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ORIGINAL ARTICLE

Development and quality evaluation of cookies supplemented with concentrated fiber powder from chiku (*Manilkara zapota L.*)

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Abstract The aim of this study was to investigate the physicochemical, textural and organoleptic attributes of developed cookies containing concentrated chiku fiber powder (CChFP) (*Manilkara zapota L.*) at different levels (0, 4.5, 7, 9.5, 12%). The results revealed that the addition of CChFP led to a noticeable improvement in dietary fiber, crude fiber and antioxidant activity of cookies. However, the protein content and the hardness of cookies were decreased. The effect of added CChFP up to 7% in texture, taste and aroma of cookies was negligible. The cookie supplemented with 7% CChFP established a superior overall acceptability score among other cookies containing CChFP, with an improved crude fiber (3.41 ± 0.26%), total dietary fiber (14.03 ± 0.57%) and radical scavenging activity (6.20 ± 0.48%).

Keywords Sapodilla · Cookie · Dietary fiber · Antioxidant activity · Physicochemical properties

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Introduction

The chiku fruit, also known as sapodilla (*Manilkara zapota L.*), is one of the significant tropical fruit in India, Mexico, central and south America (Jangam et al. 2008; Shui et al. 2004). Apart from the nutritional components such as protein, amino acid, vitamins, minerals and phytonutrients (polyphenols and antioxidants), the role of this plant in various traditional medicinal applications in India is noteworthy. Pulp, skin and seeds of chiku are edible. Besides, chiku seeds have been suggested for the treatment of bladder and kidney stone problems (Shui et al. 2004; Kulkarni et al. 2007). Chiku loss after harvesting is one of the critical issues in sub-tropical countries like India, owing to its short shelf life (Panda et al. 2014). Therefore, transforming and adding chiku to the food product with a longer shelf life might be a promising approach for the commercialization and offseason availability. In addition, chiku is rich in fiber and can be applied as a fiber supplement into other food products (Jangam et al. 2008).

Cookies are one of the popular bakery snacks, and considered as an essential source of energy by the majority of the population (Manley 2001). Nevertheless, traditional cookies are deficient in nutrients, phytonutrients and fiber (Turksoy and Özkaya 2011; Ismail et al. 2014). Recently, edible fiber has received much attention for its beneficial effects on human health (Rodriguez et al. 2006). There are some previous studies regarding the preparation of cookies incorporated with fiber from various fruits, e.g. cashew apple, pomegranate peel, papaya pulp and mosambi peel (Ogunjobi and Ogunwolu 2010; Ismail et al. 2014; Varastegani et al. 2015; Younis et al. 2016). However, according to our knowledge, the published studies lack substantial scientific reports on the incorporated cookies with concentrated chiku fiber powder (CChFP).

The purpose of the present research is to assess some proximate composition of CChFP, and quality of cookie added with CChFP at different levels (0, 4.5, 7, 9.5, 12%). The quality of developed cookies was investigated concerning physicochemical, textural and sensory properties.

Materials and methods

Raw materials

The ripen chiku (*Manilkara zapota L.*), refined sugar (Trust, India), refined wheat flour (Rajdhani Select, India), common salt (Tata, India), milk powder (Nestle, India), unsalted butter (Amul, India), vanilla liquid flavor (Ajanta Enterprises, India) and refined soybean oil (Adani Wilmar Brand, India) were obtained from local markets of Aligarh, UP, India. The laboratory-grade chemicals and solvent materials were used in this research.

