

PROXIMATE COMPOSITION AS A FORM OF NUTRITIONAL QUALITY ASSESSMENT OF BANANA PEEL

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Abstract

Banana peel, obtained as by-product of banana processing, contains sufficient amounts of nutritive and phytochemical constituents that have positive effects in human nutrition. Previous studies have shown that banana peels are rich in nutritional and bioactive compounds, which provides a number of benefits, that include antibacterial, antihypertensive, antidiabetic and anti-inflammatory properties. Proximate analysis provides valuable information about the nutritional composition of banana peels and helps to evaluate the sample quality. This work aims to determine the proximate composition of banana peels, with a view to their valorization for the development of value-added food products. The obtained results show that the nutritional parameters of banana peel provide values that vary depending on the origin of the fruit from which they were obtained: 5.21-8.21% moisture, 12.86-8.17% ash, 5.28-7.84% protein, 3.14-4.11% fat, 10.23-14.65% fiber, and 57.93- 62.72% carbohydrate. These values show that the analyzed banana peels have considerable nutritional value and could be effectively integrated into a diverse range of value-added food products

Key words: banana peel, by-products, nutritional constituents, proximate composition.

INTRODUCTION

Bananas (*Musa* spp., Musaceae family) are one of the most widely consumed fruits in the world, being an important source of nutrients, including carbohydrates, fibre, vitamins (especially vitamin B₆ and vitamin C), minerals (especially potassium), and various bioactive compounds such as phenols, carotenoids, and biogenic amines (Ogo et al., 2024; Jandal, 2024; Ansari et al., 2023; Chimdi et al., 2024; Munir et al., 2024; Rawat et al., 2024). These fruits are widely known for their high nutritional value, containing dietary fiber, pectin, high levels of minerals (potassium and phosphorus), phenolic compounds (e.g., catechins, trichothecenes, lignans, tannins, and anthocyanins), vitamins (A, B, C, and E), β -carotene, and phytosterols (Huang et al., 2024). Naturally ripened bananas contain 77.78% moisture, 0.81% fat, 2.59% ash, 2.32% fiber, 2.25% protein, 25.23% carbohydrates, 0.02 ppm Pb, 0.78 ppm Cu, 6.08 ppm Zn, 0.14 ppm

Mn, 9.12 ppm Mg, 0.01ppm Cu, 0.98 ppm Cd (Ogo et al., 2024). Bananas vary in colour, size, and firmness but are usually elongated and curved, with soft, starchy flesh and skin that can be green, yellow, red, purple, or brown, depending on the variety (Edima-Nyah et al., 2024). The nutritional content of bananas varies widely in concentration, depending on the banana variety, soil conditions, climate, cultivation, and stage of fruit development and storage conditions (Huang et al., 2024). The edible part of the banana fruit represents about 60-70% of the fruit weight (Chimdi et al., 2024; Jandal, 2024; Ansari et al., 2023; Rawat et al., 2024; Akhter et al., 2024), is usually consumed raw or processed into a variety of products, on a large or small scale, including dried fruits, snacks, smoothies, ice cream, bread, wheat, wine, and functional food additives (Sahoo & Lenka, 2024; Ansari et al., 2023).

Banana fruit processing activities generate significant quantities of banana peels, which

are considered significant by-products (Jandal, 2024). Banana peel, the outer shell of the banana fruit, is a by-product of household consumption and banana processing (Hikal et al., 2022) and is rich in nutrients (fiber, protein, crude fat, lipids, pectin, essential amino acids, polyunsaturated fatty acids, and micronutrients) (Kusumasari et al., 2024; Youssef et al., 2024) and bioactive compounds that provide many health benefits. Even though its nutritional content and bioactive compounds vary depending on the banana variety, environmental conditions, extraction methods, and evaluation methods (Ansari et al., 2023), the amount of ash, protein, crude fiber, and digestible starch in banana peel flour was reported to be significantly higher than that of pulp, which makes the banana peel flour more effective as a functional additive (Kusumasari et al., 2024; Amini Khoozani et al., 2019). In addition to its excellent nutritional value, banana peels have a variety of health benefits, treating enteritis, diarrhea, dysentery, ulcerative colitis, nephritis, gout, heart disease, hypertension, and diabetes (Youssef et al., 2024). Banana peels are also rich in phenolic compounds, with high antioxidant activity that

prevents heart disease and cancer. Banana peels contain a wide range of bioactive constituents, including flavonoids, tannins, alkaloids, glycosides, anthocyanins, and terpenoids, which confer many benefits to banana peels, including antibacterial, antihypertensive, antidiabetic, and anti-inflammatory properties (Rawat et al, 2024; Kusumasari et al, 2024; Ansari et al., 2023). Banana peels are considered richer in phytochemicals compared to pulp, which has antifungal and antibiotic properties and is beneficial for human health (Ansari et al., 2023). However, it should be noted that banana peels may also contain antinutrient compounds, such as glycosides, alkaloids, oxalates, and phytate (Bhavani et al., 2023).

Several studies have shown that banana peel has a rich nutritional content that depends on the banana variety, environmental circumstances, cultivation techniques, fruit maturity stage, and evaluation methods (Chimdi et al., 2024; Sahoo and Lenka, 2024; Hikal et al., 2022; Ansari et al., 2023). The values for some nutritional parameters of banana peels reported by researchers in the field are presented in Table 1.

