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Assessing the impact of spent coffee ground (SCG) concentrations on shortbread: A study of physicochemical attributes and sensory acceptance

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A R T I C L E I N F O

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Shortbread biscuits
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Nutritional properties

A B S T R A C T

Currently, every 1 kg of instant coffee produced results in 2 kg of wet SCG, accounting for 45% of total annual production. Instead of being wasted and causing environmental issues, SCG can be utilized for its potential to create valuable products with added value. This study explores the underutilized potential of spent coffee grounds (SCG) as a functional ingredient in shortbread biscuits, with the aim of improving their nutritional value and reducing waste in the coffee industry. In this study, six different shortbread formulations were developed using various concentrations of SCG powder (ranging from 0 to 10%). The samples were subjected to physical, sensory, proximate, and chemical analyses to assess their storage quality, physicochemical properties, and sensory acceptability. The results showed that the SCG-containing shortbread had higher moisture, protein, ash, fibre, total phenolic content, and antioxidant activity than the control sample, with the 10% SCG shortbread proving to be the most desirable in terms of aroma and hardness. Overall, this study highlights the potential of SCG as a valuable source of bioactive compounds in innovative cookies, offering opportunities for the utilization of industrial by-products, reducing waste, and improving nutritional properties.

Introduction

Coffee is a highly popular and globally consumed beverage (Lim et al., 2019), with global production reaching 171.9 million 60 kg bags in 2020 and 2021 (Shahbandeh, 2022). While warm beverages such as coffee and tea have been a part of most Malaysians' daily routines for years, Milo, a chocolate and malt powder mixture added to milk or hot water, has also gained popularity in the coffee and tea category (Hirschman, 2021). Despite lower preference for coffee amongst Malaysians, the worldwide coffee industry still produces a significant amount of waste and by-products, with spent coffee ground (SCG) being the most significant. Every 1 kg of instant coffee produced results in 2 kg of wet SCG, which accounts for 45% of total annual production (Castaldo et al., 2021). Effective waste management plans are necessary to comply with current national regulations. The SCG generated is usually collected by specialized agencies and sold for various purposes, including composting, gardening, bioenergy generation, and mushroom cultivation (Somnuk et al., 2017).

Spent coffee grounds (SCG) are the residue that remains after coffee powder is combined with hot water or steam to extract the soluble coffee (Araujo et al., 2022). The food processing industry generates millions of tons of waste products at different stages of food production, including the coffee industry (Torres-leon et al., 2018). These waste products contain carbohydrates, proteins, lipids, and bioactive substances, making their characterization and utilization crucial for minimizing environmental pollution and ensuring waste management sustainability (Wang et al., 2021). SCG, a by-product of coffee production, is a potential source of high-value-added materials. Recent studies have shown that SCG-derived antioxidant dietary fibres can be used to make high-quality bakery products, such as innovative cookies, that have the potential to prevent chronic diseases, such as diabetes, ageing, and obesity (Sarghini et al., 2021).

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Shortbread is a widely popular cookie enjoyed by people of all ages, and incorporating SCG as a functional ingredient in shortbread is feasible and has been advocated for as consumers' concern grown over the high sugar food that can trigger high glycemic response in human body, manufacturers seek to develop healthier version of cookies including high fibre and antioxidant properties with low fat and sugar. Accordingly, incorporating oat and yeast β-glucan and herbal extracts in shortbread has been successful in reducing fat content and prolonging shelf-life. Therefore, exploring the use of SCG in innovative food products is a promising avenue to investigate. The incorporation of functional ingredients from food by-products to improve natural functional properties of bakery products and spent coffee grounds could be a noteworthy endeavour. This study evaluates the physicochemical and sensory changes of shortbread with varying percentages of SCG incorporation, examining the effect on antioxidant properties during storage. This research could provide insights into the potential use of SCG as a functional ingredient, reducing waste from coffee production while enhancing the nutritional value of baked goods.

Materials and methods

Preparation of spent coffee ground (SCG) powder

Spent Coffee Ground (SCG) was supplied by Ziq Bakery in August 2022 and then stored in an airtight container at a chilling temperature (4 °C). The SCG was then dried in a drying cabinet (Protech, Malaysia) for 24 h at 60 °C. After drying, SCG was ground into fine powder and sieved (Octagon, England) through a 500 µm mesh screen for 20 min. The sieved powdered SCG was then stored at room temperature (25 °C) in a well-labelled airtight container for further analyses.

Production of shortbread

The control sample with 0% SCG was prepared as described by Duckworth (2022) with some modifications (Fig. 1). As for the preparation of SCG shortbread, the flour was incorporated with different concentrations of SCG. In comparison with the control sample or A (100% plain flour), another five blends were prepared as follows B: 98% plain flour with 2% SCG, C: 96% plain flour with 4% SCG, D: 94% plain flour with 6% SCG, E: 92% plain flour with 8% SCG and F: 90% plain flour with 10% SCG. These blends were kept in airtight containers and stored at room temperature until required (Table 1).

Physical analysis

The weight (g), diameter, thickness, spread ratio, colour and texture of the shortbread samples were assessed in triplicates according to the AACC method described by Mohd Jusoh et al. (2009). Each sample was weighed using a digital loading balance before baking and immediately after cooling. Then, samples were placed horizontally from edge to edge and rotated at 90° for reading using a digital vernier calliper to determine the diameter and thickness. The spread ratio was calculated using the formula in which the diameter of cookies is divided by thickness of cookies. These measurements were done in triplicate before and after baking.

The colour intensity of shortbread cookies was measured based on CIE L*, a*, b* colour system using Konica Minolta Colour Measuring System (Chroma meter CR-400, Minolta LTD Japan) (Trà et al., 2021). The results were expressed as L*, a* and b*, in which L* denotes colour lightness with a value of 100 or blackness (value=0), a* symbolises red (positive value) or green (negative value), and b* describes the proportion of yellow (positive value) or blue (negative value).

Texture analysis was performed immediately after baking using a texture analyser (TA-XT2i, Stable Micro Systems, UK) (Wan Mohamad Din et al., 2020). The hardness and fracturability/crumbliness were measured using a 3-point Bending Rig (HDP/3 PB) and 5 kg load cell. The distance between two beams was 15 mm. Another identical beam was brought down from above (pre-test speed of 2.0 mm/s, test speed of 2.0 mm/s, post-test speed of 2.0 mm/s, distance: 5 mm) to contact the cookie. The downward movement continued until the cookie broke. Peak force was reported as hardness (N). Both colour and texture analysis were further performed after 1 and 2 weeks of storage.

Table 1
Formulation of SCG shortbread cookies (Source from: Duckworth, 2022).

