Effect of protein enrichment on quality characteristics and glycemic index of gluten free sweet potato (*Ipomoea batatas* L.) spaghetti

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Aims and scope

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Abstract

The aim of present investigation was justifying the suitability of sweet potato flour for development of gluten free spaghetti with reduced starch digestibility and to enhance protein content by fortification of whey protein concentrate (WPC) and chickpea flour (CPF) at the rate of 5%, 10%, and 15% respectively along with control. The effect of fortification in spaghetti was assessed for its glycemic index, physical, nutritional, and sensory properties. The data revealed that increase in the level of fortification of WPC and CPF resulted with increase in optimum cooking time, weight and volume without affecting cooking loss as compared to control sample. The percent increase in protein content

of spaghetti fortified with WPC and CPF found as 192.20% and 150.08% respectively in comparison with control. However, spaghetti fortified with 15% CPF and 15% WPC showed lowest starch digestibility with reduced glycemic index to 59.43 and 58.73 respectively. The spaghetti fortified with 10% WPC and 10% CPF was found overall acceptable by panelists. Moreover, the fortification of spaghetti with WPC and CPF could significantly increase the protein content along with overall acceptability and functional characteristics.

Introduction

The spaghetti or noodles are popular extruded products of Asian countries and generally prepared from wheat flour or pure starch. These are commonly consumed because of low in fat content, cholesterol free and healthy alternative as breakfast or snack food. However, peoples with specific disorder such as gluten sensitivity also known as celiac disease couldn't consume spaghetti made from wheat or semolina (Catassi et al. 2015). The severe entropy caused in celiac patients who affect on the absorption of micronutrients such as vitamins, iron, calcium etc. by microvilli in small intestine due to ingestion of specific protein named as gluten especially present in wheat, rye and barley. The effective remedy for celiac disease is strictly to adhere to only gluten free diet for longer time.

The preparation of gluten-free (GF) spaghetti without gluten is difficult because it provides strong protein network and prevent substantial loss during cooking and improved quality attributes (Kovacs et al. 2004). The various types of GF spaghetti/pasta fortified with additional nutrients are gaining importance in the domestic and international market. Therefore, there is urgent need to develop GF spaghetti with modification in manufacturing process and essential ingredients for enhanced nutrition. Most of the GF spaghettis are available in the market made from rice, corn, and gelatinized starch, with other functional components to improve the overall quality (Padalino et al. 2013; Susanna and Prabhasankar 2013). Spaghetti/noodles from refined flour or starches also found very high in glycemic index which reduce their acceptability especially by diabetic people (Wee and Henry 2020).

Sweet potato (*Ipomoea batatas* L.) is starchy tuber crop, gluten free in nature and contains natural health promoting component having functional value for the food market, such as β-carotene, phenolic acids, anthocyanin, carbohydrates, fibers, thiamine, riboflavin, niacin, potassium, zinc, calcium, iron, vitamins A and C and high quality protein (Grace et al. 2014). It is also a valuable medicinal plant having anti-cancer, anti-diabetic and anti-inflammatory activities. In the face of being a carbohydrate rich food, sweet potato has low glycemic index (< 55), suggesting its suitability as a food for diabetic people (Bjorck et al. 2000). It is predicted that diabetic population to be increase from 4% in 1995 to 5.4% by 2025, approximately 170% in developing countries particularly India ranks first, followed by China with the rapid economic development and changing food habits. India is reported to become the diabetic capital of the world by 2030. The high incidence of metabolic diseases such as type 2 diabetes, cardiovascular conditions, obesity etc. among people consuming foods rich in carbohydrates has led to increase research efforts globally on low glycemic foods (Menon et al. 2016). Sweet potato is also best alternative to wheat flour for the development of GF foods such as spaghetti for celiac patients with reduced glycemic index which makes suitability for diabetic patient also. The sweet potato flour in combination with other non-gluten ingredients could be utilized for preparation of GF pasta/spaghetti along with, micronutrients and carbohydrates. The attempts have been made by few researchers in order to prepare sweet potato pasta or spaghetti (Jyothi et al. 2011, 2012; Renjusha et al. 2012; Menon et al. 2016; Marengo et al. 2018).

The functional spaghetti enriched in protein content with low glycemic index could gain tremendous demand by health conscious consumers. The GF spaghetti available in markets is with high starch which resulted to high glycemic index. The fortification of dairy and legume based material such as whey protein concentrate and chick pea flour can increase the nutritional properties and would be able to lower the glycemic index (Jyothi et al. 2011). Therefore, the protein rich sources can be added to GF flour blends for preparation of spaghetti to achieve nutritional enhancement without compromising the sensorial and cooking quality characteristics.

