APPLIED BIO-SYSTEMS TECHNOLOGY

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Development of a Banana Peel Powder Incorporated Ice Cream and Ice Cone Product

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Abstract

Background: Banana peel powder remains as one of the most nutritive waste products that can be utilized as a functional additive. Therefore, the current study aimed to develop a banana peel powder incorporated ice cream and ice cone product with a unique flavour profile, while enhancing the nutritional content.

Methods: Ice cream and ice cone were formulated by incorporating varying levels of banana peel powder. The samples that showed the best sensory attributes were selected. The Kruskal–Wallis test, was used to analyse the significance of differences among the sensory attributes. Proximate analysis was conducted for the best performing ice cream and ice cone products. The microbiological analysis including total plate count and yeast and mould count was performed at 24, 48, 72 hours for ice cream by comparing it against a commercial ice cream product.

Results: The ice cream produced with 15 gL^{-1} of banana peel powder (Treatment 2) and ice cone produced with 67 gkg^{-1} banana peel powder (Treatment 3) showed the highest mean scores for overall acceptability. The proximate composition of the best ice cone product reported 8.3±4.2% (w/w) of crude fibre, while the ice cream (Treatment 2) accounted for a fibre content of 0.65±0.01% (w/w). The ice cream developed in this study (Treatment 2) showed a better microbial safety as revealed by the lower total plate count and yeast and mould counts.

Conclusions: The banana peel powder-incorporated ice cream (T2) and ice cone (T3) developed in this study show greater fibre content, microbial safety, and shelf life than commercial products. Thus, the products developed in this study may serve as better alternatives for ice cream and ice cone available in the market.

Keywords: Banana Peel Powder, Ice Cream, Ice Cone, Proximate Analysis, Sensory Attributes

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INTRODUCTION

Food is one of the basic necessities of life. It is the main nutrient source that supplies essential nutrients for our growth, development, and maintenance of healthy life. Limited availability and accessibility to nutritious food have led to elevated risks of noncommunicable diseases among the population [1, 2]. With this growing interest on the avoidance of noncommunicable diseases and ensuring health and wellness, consumers are focusing more on vitamins, minerals, bioactive substances, and fibre in food items, in addition to taste. Therefore, the customer demand for functional food has increased rapidly around the world recently. Functional foods are developed by removing, or adding one or more functional components or modifying the bioavailability of the components of a food. These are enriched with various physiologically active compounds capable of providing various health benefits beyond the conventional nutritional properties to achieve a balanced diet for optimal wellness [3, 4]. Currently, the global consumer demand for functional foods is increasing by 7-10% per year [5].

The utilization of agricultural by-products for food production has gained an increasing attention across the world [4]. Numerous studies have warranted the ability of incorporating agricultural by-products to elevate the nutritional value and sustainability of food [2, 5]. Indirectly, this approach is capable of contributing to the ensuring of food security. Therefore, utilization of food waste in the formulation of functional foods has become a novel trend. This can further reduce waste, save resources, and establish a more efficient food system by converting these leftovers into useful resources [6].

Banana (*Musa balbisiana*) is one of the most widely consumed tropical and subtropical crops, which remains as a significant fruit at the global level [7]. The overall consumption of banana has shown a notably increasing trend within the last two decades, where the global banana production has reached up to around 117 million tonnes in 2019 [8]. Banana peel is a significant waste created during the processing of fresh bananas. After the fruit has been peeled, these peels are usually thrown away as waste. The weight of a banana peel is around 30 to 40 g/100 g of the total weight, accounting for around 40% of the fresh weight, and is regarded as an industrial/agricultural by-product [7]. At present, many developing countries including Sri Lanka are generating notable amounts of banana peels as waste products [9].

Banana peel is rich in dietary fibre, minerals, and bioactive substances, all having positive effects on human health. Dietary fibre is an essential component of the human diet. The inadequate intake of fibre could lead into numerous health issues such as constipation, haemorrhoids, diverticulitis, overweight and obesity, heart diseases, diabetes, and bowel cancer [7]. Banana peels are having around 12% (w/w) of fibre content (dry weight basis), which will indeed be an excellent ingredient in the development of such high-fibre functional foods [8, 10]. Minerals are micronutrients, essential for human health due to their significance in cellular and physiological functions, including strengthening teeth and bones, growth, maintenance and repair of all tissue cells in the human body, enzyme secretion, regulating nerve functions, and optimizing the immune system [11, 12]. Banana peel contains notable amounts of minerals such as potassium, calcium, sodium, iron, manganese, and zinc.

