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RESEARCH

Sustainable Use of Waste Banana Peel (*Musa × sapientum* L.) Powder for Enhancement of Nutritional Properties of Dark Chocolate

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Abstract

Dark chocolate is a very popular confectionary product among children, made by combining cocoa (55%) with cocoa butter (7.5%) and sugar (42%) has high antioxidant, anti-inflammatory, and free-radical scavenging properties. Chocolates also have a high concentration of cocoa and flavanols contents which is very beneficial for human health. The nutritional value of the dark chocolate samples prepared was further enhanced by using unripe banana peel powder. The peel of banana fruit is a waste material, but it also has antioxidant, antibacterial, and antibiotic properties which encourages its use in industries like pharmaceuticals. So, after considering the nutritional value of unripe banana fruit peel, the powder of unripe banana peel was added to the dark chocolate in the concentration of 1, 3, 5, 7, and 9% to increase the nutritional value of dark chocolate. The premix powder containing iron, folic acid, and vitamin B_{12} was also added to the dark chocolate samples in the concentration of 2% in all the variants. The nutritional value of chocolate samples made by using unripe banana peel powder and premix increased significantly but the color of the product decreased significantly as the concentration of banana powder increased.

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Statement of Sustainability: According to the Sustainable Development Goal (SDG) of waste management, this research focused on the utilization of banana peels which are usually discarded as waste. The banana peels are rich in various essential nutrients that are utilized in powdered form and incorporated in dark chocolates for consumption, giving immense health benefits to consumers.

1. Introduction

Dark chocolate is one of the healthiest products; very popular among children containing a high concentration of cocoa and flavanols content. Chocolate is also rich in antioxidant, anti-inflammatory, and free-radical scavenging properties that can improve blood flow, lower blood pressure, and also can protect against cardiovascular disease (CVD) (Alexis, 2022). According to Codex Alimentarious Commission (CAC), dark chocolate must contain cocoa solids (35%), cocoa butter (18%), and fat-free cocoa solids (14%) on a dry matter basis (CODEX, 2016). About 40 percent of cocoa butter is necessarily present in all types of chocolates, which is naturally vegetable fat (Didar, 2021). Figure 1 shows the nutritional composition of dark chocolate and its daily value. Cocoa butter is extracted from cocoa beans and these beans are bitter due to the presence of flavan-3-ols and that is why the pure cocoa is bitter. It has anti-inflammatory and antithrombotic properties and helps in preventing blood clots. Chocolate can be considered the ideal functional food that can help in improving consumers' health in the form of delightful pleasure (Gianfredi et al., 2018). Different types of chocolates are available in the market like dark chocolates, white chocolates, and milk chocolates that are consumed in large quantities by everyone from children to the elderly. However, to meet the additional/specific nutrient requirements, dark chocolate can be incorporated with raw banana peel powder to attain high dietary fiber, potassium, polyphenol, and antioxidant properties. This can result in enhancing the functionality of dark chocolate (Zaini et al., 2022).

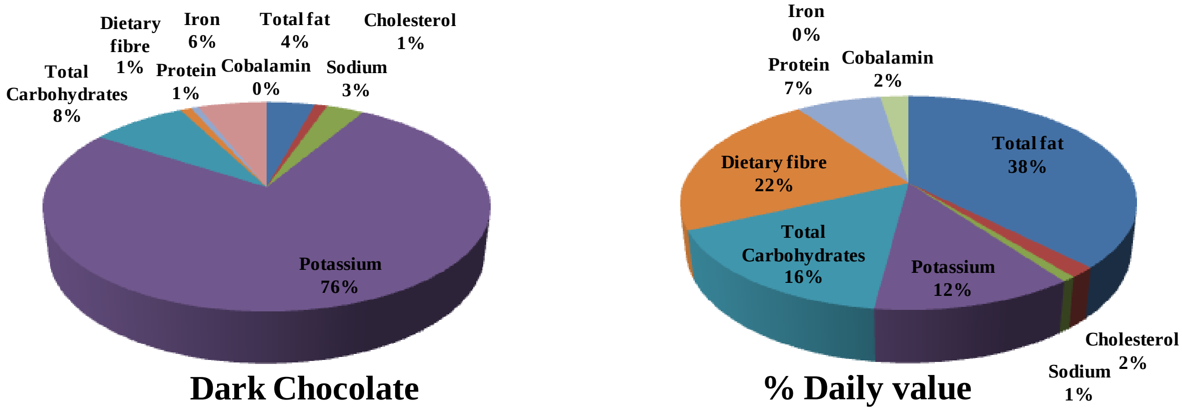

Figure 1. Nutritional composition of dark chocolate per 100 g (USDA, 2019)

