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Research article

Quality of cookies supplemented with various levels of turmeric by-product powder

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Abstract: Starch production from turmeric (*Curcuma longa*) generates residue, which contains different nutrients, dietary fiber, and antioxidants. In this study, the by-product of turmeric starch production was dried at 50 °C to a moisture content of 11–12%, milled, passed through a 70-mesh sieve, and then added to cookie formulation to increase antioxidant content and activities of the fortified cookies. The ratio of turmeric by-product powder (TBP) in the cookie formulation was varied from 0 to 12%. The greater the TBP ratio in the cookie recipe was, the greater the contents of ash and dietary fiber and the antioxidant activities of the fortified cookies. At 12% TBP level, the total phenolic content, flavonoid content, 2,2-diphenyl-1-picrylhydrazyl scavenging activity, and ferric reducing antioxidant power of the fortified cookies were increased by 6.4, 5.5, 4.7, and 6.8 times, respectively, as compared to those of the cookies without TBP supplementation. The increase in TBP ratio also enhanced the product hardness and reduced its diameter, thickness, and overall acceptability. The cookies with 9% TBP ratio were rich in antioxidants and the sensory quality was acceptable. Turmeric by-product powder was a good ingredient for antioxidant fortification in cookie products.

Keywords: antioxidant; cookie; dietary fiber; turmeric by-product powder

1. Introduction

Nowadays, foods with high antioxidant activity have attracted attention since they provide many health benefits including preventing constipation, decreasing blood cholesterol levels, and protecting the human body against negative effects of free radicals [1]. Cookies are a well-known and frequently consumed food worldwide. This product provides a relatively complete range of nutritional ingredients but is poor in bioactive compounds [2]. Plant products and their by-products contain various antioxidants including phenolics, carotenoids, and chlorophyll [3]. Addition of by-products from plant-based food processing into bakery products might improve the product quality and health properties [4].

Curcuma longa is commonly cultivated in tropical regions. The turmeric rhizome contains starch, protein, minerals, and dietary fiber. Further, turmeric has a high content of secondary metabolites, especially phenolics and terpenoids [5]. To date, about 235 phenolic and terpenoid compounds have been identified in different turmeric species, including 109 sesquiterpenes, 68 monoterpenes, 22 diarylheptanoids, 8 phenylpropenes, 5 diterpenes, 3 triterpenoids, 4 sterols, 2 alkaloids, and other compounds [6]. Nowadays, the turmeric rhizome is used to make turmeric spice, turmeric starch, and curcuminoid extract. Every year, turmeric starch production and curcuminoid extraction result in more than 200,000 tons of by-products [7]. The turmeric by-products have been used as material to make ceramic foam [8], edible coatings [9], and lactic acid by microbial fermentation [7]. However, the addition of turmeric by-products into food products has not been reported.

In this research, turmeric by-product powder (TBP) was added to a cookie recipe to increase its antioxidant content and activity. The study aimed to evaluate nutritional composition, physical characteristics, and overall acceptability of the TBP-supplemented cookies.

2. Materials and methods

2.1. Materials

The turmeric (*Curcuma longa*) originated from Dak Lak province (Vietnam), and the turmeric by-product was supplied by a local turmeric starch plant. In the turmeric starch production, the turmeric was washed with water, peeled, wet milled, and filtered through a screen; the solid residue on the screen (turmeric by-product) was pressed and dried at 50 ℃ to achieve a moisture content of 11–12%. The dried turmeric by-product was milled, sifted through a 70-mesh sieve, put into sealed plastic bags, and kept in a dark place at 2 ℃ for use.

Ingredients for cookie preparation, including wheat flour, chicken eggs, table salt, isomalt, acesulfame potassium, vanilla powder, baking powder, and butter, were collected in a local supermarket.

All chemicals with analytical grade were bought from Merck KGaA (Germany). Commercial enzymes (Alcalase 2.5 L, Termamyl SC and Dextrozyme GA) used in dietary fiber determination were purchased from Novozymes (Denmark).