Ingredients (g)	A (0%)	B (2%)	C (4%)	D (6%)	E (8%)	F (10%)
Plain flour	180	176.4	172.8	169.2	165.6	162
Unsalted butter	120	120	120	120	120	120
Castor sugar	62	62	62	62	62	62
Fine salt	4	4	4	4	4	4
SCG	0	3.6	7.2	10.8	14.4	18.0

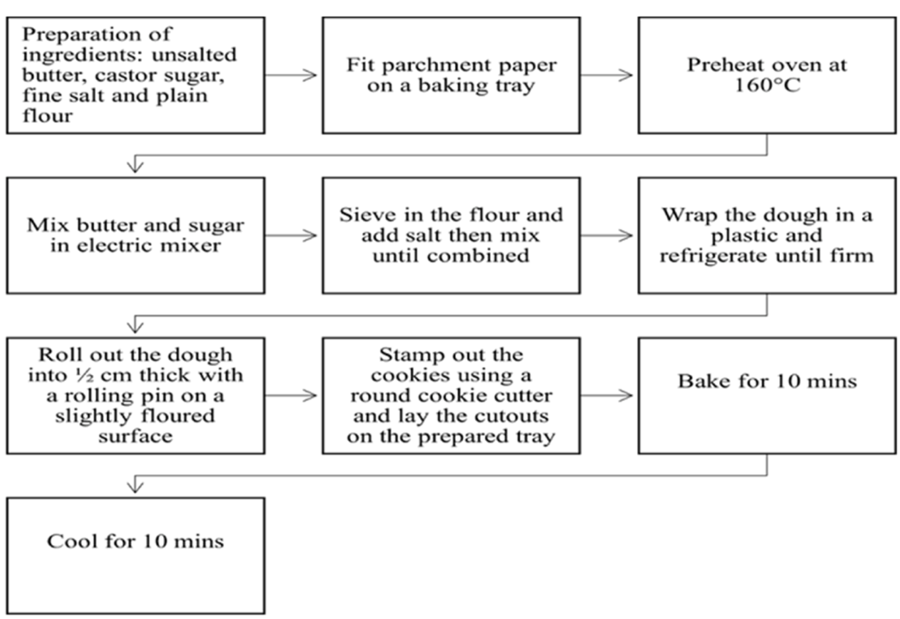

Fig. 1. The production of shortbread (Source from: Duckworth, 2022).

Proximate analysis

The moisture, ash, protein, fat, and fibre contents of shortbread cookies were determined according to the Association of Official Analytical Chemists' procedure (AOAC, 2007). Moisture content was determined by AOAC 925.09 method while ash content was determined by AOAC 930.30 method. On the other hand, crude protein was analysed by Kjeldahl procedure using AOAC 984.13 method whereas crude fat was measured by Soxtec system using AOAC 960.39 method followed by crude fibre was determined using Gerhardt Fibre Bag System. Total carbohydrate contents were then calculated by difference.

Determination of calorie content

The calorie content of shortbread was determined using a bomb calorimeter (IKA C2000, Germany) as described by Azuan et al. (2020). One gram of powdered sample was pressed into a pellet and placed in the decomposition vessel with a crucible. The vessel was tightly sealed, and the bomb calorimeter was set up. The sample's calorie content (cal/g) was determined by measuring its gross energy value after combustion.

Phenol extraction

Acidified methanol solution was prepared by mixing 50 mL of 0.8 M HCL with 50 mL methanol. Then, 0.5 g of powdered sample was added with 20 mL acidified methanol solution in a 50 mL capped centrifuge tube wrapped with aluminium foil. Next, the tube was shaken on an orbital shaker (IKA KS501, Germany) with 200 rpm at room temperature for 1 h. Then, the tube was centrifuged in a refrigerated centrifuge (Eppendorf, Germany) with 4000 rpm at 40 °C. The first supernatant for each sample was collected in a conical flask using filter paper. Then, the residues were re-extracted with 20 mL acetone: water (70:30 w/v) and shaken in the orbital shaker (200 rpm) at room temperature for 1 h followed a refrigerated centrifugation (4000 rpm) at 4 °C. The second supernatant or each sample was collected in a conical flask using filter paper. The first and second supernatants were mixed (50:50 v/v) in an aluminium-wrapped centrifuge tube and stored at −80 °C for further analyses of the antioxidant activity and total phenolic content (Magwaza et al., 2015).

Antioxidant activity using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging

The DPPH (2,2-diphenyl-1-picrylhydrazyl) ethanolic solution was prepared by mixing 3.94 mg DPPH with 100 mL of 95% ethanol in an amber bottle and dissolved for 1 h using a magnetic stirrer (Wisestir, UK) at room temperature. Then, 1 mL of phenol extract was mixed with 2 mL 0.1 mM DPPH ethanolic solution. Two positive controls (standard at 200 ppm) including the butylated hydroxytoluene (BHT) as synthetic antioxidant and ascorbic acid as natural antioxidants were also prepared as described in above. Then, each sample/standard was homogenized using a vortex (IKA MS3, Germany) for 30 s followed by incubation in dark at room temperature (25°C) for 30 min. Finally, the absorbence was read at 517 nm using a UV–vis spectrophotometer (Shimadzu, Japan). The DPPH radical scavenging activity was calculated as the percentage decrease of the absorbence at 517 nm relative to a blank (Malik et al., 2017). The% DPPH scavenging activity was calculated using the following equation:

$$\%\mathbf{DPPH\ radical\ scavenging\ activity} = (\mathbf{A} - \mathbf{B})/\mathbf{A} \times \mathbf{100}\%$$

In this equation, A= absorbence of negative control and B= absorbence of the sample. All samples were analysed in triplicates.

Determination of total phenolic content (TPC)

The total phenolic content was measured by deploying a colourimetric method described by Galvão et al. (2018) with slight modifications. Firstly, 0.5 mL phenol extract was mixed with 2.5 mL of 10% Folin–Ciocalteu reagent and 2 mL of 7.5% w/v sodium carbonate solution. The gallic acid as standard (100 ppm) was also prepared as described in above. Then, each sample/standard was homogenized using a vortex (IKA MS3, Germany) for 30 s followed by incubation in dark at room temperature for 1 h. Finally, the absorbence was read at 760 nm using a UV–vis spectrophotometer (Shimadzu, Japan). The TPC was determined according to a standard curve prepared with gallic acid as standard (5–60 ppm) and the distilled water was used as blank. The result was expressed in mg of gallic acid equivalents (GAE) per gram.

Lipid extraction

Fifty grams of powdered SCG shortbread sample were mixed with 150 mL petroleum ether (30- 65 b.p). The mixture was then agitated using a magnetic stirrer at 250C for 1 h. The first supernatant for each sample was collected in a conical flask using filter paper. After that, the residues were re- extracted twice with 150 mL petroleum ether. All the supernatants were then evaporated using a rotary evaporator (Buchi R-300, Switzerland) to separate the fat from solvent. The fat extract obtained was immediately proceeded to the determination of peroxide value (Norazlina et al., 2021).