Apart from fibre and minerals, banana peel is rich in bioactive agents including phenolic compounds (flavanols, hydroxycinnamic acids, catecholamine) that induce health benefits such as cardiovascular disease prevention, cancer prevention, diabetes prevention, and obesity prevention. Further, carotenoids such as lycopene, alpha-carotene, and beta-carotene are present in banana peels that prevent liver problems (hepatocellular carcinoma, cirrhosis, chronic hepatitis, hepatic steatosis, and acute hepatitis), aging-related disorders, susceptibility to atherosclerosis, cataracts, cancer, and oxidative damage to cells [8-9, 11]. Therefore, banana peel has been identified as an ideal functional ingredient readily available in many tropical and sub-tropical countries [13-14].

Conversion of banana peel into powder is one of the widely used approaches to formulate an easily usable ingredient from this valuable byproduct. The banana peel powder can be easily incorporated into food products at standardized compositions to derive various functional foods at the household and industrial levels [8-10]. With this background, numerous studies have attempted to develop a variety of banana peel powder incorporated functional foods ranging from biscuits, cookies, chapatti, chicken sausage, ground chicken and fish patties, Egyptian flatbreads, pasta and noodles, etc. [8-16]. Banana peel powder has the potential to be added as an ingredient in ice cream and ice cone recipes, since it would give the classic frozen sweet touch. Ice cream can be incorporated with banana flavour, while elevating the nutritional value. Therefore, the current study aimed to develop a novel ice cream product along with an ice cone incorporated with banana peel powder, as a functional food.

METHODOLOGY

Materials

Fresh cow milk and butter of acceptable organoleptic and microbial quality were purchased from a reputed local supplier (Kothmale Holdings PLC, Sri Lanka). Sugar (Orient Impex (Pvt) Ltd.), milk powder (Palwatte Dairy Industries Ltd.), corn flour (Motha Confectionary Works (Pvt) Ltd.), gelatine (Motha Confectionary Works (Pvt) Ltd.), vanilla essence (Delmage Forsyt Mills Ltd.) and eggs were purchased from reputed a local food store (COOP City, Pannala, Sri Lanka). Food grade calcium chloride and lecithin were also obtained from a reputed food ingredient store (Pettah Essence Suppliers, Colombo, Sri Lanka). Banana was obtained from an organic banana cultivation.

Preparation of Banana Peel Powder

Organically produced ripe Cavendish banana variety was selected for the banana peel powder production. The banana peels were taken and the damaged particles, the tips and the neck were removed by cutting. Then, the banana peels were cut into small pieces and washed thoroughly with salt water. Subsequently, the pieces were washed twice with lukewarm water. Then, the banana peels were boiled in hot water at 100 °C temperature for about 2 to 3 minutes. After that, the water was removed by a strainer and the peels were vacuum dried at 32 °C. Then the dried peels were ground using a grinder until they became a dusty type powder.

Preparation of Banana Peel Powder Incorporated Ice Cream

The ice cream mixture was developed with fresh milk (1 L), sugar (300 g), milk powder (10 table spoons [tbsp.]), corn flour (4 tbsp), gelatine (4 tsp), vanilla (2 tsp), and varying amounts of banana peel powder. Initially, milk powder was dissolved in water (250 ml). The corn flour was dissolved in water, while gelatine was dissolved in lukewarm water. Thereafter, the fresh milk was heated for a few minutes, and milk powder solution was added to the heated milk along with sugar. The resulting mixture was constantly stirred at low temperature to dissolve all the ingredients completely.