2.2. Cookie making

The cookie recipe for 1000 g of the product included 455.5 g blend flour (mixture of wheat flour and turmeric by-product powder), 141.5 g eggs, 212.6 g butter, 141.5 g isomalt, 0.6 g acesulfame potassium, 1.8 g vanilla, 4.9 g baking powder, 2.0 g table salt, and 39.5 g water. The ratios of TBP were 0, 3, 6, 9, and 12 g per 100 g blend flour. First, egg white and yolk were mixed in an electric mixer (HR1456, Philips Co., China) at 200 rpm for 4 min. Table salt, acesulfame potassium, isomalt, and water were then added and mixed at 200 rpm for another 4 min. In the next step, butter was added and whipped for 4 min; then, vanilla and baking powder were added and mixed at 200 rpm for 1 min. Finally, the obtained mixture and the blend flour were mixed and kneaded in a stand mixer (M8, Unie Co., China) at 120 rpm for 2 min.

The dough was rolled into a sheet with 3 mm thickness and shaped into portions, using a round mold with 40 mm diameter. The oven was pre-heated at 175 ℃ for 15 min; cookies were baked at 175 ℃ for 18 min. The obtained cookies were cooled to 25 ℃ and preserved in sealed plastic bags at room temperature for 2 days before analysis.

2.3. Analytical methods

2.3.1. Nutritional composition

Moisture was evaluated by drying at 105 ℃ to constant weight, using an MX-50 infrared moisture analyzer (A&D Co., Japan). Protein, lipid, ash, starch, total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) were measured by the AOAC 984.13, 960.39, 930.30, 996.11, 991.43, 991.42, and 993.19 methods, respectively.

2.3.2. Antioxidant contents and activities

Extraction of antioxidants from TBP, wheat flour, and cookie samples was performed at room temperature for 1 h, using 80% aqueous acetone solvent and sample/solvent ratio of 1/10 (v/v). The extract was then recovered by centrifugation at 9000×*g* and room temperature for 20 min and used for evaluation of antioxidant contents and activities. Total phenolic content was analyzed using the spectrophotometric method and Folin-Ciocalteu reagent [10]. Total flavonoid content was evaluated by the spectrophotometric method with aluminum chloride and sodium nitrite reagents [11]. Total curcumin content was determined using the spectrophotometric method and curcumin standard [12].

Antioxidant activities were measured by 1,1-diphenyl-2-picrylhydrazyl (DPPH) and ferric reducing antioxidant power (FRAP) assays [13].

2.3.3. Physical properties

Dimensional characteristics of the cookies, including diameter, thickness, spread ratio, and specific volume, were evaluated following the procedure previously reported [14]. Diameter (D, mm) was determined by placing six cookies close to each other in a horizontal row, the length of which was measured with a digital vernier caliper. Thickness (T, mm) was determined by stacking six cookies on top of each other, and the height was measured with a digital vernier caliper. Spread factor was calculated by the ratio between the diameter and thickness of the cookies. Six cookies were weighed, and the specific volume was calculated by the following formula:

$$\text{Specific volume (cm}^3\text{/g)} = \pi \times (D/2)^2 \times T \times (1/M) \quad (1)$$

where D (mm) is the diameter of the cookie, T (mm) is the thickness of the cookie, and M (g) is the weight of the cookie.

Hardness and fracturability of cookies were determined using a TA-XT texture analyzer and

HDP/3PB probe (Stable Micro Systems, UK). Color values were evaluated using a CM-3700A colorimeter (Konica Minolta, Japan) and the CIELAB system.

Oil holding capacity and water holding capacity were determined following the method previously described [15] with slight modification. About 3 g of sample and 30 mL of cooking oil were added into a centrifuge tube, vortexed for 30 s, and then stored at room temperature for 2 h and centrifuged at 1200×*g* for 10 min. The supernatant was removed, and the centrifuge tube was weighted. Oil holding capacity was calculated and presented as g oil/g sample dry basis (db). Water holding capacity was evaluated according to the procedure as mentioned above, but cooking oil was replaced by distilled water. Water holding capacity was calculated and shown as g water/g sample db.