Determination of peroxide value (PV)

The titrimetric method of AOAC (965.33) as described by Duta et al. (2019) was used to determine the peroxide value in shortbread cookies. The sample (1 g) was dissolved in a fat solvent containing glacial acetic acid and chloroform mixture (3:2). The mixture was swirled until it dissolved completely. Then, 0.1 mL of saturated potassium iodide was added and shaken vigorously for 1 min. Finally, 5 mL of distilled water was added. One minute later, 0.4 mL of 10% soluble starch indicator was added to the mixture, resulting in a blue colour. The mixture was then titrated with 0.01 N sodium thiosulfate ($Na_2S_2O_3$) while vigorously shaking until the blue colour faded. Peroxide value was calculated as:

$$(S \times B) \times N \times 1000$$

$$\mathbf{Peroxide\ value}(\mathbf{mEq\ peroxide}/\mathbf{kgfat}) = Weight\ of\ sample(g)$$

Where S = Volume of titrant used for sample (mL) B = Volume of titrant used for blank (mL) M = Normality of $Na_2S_2O_3$ solution

Sensory analysis

Sensory analysis was performed with a group of 40 volunteers, recruited from the staff and undergraduate students of Universiti Malaysia Terengganu (UMT). The SCG shortbread cookies were evaluated for aroma, colour, taste, fracturability/crumbliness, oiliness, hardness and overall acceptability. Each of the shortbread samples were packed in separate plastic pouches and presented with three-digit codes in a randomized order then served to 40 untrained panels on a tray with tissue and water to cleanse and neutralize their palates between samples. The panels were required to rate the samples for all the seven sensory attributes including hardness, colour, fracturability/crumbliness, oiliness, aroma, taste and overall acceptability on a 9-point hedonic scale, where 1=dislike extremely; 2=dislike very much; 3=dislike moderately; 4=dislike slightly; 5=neither like nor dislike; 6=like slightly; 7=like moderately; 3=like very much; 9=like extremely (Starowicz et al., 2020).

Statistical analysis

All data were collected in triplicates and expressed as mean ± standard deviation. Two-way analysis variance (ANOVA) was applied for the evaluation of the interaction effect of the independent variables (SCG concentrations and storage period) on the observed quality parameters. The statistical comparisons were analysed using Fisher's Least Significant Difference (LSD) multiple range tests by Minitab 21.2 Statistical Software. The differences amongst treatments were considered as significantly different at ($p<0.05$).

Results and discussion

Physical properties

Dimensions

Significant changes ($p<0.05$) in the dimensions of shortbread were observed in terms of diameter and thickness before and after baking whereas there are no significant changes in terms of diameter and thickness amongst samples with different percentages of SCG incorporations (Table 2). It is also found that the SCG-containing shortbread suffered the least water reduction approximately 5% as compared to the control sample. This might be due to the high-water retention capacity of fibre, which is the major composition of SCG. A slight decrease in weight and spread ratio of each sample before and after baking is contributed by baking loss as the mass was transferred from the surface of the cookies as well as evaporation of free water occurred during baking even though there are no significant differences in terms of weight and spread between samples (Aguilar-Raymundo et al., 2019). In agreement with these findings, previous reports regarding the incorporation of orange- fleshed sweet potato flour in cookies indicated an increment in thickness and reduction in spread ratio (Korese et al., 2021).

Colour

A significant difference between samples was revealed in terms of lightness (L*), redness (a*) and yellowness (b*) where the highest L* and b* values were shown in the control sample, and the least values of these parameters were exhibited by 10% SCG shortbread (Table 3). The decrease in both lightness (L*) and yellowness (b*) were attributed to the dark brown colour of SCG with high polyphenols such as anthocyanin as well as the oxidizing enzymes which lead to enzymatic browning and hence increased a* value and reduced L* and b* values of shortbread. Similar results were reported by Hussein et al. (2019) when SCG powder was partially substituted wheat flour in a sponge cake formulation.

In contrast, the a* value of shortbread displayed an elevation with an increased percentage of SCG incorporations, where a* value was −1.54 in the control sample, then significantly increased to 4.46 in the 10% SCG shortbread. This might be due to the degree of browning in Maillard reaction caused by the interaction of amino acids and caramelization of sugars during baking produce brown pigments which are known as melanoidins and eventually affect the colour attributes. This is in concordance with the previous findings by Shen et al. (2018) who found that the browning intensity of bread crust increased greatly with higher relative amount of melanoidins in white pan bread containing various sugars as compared to the control without sugar.

Apparently, as the concentrations of SCG increased, the colour of the shortbread varied from creamy yellow to dark brown, yet the effect of storage period was less evident within samples in terms of lightness and yellowness. It is also interesting to note that the higher ratio of SCG incorporations (8% and 10%) in shortbread have no storage effect, proving that SCG is a stable compound upon storage. Similarly, Paciulli et al. (2020) reported that incorporating the colour of shortbread inulin-based emulsion filled gel as fat replacer resulted in constant storage stability.

Texture

Table 4 shows that as the SCG incorporations increased, the hardness of 2% SCG shortbread experienced a minor increment compared to the control sample whereas the hardness of 8% and 10% indicated a gradual reduction, showing an anti-climax. However, across storage periods, the

Table 2
Changes in dimensions of different SCG shortbread before and after baking.

A (0%)	Before	7.80 ±0.38^{aA}	32.57 ±0.21^{bB}	7.46 ±0.38^{bBCD}	4.38 ±0.21^{aA}
B (2%) C	After Before After	7.23 ±0.38^{aA}	34.84 ±0.10^{aA}	8.59 ±0.39^{aA}	4.06 ±0.19^{aA}
(4%)	Before	7.90 ±0.40^{aA}	32.58 ±0.42^{aB}	7.27 ±0.26^{bCD}	4.49 ±0.12^{aA}
		7.47 ±0.40^{aA}	35.02 ±0.28^{bA}	8.28 ±0.24^{aABC}	4.23 ±0.09^{bA}
		7.67 ±0.21^{aA}	35.04 ±0.24^{bB}	7.50 ±0.28^{bBCD}	4.35 ±0.19^{aA}
D (6%) E (8%)	After Before After	7.27 ±0.21^{aA}	32.59 ±0.28^{aA}	8.51 ±0.29^{aAB}	4.12 ±0.17^{aA}
F (10%)	Before After Before After	7.27 ±0.45^{aA}	32.25 ±0.19^{bB}	7.38 ±0.40^{bCD}	4.28 ±0.09^{aA}
		6.80 ±0.30^{aA}	35.15 ±0.33^{aA}	8.22 ±0.20^{aABC}	4.28 ±0.09^{aA}
		7.57 ±0.61^{aA}	32.34 ±0.22^{bB}	7.10 ±0.33^{bD}	4.57 ±0.24^{aA}
		7.00 ±0.50^{aA}	35.04 ±0.25^{aA}	8.31 ±0.53^{aABC}	4.23 ±0.27^{aA}
		7.80 ±0.52^{aA}	32.34 ±0.07^{bB}	7.48 ±0.51^{aBCD}	4.34 ±0.28^{aA}
		7.33 ±0.42^{aA}	35.56 ±0.40^{aA}	8.30 ±0.42^{aABC}	4.29 ±0.27^{aA}

Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p<0.05$). The means within a column (the difference within samples during storage period) followed by different superscript letters whereas the means within a column (the difference between samples) followed by different capital letters.

