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Original Article

COMPARATIVE STUDY ON NUTRIENT COMPOSITION AND FUNCTIONAL CHARACTERISTICS OF TROPICAL FRUITS WITH EMPHASIS ON BANANA FRUIT PEEL

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ABSTRACT

Objective: To determine the nutritional and anti-nutritional components of banana peel at various stages of ripening and compared it with tropical fruits (apple and mango).

Methods: Initially, nutrient values for individual fruits and its peel (Apple, Mango, and Banana) samples were analyzed. The color values (L, a, b, and c*value,) and textural characteristics (hardness, cohesiveness, springiness and adhesiveness) were used to determine the ripening stage. Protein, sugar, carbohydrate, crude fiber, crude fat, tannin, and oxalate content were all evaluated to determine their nutritional and anti-nutritional qualities.

Results: After statistical analysis, it was investigated that banana peels in the unripe stage had lower crude fat content (1.2±0.03%) and moisture content (5.97±0.12%). The amount of crude fiber in banana peel (36.16±0.09%) was found to be high when compared to mango (26.5±0.06%) and apple peel (10.7±0.06%), which greatly boosted its nutritional value. Unripe banana peel has a low K (245.1±0.07 mg/100 gm) and high Mg (566.61±0.07 mg/100 gm) ratio. This increases its potential as an anti-diabetic source. Whereas leaky ripe banana peels have the maximum potassium content (11730±0.09 mg/100 gm), followed by ripe (7288±0.06 mg/100 gm) and unripe (245.1±0.07 mg/100 gm), making them equally nutritionally important.

Conclusion: The investigation concluded that though all fruits are tropical and readily available all year around, but banana are cheaper and nutritionally rich. Banana peel has a low level of anti-nutritional factor, which makes it safe for human consumption. All stages of the banana peel are equally significant. Leaky ripe peels contain many valuable vitamins and minerals, ranging from iron (7.7±0.09 mg/100 gm) to phosphorus (36.6±0.19) to calcium (567.4±0.06 mg/100 gm) to Na (42.5±0.09 mg/100 gm) and K (11730±0.09 mg/100 gm), which can help to enrich soil fertility, and thus could be used as an organic fertilizer. Whereas, unripe banana peels could be used for many therapeutic purposes due to their high fiber, essential fat, and mineral content. Thus, they are not recommended to be thrown and used in for more socio-economic purposes.

Keywords: Banana peel, Proximate composition, Laser-induced breakdown spectroscopy (LIBS), Nutrient composition colorimeter, Ripening, Anti-nutritional factor, BSA (bovine serum albumin)

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INTRODUCTION

India is the world's greatest producer of bananas and mangoes, as well as the second-largest producer of lime. However, most fruit is wasted due to poor management. The peel is the principal byproduct of the banana processing industry, accounting for 30% of the fruit and posing an environmental threat [1]. Banana peels' high dietary fiber and phenolic content make them intriguing for a number of nutraceutical and therapeutic applications. Banana peel extract is classified as non-toxic to normal human cells according to the National Cancer Standard Institute's guidelines [2]. The objective of this study is to explore the nutritional value of banana peels, specifically *Musa paradisica* variety Bhusawal keli, at different stages of ripening. The peel is a rich source of vitamin A, B-complex vitamins, minerals such as calcium, selenium, manganese, zinc, etc… several-fold more than its pulp [3]. Anhwange (2008) studied the chemical composition of banana (*Musa sapientum*) peels, including mineral, nutritional, and antinutritional content, and found that banana peels are rich sources of potassium and contain much more soluble and insoluble fiber than banana flesh [4]. He claims that if the peel is treated properly, it can be a high-quality, low-cost source of carbs and minerals for animals. High ash content, showing characteristics analogous to other staples, is measured as a good source of minerals [5]. The high value of organic content (lipids, proteins, and carbohydrates) indicates that banana peels are a good source of carbohydrates and fiber. High fiber content also indicates that the peels could help to improve general health and well-being. So could be used for medicinal purposes. Bananas have good nutritional and therapeutic value, so it may be possible to produce functional food from them. Short shelf life and increased production necessitate the development of non-conventional products from bananas. Therefore, the present investigation is undertaken to evaluate the effect of ripening stages on the nutritional properties of tropical fruits like apple, banana, and mango peel, where the principal objective is to emphasize the nutritional properties of banana peel. Because bananas are available throughout the year and compared to other fruits, they are much cheaper. But it is highly perishable. Rapid ripening, poor handling, inadequate storage, and transportation activities cause the loss of more than 30% of bananas [1]. Several physicochemical parameters like starch, reducing sugar, non-reducing sugar, total sugar, protein, crude fiber are present in the pulp and peel of banana.