2.3.4. Sensory assessment

Sensory quality of cookies was determined using an overall acceptance test and a 9-point scale, ranging from "extreme dislike" (1) to "extreme like" (9). A panel including 32 women and 28 men aged from 20 to 30 were selected for sensory evaluation.

2.4. Statistical analysis

All cookie samples were made in triplicate. The experimental results were presented as mean values ± standard deviation and subjected to one-way analysis of variance using Statgraphics Plus (Manugistics Inc., USA). A multiple range test ($p < 0.05$) was used to distinguish significant differences among the mean values.

3. Results and discussion

3.1. Nutritional composition and physical characteristics of turmeric by-product powder and wheat four

Table 1 shows nutritional composition and physical characteristics of the TBP and wheat flour. In general, TBP contained less starch and carbohydrates than wheat flour. However, the TBP was richer in protein and lipids; particularly, the ash content of TBP was 19.0 times greater than that of wheat flour. Different minerals such as phosphorus (0.12 mg/100 g), calcium (8.2 mg/100 g), and potassium (1.7 g/100 g) are reported in turmeric [16], and they are crucial for the human diet. Additionally, the IDF, SDF, and TDF contents of TBP were 44.0, 2.3, and 11.1 times, respectively, greater than those of wheat flour. Turmeric by-product contains a variety of dietary fiber, including lignin, cellulose, and hemicellulose [17]. Consequently, supplementation of TBP to cookie formulation would enhance mineral and dietary fiber contents of the product.

As compared to wheat flour, TBP exhibited higher antioxidant contents and activities. According to Table 1, the total phenolic and flavonoid contents of TBP were 243.4 times and 98.5 times, respectively, greater than those of wheat flour. In particular, the TBP had a high curcumin content (4421 mg/100 g db), while this antioxidant was not detected in wheat flour. The DPPH scavenging capacity and ferric reducing antioxidant power of TBP were 97.4 and 88.8 times, respectively, greater than those of wheat flour. These results suggested that the TBP-fortified cookies would have great antioxidant capacity.

Table 1. Nutritional constituents and physical characteristics of turmeric by-product powder and wheat flour used in the present research.

Component	Turmeric by-product powder	Wheat flour
Protein (g/100 g db)	10.3 ± 0.5[b]	9.3 ± 0.1[a]
Lipid (g/100 g db)	5.5 ± 0.1[b]	2.4 ± 0.1[a]
Ash (g/100 g db)	7.6 ± 0.1[b]	0.4 ± 0.0[a]
Starch (g/100 g db)	39.8 ± 1.6[a]	77.3 ± 0.1[b]
Carbohydrates (g/100 g db)	76.6 ± 0.4[a]	87.9 ± 0.1[b]
TDF (g/100 g db)	21.1 ± 0.5[b]	1.9 ± 0.1[a]
IDF (g/100 g db)	17.6 ± 0.4[b]	0.4 ± 0.0[a]
SDF (g/100 g db)	3.5 ± 0.1[b]	1.5 ± 0.0[a]
Curcumin (mg/100 g db)	4,421 ± 45	-
Total phenolics (mg gallic acid equivalent/100 g db)	4,867 ± 106[b]	20 ± 3[a]
Total flavonoids (µg quercetin equivalent/100 g db)	11,233 ± 215[b]	114 ± 6[a]
DPPH scavenging activity (µmol Trolox equivalent/100 g db)	18,994 ± 770[b]	195 ± 11[a]
Ferric reducing antioxidant power (µmol Trolox equivalent/100 g db)	14,999 ± 444[b]	169 ± 3[a]
*L**	60.8 ± 0.3[a]	93.4 ± 0.2[b]
*a**	18.5 ± 0.4[b]	0.4 ± 0.0[a]
*b**	38.3 ± 0.3[b]	8.8 ± 0.0[a]
Oil holding capacity (g oil/g db)	1.7 ± 0.0[b]	1.1 ± 0.0[a]
Water holding capacity (g water/g db)	3.0 ± 0.1[b]	1.0 ± 0.0[a]

Every value is presented as mean ± standard deviation (n = 3), and means with different superscript letters in each row are significantly different ($p < 0.05$); db: dry basis; TDF: total dietary fiber; IDF: insoluble dietary fiber; SDF: soluble dietary fiber; DPPH: 1,1-diphenyl-2-picrylhydrazyl.