Nevertheless from the nutritional point of view, spaghetti is inferior due to the lack of nutrients such as protein, micronutrients, vitamins etc. There is paucity of literature available on GF spaghetti from sweet potato flour with high protein and low glycemic index. Therefore, the attempts have been made in present investigation to develop GF spaghetti rich in protein content with reduced glycemic index from sweet potato flour with fortification of whey protein concentrate and chickpea flour and its effect on cooking and starch digestibility characteristics.

Materials and methods

The essential ingredients like sweet potato flour (SPF), cassava starch powder, rice flour, sorghum flour, sunflower oil and chickpea flour (CPF) were selected for preparation of GF spaghetti. CPF manufactured by Parakh Agro Industry LTD, Pune, Maharashtra; rice flour manufactured by Manjilas Food Tech Pvt. Ltd, Pollachi, Tamilnadu; and sorghum flour manufactured by Shree Corporation, Pune and sunflower oil were procured from local market of Aurangabad city, Maharashtra.

Whey protein concentrate (WPC), having 70% protein (Procon 3700) and guar gum was procured from Ms. Mahaan Proteins Ltd., Uttar Pradesh, India and Hindustan Gum and Chemicals Ltd., Bhiwani, Haryana, India respectively.

Sweet potato flour (SPF) were prepared from pale cream colour fleshed, white-skinned sweet potato (Cv. *Sree Arun*) having moisture 69.93%, starch 20.03%, sugar 2.2%, fat 1.6%, fiber 2.29%, and protein 0.4% of three months maturity grown in the experimental field of ICAR- Central Tuber Crops Research Institute, Trivandrum. The harvested tubers were cleaned, peeled, sliced with 5 mm thickness and dried at 60–65 °C in cabinet tray dryer for 10-12 h to get moisture content less than 10% followed by pulverization into powder with particle size of 0.177 mm. The dried SPF was packed and stored in air tight containers at room temperature until further use (Giri et al. 2016).

Cassava starch was prepared by extracting starch from cassava tubers (Cv. *Sree Pavitra*) harvested at nine month maturity from the experimental field of ICAR-CTCRI, Trivandrum. Tubers were peeled and crushed with plenty of water. The extract was filtered through muslin cloth and kept at undisturbed conditions for 2 days and supernatant was discarded and starch particles settled down were then dried at 70–80 °C and converted into powder (Krishnakumar and Sajeev 2018).

Formulations of Gluten free (GF) Sweet potato spaghetti

The GF spaghetti was prepared from sweet potato, rice and sorghum flour. The formulation details for preparation of GF spaghetti (T_1–T_6) are presented in Table 1. Each formulation had rice flour (15%), sorghum flour (15%), gelatinized cassava starch (4%), sunflower oil (5%) and guar gum (1%).

Spaghetti prepared using 60% SPF was treated as absolute control. GF spaghetti fortified with protein sources were prepared with addition of WPC and CPF at the levels of 5%, 10% and 15% respectively, by substituting SPF in formulations. The reason for use of sunflower oil at 5% level in each formulation was to make smooth textured spaghetti and reduction in starch digestibility in pasta as reported by Jyothi (2012).

Table 1 Formulations for GF sweet potato spaghetti fortified with protein

Preparation of GF spaghetti

The GF spaghetti was prepared by gelatinizing 4% cassava starch powder in a water bath at 68–70 °C for 2–3 min. using a double boiler (Tan et al. 2009) to avoid lump formation. The flour blends mentioned in Table 1 along with guar gum were mixed in gelatinized cassava starch and kneaded into dough using commercial dough mixer from Sanco Pvt., Ltd. (India) by adding warm water (43–45 °C) and dough was kneaded for 5–7 min. to obtain dough up to clean up stage. Sunflower oil was added at the end of dough preparation. Dough was kept for 30 min for uniform hydration and equilibrium at room temperature. The dough was then extruded in the form of spaghetti using noodle-making machine (Sanco, India). Each spaghetti strand was 0.2 × 23 cm (thickness × length). Long strips of spaghetti were extruded using each formulations and the wet spaghetti was dried in a tray drying oven (MSW-216) at 50 °C for 04–05 h.