After biological treatment, these nutrients are converted into useful products as value-added products, or as raw materials for other industries, or for use as food or feed [6]. However, no banana peel-based product has yet to be developed. The aim of this investigation was to compare the physicochemical characteristics of banana peel at different stages of ripening.

Key words: Banana peel, Proximate composition, Laser-induced breakdown spectroscopy (LIBS), Nutrient composition colorimeter, ripening, anti-nutritional factor, BSA (bovine serum albumin), anti-nutritional factor

MATERIALS AND METHODS

Chemicals and glassware

All the chemicals required for the experiment were purchased from Hi-Media. Folin Ciocalteu, Petroleum ether, Anthrone reagent,

sodium hydroxide, sodium carbonate, Na-K tartrates, copper sulfate, sulfuric acid, BSA (Bovine albumin serum) were purchased from Science Corporation, Allahabad. All other reagents and chemicals of analytical grade were procured from local sources, and milli-Q quality water was used.

Fruits sample collection

Banana, apple, and mango were collected from the local market in Uttar Pradesh at different stages of ripening without any ethylene and stored at-20 °C for 24hours, before being used and identified in the Botany Department, Allahabad University. Harvesting and determination of maturity were carried out by determining the color and textural parameters and by combining the following techniques: day count, chromacity, firmness, pH, and flavor of fruits determined by Sundaram *et al.* (2010) [7].

Monitoring of different ripening stages of banana peel

Determination of color

The visual colors of banana peel at different stages of ripening were measured using X-rite colorimeter and expressed in terms of the L' a' b" system. The Colorimeter was calibrated using a white reference standard tile, as described by Rangana, (2005) [8]. Color function C (Chroma) was calculated using the formula by Fugita *et al.* (2004) [9].

$$\text{Chroma} = \sqrt{(a^2 + b^2)}$$

The average of the 4 measurements of each color parameter (L', a', b") was reported in the results. In this coordinate system, the lightness and hue are determined by the L' a' b" values of the CIE model. Where L' value is a measure of brightness, ranging from 0 (black) to 100 (white), a' value ranges from-60 (green) to+60 (red), and the b" value ranges from-60 (blue) to+60 (yellow).

Assessment of rheological properties of banana

Penetrometry experiments were carried out using a textural properties analyzer, TAXT2i, Stable Micro-System, UK (XT-RAD, Rheo), connected to a data acquisition system, fitted with a 49.03 kg trigger force with a needle probe moving at a rate of 2 mm/s. Puncture strength at different stages was measured with a texture analyzer [11]. Samples were placed on a heavy-duty platform and a needle probe with a 2 mm/s test speed was allowed to penetrate up to a distance of 20 mm around the equatorial area. The peak force was measured around the equatorial region of the banana at different ripening stages and the average of the three values was reported. A 25 kg load cell was placed over the probe. The maximum in the curve of force (F) versus displacement is called Fp. The value of Fp was systematically recorded in order to assess how hard the penetration depth was set at 50% of the diameter of the fruit with peel. The work applied at perforation, S, is defined as the product of the force applied F (in N) by the displacement d (in mm), and was recorded as a function of time. Three S-measurements were taken at the center of the banana peel. Three bananas were analyzed and the mean values of the three measurements were reported. The average value of the three measurements of Fp was reported according to Kotwaliwale *et al.* (2007) [12].

Chemical analysis of different fruits

Dried peel samples of banana, mango, and apple were analyzed for moisture content, fat, crude fiber, protein, carbohydrates, total ash, and mineral content.

Determination of nutritional property of fruit peels

Estimation of protein

Prepared 10 tubes containing an increasing amount of BSA (1 mg/ml) (0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000µg) in a total volume of 1 ml. 5 ml of reagent A (alkaline solution) was added to each test tube containing protein solution, vortexed, and allowed to stand at room temperature for 10 min. 0.5 ml of Folin's phenol reagent was added and vortexed the tube for 60 min at room temperature. The absorbance was taken at 660 nm or 750 nm and p was the value A660 vs. concentration of BSA (µg). The same procedures were followed with the unknown solution, and its concentration was determined with the help of the graph. Protein was estimated by the method given by Lowry's, *et al.* (1951). A protein reacts with Folins-Ciocalteu reagent to give a colored complex. The color so formed is due to the reaction of the alkaline copper sulfate with protein and the reduction of phosphor-molybdenate by tyrosine and tryptophan present in the reaction. The intensity of the color depends on the amount of this aromatic amino acid present [13].

