as even trace amounts of gluten could trigger immune response in the patients (Gallagher et al., 2004; Rubio-Tapia and Murray, 2010; Sciarini et al., 2008). Gluten-forming proteins are necessary for proper dough development and texture of most of the baked food products (Feillet, 1988). Gluten present in the proteins of wheat, rye and barley comprises two fractions such as glutenins and gliadins (Hill et al., 2005). Glutenin has a rough rubbery texture on hydration while gliadin on hydration yields a fluid mass (Gallgher et al., 2004). These researchers found that during dough development, glutenin crosslinks with itself and then associates with gliadins to form gluten strands. Imparting the necessary dough consistency is a major challenge in the development of gluten free foods.

Cookie-type biscuits are widely consumed due to their long shelf life and crisp texture (Fasolin et al., 2007; Mareti et al., 2010). Cookies are made traditionally from wheat flour using a number of additives such as sugar, chocolate chips, peanut butter etc. (Kaushal et al., 2013). Functional cookies have been attempted by various researchers using several types of alternative non-wheat flours such as buckwheat flour, cassava flour, quinoa flour etc. (Isaballe et al., 2015; Jisha and Padmaja, 2011; Mishra et al., 2015).

Gluten-free cookies have been developed from rice, corn, buckwheat and potato flours (Arendt et al., 2002; Mishra et al., 2015; Sarabhai et al., 2015). India is one of the largest biscuit producers of the world and the bakery industry has been projected to grow annually at the rate of 15-17% (Kar et al., 2012; www.indianmirror.com). Being one of the most acceptable snack foods by both children and adults cookies/biscuits could be considered as the best vehicle for nutritional supplements.

Sweet potato (*Ipomoea batatas* L.) is the world's fourth important crop after rice, corn and cassava which is a potential source of carbohydrates and used as a staple food or as a rice substitute in many countries (Zuraida, 2003). It is commonly referred as food security or famine relief crop but under exploited. The major sweet potato producing states of India are Orissa, Bihar, Uttar Pradesh and West Bengal. Most commonly it is used as vegetable and snack food and industrial utilization is very negligible which negatively affects area of growth and production (FAO, 2013). Besides being a carbohydrate rich food, the tubers also contain contain vitamin C, vitamin E as well as dietary fiber, potassium and iron. They are very low in fat and cholesterol (Benjamin, 2007). It is a store house of micronutrients like thiamine (vitamin B1), riboflavin (vitamin B2), niacin, panthothenic acid (vitamin B5), folic acid and minerals like potassium, calcium, zinc, magnesium and having high quantities of iron (Woolfe, 1992 and Antia, 2006). Sweet potato has large potential to be used as a food in developing nations with limited resources because of its short maturity time, ability to grow under diverse climatic condition and on low fertile soil. Most of the researchers in this aspect found a substitution level of 10 – 15% for wheat flour on a dry weight basis as the most acceptable (El-sahy and Siliha, 1988). Hagenimana et al. (1992) reported that the addition of orange-fleshed sweet potato in buns, chapattis, and mandazis greatly increased the content of total carotenoids in these products. Most of the technical research on sweet potato flour has been focused on the development of new products using sweet potato flour rather than on efficient methods to produce and store the flour (Lizado and Guzman, 1982). Addition of various proportions of sweet potato flour in wheat flour can increase the nutritive values in terms of fibre and carotenoids. This also helps in lowering the gluten level and provide nutrition for celiac patients (Tilman et al., 2003).

Nevertheless, gluten-free cookie has not been hither to develop using sweet potato flour. Considering the health value of sweet potato tubers (rich in minerals such as potassium, magnesium and iron and low in glycemic index) and likely mineral deficiency in celiac patients due to mal absorption, coupled with the need to expand the utilization potential of sweet potato through value added products, the present study aimed at the development of gluten-free cookies from sweet potato flour.

Materials and Methods

Sweet potato and cassava tubers harvested, at three and ten months maturity respectively were obtained from the farm of ICAR-Central Tuber Crops Research Institute. The tubers were washed free of dirt and manually peeled and sliced to round discs of approximately 5 mm thickness. The slices were sundried for 36h till the moisture content was brought down to $< 10\%$ and powdered in a hammer mill into fine flour to pass through 85 mesh sieve of BSS standard (particle size 0.177mm). The dry flour was packed in air tight containers and stored at room temperature (30 ± 1^0C) for further use.