The banana (*Musa* × *paradisiaca* L.) is one of the cheapest, most delicious, and most nourishing fruits belonging to the family Musaceae. Banana fruit is the second largest produced fruit after citrus, with 108 million tonnes in 2013 contributing about 16% of the world's total fruit production (FAO, 2016). The fruit has several medicinal properties and is preferred by people of all age groups. But one drawback of consuming this fruit is that approximately 40 percent of the total weight of the fruit is banana peel and approximately 40 million tonnes of banana peel were generated annually (Anhwange et al., 2009 and Montelongo et al., 2010). The peel waste of banana fruit is typically disposed of in municipal landfills without being treated and it will lead to environmental pollution. Peel also has antioxidant, antibacterial, and antibiotic properties which encourages its use in the industries like pharmaceuticals and can also be used as a nutraceutical product (Zaini et al., 2022). Banana Peel is a good source of lipids, fibers, carbohydrate, protein, and many other bioactive compounds that has different health-beneficial functions (Zaini et al., 2020) (Figure 2). However, the problem of banana peel disposal can be solved by utilizing its value-added components in the food processing industries.

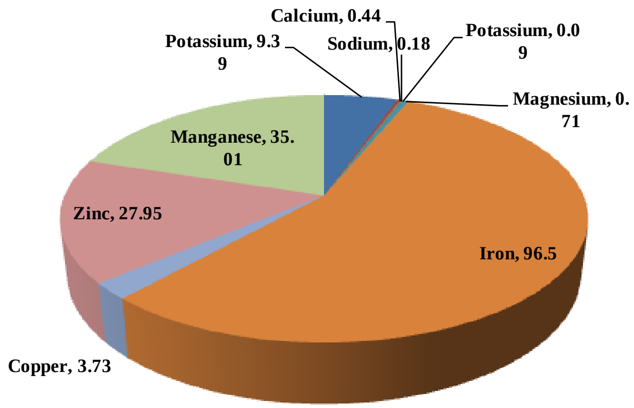

Figure 2. Micronutrient content (g/100 g) of banana peel (Enien et al., 2016)

Iron is an essential element of our diet that helps in various metabolic processes like the transport of oxygen in the blood, deoxyribonucleic acid (DNA) synthesis, and the electron transport chain. Iron is also necessary for healthy brain development and growth in growing children (ADMHFW, 2013). A deficiency of iron leads to a condition called Anaemia. Vitamin B9 also known as folic acid helps in various enzymatic reactions like amino acid synthesis, and vitamin metabolism and also played an important role in DNA replication. Folate played an important role in the growth and development of the fetus (WHO, 2012). Green leafy vegetables such as spinach, turnip, broccoli, etc, and seafood are good sources of folate. Vitamin B (cobalamin) is a water-soluble vitamin, required in cell metabolism, DNA production, red blood cell formation, and nerve function (O'Leary and Samman, 2010). This vitamin is synthesized in the gastrointestinal tract of animals by particular bacteria and subsequently absorbed by the host animal. It can be only obtained from animal-based foods. Megaloblastic is a type of anemia that is caused by a deficiency of vitamin B_{12}.

The consumption of fruits and vegetables involves the disposal of inedible parts like a banana peel, conveying challenges such as waste management and environmental pollution. They were disinfected and dried to obtain a powder that was subjected to microbiological and proximal analysis. Once its microbial safety was assured, the banana peel powder was incorporated into dark chocolates in the percentage of 1, 3, 5, 7, and 9%. The sensory evaluation of the different products was carried out and, after verifying that the products were sensory acceptable, the proximal analysis was implemented. The formulated products were suitable for the addition of BPP up to 09%, in which the Acceptability Index was higher than 80%, and significant increases in fiber and fat were achieved. We conclude that waste banana peel powder can be incorporated into dark chocolates for human consumption to provide nutrients that might contribute to reducing this type of waste and to recover nutrients from otherwise disposed banana peels.

2. Materials and Methods

2.1. Sample Preparation

2.1.1. Banana Peel Powder

Clean water was used to wash the banana peels to remove contaminating residues or excess dirt. Then the washed banana peels were disinfected using 200 ppm sodium hypochlorite (NaClO) solution for 30 min, after that peels were rinsed with clean drinking water. After cleaning and draining, banana peels were dried in a cabinet tray dryer for 24 h at 63 °C. Then the dried peels were subsequently ground in a mill (General Electric, mod. 5MB 600B-0, New Jersey, USA) using a 20 mesh to obtain a homogeneous powder.