The dissolved gelatine and corn flour were added to that mixture. Thereafter, the resulting mixture was filtered and allowed to cool at room temperature. After cooling, the mixture was transferred into a clean bowl and beaten at high speed for 15 minutes to acquire a foamy mixture using a hand beater. Subsequently, the mixture was placed in a freezer for 2 h. This step was repeated three times and finally, banana peel powder was mixed into the mixture in different quantities to form three treatments, as shown in Table 1.

The resulting mixtures were beaten for 5 minutes, followed by freezing for a period of 12 h.

Table 1: The Banana Peel Powder Content of Different Treatments

Treatment	For Ice Cream (g/L)	For Ice Cone (g/kg)
Treatment 1	30.0	200.0
Treatment 2	15.0	133.0
Treatment 3	42.0	67.0

Preparation of Ice Cone

Three different ice cone mixtures were developed by adding rice flour (5 g), wheat flour (15 g), butter (10 ml), egg-white (20 ml), sugar powder (20 g), calcium chloride (0.15 g), and lecithin (0.25 g), along with varying quantities of banana peel powder, as shown in Table 1. Initially, rice flour, wheat flour, banana peel, and sugar powder were mixed well. Thereafter, butter, egg-white, calcium chloride and lecithin were added into it and were mixed using a hand mixer, until a mixture with a thick texture formed. Subsequently, the mixture was transferred into a clean pan and heated up until a crusted thin layer was formed, which could be rolled up into a cone.

Sensory Analysis

The developed ice cream and ice cone samples were subjected to a sensory evaluation by a semi-trained panel of thirty-five panellists (twenty undergraduates and fifteen academic and non-academic staff members), separately. The samples were graded on a five-point hedonic scale (ranging from extremely dislike to extremely like) for their appearance, flavour, texture/ consistency, aroma, colour, mouthfeel and overall acceptability [17]. Water was provided for mouth-washing each time a panellist ate a sample of formulated ice cream and ice cones [18].

Proximate Analysis

Proximate analysis was carried out on a dry basis for the best sample selected based on the sensory analyses. The moisture content was determined using an Infrared Moisture Analyzer (Kett FD-660). Crude fibre content was determined using a fibre analyser (RAYPA F-6P), adhering to the guidelines of the Weende method [19]. For the fat extraction, around 2 g of ground ice cone sample was measured and stored in an air tight container. The crude fat content was determined using a fat analyser (RAYPA SX-6) according to the Soxhlet extraction method, while the crude protein content was determined using the Kjeldhal method [20]. Further, the total carbohydrate content was determined according to a standard formula as recommended by Schakel *et al.* [21]. All analyses were performed in triplicate.

Microbiological Analysis for Ice Cream

Microbial analysis was conducted for ice cream using the Nutrient Agar media (NA) and Potato Dextrose Agar media (PDA) for bacteria, yeast and mould, respectively. Initially, nutrient agar, potato dextrose agar, peptone water, and distilled water were prepared and autoclaved at 121 °C for 20 minutes at 15 psi. Subsequently, 1 g of the sample was dissolved in 10 ml of peptone water and distilled water separately to prepare inoculation samples to inoculate for yeast and mould count and total plate count, respectively. Thereafter, a dilution series was prepared until 10^{-8} concentration. Then, 1 ml of the 10^{-1} to 10^{-8} concentration series of the sample were plated with nutrient agar and potato dextrose agar, separately. Distilled water was used as the control treatment. Prepared plates were incubated in an incubator at 37 °C and the formation of colonies were recorded at 24 h, 48 h and 72 h intervals, since incubation [22].

Shelf-Life Analysis for Ice Cone

The shelf-life analysis of ice cone was conducted according to the moisture content of the ice cone product. Moisture content was estimated using an infrared moisture analyser (Kett FD-660). About 5 g of crushed ice cone sample was used for the analysis. The result was taken from the analyser directly. The moisture content of a commercial ice cone product was compared against the banana peel powder incorporated ice cone product selected according to the sensory evaluation.

Statistical Analysis
All analyses were done in triplicate except the sensory analysis. The sensory evaluation data were analysed using the Kruskal–Wallis test at 95% confidence level. Descriptive statistics was used to present the data on physicochemical properties. All the statistical analyses were conducted using SPSS (Version 23) software.