$$\text{Protein} = \frac{\text{O. D of unknown solution}}{\text{O. D of known solution}} \text{ X Concentration of known solution}$$

Estimation of carbohydrate

The anthrone reaction is a rapid and convenient method for the determination of hexoses, aldopentoses, and hexuronic acid present in polysaccharides. Pipette out into a series of test tubes, increasing volumes of sugar solution from 0.0 ml-1.0 ml, and make up the volume to 1.0 ml with distilled water. To each tube, add 5 ml of cold anthrone reagent and vortex rapidly. Cover the tube with aluminium foil and keep it in a boiling water bath for 10 min, then cool it to room temperature in a tray containing tap water. Read the absorbance at 625 nm using a blank [14].

Calculation: The concentration of the carbohydrate sample was calculated after weighing the fat residue, using the following expression:

$$\text{Carbohydrate} = \frac{\text{O. D of unknown solution}}{\text{O. D of known solution}} \text{ X Concentration of known solution}$$

Estimation of moisture

Moisture was estimated by the oven drying method. Weighed samples (approximately 2 g) on pre-weighed petriplates (W1) were dried in an oven at 60° C for 5 h. The samples were cooled in airtight desiccators to prevent moisture loss or gain from the environment. Drying was considered complete when readings of two consecutive weighings recorded at an interval of an hour did not vary by more than 5 mg. Moisture content was calculated by subtracting the dried weight from the sample weight and was expressed as a percentage [15].

Calculation: The % moisture of sample was calculated after weighing the sample after drying, using the following expression:

$$\% \text{ Moisture} = \frac{\text{Loss in weight}}{\text{Weight of sample}} \text{ X } 100$$

Determination of crude fat content

The crude fat content of banana peel was determined using the Soxhlet extraction method. 2 g of the sample was taken in a thimble and plugged with cotton. Fat was extracted from the sample with petroleum ether (B. P. 40-60 °C) in a Soxhlet apparatus for 4 h. The residual petroleum ether was evaporated from the extracted fat in a hot air oven [15].

Calculation: The percent fat in the sample was calculated after weighing the fat residue, using the following expression:

$$\% \text{ Crude Fat} = \frac{\text{Weight of fat residue}}{\text{Weight of sample}} \text{ X } 100$$

Determination of crude fiber content

Two grammes of defatted sample were boiled for exactly 30 min in 1.25% sulfuric acid before being washed with hot distilled water [15]. The residue was then boiled in a 1.25 per cent sodium hydroxide solution for exactly 30 min and washed with hot distilled water. The capsule with the residue was dried in an oven at 105 °C for 3-4 h till a constant weight was obtained.

Calculation: The difference in weight of filter paper with residue minus filter paper was reported as the crude fibre content of the sample and it was expressed as per cent crude fiber using the following formula:

$$\% \text{ Crude fibre} = \frac{(\text{Wt. of residue} + \text{Wt. of capsule}) - (\text{Wt. of sample})}{\text{Weight of sample}} \text{ X } 100$$

Estimation of total ash

A high-temperature muffle furnace capable of maintaining a constant temperature of 500 to 600 °C was used for dry ashing procedures. Two gram of a sample taken in a silica crucible were ignited on a heater and later shifted to a muffle furnace until clean ash was obtained. The temperature of the furnace was raised to 550° C±15° C [15]. The weight of residue was noted and the percent ash was calculated as below:

Calculation: The % Ash of sample was calculated after weighing the sample after drying, using the following expression:

$$\% \text{ Ash} = \frac{\text{Weight of residue}}{\text{Weight of sample}} \text{ X } 100$$

Measurement of minerals in banana peel using AAS

AAS (atomic absorption spectroscopy) is an analytical method based on the absorption of UV-Visible radiation by free atoms in the gaseous state. Samples were weighed (1 g) and sulphuric acid (2 ml) was added to it. This was evaporated to dryness and then ashing was done. After this, further concentrated nitric acid was added and heated until the ash became white. It was then cooled at room temperature and transferred to a 25 ml volumetric flask, washed with nitric acid and filled up with distilled water. Suitable dilutions were subsequently made. Concentrations of calcium (Ca), magnesium (Mg), zinc (Zn), iron (Fe), manganese (Mn), sodium (Na) and potassium were analyzed by flame atomic absorption spectroscopy (AAS). With slight modification, the concentration of phosphorus (P) was detected by the spectrophotometric method of Ranganna, (2000) [16]. Five milliliters of each sample were added into a beaker, followed by 5 ml of ammonium molybdate and 2 ml of aminonaphthol solution. The mixture was mixed thoroughly and allowed to stand for 30 min for full color development. After calibrating with different concentrations of phosphate standard solutions, the absorbance of the sample was measured [15].