Preparation of CChFP

Fresh and disease-free chiku fruits were selected for this study. After being washed under tap water, they were treated by sodium hypochlorite solution (40 mg/L) for 30 min to be sanitized as the method stated by Galla et al. (2017) followed by rinsing with running water. After manually separating the seeds from fruits, the fruit slices were converted into mashed pulp using domestic mixer-grinder (Tandem brand, India). Then the mashed pulp was squeezed in a clean double-layered muslin cloth to extract the juice. The remaining pomace was adequately blended with potable water at the ratio of 1:1 (w/v) using a blender (Tandem brand, India). Afterwards, this mixture was passed through double-layered muslin cloth to remove the extra juice and sugar. Subsequently, the pomace was dried by using a tray dryer (Biogen Scientific CAT No. BGS-123 Sr. No. 101742 U.P. India) at 58 ± 2 °C for 6 h to reach a constant weight. After cooling and grinding, the dried CChFP was sieved through 180 µm of a standard sieve (SETHI company, India) and packed in low-density polyethylene (LDPE) bags. Sealing was done using a heat sealer (Golden Eagle, India) and the package was kept at − 18 °C for the further use and analysis.

Preparation of cookies

In the current study, CChFP was used as a partial replacement of wheat flour in cookie formulations at the level of 0, 4.5, 7, 9.5 and 12%. Five cookie samples were prepared based on the formulation shown in (Table 1), as described by Kar et al. (2013), with some modifications. The ground sugar and unsalted butter were manually mixed for 3–5 min to obtain a homogenous cream. Subsequently, the suspension of sodium bicarbonate, ammonium bicarbonate, milk powder, common salt with water and vanilla liquid flavor were added to the cream. The mixture of wheat flour and CChFP was also transferred to the cream according to each cookie formulations. After kneading all ingredients, the prepared dough was kept for 5 min. Then the cookie dough was sheeted uniformly using a rolling pin at the thickness of 0.44 ± 0.05 cm. The sheeted dough was molded to a uniform 5 cm diameter by using a circle metal die. The round-shaped dough was baked using an electrical baking oven (Bake Tech Enterprises, New Delhi, India) at 168 ± 2 °C for 20 ± 2 min, and packed in LDPE pouches for further analysis.

Chemical analysis of CChFP, wheat flour and cookies

The moisture content, total fat, total protein, crude fiber, total ash and dietary fiber (total, soluble and insoluble) of wheat flour, CChFP and cookie samples were analyzed according to the methods of AOAC (1999). Total fat, total protein and crude fiber in the samples were measured by using the apparatus of Socs plus (SCS-6) with the solvent of petroleum ether, Kel plus (SUPRA LX VA) and Fibro plus (FES-3) (Pelican Equipments, Chennai, India), respectively. Dietary fiber (total, soluble and insoluble) of samples was estimated using the Fibertec TM 1023 system (Foss analytical, Sweden). The total carbohydrate content (%) was calculated by subtracting the sum of fat, ash, protein and moisture content from 100 according to the published formula by Uthumporn et al. (2015). The total energy value expressed as kcal per 100 g of dried sample, and it was determined by the sum of total fat multiplied by 9, protein and carbohydrate multiplied by 4 as the formula given by Schakel et al. (1997). The percentage of the content of dried gluten in wheat flour was measured through the method stated by the gluten-hand washing of AACC (2000). The equation for calculation is given below (1);

$$\text{Dry gluten content } (\%) = \frac{MG}{MF} \times 100 \quad (1)$$

where "MG" is the weight of dry gluten (g), "MF" represents the weight of wheat flour (g) (AACC 2000; Choudhury et al. 2015).

Preparation of methanolic extract solution

The methanolic extract solution was prepared according to the method suggested by Choudhury et al. 2015, and as done by Asadi and Khan (2019). Concisely, 1 g of the sample was blended with 10 ml of cold pure methanol.

Table 1 Formulation of cookies supplemented with CChFP at different levels

Ingredients	Cookie samples				
	C-Ck	4.5%ChF-Ck	7%ChF-Ck	9.5%ChF-Ck	12%ChF-Ck
Refined wheat flour (g)	300	286.5	279	271.5	264
CChFP (g)	–	13.5	21	28.5	36
Refined sugar (g)	144	144	144	144	144
Unsalted butter (g)	114	114	114	114	114
Milk powder (g)	6	6	6	6	6
Ammonium bicarbonate (g)	3	3	3	3	3
Sodium bicarbonate (g)	2.25	2.25	2.25	2.25	2.25
Common salt (g)	1.5	1.5	1.5	1.5	1.5
Lecithin (g)	0.42	0.42	0.42	0.42	0.42
Vanilla liquid flavor (ml)	4.5	4.5	4.5	4.5	4.5
Water (ml)	33–39	33–39	33–39	33–39	33–39