Table 1. Proximate composition of banana peels according to various authors

Sample	Proximate composition (%)						References
	Moisture	Ash	Protein	Fat	Crude fibre	Carbohydrates	
Banana peel	3.97	9.07	7.23	2.90	-	76.83	Jandal, 2024
Banana (<i>Musa acuminata</i>) peel	7.36	12.11	16.42	10.43	30.53	23.15	Chimdi et al., 2024
Banana (<i>Musa acuminata Cavendish</i> subgroup) peels	4.42	12.73	9.56	5.04	19.49 NS	46.76	Issara et al., 2024
Banana (<i>Musa sapientum</i>) peel	-	5.93	1.95	-	-	11.82	Hikal et al., 2024
Banana (<i>Musa x paradisiaca</i> L.) organically grown peel	10.50	4.61	7.70	1.28	3.81	72.1	Mahomud et al., 2024
Bantal variety banana (<i>Musa paradisiaca</i>) peel flour	8.65	6.79	11.81	6.7	11.5	66.05	Sahoo and Lenka, 2024
Ripe banana (<i>Musa sapientum</i>) peel	89.34	17.79,	8.72	8.22	34.80	-	Youssef et al., 2024
Malbhog (<i>Musa paradisiaca</i> AAB group) banana peel	7.05	12.19	9.29	3.92	11.70	67.53	Akhter et al., 2024
Yellow banana peels (<i>Musa</i> sp.)	-	11.58	10.76	6.58	19.48 NS	51.6	Alshehri et al., 2024
Nam wa mali-ong banana peels	4.93	8.20	3.76	5.22	16.56	61.34	Khamsaw et al., 2024
Ripe banana (<i>Musa</i> spp.) peel powder	15.32	14.33	3.46	5.89	15.57	-	Ahsan et al., 2024
Bananas at stage 3 of ripening supermarket	8.9	7.0	6.5	13.0	16.6	71.0	Dom et al, 2024

Sample	Proximate composition (%)						References
	Moisture	Ash	Protein	Fat	Crude fibre	Carbohydrates	
Banana (<i>Musa</i> gen) peel powders	7.50	6.70	3.22	1.81	29.52	51.25	Saeed et al., 2024
Banana (<i>Musa</i> spp.) peel waste powder	13.90	14.93	8.60	7.41	13.88	43.28	Taha et al. 2024
Banana (<i>Cavendish</i> var.) peel, dried	-	12.45	10.44	8.40	11.81	43.40	Gupta, T., & Abdollah M., 2022
Banana (<i>Musa cavendish</i>) peel powder	3.56	11.86	6.41	10.22	14.38	57.13	Segura-Badilla et al., 2022
Banana peel	-	9 – 11	5.5 – 7.87	2.24 – 11.6	-	59.51 – 76.58	Zaini et al., 2022
Banana (<i>Musa sapientum</i>) peels termed waste	63.33	9.60	1.95	5.93	8.37	11.82	Joy et al., 2022.
Banana peels from market	9.83	9.56	3.23	0.89	12.67	63.82	Tsado et al., 2021
Banana (<i>Musa cavendish</i>) peel, drying	10.03	25.19	15.10	7.04	–	44.64	Ahmed et al., 2021
Banana (<i>Musa sapientum</i>) peels	49.5	8.8	5.30	1.06	19.2	-	Pyar et al, 2018
Banana (<i>Musa sapientum</i>) peel	88.10	13.42	7.57	10.44	-	68.31	Aboul-Enein et al., 2016
Banana (<i>Musa sapientum</i>) peel	6.70	8.50	0.90	1.70	28.56	59.00	Anhwange et al., 2009

The nutritional benefits of banana peels offer ample opportunities for their use as food additives, which can produce value-added food products (Kusumasari et al., 2024; Ansari et al., 2023). The literature reviewed shows that the use of banana peels in the development of value-added food products has been explored in several studies that have shown potential formulations for obtaining functional foods (Ansari et al., 2023; Zaini et al., 2022; Jandal, 2024; Kusumasari et al., 2024). Several studies have been conducted to improve and fortify various food products using banana peels, for example: dried plant-based meat products like chicken sausages (Issara et al., 2024) or fish and beef patties (Bin Mohd Zaini et al., 2019; Dom et al., 2024), pasta and bakery products (Akhter et al., 2024; Youssef et al., 2024; Segura-Badilla et al., 2022), biscuits (Paramitasari et al., 2024; Jandal, 2024; Owuno & Wabali, 2024), muffin (Ahsan et al., 2024), chapatti as an ingredient in gluten-free cake formulation (Türker & Savlak, 2022), functional puddings (Sadek, 2024), salted noodles and yellow noodles (Pasha et al., 2022; Dom et al., 2024), anxiolytic bagels (Manzoor et al., 2024), probiotic yogurt (Mahomud et al., 2024), in recipes such as stews, soups, and curries (Kusumasari et al., 2024).

Considering the above, in this paper, the proximate composition of banana peels was analyzed, which provides valuable information about the nutritional composition of banana peels to use in the formulation of value-added foods, respectively, in obtaining functional

foods. The following parameters were evaluated: water, ash, crude protein, lipids, crude fiber, and carbohydrate content of banana peels sold in local agri-food markets.