Table 3
Changes in colour of different SCG shortbread upon storage.

Sample	Storage period (week)	L*	a*	b*
A (0%)	1	74.46 ±0.15^{aA}	−1.54±0.06^{bD}	29.99 ±0.11^{aA}
	2	72.24 ±0.83^{aA}	1.20±0.03^{aD}	30.51 ±1.11^{aA}
	3	72.98 ±1.44^{aA}	−1.39 ±0.13^{abD}	29.22 ±0.65^{aA}
B (2%)	1	55.83 ±0.91^{aB}	2.12±0.20^{aB}	18.96 ±0.79^{aB}
	2	57.33 ±1.58^{aB}	1.98±0.14^{abBC}	19.56 ±1.15^{aB}
	3	57.79 ±3.73^{aB}	1.58±0.22^{bC}	19.22 ±0.64^{aB}
E (8%)	1	40.14 ±0.81^{aC}	4.35±0.17^{aA}	12.33 ±0.72^{aC}
	2	42.08 ±0.27^{aC}	4.48±0.07^{aA}	13.19 ±0.15^{aC}
	3	40.06 ±2.92^{aC}	4.41±0.07^{aA}	12.91 ±0.99^{aC}
F (10%)	1	37.40 ±0.29^{aC}	4.46±0.23^{aA}	11.42 ±0.54^{aC}
	2	37.68 ±1.10^{aC}	4.54±0.16^{aA}	11.37 ±0.71^{aC}
	3	38.79 ±1.42^{aC}	4.24±0.22^{aA}	11.70 ±0.89^{aC}

Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p<0.05$). The means within a column (the difference within samples during storage period) followed by different superscript letters whereas the means within a column (the difference between samples) followed by different capital letters.

Table 4
Changes in texture of different SCG shortbread upon storage.

Sample	Storage period (week)	Hardness (N)	Fracturability (mm)
A (0%)	1	20.47±1.60^{CDa}	13.35±0.27^{Aa}
	2	24.15±1.53^{BCa}	12.84±0.76^{Ab}
	3	24.15±1.53^{BCa}	12.56±0.34^{Ab}
B (2%)	1	20.83±1.87^{CDb}	13.22±0.24^{Aa}
	2	31.27±2.96^{Aa}	12.84±0.76^{Aa}
	3	27.06±0.61^{Ba}	12.56±0.07^{Aa}
E (8%)	1	19.45±0.45^{Da}	12.83±0.07^{Ab}
	2	11.53±0.24^{Ec}	12.73±0.21^{Ab}
	3	17.23±0.28^{Db}	13.56±0.32^{Aa}
F (10%)	1	18.65±0.99^{Da}	13.31±0.65^{Aa}
	2	12.55±0.41^{Eb}	12.78±0.83^{Aa}
	3	8.68±0.50^{Ec}	13.11±0.75^{Aa}

Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p < 0.05$). The means within a column (the difference within samples during storage period) followed by different superscript letters whereas the means within a column (the difference between samples) followed by different capital letters.

hardness of 10% SCG shortbread decreased significantly from 18.68 N to 8.68 N which is in contrast with the control sample that increased from 20.47 N to 24.15 N. This could be explained by the partial substitution of flour with SCG. Flour with high amylopectin content has a higher tendency to hold water and result in the hardening of cookies through a retrogradation process. The disturbed amylose and amylopectin chains recombine into an ordered structure, resulting in harder cookies (Zhang et al., 2020).

In addition, low protein content in flour reduces the water absorption by the dough, resulting in less starch damage as well as harder texture. These results are in line with the study by Nandiyanto et al. (2022), showing that the low protein content in wheat flour led to less moisture retention, resulting in harder cookies. Furthermore, the decrease in hardness values of SCG shortbread may be attributed to the high-water retention capacity of SCG which eventually raised the moisture content in shortbread as the amount of SCG substitution increases.

Chemical composition

Calorie content

Statistically significant differences (p<0.05) were observed for calorie content between the control sample and different ratio of SCG-containing shortbread samples (Table 5). The control sample without SCG incorporation exhibited the highest calorie content (5225.80 cal/g), while the 10% SCG shortbread sample showed the lowest calorie content (4696.70 cal/g) with a reduction of approximately 10%. As the percentage of SCG incorporated into the shortbread increased, the energy content of the cookie samples decreased. This may be attributed to the high dietary fibre content in SCG, which is known to be associated with a low glycemic index and low-calorie content in food. These findings are consistent with previous research by Aggarwal et al. (2016) who observed a significant difference (p<0.05) in energy content between control and biscuit samples made with artificial sweeteners and fat substitutes. The energy content of control and biscuit samples was found to be 5.25 and 4.85 kcal/g, respectively. These results are also in agreement with a recent study by Ekin et al. (2021) who demonstrated a reduction of 14.5–16.2% in energy values of biscuits by replacing refined wheat flour with different levels of multigrain flour comprising finely ground wheat bran.

Table 5
Calorie content with% reduction of different SCG shortbread.

Sample	Calorie content (cal/g)	% Reduction
A (0%)	5225.80±33.33^{a}	0%
B (2%)	5137.90±33.60^{ab}	1.68%
C (4%)	5045.40±37.50^{bc}	3.45%
D (6%)	4900.40±59.10^{cd}	6.23%
E (8%)	4756.74±10.97^{de}	8.98%
F (10%)	4696.70±58.40^{e}	10.12%

Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p < 0.05$).

Proximate composition

Moisture content

The moisture content of fresh SCG was found to be between 25 and 27%. Upon drying, the SCG underwent a moisture loss and weight loss of approximately 2–3%, resulting in a total weight of 364.8 g. The moisture content of SCG shortbread increased from 2.73% to 4.64% with increasing amounts of SCG, but all samples met the standard moisture content range of 1–5% for typical biscuits. The highest moisture content was found in 10% SCG shortbread, and the lowest was in the control. During storage, there was a gradual increase in moisture content in SCG shortbread, which may be due to the higher water holding capacity of dietary fibre in SCG. Alternatively, the fluctuations may be attributed to water redistribution in the shortbread. Accordingly, the addition of collagen peptide as well as curdlan increased the water holding capacity and eventually reduced the water migration in the intermediate-moisture potato frozen cake (Shi et al., 2021).