CChFP concentrated chiku fiber powder, C-Ck control cookie, 4.5%ChF-Ck cookie added with 4.5% CChFP, 7%ChF-Ck cookie added with 7% CChFP, 9.5%ChF-Ck cookie added with 9.5% CChFP, 12%ChF-Ck cookie added with 12% CChFP

Then, it was placed in ultrasonic bath (LMUC-4 40 kHz, India) at the temperature of 12 ± 2 °C with cold water for 15 min. After keeping the sample mixture overnight at 4 °C, it was centrifuged (Remi CPR 24 plus, India) for 15 min at 7000 rpm and at 15 °C. After filtration of the supernatant using Whatman paper (No. 1), the residue was recovered with 5 ml of methanol, and then centrifuged. The radical scavenging activity as well as phenolic content were estimated using the collected supernatant (methanolic extract solution).

Determination of phenolic content

The Folin- Ciocalteau reagent was used for the determination of total phenolic content as carried out by Asadi and Khan (2019), with the help of a proposed equation by Alara et al. (2020). After mixing 0.5 ml of methanolic extract solution with 1.5 ml of 10% (v/v) Folin–Ciocalteau's solution, it was allowed to stand for 3–4 min at 30 ± 2 °C. After the addition of 2 ml of 7% (w/v) sodium carbonate solution, the incubation was performed away from the exposure of light for 60 min. The absorbance was recorded using a double beam UV–Vis spectrophotometer (Electronics Corporation of India limited, I CIL, UV5704SS) at 760 nm. The total phenolic content of each methanolic extract solution was calculated using Eq. (2), with the help of the gallic acid standard curve (0–500 mg/ml). The result was revealed as mg gallic acid equivalents for each g of the dry weight of a sample (mg GAE/g DWS).

$$\text{Total phenolic content (mgGAE/gDWS)} = \frac{C \times V}{MS} \tag{2}$$

where "C" indicates the concentration of the sample that has been obtained from the calibration curve (mg/ml), "V" represents the volume (ml) of the solvent used for the extraction, and "MS" is the weight (g) of sample on dry matter basis.

Determination of radical scavenging activity

The free radical scavenging activity of methanolic extract solution of a sample was considered to determine the total antioxidant activity based on the method recommended by Choudhury et al. 2015 with minor changes. 1.5 ml of DPPH solution (25 mg/L pure methanol) was mixed thoroughly with 20 µL of each methanolic extract solution of the sample. Then after keeping it at 30 ± 2 °C in a dark place for 30 min, the absorbance was noted at 517 nm by a double beam UV–Vis spectrophotometer. The radical scavenging activity, known as DPPH antioxidant capacity was determined using Eq. (3) and expressed as percentage inhibition of the DPPH radical;

$$\text{Radical scavenging activity (\%)} = \frac{AC - AS}{AC} \times 100 \tag{3}$$

where "AC" indicates the absorbance for control (blended of methanol and DPPH solution), "AS" represents the absorbance for the sample (blended of methanolic extract solution of the sample and DPPH solution).

Color characteristics of CChFP, wheat flour and cookies

The color parameters viz, L^*, a^* and b^* values of CChFP, wheat flour and cookies were measured using Hunter Color Lab (ColorFlex EZ, Hunter Lab. Inc., U.S.A.). Chroma (C_{ab}), hue angle ($h_{ab}°$) and global color change (ΔE) were estimated by the Eqs. (4, 5, 6) given below (Franceschinis et al. 2012);

$$\text{Hue angle } \left(h^{\circ}_{ab}\right) = \left(\frac{b^*}{a^*}\right) \quad (4)$$

$$\text{Chroma } (C_{ab}) = \left(a^{*2} + b^{*2}\right)^{\frac{1}{2}} \quad (5)$$

$$\text{Global color change } (\Delta E) = [(L_0 - L^*)^2 + (a_0 - a^*)^2 + (b_0 - b^*)^2]^{1/2} \quad (6)$$

where the values of "L_0, a_0 and b_0" are for the control, while the values of "L^*, a^* and b^*" are for a sample.