MATERIALS AND METHODS

For the experiment, samples of ripe yellow bananas (quality I) "Vela rosa Premium Banana" - of the Cavendish variety (Figure 1 a) imported from a Latin American country, sold by three traders in local agro-industrial markets, were taken. Three sets of banana samples (about 1 kg each) were made, corresponding to the three sellers from whom they were purchased. The banana fruits, well washed under cold tap water, were peeled by hand, and the peels obtained (Figure 1 b), marked with BP1, BP2, and BP3 - corresponding to the three suppliers, were cut into strips 2-3 mm wide. To prevent the initial enzymatic browning reaction, banana peels were immersed in a 0.5% (w/v) citric acid solution at a cold temperature for 10 min, after which they were rinsed with distilled water (Mahomud et al., 2024). After draining the water, the peels were dried in a ventilated oven at 50°C until a constant moisture content was reached (Figure 2 a). After drying, the banana peel samples were ground using a coffee grinder. The banana peel powder thus prepared (Figure 2 b) was stored at cold temperature in plastic boxes until analysis.

The nutritional composition of the banana peels taken in the experiment was determined in accordance with the AOAC Official Methods of

Analysis, 2000 (AOAC, 2000) and the recommendations according to the recommendations of Velciov et al. (2024) and

Sahoo & Lenka (2024). The moisture content was determined by the oven drying method at 105°C to constant mass (Velciov et al., 2024).



Figure 1. Ripe banana fruit (a) and peel (b)



Figure 2. Dried banana peel (a) and ground (powder, b)

The ash (mineral) content was determined by the calcination method at 550°C (Velciov et al., 2024). The protein content was determined by the Kjeldahl method, using a nitrogen conversion factor of 6.25. (Velciov et al., 2024; Sahoo & Lenka, 2024). Crude fat was determined using the Soxhlet method with hexane as solvent (Velciov et al., 2024; Sahoo & Lenka (2024). Crude fiber was determined by acid-base digestion method. Carbohydrate content was obtained by difference (Velciov et al., 2024). All analyses were performed using Rstatistical Software (v4.3.3; RCoreTeam2023).

The comparisons for means were done using Duncan's Multiple Range Tests (DMRT). Duncan's Multiple Range Tests or Duncan's New Multiple Range Tests provide significance levels for the difference between any pair of means, regardless of whether a significant F resulted from an initial analysis of variance. The Shapiro-Wilk test was used to assess the normality of the data (Ghosh and Mitra, 2020).

RESULTS AND DISCUSSIONS

Proximate analysis provides valuable information about the nutritional composition and helps to assess the quality of the sample, providing

information about the content of water, protein, lipids, ash, fiber and carbohydrates. (Saeed et al, 2024; Pyar & Peh, 2018).

The proximate composition of banana peels, which includes moisture, ash, protein, fat, fiber, and carbohydrates are present in Table 2.

The experimental results obtained show that the analyzed BPs have a considerable nutritional value that depends on the location and nature of the analyzed nutritional parameter: 5.21-8.21% moisture, 8.17-12.86% ash (minerals), 5.28-7.84% protein, 3.14-4.11% fats, 10.23-14.65% crude fibre, and 57.93-62.72% carbohydrate.

This can also be confirmed by numerous studies reporting that the proximal composition and nutritional properties of banana peels vary between different banana varieties and even between the same varieties from different cultivation areas (Sahoo and Lenka, 2024; Ansari et al., 2023).

The moisture content of the analyzed BPs indicates that the examined banana peels could be used in food processing, as well as in cosmetics, medicine, the textile industry, paper manufacturing, bio-absorbents, biofuel production, and the agricultural sector (Bhavani et al., 2023).

Table 2. Proximate composition (mean values) of banana peels

Specification	Nutritional parameter (% dry matter) *					
	Moisture	Ash	Proteins	Fats	Fibres	Carbohydrates
Provider 1 (BP1)	8.210.31a	8.17±0.31a	7.84±0.47a	4.11±0.29a	13.28±0.41b	57.93±2.41a
Provider 2 (BP2)	7.58±0.27a	8.42±0.27a	7.35±0.34a	3.62±0.26ab	14.65±0.42a	58.16±2.25a
Provider 3 (BP3)	5.21±0.31b	12.86±0.55a	5.28±0.37b	3.14±0.22b	10.23±0.35c	62.72±2.97a
Mean value	7.00±1.29	9.82±2.15	6.82±1.1	3.62±0.40	12.72±1.85	59.60±2.21

*Values are expressed as means ± standard deviation of triplicate determination. Different letters within a column signify significant differences ($p < 0.001$).

The moisture content of a product provides information about the amount of water contained in a given product and the amount of dry matter in that product (Velciov et al., 2024). Foods with a low moisture content, especially those with less than 10%, have a longer shelf life with limited quality deterioration due to microbial activities (Velciov et al., 2024). The moisture content of BPs varies between 5.21% (BP3) and 8.21% (BP1). Compared to these, the BP3 sample shows a much lower moisture content.

The assumption of normality moisture content distributions was assessed by using the Shapiro-Wilks test. Results indicated that the moisture contents are normally distributed (for BP1: $W=0.989$, $p=0.79$; for BP2: $W=0.976$, $p=0.70$; for GP3: $W=0.89$, $p=0.76$). A one-way ANOVA was performed to compare the effect of the three different providers on moisture contents. It revealed that there was a statistically significant difference in mean moisture contents between at least two groups ($F = 65.68$, $p < 0.001$, $\text{Eta}^2=0.96$, 95% C.I. [0.84, 1.00]). Duncan's MRT for multiple comparisons found that the mean value of moisture content was significantly different between provider 1 and provider 3 ($p < 0.001$, 95% C.I. = [2.29, 3.69]), and between provider 2 and provider 3 ($p < 0.001$, 95% C.I. = [1.69, 3]). There was no statistically significant difference in mean moisture contents between provider 1 and provider 2 ($p=0.06$).