Cooking properties

The cooking properties of GF spaghetti were determined as per standard methods (Tudorica et al. 2002). Cooking loss (%), increase in weight and volume (%) was calculated for its cooking quality parameters. Spaghetti sample (10 g) was placed into 300 ml of boiling distilled water. Samples were removed at fixed interval of time, washed with distilled water and drained for 2 min. The following equations were used for calculating cooking loss, weight and volume increase of spaghetti samples:

$${\text{Weight}}\;{\text{increase}} = \frac{{{\text{Weight}}\;{\text{of}}\;{\text{cooked}}\;{\text{spaghetti}} - {\text{Weight}}\;{\text{of}}\;{\text{uncooked}}\;{\text{spaghetti}}}}{{{\text{Weight}}\;{\text{of}}\;{\text{uncooked}}\;{\text{spaghetti}}}} \times 100$$

$${\text{Cooking}}\;{\text{loss}}\,\left(\% \right) = \frac{{\left({{\text{Weight}}\,{\text{of}}\,{\text{drained}}\,{\text{residue}}\,{\text{in}}\,{\text{cooking}}\,{\text{water}}} \right) \times 100}}{{{\text{Weight}}\,{\text{of}}\,{\text{uncooked}}\,{\text{spaghetti}}}}$$

$${\text{Volume}}\,{\text{increase}}\left(\% \right) = \frac{{\left({{\text{Volume}}\,{\text{increase}}\,{\text{of}}\,{\text{cooked}}\,{\text{spaghetti}} - {\text{Volume}}\,{\text{of}}\,{\text{uncooked}}\,{\text{spaghetti}}} \right) \times 100}}{{{\text{Volume}}\,{\text{of}}\,{\text{uncooked}}\,{\text{spaghetti}}}}$$

Spaghetti was boiled in distilled water until disappearance of white center core of spaghetti strand indicating complete gelatinization of starch to calculate the optimum cooking time (OCT).

Nutritional profile

The GF spaghetti was assessed for various physico-chemicals and nutritional characteristics viz. moisture, fat, protein, crude fiber, ash, carbohydrates (%) and calories content (kcal/100 g) as per standard methods (AOAC 2011). However, the carbohydrate and calories content were determined by difference in percentage by weight and by using the conversion factors respectively.

$${\text{Energy value }}\left({{\text{kcal}}/{1}00{\text{g}}} \right) = \left({\% {\text{Carbohydrate }} \times { 4}} \right) + \left({\% {\text{Protein }} \times { 4}} \right) + \left({\% {\text{ Fat }} \times { 9}} \right)$$

In vitro starch digestibility (IVSD)

The method described by Kim et al. (2008) as modified by Menon et al. (2015) was employed for determination of IVSD of GF spaghetti. The different starch fractions were determined including rapidly digested starch (RDS), slowly digested starch (SDS) and resistant starch (RS) by measuring starch content at 20 min [Glucose expressed as (g/100 g) × 0.9], that measured at 120 min. Moreover, starch remaining undigested after 120 min respectively. The sample of spaghetti (5 g) was mixed with HCl-KCl buffer (pH 1.5, 10.0 ml) and equilibrated at 37 °C for 10 min. Pepsin (EC 3.4.23.1; M/s SIGMA, USA) was added into sample to initiate proteolysis, then incubated at 37 °C for 1 h, followed by addition of 40 ml sodium phosphate buffer. After equilibrating for 10 min at 37 °C, 1.0 ml Panzynorm N was added and incubation continued for 20 min. Incubation of the Panzynorm assay system was further continued up to 120 min and aliquots of 1.0 ml were taken at every 20 min interval. The total starch content in sample was estimated as per method suggested by Moorthy and Padmaja (2002).

$${\text{RDS}} = {\text{ Glucose released at 2}}0{\text{ min}} \times 0.{\text{9 from 1}}00{\text{ g starch}}$$

$${\text{SDS}} = \, \left({{\text{Glucose released at 12}}0{\text{ min}} \times 0.{\text{9 from 1}}00{\text{ g starch}}} \right) \, - {\text{ RDS}}$$

where, 0.9 is the Morris factor for converting Glucose to starch.