Dimensional characteristics of cookies

The technique suggested by Ajila et al. (2008) was followed to calculate the diameter (D) and thickness (T) of cookies using a ruler and digital vernier caliper (Mitutoyo Cd-6" CSX Absolute Digimatic Digital Caliper, Japan) by average values of six cookies laid edge-to-edge and top of one another, respectively. The same process was replicated three times, with the cookies being rotated by 90° each time. The spread ratio of cookies was determined by the ratio of diameter (D) to the thickness (T) of cookies.

Texture analysis of cookies

Hardness, as the main texture quality of cookies, was assessed after 24 h of baking with Texture Analyzer (TA.HD Plus; Stable Micro Systems, Godalming, U.K.) and using three-point bending rig (HDP/3 PB). The maximum force required to break the cookies was noted as the hardness (g) of cookies.

Organoleptic assessment of cookies

The specific organoleptic features of cookies viz, color, taste, texture, aroma as well as overall acceptability were investigated using the system of 9-Point-Hedonic-Scale by a panel of twenty semi-trained assessors including staff and students. The lowest score that started from 1 indicated the lowest level of acceptance, and score 9 represented the highest level of acceptability of cookies (Ranganna 1986).

Data analysis

In the present study, all the analytical tests were replicated three times, and the results are expressed as mean of replicates ± standard errors. All data for organoleptic characteristics are average scores recorded by twenty panelist members ± standard deviation. The data were subjected to the analysis of variance (ANOVA) and Tukey's test with ($P \leq 0.05$) to find out the statistically significant difference in each specific property of cookies, and the Student's T-test was used for the comparison of two samples using SPSS software, version 22 (IBM) (Omobuwajo 2003).

Results and discussion

Chemical characteristics of CChFP and wheat flour

Data pertaining to the chemical compositions of CChFP and wheat flour are presented in Table 2. It is evident that the crude fiber, total dietary fiber, soluble and insoluble dietary fiber, total ash, fat, carbohydrate, energy content, phenolic content as well as radical scavenging activity of CChFP were more than wheat flour, however, total protein and moisture content of CChFP were lower. It can be deduced that CChFP is an excellent source of fiber, total phenolic content as well as radical scavenging activity. In this way, CChFP can be incorporated with food products such as cookies, which lack in fiber and phytonutrients. The dry gluten content of wheat flour used in this study was on a par with the results obtained by Drisya et al. (2015) and Sharma et al. (2013). There is a noticeable impact of protein and gluten content of wheat flour on the texture quality of cookies, specifically on the hardness and crispness (Manley 2001).

Color characteristics of CChFP and wheat flour

The color properties, i.e. L^* (brightness), a^* (redness), b^* (yellowness), C_{ab} (color intensity) and $h°_{ab}$ (hue angle) of wheat flour and CChFP are presented in Table 2. The $h°_{ab}$ describes the angle starting from red axis (+ a*), and shows the relative amounts of redness (+ a^*) and yellowness (+ b^*), where 0° and 360° define red color, and 90°, 180°, 270° indicate yellow, green and blue color, respectively. Besides, $h°_{ab}$ refers to the middle colors between adjoining pairs of the primary colors mentioned above (Uthumporn et al. 2015; De Simas et al. 2009; Mishra et al. 2015). According to the statement of De Simas et al. (2009), the value of 40–75° represents brown tonality, and 45° depicts orange tonality. ΔE, which denotes the global color spectrum from the control to the sample, mostly depends on processing conditions. In this research, for calculation of ΔE in the sample of CChFP, fresh chiku pulp was considered as the control. ΔE for wheat flour was not investigated. The values of a^*, b^* and C_{ab} in CChFP were significantly ($P \leq 0.05$) greater than those of wheat flour. However, the values of L^* and $h°_{ab}$ in CChFP were