These values show that the analyzed BPs are rich in organic matter, which is a good source of nutrients (Anhwange et al., 2009). In addition, the low moisture content (less than 10%) gives the analyzed BPs a longer shelf life without limited changes in their quality. (Velciov et al, 2024) The moisture values of the analyzed BPs (Table 2), as well as their average value (7.00%), are comparable to the values reported by Chimdi et al. (2024), Akhter et al.

(2024), Saeed et al. (2024) and Anhwange et al. (2009) (see Table 1).

Ash content represents the inorganic residues (mineral composition), which remain after the complete oxidation of organic materials with the removal of water by calcination of a food product (Rawat et al., 2024; Ansari et al., 2023; Pyar & Peh, 2018).). Ash content provides information on the content of mineral elements in the food (Rawat et al., 2024). High ash values indicate a high content of mineral elements (Saeed et al., 2024; Tsado et al., 2021). Banana peel is a rich source of minerals such as Ca, Fe, Mg, Zn, Na, K, P, and Cu (Jandal, 2024; Bhavani et al., 2023; Tsado et al., 2021; Rawat et al., 2024). They are essential in many physiological functions, such as metabolic pathway management, important organ formation, pH balancing, and muscular action (Ansari et al., 2023).

The ash content (Table 2) of BPs ranges from 8.17% (BP1) to 12.86% (BP3). Lower but relatively close values were determined in BP1 and BP2 (8.17, respectively, 8.72%); the BP3 sample is the richest in minerals (12.86%).

The assumption of normality ash content distributions was assessed by using the Shapiro-Wilks test. Results indicated that the ash contents are normally distributed (for BP1: $W=0.992$, $p=0.83$; for BP2: $W=0.994$, $p=0.84$; for BP3: $W=1$, $p=0.97$). A one-way ANOVA was performed to compare the effect of the three different providers on ash contents. It revealed that there was a statistically significant difference in mean ash contents between at least two groups ($F = 87.21$, $p < 0.001$, $\text{Eta}^2=0.97$, 95% C.I. [0.88, 1.00]). Duncan's MRT for multiple comparisons found that the mean value of ash content was significantly different between provider 1 and provider 3 ($p < 0.001$, 95% C.I. = [3.66, 5.69]), and between provider 2 and provider 3 ($p < 0.001$, 95% C.I. = [3.45, 5.40]). There was no statistically

significant difference in mean ash contents between provider 1 and provider 2 ($p=0.55$).

These values show that the analyzed BPs, especially BP3, contain increased amounts of mineral elements, being sources of valuable biominerals for obtaining foods with added mineral value. Comparing the ash content values of the analyzed BP samples with the values reported by different authors (see Table 1), it can be seen that it falls within the range of values determined by Jandal (2024), Chimindi et al. (2024), Issara et al. (2024), Khamsaw et al. (2024), Alshehri et al., (2024), Akhter et al. (2024), Zaini et al. (2022), Joy et al. (2022), Tsado et al. (2021), Pyar & Peh, (2018), and Anhwange et al. (2009).

Proteins are essential component of the diet needed for the survival of animals and human, they serve as source of nitrogen in the body (Velciov et al., 2024). Protein provides amino acids which are the substrates required for the support of body protein synthesis and maintenances of cell and organ protein content; thus, it furnishes amino acid the building block of all protein (Ahmed et al., 2021; Pyar & Peh, 2018). Protein deficiency is closely related to a number of diseases such as mental disorders, insufficiency of different organs, edema and immune system weakness and increased protein intake plays an important role in diseases related to diabetes and the cardiovascular system (Velciov et al., 2024). The analyzed BP samples contain relatively low amounts of protein but sufficient to contribute to their nutritional intake. The crude protein content of fruits is lower because fruits are generally not important protein sources (Pyar & Peh, 2018). The concentration of crude fibers in analyzed BPs (Table 2) shows different values, ranging between 5.28% (BP3) and 7.84% (BP1).

The assumption of normality protein content distributions was assessed by using the Shapiro-Wilks test. Results indicated that the protein contents are normally distributed (for BP1: $W=0.808$, $p=0.73$; for BP2: $W=0.916$, $p=0.73$; for BP3: $W=0.999$, $p=0.96$). A one-way ANOVA was performed to compare the effect of the three different providers on fat contents. It revealed that there was a statistically significant difference in mean protein contents between at least two groups ($F = 23.54$, $p < 0.001$, $\text{Eta}^2=0.89$, 95% C.I. [0.60, 1.00]). Duncan's

MRT for multiple comparisons found that the mean value of protein content was significantly different between provider 1 and provider 3 ($p < 0.001$, 95% C.I. = [1.55, 3.56]), and between provider 2 and provider 3 ($p < 0.01$, 95% C.I. = [1.10, 3.03]). There was no statistically significant difference in mean ash contents between provider 1 and provider 2 ($p=0.26$).

Although BPs are not important sources of protein, the protein concentration in the analyzed BPs shows that they can be helpful in the preparation of foods with added nutritional value (Dom et al., 2024) and are relatively good protein sources. The protein values determined in BP1, BP2, BP3 and their average (6.82%, see Table 1) are comparable to those reported by Jandal (2024), Mahomud et al. (2024), Dom et al. (2024), Segura-Badilla et al. (2022), Zaini et al. (2022), Pyar & Peh (2018), Aboul-Enein et al. (2016).