$${\text{RS}} = {1}00 \, - \, \left({{\text{RDS}} + {\text{SDS}}} \right)$$

The hydrolysis index (HI) is calculated as:

$${\text{HI}} = \frac{{{\text{Total}}\,{\text{Glucose}}\,{\text{released}}\,{\text{from}}\,100{\text{g}}\,{\text{sample}}\,({\text{on}}\,{\text{dry}}\,{\text{basis}})\,{\text{at}}\,120\,\min \times 100}}{{{\text{Total}}\,{\text{Glucose}}\,{\text{released}}\,{\text{from}}\,100{\text{g}}\,{\text{white}}\,{\text{bread}}\,({\text{on}}\,{\text{dry}}\,{\text{basis}})\,{\text{at}}\, \times 120\,\min }}$$

Estimated glycemic index (EGI) could be computed using following formula of Goni et al. (1997).

$${\text{EGI }} = { 39}.{71 } + \, 0.{549 } \times {\text{ HI}}$$

Texture profile analysis

The textural characteristics of spaghetti were evaluated by cooking 30 g spaghetti in 300 g of water for 8 min (Lee and Jung 2003). The cooked spaghetti were then cooled in a sieve for 30 s and left for 2 min to remove the remaining water. Spaghetti of 0.3 × 23 cm (thickness × length) were prepared for texture profile analysis using a texture analyzer (TMS-Pro, FTC, USA). A cylindrical probe (Cylindrical P/35) with a diameter of 35 mm was effectively used with following test conditions viz. mode: compression, option: repeat until count; Two counts, pre test speed: 1.0 mm/s, test speed: 1.0 mm/s, post test speed: 2.0 mm/s, distance: 2 mm, trigger force: auto 20 g. The parameters calculated were hardness (peak force of the first compression), adhesiveness (negative force area for the first bite), springiness (distance of the detected weight of product on second compression, divided by the original compression distance), cohesiveness (ratio of the area of work during the second compression by the area of work during first compression), gumminess (hardness × cohesiveness) and chewiness (gumminess × springiness).

Colour characteristics

Colour (L, a^* and b^* values) of spaghetti samples were determined by using Minolta Colorimeter (Model-CR-10, Konica, Japan). Here L represents the lightness and extends from 0 (black) to 100 (white). The remaining two coordinates 'a^*' and 'b^*' represents redness (+ a values) to greenness (– a values) and yellowness (+ b values) to blueness (– b values), respectively. h0 (Hue angle) is the attribute of the colour by means of which the colour is perceived. C* (chroma) is the attribute of colour used to indicate the degree of departure of the colour from gray of the same lightness (Hunter and Harold

1987). h0 and C* are calculated by using the following formula

$${\text{h}}0 = {\text{ tan}}^{{ - {1}}} \left({{\text{b}}/{\text{a}}} \right) \, ;{\text{ C}}* = \, \left[{{\text{a2 }} + {\text{ b2}}} \right]^{{{1}/{2}}}$$

Sensory evaluation

The sensory evaluation of cooked spaghetti was carried out by 50 semi-trained panelists comprising of students and staff of the Department of Chemical Technology. The panelists were informed that the food to be evaluated is a functional food "fortified spaghetti" which is a nutritious alternative to conventional spaghetti, and the aim of the study was to determine consumers' acceptability/liking of the fortified spaghetti samples. The evaluation is limited to organoleptic properties of the products. Each panelist was served with 7 randomly arranged cooked spaghetti samples having dimension as 0.3 × 23 cm (thickness × length) on coded disposable plates. Water was provided for mouth rinsing in-between sample tasting. Panelists were requested to evaluate the color and appearance, taste, texture, flavor, and overall acceptability of the spaghetti using 9-point hedonic scale (Amerine et al. 1965), with 1 representing dislike extremely while 9 represents like extremely.

Statistical analysis

Results were expressed as means with standard deviations of analysis performed in triplicate for each parameters and sensory characteristics (n = 50). Data were analyzed using the statistical package SPSS 16.0 to perform one way ANOVA. The treatments were considered statistically significant at 5% level of significance ($P \leq 0.05$). Duncan's Multiple Range Test (DMRT) was used for comparisons of mean.

Results and Discussions

Cooking characteristics

The quality of sweet potato based GF spaghetti fortified with WPC and CPF could be assessed with cooking characteristics such as optimum cooking time (OCT), cooking loss, increase in weight and volume are presented in Table 2. The OCT measures the time in minutes required to cook spaghetti till it becomes soft and varied from 4.33 to 6.33 min. The spaghetti fortified with WPC and CPF had higher OCT as compared to control sample. The OCT of spaghetti was significantly increased with increase in level of fortification of WPC and CPF from 05 to 15% respectively. It might be due to increase in protein content, resulting in firmer texture of product. The increase in protein content of noodles also resulted with increase in cooking time as reported by Oh et al. (1985). The fortification of chick pea and defatted soy flour in pasta caused increase in cooking time of pasta is studied by Bashir et al. (2012). The similar results are also reported by Arora et al. (2018) in mushroom fortified instant noodles.