Rice flour (fine powder from white rice), sorghum (*Sorghum bicolor*) flour, sugar, fat and baking powder were procured from the local market. Edible guar gum (supplied by M/S Lucis Colloids., Mumbai) was also added in preparation to enhance the binding properties of the flour.

Preparation of cookies

Three gluten free flour blends were prepared by using sweet potato, cassava, rice and sorghum flours. The formulations for the preparation of gluten-free cookies comprised flours from sweet potato (SPF), rice (RF), sorghum (SF) and cassava (CF) respectively in the following proportions such as T1 (40:25:20:15), T2 (50:25:15:10) and T3 (60:20:15:05), while the control cookies were made from 100% refined wheat flour (maida). Cookies were prepared by creaming methods for making cookies dough. The ingredients (g) used in preparation of sweet potato flour based gluten free cookies were gluten free flour blends-100g, powdered sugar-32g, fat-40g, baking powder-1g and guar gum-0.5g.

Cookies dough was prepared in a spiral dough mixer and sheeted to a thickness of about 5mm approximately, cut into round shape of 30mm diameter and then transferred to baking tray and baked at 165°C for 20 min. Cookies, after attaining room temperature, were packed in airtight plastic containers and evaluated for different physico-chemical parameters.

Physical properties

Gluten free cookies were evaluated for physical characteristics including diameter (mm), thickness (mm) and spread ratio. Diameter and thickness were measured with the help of digital vernier caliper whereas spread ratio of cookies was calculated by dividing values of diameter (D) by the thickness (T) value (AACC, 2000). Ten cookies samples were considered for determination of physical properties of cookies.

Textural properties

The textural properties of gluten-free cookies were determined using Food texture analyzer [(TA-HDi); Stable Micro System (U.K)]. Breaking test was used to determine hardness and toughness of cookies. The individual cookie was placed over two points of the blade. The blade was attached to the crosshead of the instrument. The size of probe used was 5mm.The peak force from the resulting curves was considered as breaking hardness of the cookie and the area under the peak force was considered as breaking toughness. Settings were kept for the texture analysis as: Pre test speed-10mm/sec, Test speed-1mm/sec, Post test speed-1mm/sec, Distance at-50% and Starin-50%.

Proximate composition

Moisture, protein, fat, ash, crude fiber and mineral (P, K, Ca, Mg, Cu and Fe) content of different samples of cookies were determined as per standard methods. (AOAC, 2000). Mineral content of cookies was determined by using atomic absorption spectrophotometer. Total carbohydrates value was calculated by subtracting the total of moisture, protein, fat, crude fiber and ash content from 100. Total calories were calculated by multiplying protein, carbohydrates and fat content by the factors 4, 4 and 9 respectively.

Sensory characteristics

Sensory evaluation of cookies was done by a group of 15 panel members selected from diverse category of staff at ICAR-CTCRI. Samples were served with three digit code numbers. Panelists were instructed about the evaluation procedure. Sensory attributes like appearance, colour, aroma, taste, texture and overall acceptability for all cookies samples were evaluated using nine point hedonic scales. The grades for hedonic scale were like extremely-9, like very much-8, like moderately-7, like slightly-6, neither like nor dislike-5, dislike slightly-4, dislike moderately-3, dislike very much-2, dislike extremely-1 (BIS, 1971).

Statistical analysis

Results were expressed as means of triplicate analyses. A one way analysis of variance and Duncan's test were used to establish the significance of differences among the mean values at the 0.05 significance level. The statistical analyses were performed using SAS 9.3 software. (SAS ,2010).