Fats, along with carbohydrates and proteins, are macronutrients that are considered the main components in proximate composition analysis (Ansari et al., 2023). Fats play important physiological and biochemical roles in the functioning of the human body, such as energy storage, structural components of biological membranes, electron carriers and cofactors of enzymes, light-absorbing pigments, hydrophobic anchors for proteins, and emulsifying agents in the digestive tract (Velciov et al., 2024). BPs have a low-fat content and therefore cannot be considered a good source of fat-soluble vitamins, but can contribute to the energy content of foods (Ahmed et al., 2021; Pyar & Peh, 2018). In addition, the low-fat content increases the shelf life of BP powders by reducing the risks of rancidity. The peel is cholesterol-free and low in calories, sugar, and fat (Joy et al., 2022).

The results obtained from the analysis of BPs taken in the experiment (Table 2) show that they contain amounts of fat ranging between 3.14% (BP3) and 4.11% (BP1).

The assumption of normality fat content distributions was assessed by using the Shapiro-Wilks test. Results indicated that the fat contents are normally distributed (for BP1: $W=0.887$, $p=0.54$; for BP2: $W=0.997$, $p=0.89$; for BP3: $W=0.996$, $p=0.93$). A one-way ANOVA was performed to compare the effect of the three different providers on fat contents. It revealed that there was a statistically significant

difference in mean fat contents between at least two groups ($F = 6.91$, $p < 0.05$, $\text{Eta}^2=0.70$, 95% C.I. [0.11, 1.00]).

Duncan's MRT for multiple comparisons found that the mean value of fat content was significantly different between provider 1 and provider 3 ($p < 0.051$, 95% C.I. = [0.30, 1.63]), There was no statistically significant difference in mean fat contents between provider 1 and provider 2 ($p=0.10$), and between provider 2 and provider 3 ($p=0.11$).

These values show that the analyzed BPs contain small amounts of fat and cannot be considered primary sources but could be used as ingredients to improve the texture, taste, and aroma of new food formulations (Velciov et al., 2024) or as an addition to low-fat foods (Ismail et al., 2024). The fat concentrations determined in BP1, BP2, and BP3 experimentally determined, and their average (3.62%) are comparable to those reported by: Akhter et al., 2024, Jandal, 2024, Issara et al., 2024, Khamsaw et al., 2024, and Zaini et al., 2022 (see Table 1).

Crude fiber, the portion of indigestible carbohydrates in food, consists mainly of cellulose, hemicellulose, pectin, and lignin (Velciov et al., 2024; Piar and Peh, 2018). Cellulose, hemicellulose, and lignin are well known for water absorption and regulation of the intestinal tract, while pectin and gums are important in cholesterol reduction and glucose regulation (Velciov et al., 2024). Crude fiber from BPs helps maintain normal peristaltic movement of the intestinal tract and, therefore, aids in food digestion and can be widely used in the food industry when incorporated into many foods to enrich their nutritional and sensory properties (Saeed et al., 2024). Therefore, diets that include foods with appreciable fiber additions may be beneficial for eliminating potential mutagens, steroids, and xenobiotics (Tsado et al., 2021).

Among the analyzed nutritional parameters, after carbohydrates (59.60%, mean value), crude fibers were determined in the highest amounts (12.72%, mean value). The concentration of crude fibers (Table 2) in BPs presents values ranging between 10.23% (BP3) and 14.65% (BP2).

The assumption of normality fibre content distributions was assessed by using the Shapiro-Wilks test. Results indicated that the fibre

contents are normally distributed (for BP1: $W=0.997$, $p=0.90$; for BP2: $W=0.972$, $p=0.67$; for BP3: $W=0.994$, $p=0.84$). A one-way ANOVA was performed to compare the effect of the three different providers on crude fiber contents. It revealed that there was a statistically significant difference in mean crude fiber contents between at least two groups ($F = 64.95$, $p < 0.001$, $\text{Eta}^2=0.96$, 95% C.I. [0.84, 1.00]). Duncan's MRT for multiple comparisons found that the mean value of crude fibre content was significantly different between provider 1 and provider 2 ($p < 0.05$, 95% C.I.= [0.39, 2.34]), and between provider 1 and provider 3 ($p < 0.001$, 95% C.I. = [2.07, 4.02]), and between provider 2 and provider 3 ($p < 0.001$, 95% C.I. = [3.41, 5.42]).

These values, but also the fact that crude fiber represents only a part of dietary fiber (Yang et al., 2017), show that the analyzed BPs contain significant amounts of fiber and could constitute a viable and cheap source of dietary fiber that promotes health, thus contributing to improving digestion (Saeed et al., 2024). In addition, incorporating BP powder into some foods can increase the total dietary fiber content and decrease their protein content, slowing down the digestion of starch and decreasing the glycemic index of foods (Tan et al., 2024). Therefore, BP powders can be helpful additives to improve foods' texture, taste, and nutritional properties (Wani & Dhanya, 2025). The values obtained for the determination of crude fibers in analyzed BPs are comparable to those reported by Sahoo and Lenka (2024), Akhter et al. (2024), Taha et al. (2024), Gupta, T., and Abdollah M. (2022), Tsado et al. (2021).

Carbohydrates are important macronutrients for the human body that act as a source of energy, help and control the metabolism of blood sugar and insulin, participate in cholesterol and triglyceride metabolism, and help in fermentation (Velciov et al., 2024; Ahmed et al., 2021). In the nutritional analysis of food, only total carbohydrates are considered, representing the totality of carbohydrates in food after other components, such as proteins, fats, moisture, and ash, have been removed (Velciov et al., 2024). Banana peel contains a significant amount of carbohydrates, indicating good sources of energy for humans and animals (Tsado et al., 2021). Banana peels'

carbohydrates consist mainly of dietary fiber and sugars, especially pectin, hemicellulose, and cellulose, which contribute to their potential as a functional ingredient in foods (Rawat et al., 2024; Chimdi et al., 2024). The presence of carbohydrates, especially indigestible fibers, can support digestive health and act as prebiotics, favoring the growth of beneficial bacteria in the gut (Chimdi et al., 2024).

