Mesopotamia Journal of Agriculture

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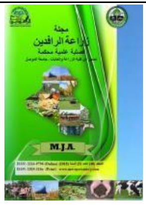

STUDY OF THE PHYSICAL, CHEMICAL, AND SENSORY PROPERTIES OF THE COOKIE PRODUCT RESULTING FROM REPLACING DIFFERENT PROPORTIONS OF BANANA PEEL POWDER

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Article information
Article history:
Received: 12/01/2024
Accepted: 09/07/2024
Published: 30/09/2024

Keywords:
antioxidant activity, banana peel, chemical and physical properties, cookies, total phenols.

DOI:
10.33899/mja.2024.146030.1346

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ABSTRACT

The study aimed to demonstrate the nutritional value of banana peels. The analysis of the chemical composition of banana peels showed that the percentage of moisture, fat, protein, ash, and carbohydrates reached 3.97, 2.90, 7.23, 9.07, and 76.83%, respectively. The total phenols in the ethanolic and methanolic extracts were 240.58 and 212.4 mg GAE/100 g, respectively, with an IC50 value of 2.39 µg/ml for banana peels. HPLC analysis revealed gallic acid, Rutin, Ferulic acid, Apigenin, Catechine, and Qurcetine in banana peels. They also contain vitamins (C, A, E, B6) and minerals (Na, P, Ca, Cu, Mg, K). Replacing cookies with different proportions of banana peels showed a change in the chemical estimates of its components. The percentages of moisture, fat, protein, ash, and carbohydrates ranged between (5.42 - 8.21) %, (23.62 - 23.87) %, (9.35 - 15.99) %, (4.39 - 5.90) %, and (50.33 -52.92) %, respectively. The substitution's effect on the cookie product's physical properties was (diameter 4.26-4.33 cm, thickness 1.45-1.62 cm, diffusion ratio 2.65-2.67). The antioxidant properties also increased significantly, as the total phenolic content ranged between 16.14−21.65 mg GAE/100 g, and the antioxidant activity ranged between 53.80−73.71% in the cookie product to which different concentrations of banana peel powder were added. Sensory evaluation of cookies with 5 and 7.5% banana peel powder revealed positive qualities.

INTRODUCTION

Bananas are among the most important fruit crops widely cultivated and consumed in tropical and subtropical regions. The average per capita consumption of bananas is 12 kg, making it the world's leading food crop after rice, wheat, and corn. Global banana production has increased over the past 20 years from about 70 million tons in 1999 to about 117 million tons in 2019. Southeast Asian countries lead in output with a rate of 47%, followed by South and Central America at 28% and Africa at 13%. India is the largest producer of bananas in the world, contributing about 27% of production, followed by China, Indonesia, Brazil, and Ecuador (Zaini *et al*., 2022). The banana plant belongs to the Musaceae family. The banana plant is derived from three genera (Musa, Ensete, and Musella) under the same family, and the Musa genus includes several species (Mathew *et al*., 2017).

Bananas are an important economic crop all over the world, as bananas are used in many food industries. This results in the availability of large quantities of peels, representing about 30-40% of the total weight of fresh bananas, which are considered significant by-products (Gomes *et al*., 2022). Banana peels represent a rich source of many nutritional components such as protein, fats, dietary fiber, and starch. The peels also contain several essential amino acids, polyunsaturated fatty acids, and mineral elements, which include copper, zinc, sodium, potassium, calcium, phosphorus, and iron. It is also an abundant source of antioxidant compounds (Rodzali *et al*., 2018).

Banana peels contain biologically active compounds such as tannins, alkaloids, flavonoids, terpenoids, glycosides, and anthocyanins, and antioxidants such as polyphenols, prodelphinidin, carotenoids, and catecholamines. These can be used in biological and pharmaceutical aspects due to their antibacterial and antimicrobial properties; they are also anti-diabetic, antihypertensive, and anti-inflammatory (Zaini *et al*., 2020). Recently, interest in banana peels has increased due to their many health benefits, and this has encouraged their use in various applications such as baked goods or meat sausages (Segura-Badilla *et al*., 2022) and in making low-calorie biscuits (Joshi, 2007).

The study aims to determine the chemical composition of banana peels, determine their content of mineral elements, vitamins, and total phenols, and diagnose the active compounds found in banana peels and their antioxidant effectiveness, using banana peels as a fortifying material in the cookie product and studying the effect of the addition on the physical, chemical and sensory properties of the product, in addition to its impact on the cookie product's antioxidant activity and total phenols content.