Table 2 Cooking characteristics and nutritional profile of protein fortified GF sweet potato spaghetti

Cooking loss is important cooking characteristics to predict the cooking quality of GF spaghetti. It measured the amount of dry matter content of spaghetti lost in cooking water and cooking loss of protein fortified sweet potato spaghetti is given in Table 2. The percent cooking loss of protein fortified GF spaghetti varied in the range of 12.02% to 13.10%. But, there was no significant difference in percent cooking loss of spaghetti added with 05% to 15% of WPC and CPF as well. This might be due to strong starch-protein network in GF sweet potato spaghetti fortified with WPC and CPF which leads to lower leaching of solids in cooking water. Leaching of solids in cooking water is negative attributes for spaghetti. The slight increase in cooking loss in WPC fortified sweet potato starch noodles are also reported by Menon et al. (2016) and in mushroom fortified instant noodles (Arora et al. 2018).

The weight and volume increase of GF sweet potato spaghetti is ranged from 102.36% to 123.89% and 51.87% to 68.60% respectively in comparison with control. The WPC and CPF fortified GF spaghetti showed significantly higher weight and volume increase as compared to control. The addition of WPC in spaghetti caused a significant increase in weight and volume from 102.36% to 123.89% and 51.87% to 68.60% and CPF from 102.36% to 120.67% and 51.87% to 65.93% respectively. The increase in weight and volume represents the water absorbed by starch and protein during cooking, utilized for gelatinization and hydration of starch and protein respectively (Menon et al. 2016).

Nutritional profile

The GF spaghetti fortified with WPC and CPF was also evaluated for moisture, protein, fat, ash, fiber, carbohydrates and energy value and the results obtained are presented in Table 2. Data revealed that moisture and fat content of protein fortified spaghetti were found in the range of 8.73% to 9.31% and 3.50% to 4.78% respectively. The fortification of protein in spaghetti resulted to increase in percent of moisture and fat content as compared to control. The addition of WPC and CPF in GF sweet potato spaghetti increased the moisture content from 8.73% (control) to 9.31% (T_3) and 8.73% (control) to 9.17% (T_6) respectively. It might be attributed to the lower moisture and fat content of WPC and CPF than sweet potato flour (SPF).

The results revealed the protein content of WPC and CPF fortified sweet potato spaghetti ranged between 6.03 and 17.62%. The substitution of SPF with WPC and CPF at the rate of 5% to 15% in GF spaghetti resulted to significant increase in protein content from 6.03% (control) to 17.62% (T_3) and

6.03% (control) to 15.08% (T_6). The percent increase in protein content was 192.20 and 150.08 with fortification of 15% WPC and 15% CPF in spaghetti respectively when compared to control. However, sweet potato flour lacks in protein content, fortification of WPC and CPF enhanced the protein level in GF spaghetti. The fortification of WPC in sweet potato starch noodles was reported by Menon et al. (2016) and Padalino et al. (2015) investigated the increased in protein content of chick pea added spaghetti.

The ash, fiber and carbohydrate content of spaghetti were found in the range between 1.87% to 3.50%, 2.09% to 3.02% and 64.54% to 75.20% respectively. The fortification of WPC and CPF were significantly affected the composition of spaghetti. The control sample was found higher in ash, fiber, and carbohydrate content than spaghetti fortified with 5% to 15% of WPC and CPF respectively. Moreover, the energy value of protein fortified spaghetti was found higher than control sample. It might be due to the higher content of ash, fiber and carbohydrates in sweet potato as compared to WPC and CPF (Dako et al. 2016).

In vitro starch digestibility and starch fractions

The amount of Glucose released on digestion of 100 g of starch in spaghetti at each interval of 20 min was calculated for different starch fractions. The results obtained are depicted in Table 3. The range of Glucose released after 20 min of digestion in the range of 28.03 g to 30.63 g. The amount of Glucose released increased as the digestion of starch proceeds fast and after 120 min as high as 40.13 g Glucose were released from control sweet potato spaghetti and gradually decreased from 40.13 g (control) to 32.63 g (T_3) and to 31.53 g (T_6). The protein fortification in spaghetti was resulted to decline in rate of release of Glucose after 2 h under in vitro conditions (Menon et al. 2016). The most reduction in starch digestion rate was observed in sweet potato based GF spaghetti fortified with CPF compared to WPC.