Table 2 Chemical and color characteristics of wheat flour and CChFP

Parameters	CChFP	Refined wheat flour
Chemical characteristics		
Moisture (%)	3.12 ± 0.16[b]	12.16 ± 0.12[a]
Crude fiber (%)	34.32 ± 0.86 [a]	0.78 ± 0.33[b]
Total dietary fiber (%)	59.59 ± 0.30 [a]	2.14 ± 0.20[b]
Soluble dietary fiber (%)	3.42 ± 0.22 [a]	0.33 ± 0.05[b]
Insoluble dietary fiber (%)	56.18 ± 0.13 [a]	1.82 ± 0.15[b]
Total protein (%)	1.62 ± 0.99 [b]	11.89 ± 0.69[a]
Total ash (%)	1.23 ± 0.26 [a]	0.64 ± 0.02 [a]
Total fat (%)	2.28 ± 0.39 [a]	1.12 ± 0.06 [b]
Carbohydrate (%)	91.75 ± 1.37 [a]	74.20 ± 0.67[b]
Total energy (kcal/100 g)	394.04 ± 1.80 [a]	354.42 ± 0.79[b]
Total phenolic content (mg GAE/g)	2.41 ± 0.59 [a]	0.01 ± 0.01[b]
Radical scavenging activity (%)	22.43 ± 0.87 [a]	0.09 ± 0.07[b]
Dry gluten (%)	ND	9.10 ± 0.96[a]
Color characteristics		
L^*	64.24 ± 0.05[b]	88.69 ± 0.0 [a]
a^*	7.22 ± 0.03[a]	0.52 ± 0.01[b]
b^*	26.83 ± 0.09[a]	10.73 ± 0.04[b]
C_{ab}	27.79 ± 0.08[a]	10.74 ± 0.04[b]
$h_{ab}°$	74.93 ± 0.11[b]	87.24 ± 0.02[a]
Global color change (ΔE)	29.99 ± 0.11	ND

Values are means of three replicates ± standard deviation. All chemical parameters except moisture content are expressed on dry matter basis. Values in the same row with the different superscript letter are significantly different ($p \leq 0.05$)

CChFP concentrated chiku fiber powder, $h_{ab}°$ hue angle, C_{ab} chroma, ND not detected

significantly ($P \leq 0.05$) lower as compared to wheat flour. The value of $h°_{ab}$ in CChFP (74.93°) was ranged within the 0–90° spectrum, which showed a reddish-yellow color, but the value of $h°_{ab}$ in wheat flour (87.24°) was near the region of yellow tonality. There was a higher intensity of brown tint in CChFP as compared to the wheat flour. The stimulus for the ΔE could be associated with several reasons, namely generating and missing some pigments during the drying process (Uthumporn et al. 2015).

Chemical characteristics of cookies

Chemical characteristics of developed cookies are given in Table 3. From this table, it can be seen that the increase of CChFP in cookies led to the increase in some proximate compositions, i.e. moisture, crude fiber, total dietary fiber, soluble and insoluble dietary fiber, total ash, fat, energy, total phenolic content as well as radical scavenging activity. However, total protein and carbohydrate were reduced. The analogous result has been published by Youssef and Mousa (2012), Ismail et al. (2014), Varastegani et al. (2015) and Mishra et al. (2015) in terms of protein and carbohydrate contents for cookies supplemented with citrus peel powder, pomegranate peel, papaya pulp flour, and gluten-free cookies substituted with water chestnut powder. However, a reverse trend has been reported regarding protein content of cookies prepared with cashew apple powder and cassava flour by Ogunjobi and Ogunwolu (2010). They demonstrated that the addition of cassava flour with cashew apple powder led to the elevation of the protein content of cookies. In the current research, the increase of CChFP from 0 to 12% in cookie formulation resulted in the negligible increment of moisture content, soluble dietary fiber and total ash. However, a noticeable enhancement was observed in total dietary fiber followed by insoluble dietary fiber and finally radical scavenging activity of cookie samples. The moisture content for all developed cookies in this study was lesser than 5%, which was also previously established by Smith (1972) and Manley (2001).