For instrumental colors, the lightness (L^*), redness (a^*), and yellowness (b^*) of the TBP were completely different from those of the wheat flour. TBP was darker (higher L^* value), while its redness and yellowness were more intense. The addition of TBP into the cookie recipe was therefore expected to modify the color of the fortified product.

The water holding capacity of the TBP was about 3.0 times as much as that of wheat flour due to high number of hydroxyl groups of soluble fiber; this group could interact with water molecules through hydrogen bonds [18]. In addition, the oil holding capacity of TBP was about 1.5 times as much as that of wheat flour. It is reported that the hydrophobic functional groups of turmeric [19], as well as the capillary structure of insoluble fibers, could hold oil [20] and improve oil retention. Consequently, the incorporation of TBP into the cookie recipe could change the rheological properties of the cookie dough and textural characteristics of the cookies.

3.2. Impact of turmeric by-product powder ratios on cookie quality

3.2.1. Impacts of TBP ratio on nutritional composition of cookies

The impacts of TBP addition ratio on nutritional composition of the fortified cookies are demonstrated in Table 2. As the TBP ratio was enhanced from 0 to 12%, the cookie moisture content slightly increased from 2.7 to 3.1%. Dietary fiber can retain water [21], resulting in an enhanced moisture content of the TBP supplemented cookies. Nevertheless, the use of TBP in the cookie recipe had no effect on lipid and protein contents of the product since the differences in lipid and protein contents between wheat flour and TBP were not so great, and the addition ratio of TBP was limited. On the contrary, the TBP supplementation significantly improved ash and dietary fiber contents of the cookies. At 12% TBP ratio, the ash content was increased by 1.5 times, while the IDF, SDF, and TDF contents were 1.1, 4.7, and 2.1 times, respectively, greater as compared to those of the control cookies. The total carbohydrate contents of all cookies remained statistically similar. It should be noted that as the addition ratio was increased, the SDF/IDF ratio was gradually augmented, ranging from 0.4 to 1.6. Previous studies report that the appropriate SDF/IDF ratio of food is about 0.5 to improve the health effects of both fractions [22]. Further experiments are needed to adjust the SDF/IDF ratio of the TPB-fortified cookies.