Table 3 In vitro starch digestibility and starch fractions of protein fortified GF sweet potato spaghetti

Starch is divided nutritionally into three fractions such as rapidly digested starch (RDS), slowly digested starch (SDS) and resistant starch (RS) (Table 3). The comparative proportions of these fractions in the food decide the digestibility of the food. Slowly digested starch (SDS) is considered as the most desirable form of starch that is digested slowly in 2 h in the small intestine. Resistant starch (RS) is the fraction that escapes digestion in the small intestine and has properties similar to dietary fiber (Englyst et al. 1992). The different starch fractions of GF sweet potato spaghetti are given in Table

3.

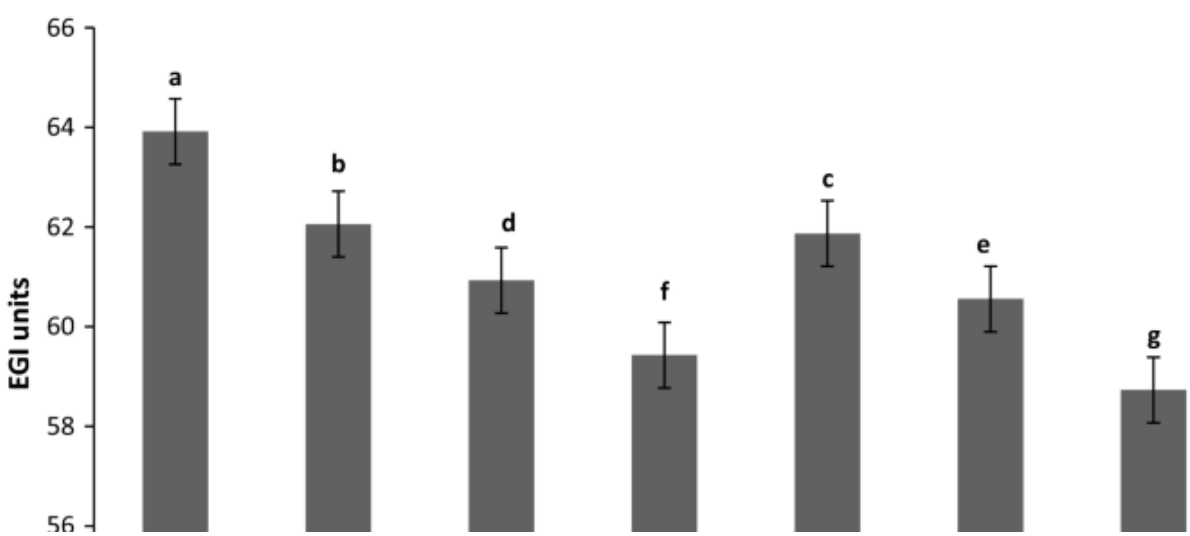
The RDS fraction was found in the range between 25.23 and 27.56%. The RDS content was found higher in spaghetti fortified with 15% WPC (T_3) as compared to control spaghetti whereas CPF fortified spaghetti showed lower RDS fractions over control. The SDS fraction was significant highest in control (36.12%), while the lowest was observed in 15% CPF (T_6) fortified spaghetti (28.38%). The increasing level of fortification of WPC and CPF resulted into decline in SDS fractions. The SPF had higher content of naturally slowly digestible starch and replacement of SPF with protein fortification caused reduction in SDS fractions of GF spaghetti (Jyothi et al. 2011; Menon et al.2016).

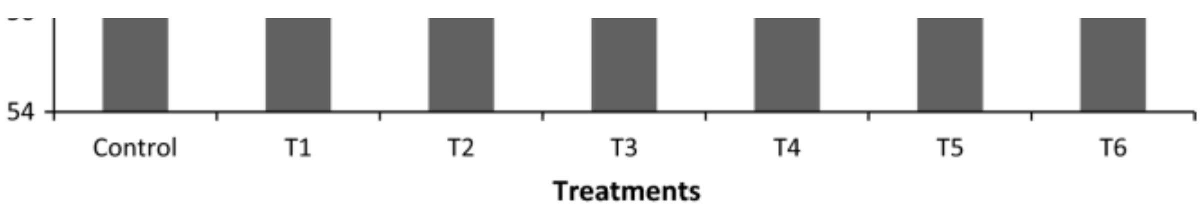
The protein fortified GF spaghetti found high in RS content as compared to control. The increase in level of addition of WPC and CPF in spaghetti enhances the RS level from 40.07% to 42.86% and 41.43% to 45.71% respectively which was higher than control (37.27%). The digestible starch fraction (RDS + SDS) was the lowest for CPF fortified spaghetti which resulted to highest RS content (Table 3).