MATERIALS AND METHODS

Collection and Preparation of Banana Peels

Banana fruits collected in August 2023 from Salah al-Din Governorate underwent meticulous processing after thorough washing to eliminate dirt. The peels were separated from the pulp and air-dried on aluminum foil at room temperature with adequate ventilation. Continuous stirring expedited the drying process. The dried peels were ground into a fine, homogeneous powder using a home electric grinder and sieved through a 60-mesh sieve. The resulting powder was stored in a cold, dry plastic container, following procedures outlined by Kareem (2018), in preparation for subsequent analyses.

Preparation of Extracts

Preparation of Methanolic Extracts

The extraction method employed was followed by Gülçin *et al*. (2003). 25 gm of banana peel powder was blended with 250 ml of 95% methanol alcohol. The mixture underwent 24 hours of stirring on a magnetic stirrer, followed by filtration through gauze and filter paper (Whatman No.1). The resulting filtrate was concentrated using a rotary evaporator. Subsequently, it dried in an electric oven at 40°C. The raw extract was then stored at -4°C for preservation.

Preparation of Ethanolic Extracts

The method of Gülçin *et al*. (2003) was used in 25 gm of banana peel powder mixed with 250 ml of 96% ethanolic alcohol. The mixture was stirred for 24 hours on a magnetic stirrer, then filtered through gauze and then using filter paper (Whatman No.1). The filtrate was then concentrated using a rotary evaporator and dried in an electric oven at a temperature of 40°C. The raw extract was stored at -4 °C.

Chemical Analysis of Banana Peels:

The analysis of banana peels included determining moisture content, ash content, protein, and crude fat on a dry weight basis, following standard procedures outlined by A.O.A.C. (2020). Total carbohydrates content was determined according to (A.O.A.C., 2020) as follows:

$$Total\ carbohydrates = 100 - (\%\, moisture\,\% + ash\,\% + protein\,\% + fat\,\%)$$

Determination of Total Phenols in Banana Peels

The total phenolic contents in banana peel ethanolic and methanolic extracts were assessed using the Folin-Ciocalteu method (Mashkor and Muhson, 2014). In this process, 0.1 ml of the banana peel extract was combined with 0.5 ml of 10% Folin-Ciocalteu reagent. After swirling, the mixture stood for 6 minutes, followed by adding 1 ml of 7.5% sodium carbonate. The resulting mixture was left in a dark place at room temperature for 2 hours, and the absorbance at 765 nm wavelength was measured using a spectrophotometer. The results were expressed as milligrams of gallic acid equivalents per 100 g sample (mg GAE/100 g).

Evaluation of Antioxidant Activity by DPPH Radical Scavenging Method in Banana Peels

The antioxidant activity of banana peel extracts was evaluated through free radical scavenging using varying concentrations of methanolic extract (0.5, 1.5, 2.5, 3.5, 5 µg/ml). The assessment followed the method described by Nasreen and Choudhury (2018). A 1,1-diphenyl-2-picrylhydrazyl (DPPH) solution was prepared at a concentration of 0.004 g (4 mg DPPH in 100 mL of methanol). One milliliter of this DPPH solution was added to 3 ml of banana peel methanol extracts in methanol at different concentrations. The mixture was shaken vigorously and allowed to stand at room temperature for 30 minutes. Absorbance was measured at 517 nm using a spectrophotometer (UV-VIS Shimadzu). The IC50 value represented the concentration needed to inhibit 50% of the DPPH free radical. The percent DPPH scavenging effect was calculated using a defined equation.

$$DPPH\ scavenging\ effect\ (\%)\ or\ Percent\ inhibition = A0 - A1 / A0 \times 100$$

Where A0 was the absorbance of blank

A1 was the absorbance in the presence of the test sample

Determination and Diagnosis of Phenolic Compounds in Banana Peels

Sample Extraction

In the extraction process, 3g of banana peel powder was mixed with 60 mL of methanol/water (40/60) for 24 hours. The resulting mixture underwent filtration, and the filtrate was concentrated under vacuum (40°C) to a final volume of 5 mL. This solution was hydrolyzed with 5 mL of (2N) NaOH for 30 minutes. After adjusting the pH to 7.00 with (2N) HCl, phenolic acids were extracted via liquid/liquid extraction using 20 mL of ethyl acetate. The extracts were combined, and ethyl acetate was removed under reduced pressure. The residue was dissolved in 7 mL of methanol and subjected to HPLC analysis using 10 µl.

HPLC Conditions

The method for assessing bioactive compounds in banana peels was adapted from Ngamsuk *et al*. (2019). High-performance liquid chromatography (HPLC) analysis was performed using a SYKAMN HPLC system (Germany) equipped with a C18-ODS column (250 × 4.6 mm, 5 µm). Injecting 100 µL of samples into the system, the mobile phase consisted of 95% acetonitrile + 0.01% Trifluoroacetic acid (solvent A) and 5% acetonitrile + 0.01% Trifluoroacetic acid (solvent B) at a flow rate of 1 mL/min. The gradient program included 10% A form 0 to 5 min, 25% A from 5 to 7 min, and 40% A from 7 to 13 min before returning to initial conditions. Detection of phenolic compounds was accomplished with a UV-visible detector at 278 nm.