2.1.2. Dark Chocolate Preparation

The dark chocolate samples were prepared using various ingredients like cocoa solids/liquid (55%), sugar (42%), cocoa butter (7.5%), and emulsifiers like lecithin in the concentration of 0.4% and Polyglycerol polyricinoleate (PGPR) in the concentration of 0.1%. A mineral premix consisting of Iron (14000–150 mg), Folic acid (37500–6250 mcg), and Vitamin B_{12} (375–625 mcg) was used as a source of the minerals in the final product. Unripe Banana Peel Powder (UBPP), purchased from the local market was also added to the dark chocolate in the concentration of 1, 3, 5, 7, and 9% in the final product. After adding all these necessary ingredients, they are mixed or blended in continuous or batch mixers for about 12–15 min at 40–50 °C to achieve better consistency. The chocolate mixture is then refined to obtain a smooth and desirable texture. This process aids in particle size reduction, homogeneous particle distribution in the phase, and lipid coating of each particle. Sugar, cocoa liquid, and other mixtures with an overall fat content of 8–24% are typically refined to 30 mm particle size using a combination of two- and five-roll refiners. Conching is another crucial process that contributes to the development of viscosity, final texture, and especially flavor as it consists mainly of mixing, shearing, and aeration of the chocolate mass at 55–65 °C for 6 to 24 h for dark chocolate. At last, the tempering process was done that involves raising and lowering of chocolate temperature to alter the crystal formation to achieve a glossy surface and distinctive snappy sound when broken.

2.2. Analytical Methods

The protein content of dark chocolate was estimated by the Kjeldahl method as described by (AOAC, 2005) using Protein Distillation Unit (Model No. KT200 Kjeltect™, Foss, Mumbai, India) while fat content in the samples was determined by Soxhlet extraction method using Fat extraction Unit (Model No. FOSS-ST 255 Soxtec™, Foss, Mumbai, India). Moisture content in the final product was estimated by the Oven drying method as per the standard AOAC method. While the ash % was estimated by the dry ashing method (AOAC, 2005) method. On the other hand, the determination of Iron was done using the spectrophotometry technique. The total dietary fiber in the final product was estimated by using a gravimetric instrument. The pH of dark chocolate was estimated by using Elico (India) digital pH meter. Carbohydrate and energy (kcal) content were mathematically determined based on the other proximate components. The carbohydrate content is calculated by using the given equation:

$$\text{Proximate Composition (100\%)} = A + M + C + P + F$$

Where, A: ash (%), M: moisture (%); C: carbohydrate content, F: fat content, and P: protein content, respectively.

3. Results and Discussion

3.1. Physico-chemical Properties of Unripe Banana Peel

The data in Table 1 shows the physico-chemical analysis of unripe banana peel powder used for the development of dark chocolate. According to the table the moisture content of Unripe Banana Peel Powder was calculated to be 7.43%, the ash content was estimated to be 03.90%, the protein content in powder was estimated to be 09.30 g, the fat content of the unripe banana peel powder was calculated to be 00.63 g, the carbohydrate content was calculated mathematically as 78.72 g using total proximate composition (100%), energy was calculated to be 357.75 kcal, the potassium content was estimated to be 1463 mg/100g using flame photometry, the iron content of unripe banana peel powder was calculated as 00.93 mg/100g using the spectrophotometry technique while total dietary fiber was determined to be 09.42 g/100g using the gravimetric method.

Table 1. Results of physico-chemical analysis of unripe banana peel powder.

Parameters	Value
Protein (g)	09.30±0.020
Fat (g)	00.63±0.015
Carbohydrate (g)	78.72±0.015
Moisture (%)	07.43±0.029
Ash (%)	03.90±0.010
Iron (mg/100g)	00.93±0.025
Dietary fiber (g/100g)	09.42±0.020
pH	05.46±0.010
Potassium (mg/100g)	1463.07±0.058
Energy (kcal)	357.75±0.010

Values are mean ± S.D. of three replicates.