The results of the present study showed that carbohydrates are the most abundant components in banana peel. The concentrations of carbohydrates determined in the analyzed BPs (Table 2) show similar values, ranging from 57.97% (BP1) to 62.72% (BP3).

The assumption of normality carbohydrate content distributions was assessed by using the Shapiro-Wilks test. Results indicated that the carbohydrate contents are normally distributed (for BP1: $W = 0.844$, $p = 0.52$; for BP2: $W = 0.907$, $p = 0.50$; for GP3: $W = 1$, $p = 0.97$). A one-way ANOVA was performed to compare the effect of the three different providers on carbohydrate contents. It revealed that there was not a statistically significant difference in mean carbohydrate contents between the groups ($F = 2.22$, $p = 0.19$, $\eta^2 = 0.43$, 95 % C.I. [0, 1]).

These values and their average show that the analyzed BPs contain increased amounts of carbohydrates and can be used as additives to improve the texture and general quality of foods (Saeed et al., 2024). Therefore, increased carbohydrate content is recommended for use in the formulation of value-added and functional foods. Comparing the carbohydrate content values of BP1, BP2, BP3 and their average with the values determined by: Sahoo & Lenka, 2024, Khamsaw et al., 2024, Segura-Badilla et al., 2022, Zaini et al., 2022, Tsado et al., 2021 and Anhwange et al., 2009, no apparent differences are recorded.

From what is presented, it can be stated that the analyzed BPs contain important amounts of nutritional compounds, especially carbohydrates and minerals, moderate amounts of crude fiber and proteins, and lower amounts of fats. Considering the proximate analysis of the analyzed BPs, it can be stated that they could be considered for improving the nutritional quality and obtaining foods with

added value. In addition, apart from the analyzed nutritional parameters, BPs contain increased amounts of biologically active compounds with anti-allergenic, anti-atherogenic, anti-inflammatory, anti-microbial effects and antioxidant, anti-thrombotic, cardio-protective, and anti-carcinogenic properties that present numerous health benefits, such as the prevention of diabetes, immunological disorders, and neurogenerative diseases (Taha et al., 2024). However, it must be pointed out that using banana peels in powder form requires a preliminary operation necessary to remove unwanted impurities and any pesticides or other substances used in banana cultivation techniques.

CONCLUSIONS

The values obtained from the proximate analysis of banana peels, which provide information on their nutritional value, show that banana peels obtained by peeling ripe yellow bananas "Vela rosa Premium Banana" (Cavendish variety), sold in local markets, contain increased amounts of nutritional compounds, especially carbohydrates, minerals, and organic compounds, moderate amounts of crude fiber and protein and relatively low amounts of fat.

The nutritional parameters of the analyzed banana peels show that this by-product could be used to develop food products with added value, having potential applications for obtaining functional foods.

We consider that the use of banana peels to improve the nutritional quality of foods requires further investigations to improve the procedures for obtaining powders from banana peels with increased contents of carbohydrates, fiber, minerals, protein, fat, and biologically active substances and the development of efficient, promising ways to open new horizons in the field of food fortification.

The use of banana peels, after a prior operation to remove impurities and possible pesticide residues, in food formulations creates opportunities to reduce waste and generate additional income for the banana processing industry.