Determination of Vitamins

The content of vitamins (C, A, E, and B6) was determined by methods described by Kozhanova *et al*., (2002). These analyses were determined in the laboratories of the Ministry of Science and Technology / Baghdad.

Measurement of Minerals in Banana Peel

Mineral elements in banana peels were estimated according to the method proposed by (Ayo *et al*., 2020), by drying 2 g of banana peels in a drying oven at a temperature of 105 °C for 3 hours. The sample was then incinerated in an incineration furnace at a temperature of 550 °C until white ash was obtained. The ash was treated with concentrated hydrochloric acid, transferred to a volumetric and made up to 100 mL before submission to atomic absorption spectrophotometry (SHEMADZU AA 7000).

Preparation of Cookies Product

The cookie production process followed the method outlined by Jandal and Naji (2021), with slight modifications involving varying concentrations of banana peel and flour, as detailed in Table (1). In the formulation, 100g of wheat flour was combined with 40g of fat, followed by the addition of 2g of skimmed milk powder, 30g of sugar, 2g of ammonium bicarbonate, 1.5g of sodium bicarbonate, and 0.4g of table salt dissolved in a small amount of water (total volume limited to 25 ml). The dough samples were rolled to a thickness of 3.5 mm, cut into round shapes using a 45 mm diameter cutter, placed on aluminum trays, and baked at 190°C for 10 min in the oven, followed by cooling at room temperature.

Table (1): Flour and banana peel ratios used in the preparation of cookies.

Treatment	Flour ratio	Peels ratio	The total content of flour and peels
Control	100	zero	100
T1	97.5	2.5	100
T2	95	5	100
T3	92.5	7.5	100

Chemical Analysis of Cookies Product

The cookies product was analyzed for moisture, ash, protein, and crude fat according to the standard procedures recommended by A.O.A.C. (2020). Total carbohydrates content was determined according to (A.O.A.C., 2020) as follows:

$$Total\ carbohydrates = 100 - (\%\ moisture\ \% + ash\ \% + protein\ \% + fat\ \%)$$

Physical Properties of Cookies Product

Cookies were measured for thickness (cm), width (cm), and spread ratio, according to (Alshehry, 2022).

Estimation of Total Phenolic Content and Antioxidant Activity in a Cookie Product

Prepare Sample

For each cookie sample, 10g was taken and mixed with 100 ml of 80% ethanol using a shaker. The mixture was homogenized overnight at room temperature. Subsequently, the homogenized mixture was filtered through the Whatman No.1 filter paper. The resulting filtrate was concentrated at 40°C under vacuum using a rotary evaporator. The concentrated liquid obtained was then stored at -18°C until further analysis, following the procedure outlined by Salama *et al*. (2020).

Estimation of Total Phenols of Cookies Product

The total phenol content (TPC) of cookie extracts was assessed using the Folin-Ciocalteu method, employing gallic acid as a calibration standard, according to Canalis *et al*. (2020). The absorbance of cookie extract samples was measured at 750 nm after adding Folin-Ciocalteu reagent and a 20% aqueous solution of sodium carbonate. The mixtures were left in a dark place for 30 minutes. TPC was calculated using a calibration curve constructed with gallic acid, and results were expressed as micrograms of polyphenols (equivalent to gallic acid) per 100 g. Blank samples containing only the reagents were utilized to discount the absorbance due to solvents and reagents.

Determination of Antioxidant Efficacy in Cookies Product

The antioxidant activity of the cookies was estimated according to the method described by Ahmed (2022), where a solution of 1,1-diphenyl -2- picrylhydrazyl (DPPH) was prepared (weighed 6 mg of DPPH and dissolved in 100 ml of methanol). Take 1 ml of sample extract and add 2 ml of DPPH solution. After giving the mixture a gentle shake, it was allowed to sit at room temperature in the dark for 30 minutes. A UV-VIS spectrophotometer set at 517 nm was used to measure the absorption. 1 ml of methanol was used as a blank to create the control by mixing it with two ml of DPPH solution. Results were expressed as a percentage of inhibition of the DPPH radical, which was calculated according to the following equation:

$$\%\ of\ inhibition = (Control\ absorbance - Sample\ OD / Control\ OD) \times 100)$$

Sensory Evaluation of Cookies Product

Twenty evaluators from professors of food science and the College of Basic Education/Sharqat, Department of Science / University of Tikrit conducted the sensory evaluation of cookies made in the laboratory. According to (Jandal 2021), different blends of cookies were evaluated for color, appearance, flavor, taste, texture, and overall acceptability by a 9-point Hedonic scale.