Laser-induced breakdown spectroscopy for mineral content

LIBS is a type of atomic emission spectroscopy that uses a highly energetic laser pulse as the excitation source. It consists of a Q-switched Nd: YAG (neodymium-doped yttrium aluminium garnet) laser (continuum lasers, Surelite III-10) that delivers maximum energy of up to 425 mJ at 532 nm (2nd harmonics of Nd: YAG emission), within a 3-4 ns pulse duration, at a 10 shot per second repetition rate, for the ablation of sample material and the generation of LIBS plasma. The plant samples were mounted on the sample holder, which was controlled by a motorized linear stage. By continuing to move the sample, a nearly fresh surface was provided for each shot in the experiment [17]. This improves the reproducibility of mass ablation by avoiding the formation of deep craters by successive ablation. It is very important for plant samples to acquire integrity spectra. The lines are from different metal elements such as Ca, Na, Mg, Fe, Al, Mn, etc. and nonmetal elements such as C, O, and Si were recorded. The LIBS2000+spectrometer allowed the acquisition of laser-induced breakdown (LIB) spectra ranging from 200 to 1100 nm.

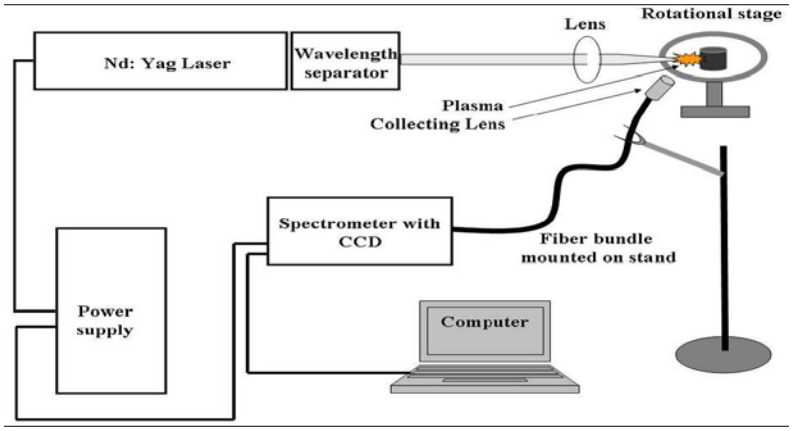


Fig. 1: Experimental setup of Laser-induced breakdown spectroscopy (LIBS) determination of mineral content and nutritional property of fruit peels

Determination of tannin content

The amount of total tannin content was determined according to the Folin–Denis method [18] with a slight modification. Banana peel powder (2 g) was transferred into a 250 ml conical flask and boiled gently for 30 min after adding water, then centrifuged at 2000 rpm for 20 min. The supernatant was collected in a 100 ml volumetric flask to make up the volume and shaken well, incubated for 30 min, and the absorbance was read at 700 nm. A standard graph was prepared by using 20-100 mg of tannic acid.

Determination of oxalate content

Each sample's oxylate concentration was determined using the sigma (Urinalysis Diagnostics Kit; Procedure Number 591, SIGMA) protocol: Oxalate reagents were warmed at 37 °C and the tubes were labeled with blank, control, standard, and sample. 1 ml oxalate reagent A (DMA-3 dimethylaniline+MBTH-3 methyl-2-benzothiazolinone hydrazone), pH 3.1 was added to each tube, 0.5 ml banana peel sample were added to each tube, 0.5 ml of milli Q water (Distilled water) were added to blank and control tube, 0.5 ml of oxalate standard were added to the standard tube and 0.1 ml oxalate reagent B (Oxalate oxidase and peroxidase) was added to all tube, inverse all the tube immediately and incubate it for 37 °C for 5 min. The absorbance was taken at 590 nm by a spectrophotometer. Calculations to determine oxalate concentrations in milligrams and percentage dry mass was determined [19].

Data record and statistical analysis

The statistical significance of the data was determined by a two-way analysis of variance. Differences between the means were analysed by using Duncan's multiple range tests ($p<0.05$).