Therefore, changes in most proximate composition of cookie incorporated with CChFP resulted due to the replacement of wheat flour by CChFP. In this perspective, an enriched fiber cookie can be produced through the substitution of wheat flour with CChFP in which the nutritional and phyto-nutritional value of cookie incorporated with CChFP could be better than those of control cookie.

Table 3 Chemical and color characteristics of cookie samples

Parameters	Cookie samples				
	C-Ck	4.5%ChF-Ck	7%ChF-Ck	9.5%ChF-Ck	12%ChF-Ck
Chemical characteristics					
Moisture (%)	2.10 ± 0.13^{b}	2.24 ± 0.03^{ab}	2.27 ± 0.02^{ab}	2.32 ± 0.06^{a}	2.37 ± 0.02^{a}
Crude fiber (%)	0.89 ± 0.25^{d}	2.84 ± 0.22^{c}	3.41 ± 0.26^{c}	4.39 ± 0.15^{b}	5.17 ± 0.21^{a}
Total dietary fiber (%)	2.38 ± 0.18^{e}	12.46 ± 0.45^{d}	14.03 ± 0.57^{c}	15.52 ± 0.58^{b}	16.94 ± 0.24^{a}
Soluble dietary fiber (%)	0.51 ± 0.14^{a}	0.57 ± 0.03^{a}	0.60 ± 0.03^{a}	0.63 ± 0.01^{a}	0.67 ± 0.02^{a}
Insoluble dietary fiber (%)	1.88 ± 0.23^{e}	11.89 ± 0.43^{d}	13.43 ± 0.57^{c}	14.89 ± 0.58^{b}	16.26 ± 0.24^{a}
Total protein (%)	6.05 ± 0.15^{a}	5.81 ± 0.13^{ab}	5.72 ± 0.07^{b}	5.58 ± 0.12^{b}	5.27 ± 0.07^{c}
Total ash (%)	0.48 ± 0.06^{a}	0.59 ± 0.07^{a}	0.63 ± 0.25^{a}	0.67 ± 0.10^{a}	0.71 ± 0.08^{a}
Total fat (%)	17.10 ± 0.27^{d}	17.85 ± 0.18^{c}	18.69 ± 0.29^{b}	19.06 ± 0.25^{b}	21.16 ± 0.1^{a}
Carbohydrate (%)	74.27 ± 0.17^{a}	73.51 ± 0.37^{ab}	72.68 ± 0.53^{bc}	72.37 ± 0.24^{c}	70.49 ± 0.04^{d}
Total energy (kcal/100 g)	475.19 ± 1.27^{d}	477.93 ± 0.64^{c}	481.82 ± 0.61^{b}	483.32 ± 0.89^{b}	493.45 ± 0.87^{a}
Total phenolic content (mg GAE/g)	0.42 ± 0.23^{b}	0.64 ± 0.14^{ab}	0.67 ± 0.10^{ab}	0.74 ± 0.06^{ab}	0.97 ± 0.14^{a}
Radical scavenging activity (%)	0.27 ± 0.11^{c}	5.94 ± 0.32^{b}	6.20 ± 0.48^{ab}	6.84 ± 0.51^{ab}	7.13 ± 0.25^{a}
Color characteristics					
L^*	71.49 ± 0.40^{a}	57.99 ± 0.74^{b}	55.91 ± 0.10^{c}	54.72 ± 0.68^{c}	51.85 ± 0.54^{d}
a^*	10.74 ± 0.29^{c}	12.46 ± 0.11^{b}	12.63 ± 0.12^{b}	13.41 ± 0.29^{a}	13.56 ± 0.39^{a}
b^*	37.53 ± 0.65^{a}	33.45 ± 0.61^{b}	32.17 ± 0.32^{bc}	32.09 ± 0.18^{c}	30.75 ± 0.45^{d}
C_{ab}	39.04 ± 0.56^{a}	35.69 ± 0.61^{b}	34.86 ± 0.18^{bc}	34.49 ± 0.21^{cd}	33.61 ± 0.39^{d}
$h_{ab}°$	74.02 ± 0.64^{a}	69.57 ± 0.21^{b}	68.52 ± 0.10^{bc}	67.36 ± 0.64^{cd}	66.21 ± 0.78^{d}
Global color change (ΔE)	0.00 ± 0.00^{d}	14.22 ± 1.10^{c}	16.62 ± 0.69^{bc}	17.82 ± 1.29^{b}	20.98 ± 0.85^{a}