Statistical Analysis

The results were analyzed statistically using the (SAS 2001) program and according to a one-way analysis of variance. Analysis Of variance (ANOVA) of the parameters was tested using the Duncun multiple ranges test with a significance level of P≤0.05 to determine the significant differences between groups.

RESULTS AND DISCUSSION

Chemical Analysis of banana peel

Table (2) presents the chemical composition of a banana peel sample, with moisture, fat, protein, ash, and carbohydrates at 3.97%, 2.90%, 7.23%, 9.07%, and 76.83%, respectively. These findings align with Segura-Badilla *et al*. (2022), who reported a moisture content of 3.56%. Zaini *et al*. (2022) noted a fat range of 2.24 - 11.6%, while Tsado *et al*. (2021) found ash content to be 9.56%. Gouda (2018) reported protein content at 7.21%. Mosa and Kkalil (2015) indicated carbohydrates at 79.87% in dried banana peels. Discrepancies in chemical components among studies are attributed to variations in banana varieties, cultivation conditions, soil service operations, storage, and sampling methods. Differences in carbohydrate percentages stem from variations in other components, as indicated by Kareem (2018).

Table (2): Nutritional value of banana peels based on dry weight

Chemical Analysis %	Banana peel	Vitamin (µg/gm)	Banana peel	Mineral (mg/100 g)	Banana peel
Moisture	3.97d	Vit C	522.8a	Na	80.9c
Fat	2.90e	Vit A[a]	188.7c	P	255.0b
Protein	7.23c	Vit E	96.9d	Ca	39e
Ash	9.07b	Vit B6	385.6b	Cu	5.1f
Carbohydrates	76.83a			Mg	70.8d
		[a]: (IU)		K	440.5a

The numbers in the table refer to three-repeat rates
Differences in lowercase letters indicate a significant effect at (P≤0.05).

Total phenols content in banana peels

In Figure (1), the total phenol concentration in both ethanolic and methanolic extracts of banana peels was found to be 240.58 mg gallic acid/100g and 212.4 mg gallic acid/100g, respectively.

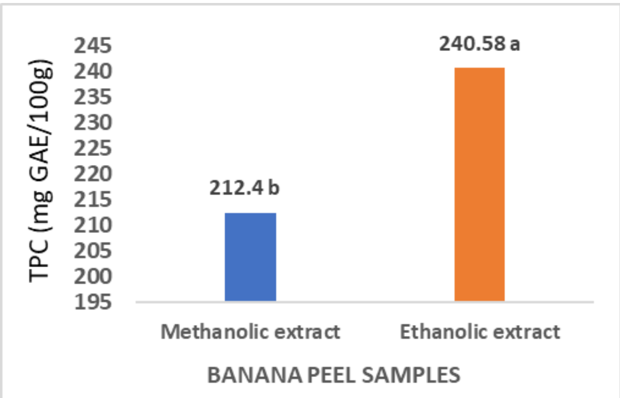

Figure (1): Total phenols content in banana peels

These results align with the range reported by (Noor *et al*. 2016) of 91.8 - 602.26 mg gallic acid/100 g and with (Fatemeh *et al*. 2012) stating a range of 75.01 - 685.57 mg gallic acid/100 g in banana peels. (Okolie *et al*. 2016) reported higher total phenolic content in ethanolic extracts (336.83 and 383.33 mg as gallic acid/100g) compared to methanolic extracts (344.29 and 299.42 mg gallic acid/100g). However, our results differ from those of (Pasha *et al*. 2022), who found ripe banana peel powder to have 581.44 mg gallic acid/100 g. The discrepancies are attributed to genetic varieties, growing seasons, sample numbers, and estimation methods, as (Kabir *et al*. 2021).

Antioxidant activity of banana peel extract

Figure (2) shows the percentage of free radical scavenging activity for the methanolic extract of banana peels and vitamin C at various concentrations. Notably, an upward trend in scavenging activity is observed with increasing concentrations. Specifically, concentrations of (0.5, 1.5, 2.5, 3.5, and 5) micrograms/ml of banana peel extract demonstrated scavenging capacities of (18.9, 31.5, 52.9, 77.8, and 85.9) %, respectively. In comparison, the same concentrations of vitamin C exhibited scavenging capacities of (24.9, 48.9, 70.9, 88.9, and 94.5) %, respectively. These findings agree with Kumari *et al*. (2020), who reported free radical-suppressing activity of Estonian banana peel extract ranging between 7.41-71.21%. In contrast, Rodzali *et al*. (2018) noted that ascorbic acid's free radical inhibitory activity reached 98.17%, and Pasha *et al*. (2022) found the antioxidant activity of ripe banana peel to be 39.77%.