REFERENCES

- Aboul-Enein, A. M., Salama, Z. A., Gaafar, A. A., Aly, H. F., Abou-Elella, F., & Ahmed, H. A. (2016). Identification of phenolic compounds from banana peel (*Musa paradaisica* L.) as antioxidant and antimicrobial agents. *Journal of chemical and pharmaceutical research*, 8(4), 46-55.
- Ahmed, Z., El-Sharnouby, G. & El-Waseif, M. (2021). Use of banana peel as a by-product to increase the nutritive value of the cake. *Journal of Food and Dairy Sciences*, 12, 87-97.
- Ahsan, M., Ashraf, H., Liaquat, A., Nayik, G. A., Ramniwas, S., Alfarrarj, S., Ansari, M.J, & Gere, A. (2024). Exploring pectin from ripe and unripe Banana Peel: A novel functional fat replacer in muffins. *Food Chemistry*: X, 101539.
- Akhter, M. J., Al-Amin, M., Hossain, M. A., & Kamal, M. M. (2024). Enriching Wheat Bread with Banana Peel Powder: Impact on Nutritional Attributes, Bioactive Compounds, and Antioxidant Activity. *International Journal of Food Science*, 2024(1), 2662967.
- Alshehri, A. A., Younes, N. M., Kamel, R., & Shawir, S. M. (2024). Characterization and potential health benefits of millet flour and banana peel mixtures on rats fed with a high-fat diet. *Heliyon*.
- Amini Khoozani, A., Birch, J., & Bekhit, A. E. D. A. (2019). Production, application and health effects of banana pulp and peel flour in the food industry. *Journal of food science and technology*, 56, 548-559.
- Anhwange, B. A., Ugye, T. J., & Nyiaatagher, T. D. (2009). Chemical composition of *Musa sapientum* (banana) peels, *EJEAFChe*, 8(6), 437-442.
- Ansari, N. A. I. M., Ramly, N., Faujan, N.H., & Arifin, N. (2023). Nutritional Content and Bioactive Compounds of Banana Peel and Its Potential Utilization: A Review. *Malaysian Journal of Science Health & Technology*, 9(1), 74-86.
- AOAC. Official Methods of Analysis, Association of Official Analytical Chemist. EUA; 2000.
- Bhavani, M., Morya, S., Saxena, D., & Awuchi, C. G. (2023). Bioactive, antioxidant, industrial, and nutraceutical applications of banana peel. *International Journal of Food Properties*, 26(1), 1277-1289.
- Bin Mohd Zaini, H., Bin Sintang, M. D., Dan, Y. N., Ab Wahab, N., Bin Abdul Hamid, M., & Pindi, W. (2019). Effect of addition of banana peel powder (*Musa balbisiana*) on physicochemical and sensory properties of fish patty. *British Food Journal*, 121(9), 2179-2189.
- Chimdi, E. E., Iheme, C. I., Njoku, O. C., Agwu, L. O., & Airaodion, A. I. (2024). Investigation of Proximate Composition and Bioactive Components in Banana (*Musa acuminata*) Peels Using Advanced Analytical Techniques. *J. Nutrition and Food Processing*, 7(10).
- Dom, Z.M., Chan, W.Q. and Ab Aziz, N.A. (2024). Utilising Banana Peel as a Food Ingredient for Enhancing Nutritional Value of Yellow Noodles and Beef Patties. *Advances in Agricultural and Food Research Journal*, 5(2).
- Edima-Nyah, A. P., Ntukidem, V. E., & Ogbonna, C. V. (2024). Chemical, Microbial, and Sensory Properties of Breakfast Cereals Made from Yellow Maize and Soybean Flour Blends with Firmly Ripe Banana Flavoring. *IPS Journal of Nutrition and Food Science*, 3(3), 227-233.
- Ghosh, S. & Mitra J. (2020). Importance of Normality Testing, Parametric and Non-Parametric Approach, Association, Correlation and Linear Regression (Multiple & Multivariate) of Data in Food & Bio-Process Engineering. *Mathematical and Statistical Applications in Food Engineering*. CRC Press, 112-126.
- Gupta, T., and Abdollah, M. (2022). Proximate and mineral composition of some fruit peels in the environment. *International Contemporary Journal of Science Education and Technology*, 1, 1-12
- Hikal, W. M., Said-Al Ahl, H. A., Bratovcic, A., Tkachenko, K. G., Sharifi-Rad, J., Kačaniová, M., Elhourri M., & Atanassova, M. (2022). Banana peels: A waste treasure for human being. *Evidence-Based Complementary and Alternative Medicine*, 1, 7616452
- Huang, P.-H., Cheng, Y.-T., Lu, W.-C., Chiang, P.-Y., Yeh, J.-L., Wang, C.-C., Liang, Y.-S., & Li, P.-H. (2024). Changes in Nutrient Content and Physicochemical Properties of Cavendish Bananas var. Pei Chiao during Ripening. *Horticulturae*, 10, 384. <https://doi.org/10.3390/horticulturae10040384>.
- Ismail, S., Dubey, P. K., Mishra, A. A., & Ashka, F. (2024). Valorisation of banana peel and mango peel as functional ingredients in baked products: a review. *International Journal of Food Science and Technology*, 59(9), 5938-5950.
- Issara, U., Tiwasiri, N., Keawwong, P., Lamphao, O., Chana, S., Sangketkit, W., & Changpasert, W. (2024). The utilization of banana peels (*Musa acuminata* Cavendish subgroup) as an alternative ingredient for producing dried plant-based meat products. *Food Research*, 8(4), 384-39
- Jandal, M. J. (2024). Study of the physical, chemical, and sensory properties of the cookie product resulting from replacing different proportions of banana peel powder. *Mesopotamia Journal of Agriculture*, 52(3), 71-0.
- Joy, G. F. F., Sunday, O. Z., Remilekun, A. and Olusegun, A. D. (2022). Waste-to-wealth; nutritional potential of five selected fruit peels and their health benefits: A review. *African Journal of Food Science*, 16(7), 172-183.
- Khamsaw, P., Sommano, S.R., Wongkaew, M., Willats, W.G.T., Bakshani, C.R., Sirilun, S., Sunanta, P. (2024). Banana Peel (*Musa ABB cv. NamWa Mali-Ong*) as a Source of Value-Adding Components and the Functional Properties of Its Bioactive Ingredients. *Plants*, 13, 593. <https://doi.org/10.3390/plants13050593>
- Kusumasari, S., Syabana, M. A., Pamela, V. Y., & Meindrawan, B. (2024). Potential use of food waste in food processing to add nutritional value. in *E3S Web of Conferences*, 483, 02006). EDP Sciences.