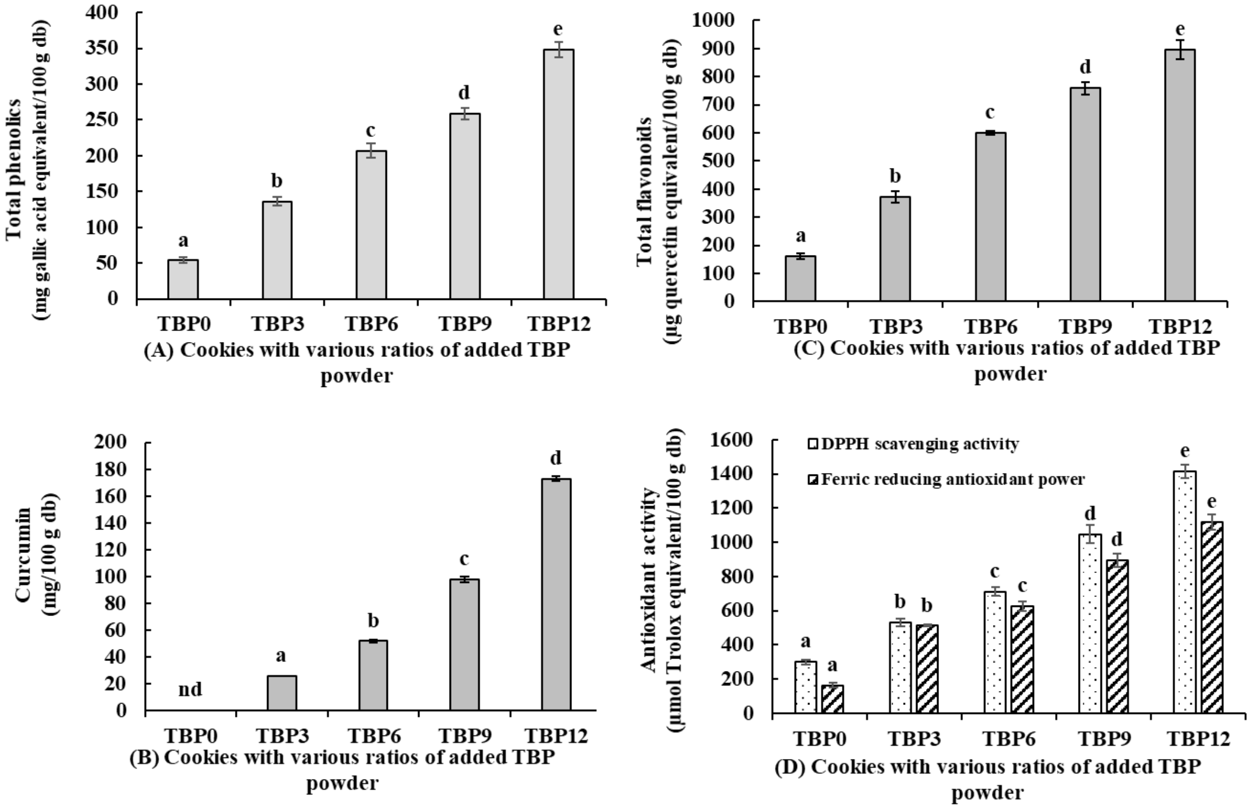
Table 2. Effects of ratio of turmeric by-product powder in cookie recipe on the nutritional composition of cookies.

	Ratio of turmeric by-product in cookie recipe (%)				
	0	3	6	9	12
Moisture (g/100 g product)	2.7 ± 0.1^{a}	2.7 ± 0.1^{a}	2.7 ± 0.1^{a}	2.9 ± 0.1^{b}	3.1 ± 0.1^{c}
Protein (g/100 g db)	8.3 ± 0.2^{a}	8.4 ± 0.3^{a}	8.4 ± 0.1^{a}	8.4 ± 0.3^{a}	8.5 ± 0.1^{a}
Lipid (g/100 g db)	24.7 ± 0.8^{a}	24.4 ± 0.8^{a}	24.2 ± 0.4^{a}	24.1 ± 0.2^{a}	23.8 ± 0.8^{a}
Ash (g/100 g db)	1.2 ± 0.1^{a}	1.3 ± 0.1^{ab}	1.4 ± 0.1^{b}	1.6 ± 0.0^{c}	1.8 ± 0.0^{d}
Carbohydrate (g/100 g db)	65.8 ± 0.9^{a}	66.0 ± 0.6^{a}	66.0 ± 0.4^{a}	65.9 ± 0.4^{a}	65.9 ± 0.8^{a}
Starch (g/100 g db)	41.6 ± 0.8^{b}	39.2 ± 0.6^{a}	38.6 ± 1.0^{a}	38.1 ± 0.6^{a}	38.0 ± 0.1^{a}
TDF (g/100 g db)	1.1 ± 0.0^{a}	1.3 ± 0.0^{b}	1.7 ± 0.0^{c}	2.0 ± 0.1^{d}	2.3 ± 0.0^{e}
IDF (g/100 g db)	0.8 ± 0.0^{a}	0.8 ± 0.0^{ab}	0.8 ± 0.0^{ab}	0.9 ± 0.0^{ab}	0.9 ± 0.0^{b}
SDF (g/100 g db)	0.3 ± 0.0^{a}	0.5 ± 0.0^{b}	0.9 ± 0.0^{c}	1.1 ± 0.0^{d}	1.4 ± 0.0^{e}
SDF/IDF	0.4 ± 0.0^{a}	0.6 ± 0.0^{b}	1.1 ± 0.0^{c}	1.2 ± 0.0^{d}	1.6 ± 0.0^{e}

Every value is presented as mean ± standard deviation (n = 3), and means with different superscript letters in each row are significantly different ($p < 0.05$); db: dry basis; TDF: total dietary fiber; IDF: insoluble dietary fiber; SDF: soluble dietary fiber.