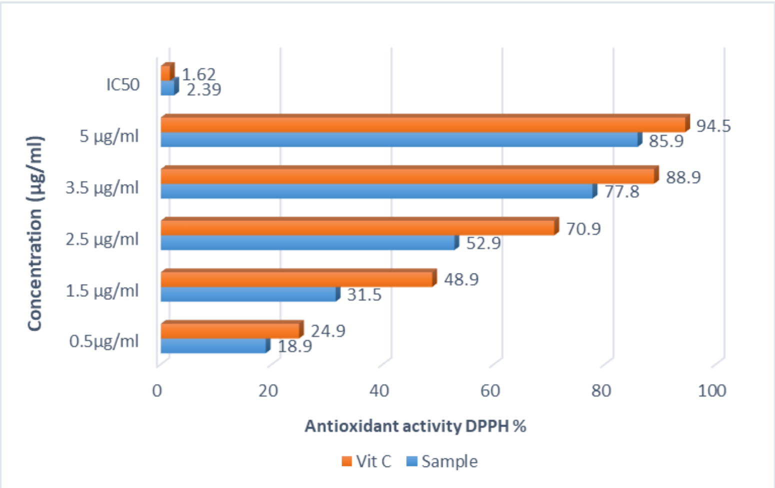

Figure (2): shows that the IC50 value of the methanolic extract of banana peels and ascorbic acid

In Figure (2), the IC50 value for the methanolic extract of banana peels is 2.39 µg/ml, while for ascorbic acid, it is 1.62 µg/ml. These results align with (Ahmed *et al*. 2021), who reported an IC50 value of 2.297 µg/ml for banana peel powder extract, and (Rodzali *et al*. 2018), who found an IC50 value of 2.04 µg/ml for ascorbic acid. (Arnisah *et al*. 2023) highlighted the protective effect of banana peel extracts against oxidative damage attributed to additional phenolic compounds compared to pulp remains. (Pereira and Maraschin 2018) further emphasized that banana peels, rich in carotenoids, ascorbic acid, xanthophylls, and phenolic compounds, contribute significantly to antioxidant activity, as corroborated by (Okolie *et al*. 2016).

Identification of phenolic compounds in banana peels

Figure (3) the profile of isolated phenolic compounds from the banana peel sample is illustrated, showcasing each compound's appearance time. Table (3) details the identified and isolated phenolic compounds' concentrations. Notably, Gallic acid is present at 41.05 µg/gm, followed by Rutin at 30.55 µg/gm. Other compounds, including Ferulic acid, Apigenin, Catechin, and Quercetin, are also identified, with concentrations of 27.80, 20.88, 18.98, and 13.98 µg/gm, respectively. These findings align with (Arnisah *et al*. 2023), who reported the presence of Rutin, Catechin, and Gallic acid in banana peels at concentrations of 227.507, 191.719, and 17.298 µg/gm, respectively. (Aboul-Enein *et al.* 2016) also identified Quercetin and Catechin in Estonian banana peel extracts. (Zhang *et al*. 2022) stated that the type and content of phenolic compounds in banana peels vary depending on banana varieties and that ripening stages significantly impact the total range of phenolic compounds in banana peels (Vu *et al*., 2018).

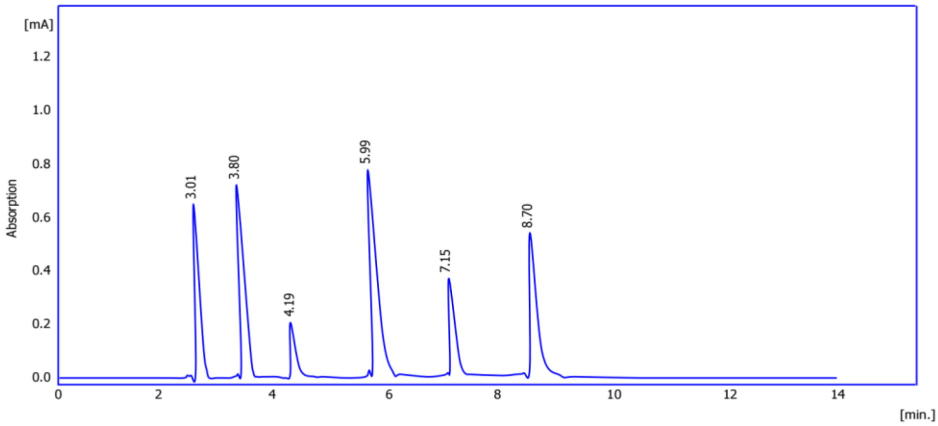

Figure (3): Identification of compounds for extracted banana peel

Table (3): Identified Phenolic Compounds in Banana Peel.