Values are means of three replicates ± standard deviation. All chemical parameters except moisture content are expressed on dry matter basis. Values in the same row with the different superscript letter are significantly different ($p \leq 0.05$)

CChFP concentrated chiku fiber powder, C-Ck control cookie, 4.5%ChF-Ck cookie added with 4.5% CChFP, 7%ChF-Ck cookie added with 7% CChFP, 9.5%ChF-Ck cookie added with 9.5% CChFP, 12%ChF-Ck cookie added with 12% CChFP, $h_{ab}°$ hue angle, C_{ab} chroma

Color characteristics of cookies

Table 3 shows the color parameters of cookies' surface area. With the increase of CChFP in cookie formulation, the values of L^*, b^*, C_{ab}, and $h°_{ab}$ gradually declined, however, the values of a^* and ΔE increased. The value of $h°_{ab}$ in control cookie (74.02°) indicated brown tonality with high intensity of yellow color that is similar to the findings of De Simas et al. (2009). Nevertheless, all cookies containing CChFP had less than 60° h_{ab} value, which contributed red tonality in cookies. With the addition of CChFP into cookie formulation from 0 to 12%, the color of cookies changed from the bright-cream color to dark-cream with little red tint. The value of ΔE for developed cookies represents the global color change from the control cookie without any fiber supplementation to cookie containing CChFP. From Table 3, it can be seen that the value of ΔE in cookie incorporated with 12% CChFP was more than that of other developed cookies containing CChFP. Although the b^* value in CChFP (7.22) was significantly ($P \leq 0.05$) greater than wheat flour (0.52) (Table 2), it was decreased in cookies with increasing CChFP in cookie formulation (Table 3). This variation in b^* value of cookies can be attributed to the degradation or creation of some color pigments during baking process. It has been noted that the formation of brown pigments due to chemical reaction of Maillard and Caramelization throughout baking process could be the reason for color variance in cookies (Uthumporn et al. 2015). Thus, the color of cookies is not only dependent on the color of ingredients used in cookies, but process conditions can also affect the final color of cookies.

Physical characteristics of cookies

The dimensional characteristics of cookies are presented in Table 4. It is evident from the data that with the increase of CChFP in cookie formulations, the diameter of cookies slightly reduced, however, there was no significant difference ($p > 0.05$) in thickness of cookies. Therefore, the spread ratio of cookies decreased marginally. This pattern in spread ratio of cookies might be owing to the

Table 4 Physical and organoleptic characteristics of cookie samples

Physical characteristics	Cookie samples				
	C-Ck	4.5%ChF-Ck	7%ChF-Ck	9.5%ChF-Ck	12%ChF-Ck
Diameter (cm)	5.82 ± 0.05^{a}	5.60 ± 0.03^{b}	5.62 ± 0.04^{b}	5.57 ± 0.03^{b}	5.52 ± 0.04^{b}
Thickness (cm)	0.82 ± 0.03^{a}	0.80 ± 0.02^{a}	0.80 ± 0.03^{a}	0.80 ± 0.03^{a}	0.80 ± 0.04^{a}
Spread ratio	7.09 ± 0.25^{a}	6.98 ± 0.19^{a}	7.02 ± 0.27^{a}	6.97 ± 0.27^{a}	6.92 ± 0.31^{a}
Hardness (g)	2266.10 ± 0.90^{a}	1840.30 ± 0.89^{b}	1626.80 ± 0.92^{c}	1508.20 ± 0.75^{d}	1383.40 ± 0.87^{e}
Organoleptic characteristics					
Color	8.65 ± 0.49^{a}	7.90 ± 0.85^{ab}	7.45 ± 1.15^{bc}	7.20 ± 1.20^{bc}	6.90 ± 1.33^{c}
Texture	8.00 ± 0.79^{a}	8 ± 0.97^{a}	8 ± 0.72^{a}	8.25 ± 0.85^{a}	8.15 ± 0.99^{a}
Taste	8.35 ± 0.49^{a}	7.65 ± 1.09^{a}	7.85 ± 0.67^{a}	6.65 ± 1.42^{b}	5.95 ± 1.36^{b}
Aroma	8.20 ± 0.62^{a}	7.70 ± 1.03^{ab}	7.75 ± 0.72^{ab}	6.90 ± 0.97^{c}	6.30 ± 1.34^{c}
Overall acceptability	8.10 ± 0.3^{a}	7.58 ± 0.41^{bc}	7.79 ± 0.38^{ab}	7.27 ± 0.46^{c}	6.89 ± 0.52^{d}