Ash content

Incorporating spent coffee ground (SCG) into shortbread formulations led to a significant increase in the ash content, as shown in Table 6. A study by Galla et al. (2017) also reported the similar increment of both ash and moisture contents in the cookies that enriched with spinach (5-15%). The higher ash content in SCG-containing shortbread can be attributed to the high fibre fraction present in coffee silverskin, despite the loss of minerals and ash during industrial coffee extraction and brewing. Previous studies by Campos-Vega et al. (2015) demonstrated that the mean ash content in Arabica ranged from 2.5 to 4.5%, whereas Robusta coffee was 4.64%, supporting the assumption that SCG still contains a significant amount of ash content after percolation compared to the coffee bean. Gottstein et al. (2021) reported high ash content of coffee silverskin ranging from 8.15 to 11.24%, indicating a substantial mineral content. Additionally, Pigozzi et al. (2018) found that the mean ash content observed in different roasted ground coffee samples ranged from 4.48 to 9.44%, which could be linked to the nutritional state of the coffee plantation and its location, influencing the mineral composition of the coffee.

Crude protein

The crude protein content of the shortbread samples showed significant differences, with protein content ranging from 5.54 to 7.08% amongst the composite shortbread samples (Table 6). The 10% SCG shortbread sample had the highest protein content, while the control sample had the least amount of protein content. The protein content of the shortbread samples increased proportionally with the amount of SCG added. This may be attributed to the high protein content impacting the water absorption in the cookies, resulting in a reduction in the hardness of SCG shortbread while maintaining its crisp texture. Similar findings were reported by Bertolino et al. (2019) and Ibrahim et al. (2021) in their studies on cookies fortified with coffee silverskin and Egyptian kishk, respectively. Nevertheless, SCG possessed high levels of essential branched-chain amino acids (BCAA), such as leucine, making it a good source of protein for malnourished individuals or children with milk protein allergies. Storage studies showed that protein content increased across storage time in SCG- containing shortbread, but only the control sample had a significant decrease in protein content (Table 7). The presence of abundant essential amino acids contributes to its bioavailability and thermal stability, as shown in studies by Pérez-Burillo et al. (2022) and Pathania et al. (2019), where the presence of chelating agents and caffeine in SCG and EDTA in whey protein

Table 6
Proximate composition of different SCG formulations in shortbread.

Sample	Moisture	Ash	Protein	Fat	Fibre	Carbohydrates
A (0%)	2.73 ± 0.05^{d}	0.73 ± 0.05^{e}	5.54 ± 0.09^{d}	31.21 ± 0.74^{a}	20.40 ± 0.35^{e}	39.39 ± 1.17^{a}
B (2%)	3.34 ± 0.02^{c}	1.32 ± 0.06^{d}	5.77 ± 0.16^{cd}	31.60 ± 0.36^{a}	25.75 ± 0.04^{d}	32.21 ± 0.33^{b}
C (4%)	3.56 ± 0.34^{c}	1.54 ± 0.05^{cd}	5.80 ± 0.12^{cd}	31.50 ± 0.23^{a}	27.11 ± 0.29^{c}	30.49 ± 0.42^{c}
D (6%)	3.64 ± 0.10^{bc}	1.61 ± 0.04^{bc}	6.03 ± 0.15^{c}	31.68 ± 0.26^{a}	27.38 ± 0.30^{c}	29.66 ± 0.18^{c}
E (8%)	3.99 ± 0.06^{b}	1.78 ± 0.03^{b}	6.41 ± 0.20^{b}	31.78 ± 0.54^{a}	29.71 ± 0.38^{b}	26.34 ± 0.32^{d}
F (10%)	4.64 ± 0.07^{a}	2.04 ± 0.17^{a}	7.08 ± 0.04^{a}	30.68 ± 0.18^{a}	32.09 ± 0.25^{a}	23.46 ± 0.32^{e}

Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p < 0.05$).

Table 7
Changes in moisture content, crude fat and crude protein of different SCG shortbread upon storage.

Sample	Storage period (week)	Moisture content	Crude fat	Crude protein
A (0%)	1	2.73 ± 0.05^{Da}	31.21 ± 0.74^{Ab}	5.54 ± 0.09^{Ca}
	2	3.53 ± 0.03^{Ba}	31.73 ± 0.30^{Aab}	5.52 ± 0.07^{Da}
	3	4.27 ± 0.34^{Ca}	32.56 ± 0.35^{Aa}	4.43 ± 0.47^{Cb}
B (2%)	1	3.34 ± 0.02^{Cb}	31.60 ± 0.36^{Aa}	5.77 ± 0.16^{Bc}
	2	3.51 ± 0.17^{Bb}	31.22 ± 0.78^{ABab}	6.13 ± 0.14^{Cb}
	3	3.89 ± 0.20^{BCa}	30.17 ± 0.17^{Bb}	6.51 ± 0.09^{Aa}
E (8%)	1	3.99 ± 0.06^{Bb}	31.78 ± 0.54^{Aa}	6.41 ± 0.20^{Ac}
	2	4.78 ± 0.01^{Aa}	30.72 ± 0.51^{ABab}	7.13 ± 0.07^{Bb}
	3	4.70 ± 0.10^{ABa}	29.93 ± 0.17^{Bb}	7.55 ± 0.09^{Aa}
F (10%)	1	4.64 ± 0.07^{Ab}	30.68 ± 0.18^{Aa}	7.08 ± 0.04^{Ab}
	2	4.85 ± 0.18^{Ab}	30.15 ± 0.29^{Bab}	7.55 ± 0.09^{Aa}
	3	5.16 ± 0.04^{Aa}	29.68 ± 0.18^{Bb}	7.77 ± 0.17^{Aa}

Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p < 0.05$). The means within a column (the difference within samples during storage period) followed by different superscript letters whereas the means within a column (the difference between samples) followed by different capital letters.

emulsions helped to prevent protein damage.

Crude fat

It is interesting to note that there was no variation in crude fat content between the control sample and SCG shortbread samples despite the changes observed in both dimensions and texture of shortbread. This is probably due to the fat substitution where the saturated fat in control sample was substituted by the unsaturated fat in SCG. This assumption is in agreement with the previous findings by Kouhsari et al. (2022) who reported that the fat replacement in hard dough biscuits with canola oil (very low saturated fat) led to lower spread and increased thickness, which has an obvious impact on the breaking strength and hardness. Similarly, Kouhsari et al. (2022) revealed that the biscuits incorporated with palm-based fat dictated high fat spreadability where the fat particles completely covered the protein and made the dough to be more stretchable thus giving a softer texture. However, the fats in shortbread tend to ooze out which fails to eradicate the gluten development and eventually lead to harder texture of the control sample as compared to the SCG shortbread samples upon storage (Table 7).