RESULTS AND DISCUSSION

Sensory Evaluation
Based on the sensory evaluation, Treatment 3 (T3) was recognized as the best treatment for ice cone, which showed the highest mean scores for all the sensory attributes (Figure 1). Based on the statistics of the Kruskal–Wallis test, all the sensory attributes of ice cone denoted significant differences at 95% confidence level ($P<0.05$). The banana peel powder (67 g/kg) incorporated ice cone (Treatment 3) showed the highest mean overall acceptability of 4.2±0.4. Meanwhile, only appearance and overall acceptability attributes of the ice cream exhibited significant differences, among the treatments ($P<0.05$). In the case of the Ice cream, the T2 combination was identified as the best treatment (Figure 2).

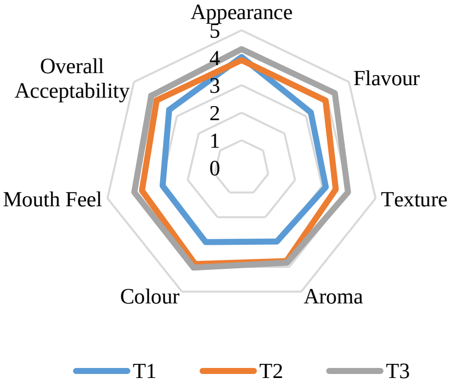

Figure 1: Mean Scores for Sensory Attributes of the Ice Cone
Note: *T1: Ice cone produced under Treatment 1; T2: Ice cone produced under Treatment 2; T3: Ice cone produced under Treatment 3*

Proximate Analysis of Ice Cone
According to the proximate analysis of ice cone, carbohydrates accounted for 77.5 ± 0.3% (w/w), emerging as the prominent nutrient of the ice cone product (Table 2). Because of the high usage of flour and sugar for the product, the carbohydrate amount accounts for a high weight percentage of the ice cone. Carbohydrate is a source of energy and can contribute to the overall calorie content of the dessert [17].

Starches in particular play a significant role in giving the ice cone the proper texture and shape. The stability and shelf life of the ice cone can also be improved by carbohydrates. Further, the browning and visual appeal of the ice cone product are influenced by carbohydrates, since carbohydrates undergo Maillard browning processes while baking or frying, giving the finished product an attractive golden-brown colour [16]. Moreover, caramelization may have contributed to the appealing colour and flavour of ice cone [15]. Therefore, carbohydrates play a vital role in the quality of the ice cone product.

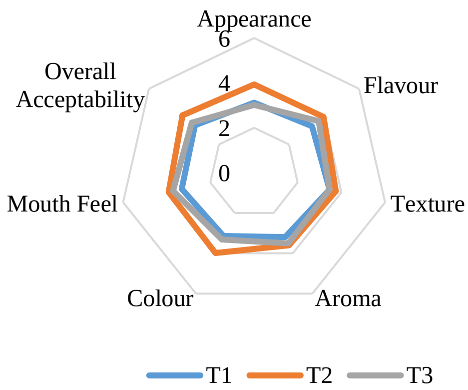

Figure 2: Mean Scores for Sensory Attributes of the Ice Cream
Note: *T1: Ice cream produced under Treatment 1; T2: Ice cream produced under Treatment 2; T3: Ice cream produced under Treatment 3*

The crude protein accounted for 9.3±0.1% (w/w), followed by crude fibre (8.3±4.2% w/w) and crude fat (7.3±0.3% w/w). The main contributors of fat and protein into ice cones are the recipe ingredients like butter and egg. The banana peel powder is the main reason for the high fibre content of the ice cone product [9]. Meanwhile, the total ash content accounted for a lower amount (1.7±0.1% w/w), compared to other food constituents of ice cone (Table 2).