The estimated glycemic index (EGI)

The highest estimated glycemic index (63.92) was recorded for the control sample of spaghetti, while fortification of WPC at 5% (T_1), 10% (T_2) and 15% (T_3) significantly reduced the EGI to 62.06, 60.93 and 59.43 respectively (Fig. 1). The spaghetti fortified with CPF (5%–15%) had EGI in the range of 58.73 to 61.87 which was lower than control as well as spaghetti fortified with WPC. It revealed that, increasing level of fortification of WPC and CPF resulted to gradual decrease in EGI of GF spaghetti. The study showed that protein fortified GF spaghetti could lower the EGI from 63.92 to 58.73% (Fig. 1). The GI of spaghetti was reduced as compared to control but it will falls under the class of moderate GI only (GI 56–69).

Fig. 1





Estimated glycemic index (EGI) of protein fortified GF sweet potato spaghetti

Glycemic index of food is closely related to the management of type 2 diabetes. Sweet potato is low glycemic (GI ≤ 55) food and has limited consumption (Bjorck et al. 2000). Pasta or spaghetti/noodles is getting wide acceptance in many countries as a health food which could slow down the glycemic response and hence used in the management of Type 2 diabetes and obesity (Gelencse´r et al. 2008). EGI was positively correlated to RDS and negatively correlated to the RS values in the spaghetti (Sandhu and Lim 2008).

Texture profile analysis

The data on texture profile analysis of sweet potato spaghetti and protein fortified spaghetti is presented in Table 4. The data revealed that textural attributes of spaghetti such as hardness, cohesiveness, springiness and chewiness found significantly increased with increase in the level of fortification of WPC and CPF from 5 to 15% (Marengo et al. 2018; Menon et al. 2015). The hardness of fortified spaghetti was in the range of 4.70 to 5.06 kg, while for control–sweet potato spaghetti as 4.57 kg. This can be due to the higher protein content of WPC and CPF.

Table 4 Texture profile analysis and colour value of protein fortified GF sweet potato spaghetti

Colour assessment

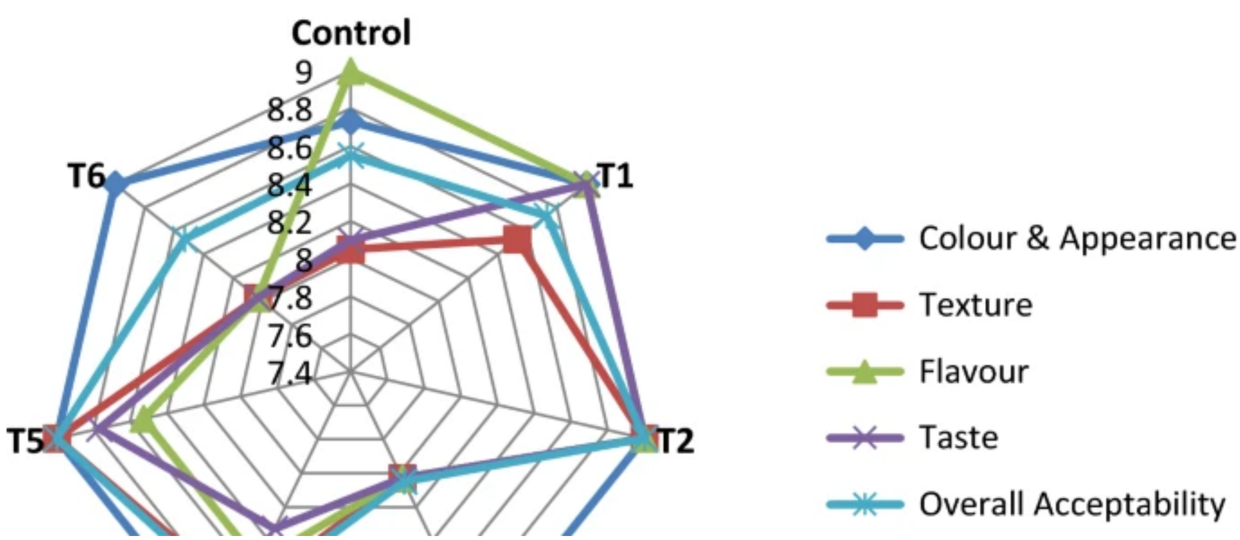
Colour is important attributes of food which represents the consumer acceptability of food products. The GF spaghetti fortified with WPC and CPF at the level of 5%, 10% and 15% analyzed for measurement of colour in terms of L, *a**, *b**, hue and chroma. The values obtained are presented in Table 4. The L value indicates the lightness, 0–100 representing dark to light. However, *a** value showed the degree of the red to green colour, with a higher positive *a** value indicating higher redness. *b** value indicates the degree of yellow to blue colour, with higher positive *b** value indicating more yellowness. Hue is nothing but the particular colour perceived and chroma is the intensity of colour perceived by the products.