3.2. Nutritional Information of Final Product

The nutritional composition of the dark chocolate increased as the percentage of unripe banana peel powder and B_{12} premix increased as compared to the (control) chocolate sample. The result provided in Table 2 showed that the protein content of dark chocolate increased from (07.55 to 8.23 g/100g) as compared to the control sample (05.0 g/100g). A similar result was also shown in the products like pasta and bread prepared by the addition of 5, 10, and 20% banana peel powder in the final product formulation (Segura-Badilla et al., 2022). The total fat content of the final product increased from (36.37 to 36.57%) while the control sample contain (33.0 g/100g) fat content. This could be due to the presence of fatty acids in banana peel like linoleic acid (ω-6) and linolenic acid (ω-3), which comprise almost 40% of the total amount of fatty acids (Gonzales-Condori et al., 2021). A similar pattern of increasing fat content was also noted in the bakery products prepared by the addition of unripe banana peel powder in different concentrations (Castelo-Branco et al., 2017). The moisture content decreased from (1.42 to 0.98%) in the final product while the control sample had a moisture content (of 0.146%). This could be due to the hygroscopic nature of the raw banana peel powder, which is likely to affect the decrease in moisture content of the final product. A similar trend was also reported in the biscuits prepared with the addition of 20% banana peel powder in the dough which results in the dryness of dough (Oguntoyinbo et al., 2020).

Table 2. Nutritional composition of dark chocolate incorporated with various % of Unripe Banana Peel Powder (UBPP)

Parameters	Control Sample	1% UBPP	3% UBPP	5% UBPP	7% UBPP	9% UBPP	One Way ANOVA
Protein (%)	05.00±0.82^{a}	07.55±0.18^{b}	07.69±0.25^{b}	07.86±0.32^{b}	08.06±0.42^{b}	08.23±0.62^{b}	p<0.05
Fat (%)	33.00±0.62^{a}	36.37±0.42^{b}	36.42±0.26^{b}	36.37±0.25^{b}	36.49±0.48^{b}	36.57±0.38^{b}	p<0.05
Carbohydrate (g)	46.42±0.37^{a}	48.72±0.26^{b}	52.65±0.78^{b}	57.16±0.32^{b}	63.26±0.32^{b}	70.34±0.42^{b}	p<0.05
Dietary fiber (g/100g)	07.00±0.83^{a}	03.08±0.08^{c}	04.34±0.58^{c}	5.71±0.28^{c}	7.23±0.42^{b}	08.15±0.36^{b}	p<0.05
Vitamin B_9 (mcg/100g)	60.80±0.07^{a}	72.20±0.72^{b}	74.70±0.64^{b}	75.5±0.38^{b}	77.7±0.52^{b}	80.60±0.56^{b}	p<0.05
Vitamin B_{12} (mcg/100g)	00.98±0.08^{a}	01.54±0.52^{b}	01.64±0.52^{b}	01.72±0.47^{b}	01.80±0.28^{b}	01.88±0.64^{b}	p<0.05
Iron (mg/100g)	07.00±0.04^{a}	08.68±0.68^{b}	09.35±0.23^{b}	10.22±0.57^{b}	10.90±0.67^{b}	11.39±0.38^{b}	p<0.05
Potassium (mg/100g)	203.00±0.01^{a}	217.63±0.49^{b}	246.89±0.39^{b}	276.15±0.28^{b}	305.41±0.72^{b}	334.67±0.12^{b}	p<0.05
Moisture %	01.46±0.03^{a}	01.42±0.28^{c}	01.39±0.54^{c}	01.27±0.38^{c}	01.03±0.72^{c}	00.98±0.22^{c}	p<0.05
Ash %	02.24±0.32^{a}	02.27±0.38^{a}	02.38±0.42^{b}	02.57±0.42	02.84±0.76^{b}	03.19±0.38^{b}	p<0.05
Energy (kcal)	527.23±0.28^{a}	567.49±0.42^{b}	567.87±0.67^{b}	568.69±0.26	569.52±0.52^{b}	570.17±0.18^{b}	p<0.05

The same letters (a-c) indicate no significant difference between the samples at p<0.05

According to the data presented in Table 2, the dark chocolate sample incorporated with 7% unripe banana peel powder and B_{12} premix also showed improvement in the vitamins and mineral contents of the chocolate as compared to the control sample. The iron content in the dark chocolate sample incorporated with 9% unripe banana peel powder and B_{12} premix was estimated to be 11.39 mg/100g which was higher than the control sample (07.00 mg/100g). Vitamin B_9 and B_{12} content in 9% unripe banana peel powder and premix incorporated dark chocolate was estimated to be 80.60 mcg/100g and 1.88 mcg/100g. While potassium content was estimated to be 334.67 mg/100g in the dark chocolate sample which was higher than the standard dark chocolate (203 g/100mg). Similar results were also reported in the bread, biscuits, and pasta products formulation after the addition of different concentrations of banana peel powder (Mahloko et al., 2019).