Table 2: Results of Proximate Analysis of Ice Cone

Food Constituent	Available Percentage (% w/w) Mean ± Standard Error
Carbohydrate	77.5 ± 0.3
Crude Protein	9.3 ± 0.1
Crude Fibre	8.3 ± 4.2
Crude Fat	7.3 ± 0.3
Total Ash	1.7 ± 0.1

Proximate Analysis for Ice Cream
Similar to the case of ice cone, the major food constituent of ice cream was carbohydrates, which accounted for 92.0±0.4% (w/w). In addition, the ice cream contained a notable level of protein (5.5±0.01% w/w), followed by crude fat (1.1±0.03% w/w). Previous studies have evidenced that banana peel powder is a good source of amino acids, and thus will contribute to good health [23]. The fibre content was 0.7±0.01% (w/w), and thus it may be beneficial for the gut health too (Table 3).

Table 3: Results of Proximate Analysis of Ice Cream

Food Constituent	Available Percentage (% w/w) Mean ± Standard Error
Carbohydrate	92.0 ± 0.4
Crude Protein	5.5 ± 0.01
Crude Fibre	0.7 ± 0.01
Crude Fat	1.1 ± 0.03
Total Ash	0.7 ± 0.002

Microbial Analysis of Ice Cream
The microbial analysis of the best ice cream product developed in this study (Treatment 2) was conducted and compared against a commercial ice cream product. The total plate count and yeast and mould count obtained for the ice cream produced (Treatment 2) were lower than those obtained for the commercial ice cream product (Figure 3). Therefore, the ice cream produced under Treatment 2 is highly microbially safe to consume.

Previous studies have highlighted antibacterial properties of banana peel powder, especially against various gram-positive and gram-negative bacteria, such as *Bacillus subtilis*, *Staphylococcus aureus* and *Pseudomonas aeruginosa* [24]. The presence of active ingredients such as ß-sitosterol, malic acid, succinic acid, palmitic acid, 12-hydroxystrearic acid, glycoside, d-malic and 12-hydroxystrearic acid in banana peel has been recognized as the reason for this antibacterial characteristic [25].

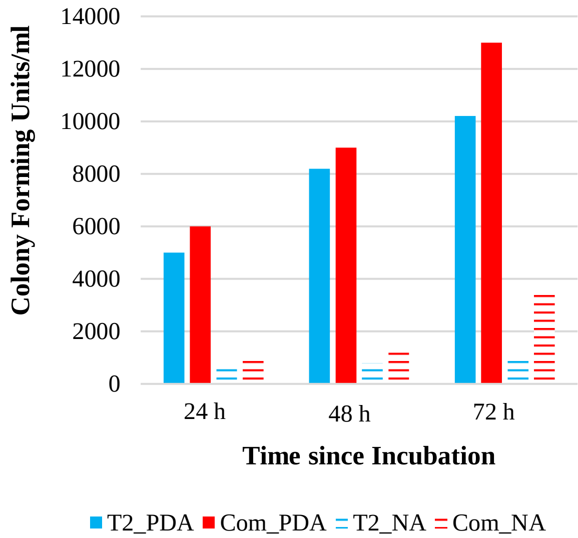

Figure 3: Results of Microbial Analysis of Ice Cream
Note: *Com_PDA: Commercial Ice Cream in PDA, Com_NA: Commercial Ice Cream in NA; T2_PDA: Ice Cream (Treatment 2) in PDA, T2_NA: Ice Cream (Treatment 2) in NA*

Shelf-Life Analysis of Ice Cone
Based on the moisture analysis, the ice cone produced (Treatment 3) showed lower moisture levels even after 6 days (8.9±0.9%), compared to the commercial product, which reported a moisture content of 11.4±1.7% at