Crude fibre

There is a significant difference between samples in terms of crude fibre content as the crude fibre content is elevated with the increasing SCG concentrations in shortbread samples. Particularly, 10% SCG shortbread possessed the highest value (32.09%) of crude fibre content whereas the lowest value (20.40%) crude fibre content was depicted by the control sample. The high content of crude fibre in SCG is explained by the presence of cellulose, hemicellulose, and lignin, which are fundamental constituents of the plant cell walls (Zeng et al., 2017). Similarly, berry pomaces are fibre- rich food by-products with a high phenolic content and the higher fibre content was found in the berry pomace powder incorporated cookie in food that also eventually increased the water-holding capacity (Jurevičiūtė et al., 2022). As an illustration, the amount of fibre present in SCG with abundant phenols is higher than in flour, which absorbs more water and thus increases both moisture as well as crude fibre content which had been attributed to the preferable sensory attributes in terms of texture. These results are in conformity with the findings of Adeola & Ohizua (2018) who showed that the crude protein and crude fibre of biscuits increased as the ratio of pigeon pea flour augmented.

Carbohydrates

Table 6 shows that a significant variation in the carbohydrate content of shortbread samples, ranging from 23.46% to 39.39%. The control sample had the highest value, whereas the 10% SCG shortbread had the lowest. High carbohydrate intake is associated with high glycemic index (GI), which leads to an immediate spike in blood sugar levels upon digestion as well as absorption and increase the risk of chronic diseases such as cardiovascular disease, cancer, and diabetes. The Malaysia Dietary Guidelines (2020) recommend a daily carbohydrate intake of 130 g for active individuals. This study found that incorporating SCG, a low glycemic sugar and fibre-rich source of carbohydrates, into shortbread reduced the carbohydrate content, which can be regarded as a positive result that is consistent with previous studies by Martinez-Saez et al. (2017). SCG is rich in galactomannan, that has higher thermal stability than locust bean gum due to its lower degree of branching, resulting in higher inter-chain hydrogen bonding and a more ordered structure. Thus, galactomannan in SCG contributes to the high thermal stability, characterized by desirable sensory quality in SCG-containing shortbread during baking. Thermal stability is related to the activation energy required for thermal degradation. As noted by Simões et al. (2014), coffee galactomannan requires higher activation energy (138 kJ/mol) than arabinogalactan fractions (94 kJ/mol), which have higher heat lability. Consequently, SCG can be used as a stable food ingredient in bakery products without affecting the conventional food preparation and the final product quality.

Antioxidant activity

Fig. 2 illustrates that as the level of spent coffee grounds (SCG) in shortbread samples increased, the DPPH radical scavenging activity also increased. The highest value (88.68%) was observed in the 10% SCG shortbread sample, whereas the control sample had the lowest value (85.32%). The SCG- containing shortbread exhibited a higher potential for scavenging free radical DPPH compared to the control sample. The formation of melanoidin due to the Maillard reaction positively correlated with the antioxidant activity in SCG shortbread samples. The thermal treatment did not have a significant effect on the degradation of SCG, even though the high-fibre antioxidants in SCG shortbread were baked at high temperature. In addition, the high concentration of

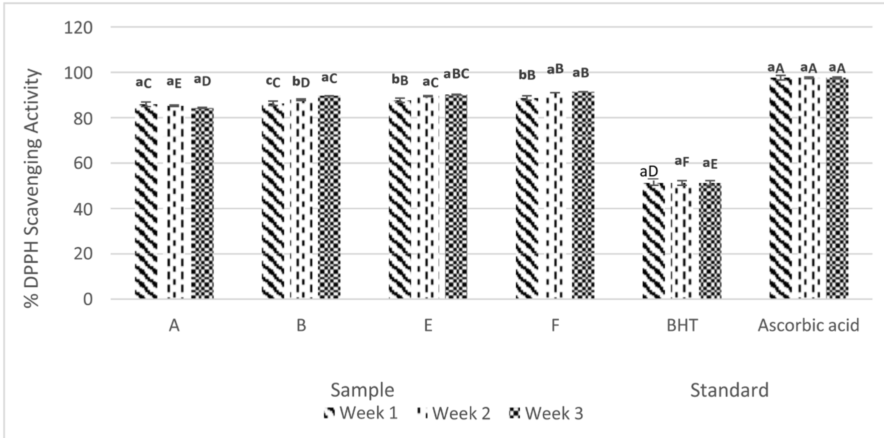

Fig. 2. Percentage of DPPH scavenging activity in different SCG shortbread upon storage Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p < 0.05$). The means within a column (the difference within samples during storage period) followed by different superscript letters whereas the means within a column (the difference between samples) followed by different capital letters.

bioactive compounds in Zizyphus lotus powder. contributed to an elevation in the antioxidant potential of the composite cookies (Zarroug et al., 2021). The antioxidant potential of SCG is attributed to the interaction between chlorogenic acid (CGA), the most important phenolic compound in SCG, and melanoidin, which were not extracted during coffee brewing. The% DPPH scavenging activity in different levels of SCG shortbread samples ranged from 86.3% to 88.68% and was comparable to the natural antioxidant ascorbic acid (51.28%) and the synthetic antioxidant butylated hydroxytoluene (97.61%). The use of SCG as a natural antioxidant in food products could replace synthetic antioxidants, which have been linked to adverse health effects. Moreover, the SCG-containing shortbread exhibited an increment in antioxidant capacity after one week of storage, whereas the ascorbic acid with low shelf-life stability was degraded after 7 days of storage at 25 °C and 35 °C despite the high antioxidant activity (Yin et al., 2022). SCG could also serve as a natural colouring agent in bakery formulations. Furthermore, the% DPPH scavenging activity in different ratios of SCG-containing shortbread gradually increased during storage time.

Total phenolic content (TPC)

The results presented in Fig. 3 demonstrate a significant increase in total phenolic content (TPC) in SCG shortbread with increasing concentrations of SCG incorporation and upon storage. The TPC of SCG shortbread ranged from 21.52 mg GAE/g to 52.31 mg GAE/g, which is significantly higher than the control sample (9.35 mg GAE/g). This increase in phenolic compounds can be attributed to the percentage of SCG substitution, as observed in previous studies by Trà et al. (2021) who reported that the total phenolic content of SCG was 23.5 times higher than that of wheat flour. Additionally, the incorporation of SCG resulted in a positive relationship between polyphenols and antioxidant capacity, as evidenced by the highest DPPH radical scavenging activity in 10% SCG shortbread with the highest TPC. These results are consistent with previous studies showing an increase in polyphenolic compounds in bread formulations incorporated with the methanolic extract of SCG (Czajkowska–González et al., 2021).

However, all samples illustrated a gradual decline in TPC during storage, which may be due to the absence of food additives that have been extensively used to augment shelf-life stability. Nonetheless, the TPC of SCG-containing shortbread contributed to a lower decrease upon storage compared to the control sample, likely due to the presence of chlorogenic, caffeic, and coumaric acids which are potent antioxidants and responsible for shelf-life stability. These findings are consistent with previous research, showing that the inclusion of SCG phenolics into the protein films in active packaging material improved their UV-light resistance and increased antioxidant properties. Furthermore, the polyphenols in SCG are abundant and exhibit mild antibacterial effects, making them valuable functional ingredients in food products. These findings suggest that the polyphenols in SCG can be potentially utilized in both food products and packaging materials for the enhancement of long-term storage with lower lipid oxidative susceptibility.