Samples	Gallic acid (µg/gm)	Rutin (µg/gm)	Ferulic acid (µg/gm)	Apigenin (µg/gm)	Catechine (µg/gm)	Qurcetine (µg/gm)
Banana Peel	41.05	30.55	27.80	20.88	18.98	13.98

Vitamin content in banana peels

Table (2) displays the type and quantity of water-soluble vitamins and fat-soluble in a banana peel sample. The recorded percentages are 522.8 for vitamin C, 385.6 for vitamin B6, 96.9 for vitamin E, and 188.7 IU for vitamin A. These results differ from the values reported by Mosa and Khalil (2015), who estimated vitamin (A, C, B6, E) in banana peels at (3.13, 1.86, 2.93, 1.03) mg/g, respectively. Gouda (2018) also acknowledged the presence of several vitamins, including (A, C, B6, E), in banana peels. Zahra *et al*. (2021) emphasized that banana peels are a good source of vitamins C and E, known as natural antioxidants. Discrepancies in vitamin values compared to previous studies may stem from variations in banana varieties, maturity stages, fertilization methods, harvesting procedures, and post-harvesting and storage methods.

Mineral content of banana peels

Table (2) presents the mineral element content in banana peels, with the highest concentrations observed for potassium (440.5 mg/100g) and phosphorus

(255.0 mg/100g). Calcium and copper have the lowest concentrations at (39 and 5.1) mg/100g, respectively, while sodium and magnesium average (80.9 and 70.8) mg/100g, respectively. These results agree with Ahmed *et al*. (2021), who reported mineral element content (phosphorus, potassium, and copper) in banana peels at (204.15, 454.4, and 5.60) mg/100g, respectively. They also coincide with Mosa and Khalil (2015), stating a magnesium concentration of 76.20 mg/100 grams. However, Islam *et al*. (2023) reported a phosphorus percentage of 250.93 mg/100 grams in banana peels. Hassan *et al*. (2018) indicated mineral element content (phosphorus, magnesium, sodium, calcium, copper, and potassium) in banana peels as (211.30, 44.50, 115.10, 59.10, 0.51, 4.39) mg/100g, respectively. Our study emphasizes that banana peels are a rich source of calcium and phosphorus, crucial for teeth, skeleton, muscle activity, and nerve control (Ansari *et al*., 2023; Tsado *et al*., 2021). The high potassium content aids in regulating body fluids, maintaining normal blood pressure, and preventing heart disorders (Anhwange *et al*., 2009). Copper plays a vital role in oxidation, growth, and development, while sodium maintains fluid balance in the body (Ahmed *et al*., 2021).

Chemical properties of cookies

Table (4) outlines the characteristics of the cookie product fortified with banana peel powder at proportions (2.5%, 5%, 7.5%), revealing moisture percentages of (5.42%, 7.54%, 8.21%), respectively, compared to 3.38% in the control group (T0). These align closely with Shafi *et al*. (2022), who reported moisture percentages in banana peel flour-enriched cookies ranging from (3.9% to 7.5%) for various peel proportions. In the same table, the fat percentage in the control group (T0) is 23.89%, while it slightly decreases with increased banana peel concentrations, reaching (23.87%, 23.78%, and 23.62%) for samples (T1, T2, and T3). These results align with Salama *et al*. (2022), who observed fat percentages ranging from (25.84% to 20.84%) in cookies with different banana peel concentrations.

Table (4): The chemical composition of the cookie’s product containing different percentages of banana peel

Components Treatment	Moisture %	Fat %	Protein %	Ash %	Carbohydrates %
T0	3.38d	23.89a	17.39a	2.13d	53.21a
T1	5.42c	23.87a	15.99b	4.39c	50.33d
T2	7.54b	23.78b	12.79c	4.72b	51.17c
T3	8.21a	23.62c	9.35d	5.90a	52.92b

The numbers in the table refer to three-repeat rates

Differences in lowercase letters indicate a significant effect at ($P \leq 0.05$).

The sample represents T0 (control group), T1 (2.5% banana peel + 97.5% flour), T2 (5% banana peel, +95% flour), T3 (7.5% banana peel + 92.5% flour).

The protein percentage in cookie samples increases with higher banana peel concentrations, reaching (17.39%, 15.99%, 12.79%, and 9.35%) for samples (T0, T1, T2, and T3). These findings correspond with Alam *et al*. (2020), who noted a decrease in protein percentage in cookies fortified with banana and banana peel flour. The ash percentage in the cookie product rises with increased banana peel concentrations, reaching (2.13%, 4.39%, 4.72%, and 5.90%) for samples (T0, T1, T2, and T3), consistent with (Oguntoyinbo *et al*. 2021). Carbohydrate percentages decreased in samples (T1, T2, T3) compared to the control (T0), reaching (50.33%, 51.17%, and 52.92%), respectively, in contrast to 53.21% in the control. Salama *et al*. (2022) observed carbohydrate percentages ranging from (64.42% to 63.76%) in cookies enriched with banana peels. Differences in carbohydrate percentages among samples may result from variations in other components, as carbohydrate estimation employed the difference between components method.