- Mahomud, M. S., Islam, M. N., Hossen, D., Wazed, M. A., Yasmin, S., & Sarker, M. S. H. (2024). Innovative probiotic yogurt: Leveraging green banana peel for enhanced quality, functionality, and sensory attributes. *Heliyon*, 10(19).
- Manzoor, S., Rakha, A., Rasheed, H., Munir, S., Abdi, G., Bhat, Z. F., & Aadil, R. M. (2024). Development and evaluation of anxiolytic potential of bagels incorporated with banana peel flour and lavender. *Journal of Agriculture and Food Research*, 15, 101029.
- Munir, H., Alam, H., Nadeem, M. T., Almalki, R. S., Arshad, M. S., & Suleria, H. A. R. (2024). Green banana resistant starch: A promising potential as functional ingredient against certain maladies. *Food Sci Nutr*, 12, 3787–3805.
- Ogo, O., Amos, F., Ijeoma, P., & El-Khalid, A. (2024). Post-harvest Treatment of Banana with Artificial Ripening Agent Influences Its Nutritional Quality and Antioxidant Potential. *European Journal of Nutrition & Food Safety*, 16(5), 1-10.
- Owuno, F., & Wabali, V. (2024). Effect of banana peel addition on the chemical, functional and organoleptic properties of cookies. *RJFSQC*, 10(2). www.iiardjournals.org.
- Pasha, I., Basit, A., Ahsin, M., & Ahmad, F. (2022). Probing nutritional and functional properties of salted noodles supplemented with ripen Banana peel powder. *Food Production, Processing and Nutrition*, 4(1), 22.
- Paramitasari, D., Pramana, Y. S., Suparman, S., Putra, O. N., Musa, M., Pudjianto, K., ... & Ulinuhayani, M. (2024). Valorization of Lampung Province banana peel cultivars: nutritional and functional characterizations for biscuit production and wheat flour substitution. *Journal of Food Measurement and Characterization*, 1-15.
- Pyar, H., & Peh, K. K. (2018). Chemical compositions of banana peels (*Musa sapientum*) fruits cultivated in Malaysia using proximate analysis. *Res. J. Chem. Environ*, 22(2), 108-111
- RCoreTeam. R: A Language and Environment for Statistical Computing; R Foundation for Statistical Computing: Vienna, Austria, 2023; Available online: <https://www.R-project.org/> (accessed on 14 March 2024).
- Ra, R., Chakraborty, A., Menon, C. K. M., & Verma, S. (2023). Banana peel: precious waste & its astounding properties. *Journal Of Advanced Applied Scientific Research*, 5(5):158-174.
- Rawat, N., Das, S., Ab Waheed Wani, K. J., & Qureshi, S. N. (2024). Antioxidant potential and bioactive compounds in banana peel: A review. *International Journal of Research in Agronomy*, 7(7), 07-16.
- Saeed, M. K., Zahra, N., Saeed, A., Quratulain, S. Y. E. D., & Abidi, S. H. I. (2024). Banana peels a contemptible source of dietary fiber and natural antioxidants. *ACTA Pharmaceutica Scientia*, 62(1).
- Sadek, N.F. (2024). Utilization of banana peel as functional ingredient in pudding: physicochemical and sensory aspects. In *IOP Conference Series: Earth and Environmental Science*, 1324(1), 012117. IOP Publishing.
- Sahoo, A. and Lenka, C. (2024). A Comparative Study on Proximate Composition of Odisha's Local Bantal Variety Banana Peel (*Musa Paradisiaca*) Flour with Cereals Flour for Their Value Addition. *Asian Food Science Journal* 23(10), 17-27. <https://doi.org/10.9734/afsj/2024/v23i10745>.
- Segura-Badilla, O., Kammar-García, A., Mosso-Vázquez, J., Sánchez, R. A. S., Ochoa-Velasco, C., Hernández-Carranza, P., & Navarro-Cruz, A. R. (2022). Potential use of banana peel (*Musa cavendish*) as ingredient for pasta and bakery products. *Heliyon*, 8(10), e11044.
- Taha, Soad H., Fouad M.F. Elshaghabee, and Mostafa Ahmed M. A. (2024). Nutritional Value, Antioxidant and Anticancer Activities of Some Nano Fruit Wastes. *Egyptian Journal of Chemistry* 67(8), 187-201.
- Tan, C. Y., Arifin, N. N. M., & Sabran, M. R. (2024). Banana Peels as Potential Prebiotic and Functional Ingredient. *Jurnal Gizi dan Pangan*, 19(Supp. 1), 119-126.
- Tsado, A. N., Okoli, N. R., Jiya, A. G., Gana, D., Saidu, B., Zubairu, R., & Salihu, I. Z. (2021). Proximate, minerals, and amino acid compositions of banana and plantain peels. *BIOMED natural and applied science*, 1(01), 032-042.
- Türker, B., & Savlak, N. (2022). Gluten-free cake with unripe banana peel flour substitution: impact on nutritional, functional and sensorial properties. *Nutrition & Food Science*, 52(6), 980-995.
- Velciov, A. B., Danci, M., Cozma, A., Lalescu, V. D., Rădulescu, L., Popescu, G. S., & Rada, M. (2024). Evaluation Of Some Nutritional Compounds of Garlic (*Allium Sativum* L.) Peel Waste. *Scientific Papers. Series B, Horticulture*, LXVIII(2). Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653.
- Zaini, H. M., Roslan, J., Saallah, S., Munsu, E., Sulaiman, N. S., & Pindi, W. (2022). Banana peels as a bioactive ingredient and its potential application in the food industry. *Journal of Functional Foods*, 92, 105054.
- Youssef, E., Shaltout, O., & Abouel -Yazeed, A. (2024). Chemical and Nutritional Evaluation of Banana Peels and Their Potential Use in Improving the Egyptian Balady Bread. *Journal of the Advances in Agricultural Researches*, 29(1), 107-115.
- Yang, Y.Y., Ma, S., Wang, X.X. & Zheng, X.L. (2017). Modification and application of dietary fiber in foods. *Journal of Chemistry*, 2017.
- Wani, K. M., & Dhanya, M. (2025). Unlocking the potential of banana peel bioactives: extraction methods, benefits, and industrial applications. *Discover Food*, 5(1), 1-25.