Results and Discussion

Physical properties of sweet potato flour based gluten free cookies

The physical properties of gluten-free cookies such as diameter, thickness and spread ratio indicated that the diameter and spread ratio decreased proportionately with increase in the level of fortification with sweet potato flour (Table 1). On the contrary, thickness of cookies increased significantly with increase in sweet potato flour addition. This indicated that replacement of wheat flour with sweet potato flour resulted in reduction in lateral expansion of cookies, while it led to increased vertical expansion. Increase in thickness of sweet potato flour cookies led to a reduction in the spread ratio (D/T) and when compared to a spread ratio of 8.26 for maida-based control cookies, very low spread ratio of 3.95 was observed in cookies made from 60% sweet potato flour based blend. Decrease in spread ratio of biscuits has been reported in biscuits made from wheat flour fortified with functional additives such as defatted soy flour, cassava-soybean mix, chick pea, bran etc. (Hooda and Jood, 2005; Jisha et al., 2010; Jisha and Padmaja, 2011; Onweluzo and Iwezu, 1998; Patel and Rao, 1996;Singh et al., 1996;). Singh et al., (1993) found that high protein biscuits made from wheat-legume blends had low spread ratio. The poor spread ratio of biscuits made from composite flour might be associated with the altered elastic behaviour of the dough. Mcwatters (1978) attributed the spread ratio depression in biscuits made from composite flours to an increase in the relative quantity of hydrophilic additives, which compete for water in the dough. It is well established that root crop flours have a high affinity for water and their water holding capacity is also high. Singh et al., (2008) reported that the water absorption capacity (WAC) of sweet potato flour was 172% and much higher than wheat flour and it was because of high fiber and sugar content in the sweet potato flour and this might have led to the low spread ratio of sweet potato flour based cookies in the present study. Srivastava et al., (2012) also found that increase in the level of sweet potato flour resulted in linear decrease in spread ratio of biscuits.

Breaking hardness of sweet potato flour based gluten free cookies varied between 40.75±0.005N to 49.81±0.017N (Table 1). As the level of sweet potato flour was increased to 60%, breaking hardness significantly increased and similar results were reported by other researchers also (Manohar and Haridas, 1999; Herawati et al., 2015). This was probably caused by changes in the rheological properties of the dough of sweet potato cookies due to the presence of fibre, minerals etc. in sweet potato and other flours. Rheological properties such as water absorption capacity, dough development time and dough stability time, have been reported to change in whole wheat dough as a result of iron and zinc fortification (Akhtar et al ., 2008).

Singh et al., (1996) obtained hardness value of 26.97 N for biscuits made from refined wheat flour and found that defatted soy flour fortification enhanced the hardness. Jisha et al., (2010) reported lower hardness in cassava flour based biscuits than control, similar to the gluten-free cookies in the present study. Although brittleness is preferred to some extent by the consumers, too brittle products could result in packaging problems. However, subsequent sensory evaluation studies reported in the present study showed that 60% sweet potato flour based cookies (T3) had high acceptability.

Nutritional composition of sweet potato flour based gluten free cookies

Nutritional composition of sweet potato flour based gluten free cookies is presented in Table 2. Moisture content of cookies varied in between 3.29±0.19% to 5.96±0.05%. Cookie made with 50% sweet potato flour based blend had the highest moisture content and was significantly different from rest of the cookies. Srivastava et al., (2012) observed that moisture content of biscuits increased with increased concentration of sweet potato and this was attributed to high water binding capacity of sweet potato.

Crude protein content in the sweet potato flour based cookies was significantly lower (2.53-2.73%) than the control cookies (6.73%), mainly because sweet potato is reported to contain low protein (*Ca.* 2.3% only on dry basis) compared to 10-12% in refined wheat flour (Singh et al., 2008).Similarly, the ash content in sweet potato based cookies was significantly lower than the control cookies (Table 2). Control cookies had only very low crude fiber content (0.20%) as compared to 4.62-8.51% in the sweet potato based cookies. Sweet potato flour has been reported to contain 9.4 % crude fiber which is relatively higher than many cereal flours (Singh et al., 2008). Despite being rich in carbohydrate, the high fiber content in sweet potato flour might have led to the low energy density in the gluten-free cookies (Fig.1). Hager et al., (2011) observed that the intake of refined sugar is generally high in coeliac patients, which might lead to hyperglycaemia. The low calorie content of the sweet potato based gluten-free cookies might be advantageous to coeliac patients.