The Physical Properties of Cookies

Table (5) illustrates the impact of adding banana peel powder on the physical properties of cookies, including diameter, thickness, and spreading rate. The diameter of the cookie product ranged from 4.48 to 4.26 cm, with a significant decrease observed in the sample containing 2.5% banana peels (T1) at 4.33 cm compared to the control (T0) at 4.48 cm. Samples T2 and T3, containing 5% and 7.5% banana peel powder, also significantly differed from the control. This aligns with (Alshehry *et al*. 2022), who reported a decrease in cookie diameter when fortified with banana peels, which is attributed to the high fiber content in the peels. Thickness showed no significant differences between some treatments, with a slight decrease observed with increasing peel concentrations, reaching (1.69, 1.62, 1.61, 1.45) cm for treatments T0, T1, T2, and T3, respectively. These findings are consistent with (Alam *et al*. 2020), who observed a decrease in cookie thickness with banana and banana peel flour additions. Changes in diameter and thickness were reflected in the spreading rate, which reached 2.94 in the control (T0) and 2.67, 2.67, and 2.65 in samples T1, T2, and T3, respectively. This is in line with (Oguntoyinbo *et al*. 2022), who observed a decrease in spreading rate with added concentrations of banana peel powder.

Table (5): Physical properties of the cookie product containing different percentages of banana peels

Treatments	Diameter (cm)	Thickness(cm)	Spread ratio
control	4.48 a	1.69 a	2.94 a
T1	4.33 ab	1.62 b	2.67 b
T2	4.30 ab	1.61 b	2.67 b
T3	4.26 b	1.45 c	2.65 b

The numbers in the table refer to three-repeat rates
Differences in lowercase letters indicate a significant effect at ($P \leq 0.05$).
The sample represents T0 (control group), T1 (2.5% banana peel + 97.5% flour), T2 (5% banana peel, +95% flour), T3 (7.5% banana peel + 92.5% flour).

Total phenols content and antioxidant activity in cookie product

Table (6) reveals the total phenol content in cookie samples with varying concentrations of added banana peels. Significant differences ($P \leq 0.05$) were observed among all samples, with total phenols reaching (10.51, 16.14, 18.27, and 21.65) mg/100 g for samples T0, T1, T2, and T3, respectively. Shafi *et al*. (2022) reported phenolic content in cookies supplemented with banana peels at ratios (7.5, 10, 12.5, 15) % as 0.561 mg GAE/g, 0.713 mg GAE/g, 0.828 mg GAE/g, and 0.921 mg GAE/g, respectively. The increase in total phenolic content is attributed to added banana peels, with higher concentrations leading to higher phenolic content. Table (6) also illustrates the percentage of free radical scavenging activity in cookie samples. The control group (T0) showed 35.80% activity, while treatments T1, T2, and T3 exhibited (53.30, 66.66, and 73.71) %, respectively. This antioxidant activity increased with higher concentrations of added banana peels. These results align with Shafi *et al*. (2022), who reported free radical-suppressing activity in cookies with banana peels at (0, 7.5, 10, 12.5, 15) % ratios as (47.76, 62.02, 68.13, 68.51, and 70.29) %, respectively. Despite the baking process causing some loss of phenolic compounds, adding banana peel powder increased the antioxidant capacity of the cookie product due to the high total phenol content in banana peels.

Table (6): The phenolic content and the percentage of antioxidant activity in cookies supplemented with different proportions of banana peels

Sample	TPC (mg GAE/100g)	Antioxidant activity DPPH %
T0	10.51 d	35.80 d
T1	16.14 c	53.30 c
T2	18.27 b	66.66 b
T3	21.65 a	73.71 a

The numbers in the table refer to three-repeat rates
Differences in lowercase letters indicate a significant effect at ($P \leq 0.05$).
The sample represents T0 (control group), T1 (2.5% banana peel + 97.5% flour), T2 (5% banana peel, +95% flour), T3 (7.5% banana peel + 92.5% flour).

Sensory Evaluation of the Cookies Product

Figure (4) displays the sensory evaluation results of the cookie product. Treatment T1 stands out as superior in overall product acceptance. There were no significant differences ($P \leq 0.05$) in crispiness and texture between treatments T0 and T1 and T2 and T3 in terms of texture. However, there were significant differences in taste, color, and overall acceptance among treatments T0, T1, T2, and T3. These results align with the findings of Salama *et al*. (2022), indicating that as the concentrations of banana peel powder increase in the cookie product, there is a decrease in evaluation scores. Optimal sensory results are observed at lower concentrations, such as 5% and 10% banana peel powder, improving the overall product acceptance.