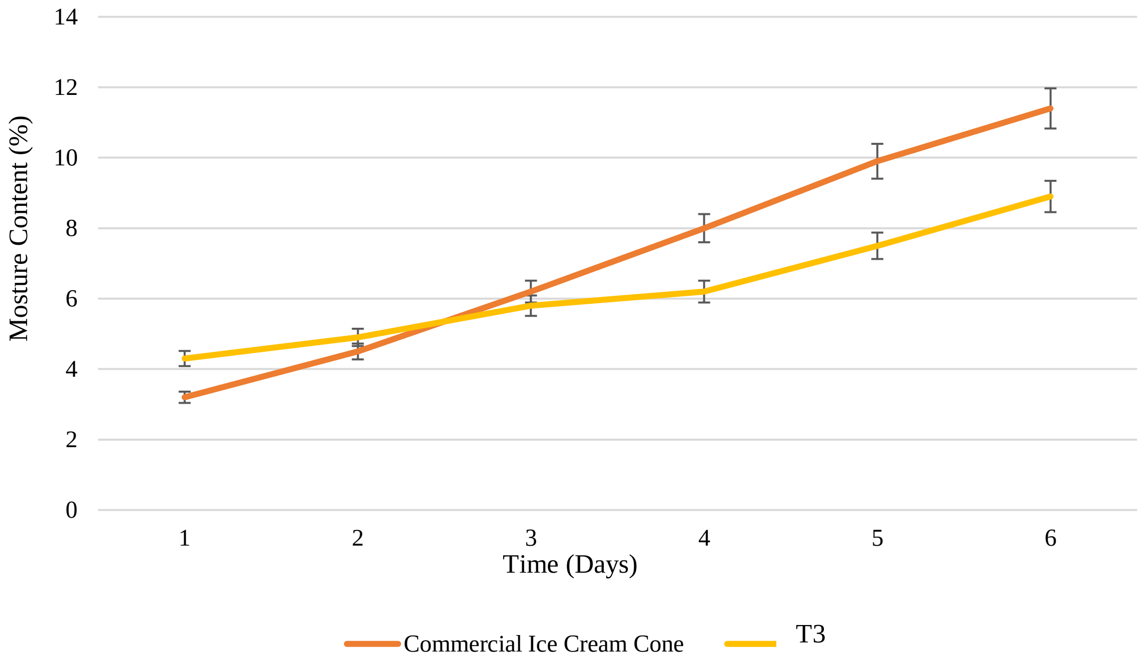

Figure 4: Moisture Analysis of Ice Cone
Note: *T3: Ice cone produced under Treatment 3*

the end of 6 days (Figure 4). Therefore, findings of this study suggest that the ice cone produced (Treatment 3) has a satisfactory shelf life compared to commercial products.

CONCLUSIONS

The findings of this study emphasize that the incorporation of banana peel powder can elevate the taste and overall acceptability of ice cone and ice cream, which are valuable sources of essential nutrients. Based on the sensory evaluation, ice cone (Treatment 3) and ice cream (Treatment 2) scored the highest mean values for overall acceptability. Hence, ice cream prepared by incorporating 15 g/L banana peel powder and ice cone prepared by incorporating 67 g/kg may show higher consumer acceptance. The greater microbial safety of the chosen ice cream and the lower moisture content of the chosen ice cone than the commercial products indicate that the best products according to this study may show greater or comparable shelf-life than the commercial ones. Further studies are recommended to improve the overall quality of these products.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTIONS

HE: Wrote the manuscript and conducted the experiments. IJ, PJ and MW: Conducted the experiments. LU: Conceptualized the study, supervised and wrote the manuscript. GP: Conceptualized the study and reviewed the manuscript. All authors read and approved the manuscript.