It was found that except for calcium, other minerals such as phosphorus, potassium, magnesium cooper and iron were significantly higher in the sweet potato based cookies (Table 3). Several authors had reported that sweet potato was one of the richest sources of potassium, phosphorus,

Table 1. Physical and textural properties of sweet potato flour based gluten free cookies

Cookies sample	Diameter (mm)	Thickness (mm)	Spread ratio	Breaking hardness (N)	Breaking toughness (NS)
Control	41.85±0.7[a]	5.06±0.04[d]	8.26±0.07[a]	40.63±0.53[c]	71.13±0.90[b]
T1	33.23±0.58[b]	6.05±0.14[c]	5.49±0.04[b]	43.07±0.005[b]	69.59±0.005[c]
T2	31.87±0.51[c]	6.95±0.16[b]	4.58±0.05[c]	40.75±0.005[c]	81.83±0.01[a]
T3	30.93±0.23[c]	7.83±0.24[a]	3.95±0.15[d]	49.81±0.017[a]	68.05±0.04[d]

The values are mean±S.D. from three replicates. Mean values followed by different superscripts in each column are significantly different at Pd”0.05

Table 2. Nutritional composition of sweet potato flour based gluten free cookies

Cookies sample	Moisture %	Protein %	Fat %	Ash%	Crude fiber %	Carbohydrates %
Control	3.29 ± 0.19^{d}	6.73 ± 0.40^{a}	25.03 ± 0.08^{a}	1.17 ± 0.03^{a}	0.20 ± 0.01^{d}	63.57 ± 0.38^{a}
T1	5.56 ± 0.03^{b}	2.73 ± 0.05^{b}	25.53 ± 1.55^{a}	1.175 ± 0.001^{a}	4.62 ± 0.05^{c}	60.37 ± 1.55^{b}
T2	5.96 ± 0.05^{a}	2.63 ± 0.05^{b}	26.89 ± 4.12^{a}	1.114 ± 0.005^{b}	8.51 ± 0.18^{a}	54.88 ± 4.26^{b}
T3	5.04 ± 0.05^{c}	2.53 ± 0.05^{b}	26.91 ± 4.41^{a}	1.046 ± 0.30^{c}	7.44 ± 0.10^{b}	57.02 ± 4.41^{b}

The values are mean±S.D. from three replicates. Mean values followed by different superscripts in each column are significantly different at Pd”0.05

Table 3. Mineral content of sweet potato flour based gluten free cookies

Cookies sample	P (mg/100g)	K (mg/100g)	Ca (mg/100g)	Mg (mg/100g)	Cu (mg/100g)	Fe (mg/100)
Control	84.33 ± 4.50^{ab}	168.66 ± 24.68^{b}	21.13 ± 32.50^{a}	0.008 ± 0.05^{d}	0.26 ± 0.450^{b}	0.35 ± 0.02^{d}
T1	79.66 ± 0.57^{c}	269.66 ± 0.57^{a}	11.16 ± 0.01^{b}	0.93 ± 0.05^{c}	0.36 ± 0.05^{a}	24.33 ± 0.01^{b}
T2	81.96 ± 0.05^{bc}	269.33 ± 1.15^{a}	11.19 ± 0.35^{b}	1.07 ± 0.05^{a}	0.32 ± 0.05^{a}	23.60 ± 0.03^{c}
T3	88.33 ± 0.57^{a}	270.33 ± 0.57^{a}	12.03 ± 0.02^{b}	0.96 ± 0.01^{b}	0.36 ± 0.05^{a}	24.67 ± 0.01^{a}

The values are mean±S.D. from three replicates. Mean values followed by different superscripts in each column are significantly different at Pd”0.05