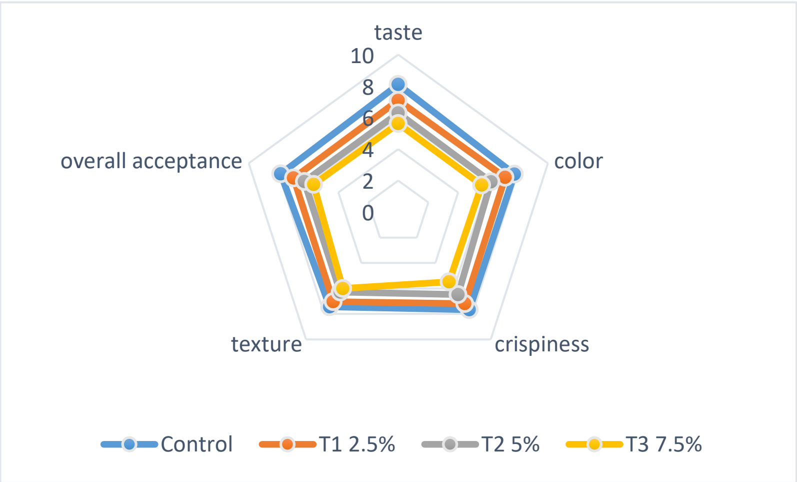

Figure (4): Sensory evaluation of cookies fortified with banana peel powder.

CONCLUSIONS

The study revealed notable changes in the chemical composition of banana peels, with increased nutrient content, mainly carbohydrates. Banana peels exhibited robust antioxidant activity due to their phenolic compounds and being rich in vitamins and minerals. Fortifying cookies with varying levels of banana peels resulted in increased moisture, ash, and carbohydrate content, while fat and protein percentages decreased. The diffusion rate decreased with higher peel concentrations, potentially influenced by differences in diameter and thickness during dough processing. The cookies ' phenolic content and free radical-scavenging activity increased proportionally with higher banana peel concentrations. Sensory evaluations indicated positive reception for cookies enriched with up to 5% banana peels. In conclusion, banana peels could serve as a promising alternative for enhancing cookies' and other products' functional and nutritional properties.

ACKNOWLEDGMENT

The author wishes to thank Colleges of Agriculture at the Tikrit University for their support and provide the requirements for the completion of this research.

CONFLICT OF INTEREST

The authors state that there are no conflicts of interest with the publication of this work.

دراسة الخواص الفيزيائية والكيميائية والحسية لمنتج الكوكيز الناتج عن استبدال نسب مختلفة من مسحوق قشور الموز

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الخلاصة

هدفت الدراسة إلى ايجاد القيمة الغذائية لقشور الموز، حيث أظهرت دراسة التركيب الكيميائي لقشور الموز أن نسبة الرطوبة والدهن والبروتين والرماد والكربوهيدرات بلغت 3.97، 2.90، 7.23، 9.07، و76.83%، على التوالي. وبلغ محتوى الفينولات الكلية في المستخلصات الإيثانولية والميثانولية لقشور الموز 240.58 و212.4 ملجم GAE/100غم على التوالي. بينما بلغت قيمة IC50 2.39 ميكروغرام/مل لقشور الموز. وأظهرت نتائج التحليل الكروماتوغرافي السائل عالي الأداء (HPLC) وجود حامض الغاليك، والروتين، وحامض الفيروليك، والأبيجينين، والكاتشين، والكورسيتين في قشور الموز. كما أنها تحتوي على الفيتامينات (C، A، E، B6) والمعادن (Na، P، Ca، Cu، Mg، K). أدى استبدال الكوكيز بنسب مختلفة من قشور الموز تغيراً في التقديرات الكيميائية لمكوناته اذ بلغت (الرطوبة 5.42–8.21%، الدهون 23.62–23.87%، البروتين 9.35–15.99%، الرماد 4.39–5.90%، الكربوهيدرات 50.33–52.92%). اما تأثير الاستبدال على الخواص الفيزيائية للكوكيز المنتج قد بلغ (القطر 4.26–4.33 سم، والسمك 1.45–1.62 سم، ونسبة

الانتشار 2.65–2.67). كما زادت خصائص المضادة للأكسدة بشكل ملحوظ اذ تراوح إجمالي المحتوى الفينولي بين 16.14–21.65 مجم GAE/100 غم، والفعالية المضادة للأكسدة بين 53.80–73.71% في منتج الكوكيز المضاف لها تراكيز مختلفة من مسحوق قشور الموز، كما أظهرت نتائج التقييم الحسي لمنتج الكوكيز التي تحتوي على 5 و7.5% من مسحوق قشور الموز صفات إيجابية.

الكلمات المفتاحية: قشور الموز، النشاط المضاد للأكسدة، الفينولات الكلية، الكوكيز، الخصائص الكيميائية والفيزيائية.

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