3.2.2. Impacts of TBP ratio on antioxidant content and activities of cookies

Figure 1 presents antioxidant contents and activities of the cookies supplemented with various TBP ratios. The greater the TBP ratio in the cookie formulation was, the greater the curcumin, total phenolic and flavonoid contents. At 12% TBP ratio, the total phenolic and flavonoid contents of the supplemented cookies were increased by 6.4 and 5.5 times, respectively, as compared to those of the control cookies. Moreover, curcumin was not detected in the control cookies, while its amount was 173 mg/100 g dry basis in the 12% TBP-added cookies. Due to the elevated contents of phenolics, flavonoids, and curcumin in the 12% TBP added cookies, their DPPH scavenging activity and ferric reducing antioxidant power were improved by 4.7 and 6.8 times, respectively, in comparison to those of the control cookies. When mango peel powder [20] or pomegranate peel powder [23] were added to the cookie formulation, similar improvements in the antioxidant activity of the product were also reported. In summary, TBP was a distinctive source of antioxidants that might be used to produce cookies with high antioxidant activities.



TBP0: cookies with 100% wheat flour; TBP3: cookies with 3% TBP and 97% wheat flour; TBP6: cookies with 6% TBP and 94% wheat flour; TBP9: cookies with 9% TBP and 91% wheat flour; TBP12: cookies with 12% TBP and 88% wheat flour); db: dry basis; Values with various superscript letters within the same category of value are significantly different ($p < 0.05$).

Figure 1. Antioxidant contents and activities of cookies with various ratios of turmeric by-product powder (TBP).

3.2.3. Impacts of turmeric by-product ratios on physical characteristics and sensory acceptability of cookies

The impacts of TBP ratios on physical characteristics of the cookies are illustrated in Table 3. When the TBP ratio in the cookie recipe was augmented from 0 to 12%, the diameter, thickness, and specific volume of the fortified cookies tended to decrease, while the spread factor was not statistically changed. For cookies supplemented with 12% TBP, the diameter and thickness were reduced by 2% and 3%, respectively, in comparison with those of the control cookies. Slight reduction in diameter and thickness of the TBP fortified cookies was due to a reduced gluten content, which was responsible for the spread of bakery products [20]. It can be noted that the specific volume of cookies supplemented with 12% TBP was decreased by 6% as compared to that of the control cookies. The addition of grape skin and grape seed powder into the cookie recipe also reduced diameter and thickness of the final product [24].

The use of TBP significantly enhanced the cookie hardness. At 12% TBP level, the hardness of fortified cookies was elevated by 38% in comparison to that of the control cookies. That could be justified by an increased total dietary fiber content [25]. Similar increased hardness was also recorded when papaya pulp powder was added into cookie formulation [26]. However, the fracturability values of all cookie samples were statistically similar.

Figure 2 shows that the cookies became gradually darker as the supplementation ratio of TBP was increased. This observation was strongly confirmed by the reduced *L** value of the cookies with the elevated TBP ratio. The redness *(a** value) of the fortified cookies was slightly enhanced, while the yellowness (*b** value) was decreased. Change in cookie color was due to different colors of both wheat flour and TBP.

TBP0: cookies with 100% wheat flour; TBP3: cookies with 3% TBP and 97% wheat flour; TBP6: cookies with 6% TBP and 94% wheat flour; TBP9: cookies with 9% TBP and 91% wheat flour; TBP12: cookies with 12% TBP and 88% wheat flour.