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REFERENCES

1 Wagner KH, Brath H. A global view on the development of non-communicable

diseases. Preventive Medicine. 2012 May;54:S38–41.
2 Lallukka T, Laaksonen M, Rahkonen O, Roos E, Lahelma E. Multiple socio-economic circumstances and healthy food habits. European Journal of Clinical Nutrition. 2006 Dec 20;61(6):701–710.
3 Milner JA. Functional foods: the US perspective. The American Journal of Clinical Nutrition. 2000 Jun 1;71(6):1654S-9S.
4 Alongi M, Anese M. 2021. Re-thinking functional food development through a holistic approach. Journal of Functional Foods 81:104466.
5 Doyon M, Labrecque J. Functional foods: A conceptual definition. British Food Journal. 2008 Oct 24;110(11):1133-1149.
6 Helkar PB, Sahoo AK, Patil NJ. Review: Food industry by products used as a functional food ingredients. International Journal of Waste Resources. 2016;6(3):1-6.
7 Khatun M, Ahmed MW, Hossain MM, Karmoker P, Iqbal A. Utilization of banana peel flour in biscuit making as wheat flour substitute. European Journal of Agriculture and Food Sciences. 2021 Nov 26;3(6):32-35.
8 Zaini HB, Sintang MD, Pindi W. The roles of banana peel powders to alter technological functionality, sensory and nutritional quality of chicken sausage. Food Science & Nutrition. 2020 Oct;8(10):5497-5507.
9 Gomes S, Vieira B, Barbosa C, Pinheiro R. Evaluation of mature banana peel flour on physical, chemical, and texture properties of a gluten-free Rissol. Journal of Food Processing and preservation. 2022 Aug;46(8):e14441.
10 Ansari NA, Ramly NZ, Huda-Faujan N, Arifin N. Nutritional Content and Bioactive Compounds of Banana Peel and Its Potential Utilization: A Review. Malaysian Journal of Science, Health & Technology (MJoSHT). 2023.
11 Ali AA. Overview of the vital roles of macro minerals in the human body. Journal of Trace Elements and Minerals. 2023 Jun 2:100076.
12 Weyh C, Krüger K, Peeling P, Castell L. The role of minerals in the optimal functioning of the immune system. Nutrients. 2022 Feb 2;14(3):644.
13 Zaini HM, Roslan J, Saallah S, Munsu E, Sulaiman NS, Pindi W. Banana peels as a bioactive ingredient and its potential application in the food industry. Journal of Functional Foods. 2022 May 1;92:105054.
14 Segura-Badilla O, Kammar-García A, Mosso-Vázquez J, Sánchez RÁ, Ochoa-Velasco C, Hernández-Carranza P, Navarro-Cruz AR. Potential use of banana peel (*Musa cavendish*) as ingredient for pasta and bakery products. Heliyon. 2022 Oct 1;8(10).
15 Zaini BMH, Sintang BMD, Dan YN, Wahab AN, Hamid BAM, Pindi W. Effect of addition of banana peel powder (*Musa balbisiana*) on physicochemical and sensory properties of fish patty. British Food Journal. 2019 Aug 1;121(9):2179-2189.
16 Kurhade A, Patil S, Sonawane SK, Waghmare JS, Arya SS. Effect of banana peel powder on bioactive constituents and microstructural quality of chapatti: unleavened Indian flat bread. Journal of Food Measurement and Characterization. 2016 Mar;10:32-41.
17 Carvalho VS, Conti-Silva AC. Cereal bars produced with banana peel flour: Evaluation of acceptability and sensory profile. Journal of the Science of Food and Agriculture. 2018 Jan;98(1):134-139.
18 Mahajan K, Kumar S, Bhat ZF, Singh M, Bhat HF, Bhatti MA, Bekhit AE. Aloe vera and carrageenan based edible film improves storage stability of ice-cream. Applied Food Research. 2022 Jun 1;2(1):100128.
19 Lbpper W. Shorter digestion period in the estimation of crude fibre by the Weende process. Zeitschrift fur Tierernahrung und Futtermittelkunde. 1940;4:217-219.

20 Thiex N. Evaluation of analytical methods for the determination of moisture, crude protein, crude fat, and crude fibre in distillers dried grains with solubles. Journal of AOAC international. 2009 Jan 1;92(1):61-73.

21 Schakel SF, Buzzard IM, Gebhardt SE. Procedures for estimating nutrient values for food composition databases. Journal of Food Composition and Analysis. 1997 Jun 1;10(2):102-114.

22 Food and Drug Administration of USA. *BAM: Rapid Methods for Detecting Foodborne Pathogens*. Food and Drug Administration US. 2001 Jan.

23 Lee EH, Yeom HJ, Ha MS, Bae DH. Development of banana peel jelly and its antioxidant and textural properties. Food Science and Biotechnology. 2010 Apr;19:449-455.

24 Jain PJ, Bhuiyan MH, Hossain KR, Bachar SC. Antibacterial and antioxidant activities of local seeded banana fruits. African Journal of Pharmacy and Pharmacology. 2011;5(11): 1398-1403.

25 Mokbel MS and Hashinaga F. Antibacterial and antioxidant activities of banana (Musa, AAA cv. Cavendish) fruits peel. American Journal of Biochemistry and Biotechnology. 2005 Sep;1(3):125-131.