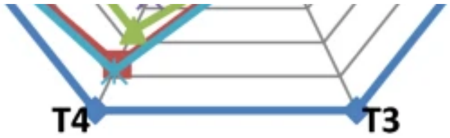
The study showed that, fortification of WPC and CPF in spaghetti leads to increase in brightness of spaghetti as compared to control-sweet potato spaghetti, which significantly increased the L value from 38.35 to 49.46. However, the increase in level of CPF in spaghetti from 5 to 15% resulted with decrease in L value from 43.81 to 40.34 which were higher than control. Moreover, *a** and *b** values of control-sweet potato spaghetti was found lower than protein fortified spaghetti. With increase in level of fortification, there were significant increase in redness and yellowness of spaghetti. It might be due to the natural yellow pigment of CPF. There was no significant difference noticed in hue value of control-sweet potato spaghetti (59.76) and spaghetti with 15% WPC (60.54). However, the intensity of colour perceived found highest in protein fortified spaghetti and lowest in control. Similar results were found by Marco and Rosell (2008) and Marti et al. (2014) also reported similar findings for protein enriched pasta with soy and whey respectively.

Sensory attributes

The cooked GF spaghetti fortified with WPC and CPF was assessed for various sensory attributes in terms of colour and appearance, texture, flavor, taste and overall acceptability. The average sensory scores obtained are graphically presented in Fig. 2. The sensory score for colour and appearance increased for the protein fortified spaghetti as compared to control-sweet potato spaghetti. It could be due to improvement in lightness of spaghetti with addition of WPC and CPF. Thao and Noomhorm (2011) also reported the lowest scores for appearance for 100% sweet potato starch noodles as compared to fortified noodles. Olorunsogo et al. (2019) reported that sensory score of instant noodles containing blend of 23.31% of sweet potato flour, 28.53% of soya bean flour and 18.02% of corn flour was most acceptable.

Fig. 2





The average sensory score of protein fortified GF sweet potato spaghetti

The sensory score in terms of texture and overall acceptability of cooked spaghetti fortified with 10% WPC (T_2) and 10% CPF (T_5) was found higher than control and rest of the treatments. Thus, the maximum level of WPC and CPF both that can be used for GF spaghetti fortification for better consumers' acceptability is 10%. Lower sensory scores recorded for flavour and overall acceptance of spaghetti fortified with > 10% CPF could be due to earthy and nutty taste of CPF, which adversely affected the overall acceptance of the densely fortified spaghetti.

Conclusion

The sweet potato based GF spaghetti can be prepared with enhanced protein content (8.31%–17.62%) through fortification with WPC and CPF. The starch digestibility of GF spaghetti found significantly reduced with addition of WPC and CPF at the level of 5%, 10%, and 15% along with retention of maximum resistant starch in spaghetti. The higher resistant starch content in protein fortified GF spaghetti showed decrease in the glycemic index from 63.92 to 58.73%. However, the textural and colour attributes of GF spaghetti found improved with addition of WPC and CPF respectively. The cooking quality characteristics like as optimum cooking time, increase in weight and volume resulted with increase in protein fortified spaghetti without significant difference in cooking loss of protein fortified spaghetti. The sweet potato based GF spaghetti fortified with protein up to 10% WPC (T_2) and 10% CPF (T_5) found overall acceptable in terms of sensory attributes. The developed sweet potato based GF protein fortified spaghetti with high RS and medium glycemic index has proved as an ideal food not only for celiac patients but for those suffering from obesity linked complications also.

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Ethics declarations

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The authors declare that they don’t have any conflict of interest.

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