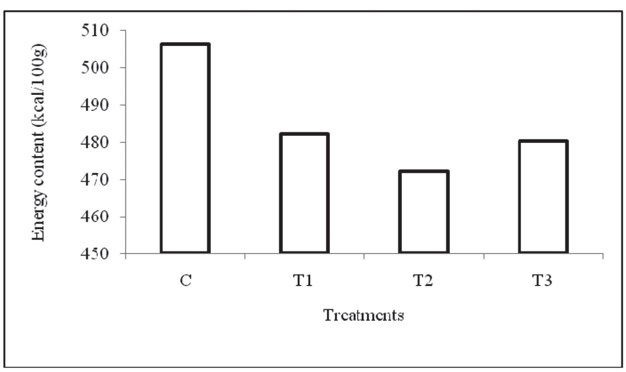

Fig.1. Energy content in sweet potato flour based gluten-free cookies

magnesium, iron and copper (Benjamin, 2007; Woolfe, 1992; Antia, 2006). Sweet potato flour has been reported as a rich source of minerals and provides 14% -20% of the dietary reference intake (DRI) for management of magnesium and 20%-39% for the potassium (Van Hal, 2000). Proportionate increase in K content was observed in the gluten-free cookies with the increase in sweet potato flour addition. As potassium is beneficial to hypertensive patients, this may be considered beneficial for such people. Magnesium content ranged from 0.93-1.07 mg/100 g in the gluten-free cookies, when compared to only 0.008 mg in the control cookies. Copper content ranged from 0.32-0.36 mg/100 g in the sweet potato based cookies. Iron content ranged from 23.60-24.67 mg/100g in the gluten-free cookies, when compared to only 0.35 mg in the control cookies. Minerals such as magnesium and copper have been associated with several vital enzyme activities and biological functions in the body (Cowan, 2002; Osredkar and Sustar, 2011). Although the calcium content in the sweet potato based cookies was lower than the control cookies, they still had high calcium (11.16-12.03 mg/100 g). The rich complement of minerals in the gluten-free cookies shall be considered beneficial for coeliac patients, as the villous atrophy in these patients leads to malabsorption of minerals (Green and Cellier, 2007).

Sensory evaluation of sweet potato flour based gluten free cookies

Mean sensory scores for different sensory characteristics of sweet potato flour based gluten free cookies are presented in Table 4. The mean sensory score for all the sensory characteristics, for all the cookies samples were more than minimum acceptable score of 6 (Table 4). It was observed that cookies were prepared using different level of sweet potato flour were accepted by the panelists.

Overall sensory acceptability for cookies prepared using 60% sweet potato flour was more than cookies with 40% and 50% sweet potato flour. The mean score for colour, taste, texture and overall acceptability were statistically non significant for the sweet potato flour based gluten

Table 4. Sensory evaluation of sweet potato flour flour based gluten free cookies

Cookies sample	Appearance	Colour	Aroma	Taste	Texture	Overall acceptability
Control	8.00±0.67[a]	7.78±0.97[a]	7.64±1.00[a]	7.92±0.82[a]	7.92±1.07[a]	7.85±0.71[a]
T1	6.42±1.15[c]	7.0±0.67[b]	7.21±1.05[a]	6.28±1.3[b]	6.14±1.16[b]	6.61±0.88[b]
T2	6.85±0.77[bc]	6.50±1.01[b]	6.78±1.12[a]	6.21±1.18[b]	6.57±1.01[b]	6.58±0.78[b]
T3	7.14±0.86[b]	7.14±0.66[ab]	6.92±1.14[a]	6.64±1.08[b]	6.50±1.50[b]	6.87±0.78[b]

The values are mean±S.D. from fifteen replicates. Mean values followed by different superscripts in each column are significantly different at Pd"0.05

free cookies and significantly different from wheat based cookie but based on mean value it was concluded that gluten free cookie containing 60% sweet potato flour, scored higher for sensory characteristics than other gluten free cookies.

The maximum mean score for different sensory characteristics of gluten free cookies developed using 60% sweet potato flour with 20% rice flour, 15% sorghum flour and 5% cassava flour indicated the commercial scope for manufacturing of good quality sweet potato flour based gluten free cookies which can be consumed by people with gluten allergy.

Eneche (1999) found that gluten played only a limited role in the dough characteristics and end product quality of unlike in the case of bread where leavening of dough is essential for puffing. In present study it was found that the gluten free cookies could be developed using sweet potato flour maximum up to 60% along with other non gluten flour for the preparation of gluten free cookies for coeliac patient.

Conclusion

Nutritional and physico-mechanical evaluation of gluten-free cookies showed that sweet potato flour could be successfully utilized along with other flours such as rice, sorghum and cassava for the development of cookies which could be safely consumed by coeliac patients. The low calorie density in the cookies coupled with the high content of minerals such as phosphorus, potassium, magnesium, copper and iron could be added advantage for sweet potato flour based gluten-free cookies. Based on the high scores for all the sensory parameters, it could be concluded that sweet potato flour based blend containing 60% sweet potato flour, 20% rice flour, 15% sorghum flour and 05% cassava flour was the best combination for making gluten-free cookies.

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