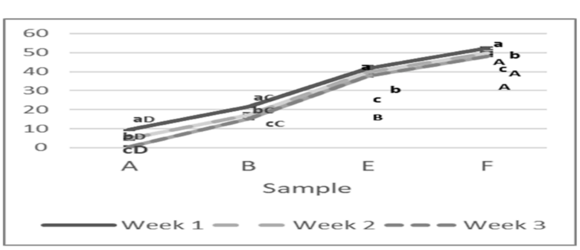

Fig. 3. Total phenolic content (TPC) in different SCG shortbread upon storage Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p < 0.05$). The means within a column (the difference within samples during storage period) followed by different superscript letters whereas the means within a column (the difference between samples) followed by different capital letters.

Peroxide value (PV)

The analysis revealed a significant difference in peroxide value (PV) amongst the samples, as well as across the storage periods (Table 8). PV

Table 8
Change in PV of different SCG of shortbread upon storage.

Sample	Storage period (week)	Peroxide value (mEq peroxide/kg fat)
A (0%)	1	$1.98{\pm}0.03^{Ac}$
	2	$5.74{\pm}0.54^{Ab}$
	3	$9.47{\pm}0.21^{Aa}$
B (2%)	1	$1.63{\pm}0.13^{Bb}$
	2	$3.57{\pm}0.20^{Ba}$
	3	$4.03{\pm}0.05^{Ba}$
E (8%)	1	$0.72{\pm}0.10^{Cb}$
	2	$2.46{\pm}0.57^{BCa}$
	3	$3.51{\pm}0.11^{Ca}$
F (10%)	1	$0.61{\pm}0.02^{Cc}$
	2	$1.25{\pm}0.23^{Cb}$
	3	$2.13{\pm}0.01^{Da}$

Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p < 0.05$). The means within a column (the difference within samples during storage period) followed by different superscript letters whereas the means within a column (the difference between samples) followed by different capital letters.

is an important initial product that plays a crucial role in lipid oxidation. It is the measure of peroxides of autoxidation, which occurs due to oxidation caused by air at room temperature (Ahmed et al., 2016). The gradual decrease in PV with the increasing level of SCG incorporation in shortbread was evident in the samples. The control sample had the highest value of PV (1.98 mEq peroxide/kg fat), while the 10% SCG shortbread exhibited the lowest value of PV (0.61 mEq peroxide/kg fat). This decrease in PV may be due to the presence of SCG as natural antioxidants, which enhanced the stability of shortbread against lipid oxidation. This observation is supported by the high TPC and antioxidant activity in SCG, which contributes to the delay of lipid rancidity and exerts a protective effect on unsaturated fatty acids (Fernandes et al., 2018).

Across storage periods, the PV of all samples increased, indicating the occurrence of fat oxidation. The control sample showed the highest value of PV (9.47 mEq peroxide/kg fat) during the third week of storage. However, it is still considered under the safe limit, as the PV of fresh oils is generally less than 10 mEq peroxide/kg fat (Singh et al., 2022). Interestingly, the incorporation of SCG in shortbread resulted in a lower elevation of PV. PV can be used as an oxidative index for the early stages of lipid oxidation with a slower increase to secondary oxidation. In particular, the 10% SCG shortbread initially showed a PV of 0.61 mEq peroxide/kg fat, which doubled to 1.25 mEq peroxide/kg fat in the second week of storage, followed by a slower increase and the lowest PV value (2.13 mEq peroxide/kg fat) during the third week of storage. This downward trend of PV concurred with the previous studies by Aung Moon et al. (2022), who reported that the PV of Arabica green coffee beans increased substantially until day 15 of storage and then slowed down after nine weeks of regular storage.

Sensory acceptability

Colour acceptance. Table 9 revealed the sensory attributes of shortbread incorporated with different concentrations of SCG. As SCG incorporations increased, the colour acceptability of the shortbread decreased, apparently due to the dark colouration of SCG. There was a significant difference between control samples with sample B, C and E in terms of colour acceptance amongst the panellists where the control indicated the highest mean score (7.15) whereas the 2% SCG shortbread had the least preference (5.95). This may be due to no masking of colour between the controls (bright yellowish colour) with other SCG-containing shortbread (gradual increment of dark brown hue). As compared to the colour profile analysis in Table 3, the control (0% SCG) demonstrated the highest L* value (lightness) which was 74.46 amongst all the formulations followed by the 2% SCG shortbread with 55.83 (L* value) that indicated a slightly dark colour. Yet, it is interesting to note that the highest percentage of 10% SCG-containing shortbread has second highest popularity right after the control. It is probably due to the more intense colour of 10% SCG shortbread was perceived better by the panellists compared to the 2% SCG shortbread.

Aroma acceptance

The average aroma likeness scores of SCG shortbread with varying levels of spent coffee grounds (SCG) ranged from 5.7 to 7.0. Results indicated a significant difference between shortbread containing 10% SCG and the other formulations, as evidenced in Table 5. These findings suggest that higher concentrations of SCG can contribute to a more desirable aroma, ultimately enhancing the sensory quality of the shortbread. Conversely, shortbread containing 6% and 8% SCG did not exhibit a significant difference in aroma, which may be attributed to the loss of volatile aromatic compounds during coffee brewing, leading to a reduction in the number of available aromatics in SCG. Notably, shortbread with 2% SCG had the lowest aroma similarity score, indicating that insufficient amounts of SCG may not provide enough aroma intensity to be detected by panelists. Roasted coffee is known to contain over 900 volatile compounds, which are powerful olfactory stimulants activating a diverse array of olfactory receptors. Upon consumption, the bitter substances in coffee trigger gustatory receptors, while orthonasal aromas entice consumers. The binding of odorant molecules to olfactory receptors initiates the olfactory process, which ultimately leads to olfactory adaptation (Horgue et al., 2022).

Taste acceptance

Generally, shortbread with intermediate SCG incorporations ranging from 2 to 8% evinced no significant differences amongst the samples. This phenomenon may be postulated as inadequate amount of SCG incorporated and thus less perceived by the panellists. On the contrary, the taste likeness scores were significantly higher ($p < 0.05$) in control sample compared to 10% SCG shortbread. To a lesser extent, the odour and taste acceptability were affected by the presence of more glycaemic reduced sugars, which were attributed to the roasted aroma that were perceived as the main positive sensory attributes. Other than that, taste detection threshold was considered where the bitter xanthine such as caffeine in SCG induced bitter taste. Kaur et al. (2021) also proclaimed that bitter tastants were categorically rejected for consumption according to the gustatory evaluation yet are now well-accepted and indulged as preferences. This is highlighted by the overwhelming popularity of coffee which corresponds to the sensory acceptability of 10% SCG shortbread which ranked as second right after the control sample. This is consistent with the findings of Fjaeldstad and Fernandes (2020), who explored that the detection threshold for the sweet tastant was greater in a group of subjects who regularly consumed coffee, whereas the detection threshold for the bitter tastant was considerably lower in a group of participants who regularly consumed decaffeinated coffee.