Values of physical characteristics are means of three replicates ± standard deviation. Values of sensory characteristics are means of twenty recorded scores ± standard deviation. Values in the same row with the different superscript letter are significantly different ($p \leq 0.05$)

CChFP concentrated chiku fiber powder, C-Ck control cookie, 4.5%ChF-Ck cookie added with 4.5% CChFP, 7%ChF-Ck cookie added with 7% CChFP, 9.5%ChF-Ck cookie added with 9.5% CChFP, 12%ChF-Ck cookie added with 12% CChFP

competition of cookies' ingredients in absorbing available water during dough making (De Simas et al. 2009; Drisya et al. 2015). Moreover, the reduction in spread ratio of cookies can be affected by the decrease in gluten content of dough, which was resulted from the substitution of wheat flour with non-wheat powder (Choudhury et al. 2015).

The data related to the texture evaluation of cookies are presented in Table 4. Hardness is noticed as one of the important texture characteristics of cookies in assessing consumer acceptance. It is evident from the data that hardness of cookies was markedly affected by the addition of CChFP, while with the increase in the level of CChFP from 0 to 12%, the hardness of cookies significantly ($p \leq 0.05$) reduced. Hence, the most considerable hardness value was recorded for the control cookie without any fiber incorporation. This outcome, however, was contrary to the result of Varastegani et al. (2015), who found an increase in hardness of cookies with the elevation in the percentages of papaya powder in cookie formulation. The ingredients used in cookie can tremendously influence the hardness, which is the crucial texture quality of cookies. The hardness of cookie might be associated with the interplay of protein and starch by bonded hydrogen during the dough making and baking process (De Simas et al. 2009; Varastegani et al. 2015).

Organoleptic characteristics of cookies

The results of the organoleptic evaluation of cookies are shown in Table 4. It can be seen that the increase of CChFP in cookies from 0 to 12%, reduced the average score of color, taste, aroma and overall acceptability. However, a reverse result was observed concerning the texture score, which probably associated with the decrease in the hardness of cookies. There was no significant difference ($P > 0.05$) in texture score among all cookie samples. Furthermore, there were no significant differences ($p > 0.05$) between the control cookie and cookie added with 7% CChFP in respect of taste, aroma and overall acceptability. The cookie containing 7% CChFP received the highest score in overall acceptability among other cookies supplemented with CChFP, where the cookie incorporated with 9 and 12% of CChFP gained the smaller sensory score.

Conclusion

The present research revealed that CChFP could be added into cookie formulation as a rich source of fiber, polyphenols as well as antioxidants to develop the nutritional value of cookies. The supplementation of cookies up to 7% of CChFP served promising effects on color, taste, aroma and texture quality of cookies. The cookie containing 7% CChFP had the superior overall acceptability score of organoleptic assessment amongst other cookies incorporated with CChFP. The addition of CChFP into cookie formulation can be a new and crucial step for the industry and one of the unique approaches for providing value-added cookies for health conscious people.

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Compliance with ethical standards

Conflict of interest The authors express no conflict of interest in this work.

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