Figure 2. Photograph of cookies with various ratios of turmeric by-product powder (TBP).

Table 3. Effects of ratio of turmeric by-product powder on physical characteristics and sensory acceptability of cookies.

Properties	Ratio of turmeric by-product in cookie recipe (%)				
	0	3	6	9	12
Diameter (mm)	40.3 ± 0.2^{c}	39.9 ± 0.1^{b}	39.7 ± 0.1^{ab}	39.6 ± 0.2^{a}	39.5 ± 0.1^{a}
Thickness (mm)	6.6 ± 0.0^{d}	6.5 ± 0.0^{cd}	6.5 ± 0.0^{bc}	6.5 ± 0.1^{b}	6.4 ± 0.0^{a}
Spread factor	6.1 ± 0.0^{a}	6.1 ± 0.0^{a}	6.1 ± 0.0^{a}	6.1 ± 0.1^{a}	6.1 ± 0.1^{a}
Specific volume (cm^3/g)	1.6 ± 0.0^{c}	1.6 ± 0.0^{b}	1.6 ± 0.0^{ab}	1.5 ± 0.0^{a}	1.5 ± 0.0^{a}
Hardness (g)	1,289 ± 84^{a}	1,413 ± 197^{ab}	1,550 ± 157^{b}	1,635 ± 65^{bc}	1,775 ± 28^{c}
Fracturability (mm)	37.4 ± 0.2^{a}	37.2 ± 0.2^{a}	37.5 ± 0.4^{a}	37.1 ± 0.1^{a}	37.0 ± 0.5^{a}
*L**	63.7 ± 0.4^{c}	51.8 ± 1.7^{b}	49.8 ± 0.2^{b}	47.5 ± 0.1^{a}	45.6 ± 0.3^{a}
*a**	11.8 ± 0.0^{a}	11.7 ± 0.1^{a}	14.3 ± 0.2^{b}	15.9 ± 0.0^{c}	15.7 ± 0.1^{c}
*b**	29.0 ± 0.1^{d}	29.5 ± 0.2^{d}	24.7 ± 0.2^{c}	21.8 ± 0.1^{b}	20.3 ± 0.3^{a}
ΔE	-	11.9 ± 2.2^{a}	14.7 ± 0.2^{a}	18.1 ± 0.3^{b}	20.4 ± 0.6^{b}
Sensory acceptability	7.1 ± 1.3^{d}	6.3 ± 1.3^{c}	6.1 ± 1.5^{bc}	5.6 ± 1.4^{b}	4.6 ± 1.6^{a}

Every value is presented as mean ± standard deviation (n = 3), and means with different superscript letters in each row are significantly different ($p < 0.05$).

Table 3 also demonstrates that the sensory score of cookies was gradually reduced as the TBP ratio was enhanced in the blend flour. This was explained by the enhanced hardness of the TBP supplemented cookies. At the 3–9% TBP levels, the obtained product was considered acceptable by the panelists, since the average score was greater than 5.0. However, the overall acceptability of cookies with 12% added was lower than 5.0, probably due to an intense hardness and pronounced turmeric taste. Reduction in sensory quality of cookies was also reported when grape seed powder was incorporated into the cookie formulation [27].

4. Conclusions

TBP is a by-product rich with minerals, dietary fiber, and antioxidants. The incorporation of TBP into cookie formulation increased ash and dietary fiber contents of the final product. Particularly, the TBP supplemented cookies contained much more total phenolics and flavonoids and had much greater DPPH scavenging activity and ferric reducing antioxidant power as compared to the control cookies without TBP addition. However, the TBP fortified cookies had an increased hardness and reduced diameter, thickness, and overall acceptability. At 9% TBP level, the sensory quality of TBP supplemented cookies was acceptable. In the future, the bioaccessibility and bioavailability of antioxidants in the fortified cookies should be investigated to confirm their positive impacts on human health. TBP was a potential source of antioxidants for fortification of various bakery products.

Use of AI tools declaration

The authors declare they have not used artificial intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare no conflict of interest.

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