Hardness acceptance

Surprisingly, the texture of 10% SCG shortbread (7.13) in terms of hardness had no significant difference as compared to the control sample (7.80) (Table 9). This might be due to the superlative emulsifying activity and prolonged emulsion stability of SCG in bakery products which was previously declared by Silva et al. (2018). Besides, there is a

Table 9
Sensory evaluation of different formulations of SCG shortbread.

Sample	Colour	Aroma	Taste	Hardness	Fracturability/ crumbliness	Oiliness	Overall acceptabilit y
A (0%)	7.15±2.00^{a}	6.80±1.91^{ab}	7.60±1.67^{a}	7.80±1.34^{a}	7.90±1.11^{a}	6.85±1.78^{a}	7.88±1.27^{a}
B (2%)	5.95±1.83^{b}	5.70±2.02^{c}	6.05±2.08^{bc}	5.50±2.09^{c}	5.30±1.91^{c}	6.13±1.87^{ab}	6.15±2.02^{bcd}
C (4%)	6.00±1.75^{b}	6.10±1.60^{bc}	5.53±1.78^{c}	5.00±1.83^{c}	4.73±1.78^{c}	5.58±1.68^{b}	5.60±1.74^{d}
D (6%)	6.40±1.63^{ab}	6.53±1.91^{abc}	5.90±1.92^{bc}	4.70±2.00^{c}	4.78±1.98^{c}	5.58±1.97^{b}	5.88±1.74^{cd}
E (8%)	6.13±1.88^{b}	6.45±2.01^{abc}	6.00±2.22^{bc}	6.34±2.13^{b}	6.60±2.21^{b}	6.23±1.86^{ab}	6.40±2.06^{bc}
F (10%)	6.58±1.74^{ab}	7.00±1.81^{a}	6.60±1.74^{b}	7.13±1.34^{ab}	6.95±1.50^{b}	6.43±1.78^{a}	6.90±1.57^{b}

Values represent the mean ± standard deviation. Values with different superscript letters within the same column are statistically different ($p < 0.05$).

significant difference between control sample and all the shortbread with different SCG incorporations except for 10% SCG shortbread. The highest concentration of SCG incorporation was desirable in enhancing the hardness of shortbread. As compared to the texture profile analysis in Table 3, the hardness of shortbread dictated a gradual decrease when the percentage of SCG incorporations increased. These results are in accordance with Budžaki et al. (2014) who reported the higher initial water content significantly affects texture properties in which cookies with wet formula had lower hardness as compared to the dry formula.

Moreover, SCG shortbread was softer in correspondence with similar studies by Najjar et al. (2022) on the incorporation of date seed powder in cookie formulation. Additionally, it can be postulated that high fibre content in SCG leads to higher water retention and interferes with gluten development. This was proven by Bouaziz et al. (2020) who incorporated the extracted dietary fibre from date seeds resulting in a decrease in bread hardness. This can be justified as in the reduction in hardness of SCG shortbread since SCG is also rich in dietary fibre. Apparently, in terms of texture sensory quality, sensory acceptability of panellists is high in the samples with high SCG incorporations (10%). In a nutshell, hardness is a textural property that plays a crucial role in the evaluation of bakery products, as it is associated with the freshness perception by consumers in which the lower this parameter is, the more desirable the product (Guiné, 2022).

Fracturability/crumbliness acceptance

The fracturability between control samples and SCG shortbread ranged from 12.83 to 13.35. Hence, it can be assumed that the addition of SCG in shortbread is acceptable without adverse effect on the crumbliness which is the most significant characteristic of shortbread. Besides, the similar fracturability value dictated can be related to the crude fat content which showed no significant difference between samples as well. This finding agreed with previous studies about varying fat content in biscuit formulations as Jauharah et al. (2014) reported that sensory acceptance of muffin and biscuit incorporated with young corn powder was averagely high since the quantity of fracture indicating its brittleness corresponds to the crispness and crunchiness of the cookie when bitten. Hence, the consistency of fracturability is desirable in the bakery products particularly for crumbly shortbread (Mounjouenpou et al., 2018).

Oiliness acceptance

The oiliness scores of shortbread varied between 5.58 and 6.85 (Table 9). There was a significant difference between the 10% SCG shortbread (6.43) and shortbread with 6% and 8% SCG which indicated the similar values (5.58). Higher concentrations of SCG incorporated shortbread is more desirable and cater to the preference of all the panellists. The control sample did not exhibit a statistically significant difference in terms of oiliness acceptability when compared to the 10% SCG shortbread. It is possible that the lack of noticeable changes in the acceptability of oiliness between the control sample and the 10% SCG shortbread could be attributed to the similarity in their fat content. As a result, the crumbliness consistency may have been maintained without any significant impact on the overall texture. This highlights the importance of oiliness in reducing saturated fat in cookies without affecting sensory attributes compared to control samples. In a similar vein, Ekin et al. (2021) found that incorporating oil-based nanoemulsions into cookie formulations with reduced fat did not impact the oiliness of shortbread. This finding corroborates our own interesting discovery in this study.

Overall acceptability

The control sample received the highest overall acceptance scores, followed by the 10% SCG shortbread (6.90), 8% SCG shortbread (6.40), and 2% SCG shortbread (6.15). This aligns with previous studies by Aljobair (2022), who reported high acceptance scores in control cookies and those fortified with 0.5%, 1%, and 1.5% clove powder, and Galla et al. (2017), who found that cookies containing 5% spinach powder were well-accepted without adverse effects on sensory quality. Overall, the 10% SCG shortbread was rated as more acceptable than other SCG shortbread formulations. Therefore, the 10% SCG shortbread, control sample, 2% SCG, and 8% SCG shortbread were chosen as the optimum blend ratios for subsequent chemical analyses based on their overall acceptability scores.

Conclusion

The study demonstrated that the addition of SCG improved the final product's properties, including higher fibre, protein, and moisture content with lower carbohydrates and calorie content as well as enhanced antioxidative properties. Notably, sample F, containing 10% SCG, exhibited the lowest hardness value with profound aroma as well as promising antioxidative properties and shelf-life stability. Moreover, sensory evaluation revealed that sample A was the most preferred, followed by 10% and 8% SCG-shortbread. These findings suggest that SCG-based shortbread has the potential to be a good fat replacer and natural antioxidant, mitigating oxidative damage to both food products and human body. The utilization of SCG as a potential antioxidant dietary fibre can improve the nutritional composition and sensory quality of various food products while addressing the underutilization of this value-added functional food by-product.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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