On the other hand, dietary fiber also showed an increasing trend and it increased from 07.00 (control sample) to 08.15 mg/100g (9% unripe banana peel powder and premix incorporated dark chocolate). A similar pattern of the increasing trend was also noticed in fiber contents in the biscuits, bread, and pasta prepared by the addition of banana peel powder. For pasta, the fiber content increased by 35.7% and 71.4% with 5 and 10% banana peel powder, respectively while fiber content was increased by 12.5% in bread with 20% and 10% banana peel powder, respectively (Eshak, 2016; Castelo-Branco et al., 2017; Gouda, 2018; Mahloko et al., 2019).

3.3. Sensory Evaluation of UBPP and Premix-incorporated Dark Chocolate Variants

Sensory analysis of dark chocolate variants incorporated with unripe banana peel powder (1, 3, 5, 7, and 9%) and 2.0% premix was carried out using nine points hedonic scale to evaluate different sensory attributes such as appearance, aroma, taste, texture, and flavor.

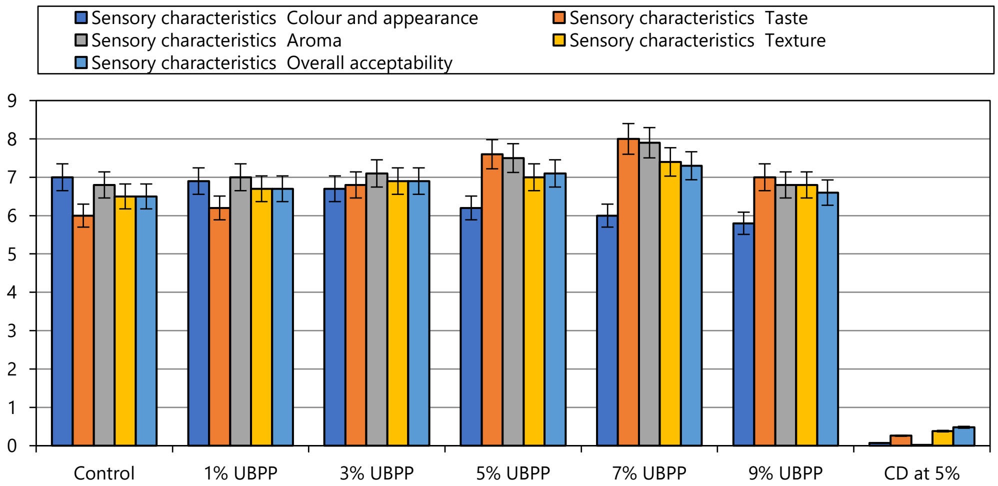

Figure 3. Sensory analysis of dark chocolate variants.

Table 3. Sensory analysis of Dark chocolate variants.

Dark Chocolate + UBPP (%)	Sensory Characteristics				
	Color and appearance	Taste	Aroma	Texture	Overall Acceptability
Control	7.0	6.0	6.8	6.5	6.5
1% UBPP	6.9	6.2	7.0	6.7	6.7
3% UBPP	6.7	6.8	7.1	6.9	6.9
5% UBPP	6.2	7.6	7.5	7.0	7.1
7% UBPP	6.0	8.0	7.9	7.4	7.3
9% UBPP	5.8	7.0	6.8	6.8	6.6
CD at 5%	0.07	0.26	0.02	0.38	0.48

UBPP: unripe banana peel powder.

According to Figure 3, the chocolate variant with 7% unripe banana peel powder had the highest overall acceptability among other variants based on sensory evaluation but the color of the control same was most preferred by the consumers. Similar results were also reported in the pasta products prepared by the addition of 5% and 10%

unripe banana peel powder. On the other hand, biscuits with 20% unripe banana peel powder had a maximum acceptability index of 62% in the odor parameter, whereas taste and color acceptability were not higher than 20%. This could be due to the dark color of the products after the addition of banana peel powder (Castelo-Branco et al., 2017).

4. Conclusion

Banana peel wastes can be transformed into biologically safe flour. Unripe banana peel powder incorporated into some foods at 5–10% levels can provide extra nutritional value without affecting its acceptability. The dark color imparted by the addition of unripe banana peel powder did not affect the acceptance of the products by panellists. Therefore, it could be possible to further increase the levels of the addition of unripe banana peel powder in products derived from cereals like biscuits, bread, and pasta. Despite this study not being focused on functional compounds, it would be interesting to quantify these compounds in products supplemented with banana peel waste since there is a growing interest in the health benefits of a wide range of bioactive ingredients.

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