RESULTS

Fig. 2 depicts the proximate content of various fruits (apple, banana, and mango) as a representation of the nutritional components of their pulp extracts. Apple pulp had a moisture content of 79.04+0.04 percent; mango pulp had a moisture content of 76.24+0.07 percent, and banana pulp had a moisture content of 77.49+0.07 percent. The highest ash concentration was found in mango pulp (1.60+0.07 gm/100g) and apple pulp (1.44+0.05 gm/100 gm), while the lowest was observed in banana pulp (1.2±0.06 gm/1oogm). The fat content in apple pulp ranged from 0.3±0.06 gm/100 gm to 0.45±0.08 gm/100 gm in mango pulp, while the fat level in banana pulp was assessed to be 0.9±0.08 gm/100 gm. In apple and banana pulp, crude fiber content was 1.4±0.03 gm/100 gm and 1.6±0.05 gm/100

gm, respectively, while it was 2.8±0.05 gm/100 gm in mango pulp. Apple pulp had a crude protein concentration of 0.3±0.05 gm/100 gm. Mango pulp had a crude protein content of 0.5±0.03 gm/100 gm, and banana pulp had a crude protein content of 1.1±0.05 gm/100 gm. The total carbohydrate content of mango pulp ranged from 7.8±0.06 gm/100 gm to 18.5±0.09 gm/100 gm in mango pulp extract, while banana pulp had a carbohydrate level of roughly 24.5±0.06.

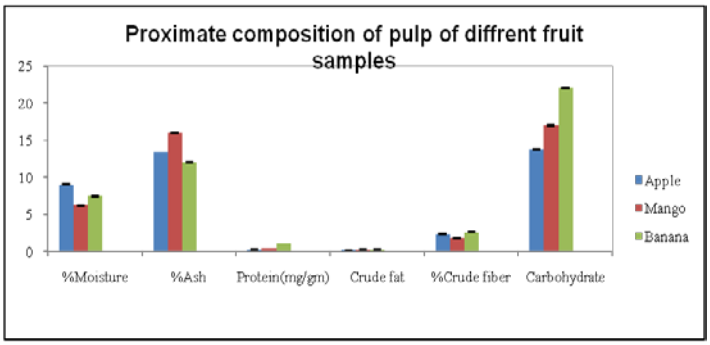


Fig. 2: Graphical representation of the proximate composition of different fruits samples. The data are displayed with mean±standard deviation (bars) of three replications (sample size±3)

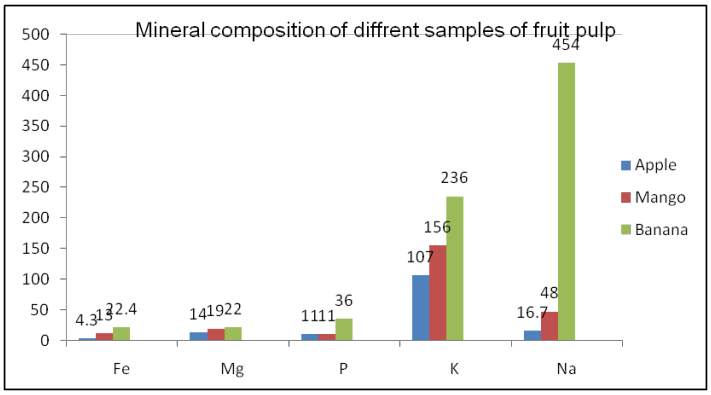


Fig. 3: Graphical representation of mineral contents of different fruit pulp. The data are displayed with mean±standard deviation (bars) of three replications (sample size±3)

Fig. 3 shows the comparative mineral content, of different fruits (apple, banana, and mango) pulp extracts. Sodium content was highest in the banana pulp at approximately (520.0±0.06 mg/100 g), while potassium content was approximately in (236±0.07 mg/100 g), whereas potassium content ranged (156.0±0.04 mg/100 gm) in mango pulp to 107.0±0.03 mg/100 gm in apple pulp. K was discovered to be the most abundant mineral in banana pulp when compared to other minerals. Similarly, Magnesium content was highest in the banana pulp (22.0±0.05 mg/100 g) whereas, as in mango and apple pulp extracts; it's ranged (19.0±0.02 mg/100 g to 14.0±0.02 mg/100 gm) respectively. Iron content ranged from 4.3±0.03 mg/100 gm in apple pulp to 13±0.03 mg/100 gm in mango pulp, where, as in banana pulp, the iron content is ranged 19.0±0.04 mg/100 gm, respectively. Iron content was highest in banana pulp (19.0±0.04 mg/100 gm), while it in other fruit sample it was low in content. Phosphorus content was returned in appreciably and was the highest in the banana pulp (36.0±0.06 mg/100 g). Where, as in apple and mango pulp, it was the almost same amount, almost 11.0±0.02 mg/100 gm, respectively. Generally, fruit extract with low K and high Mg content increases its potential as an antidiabetic source; furthermore, banana pulp is a good source of iron content too.

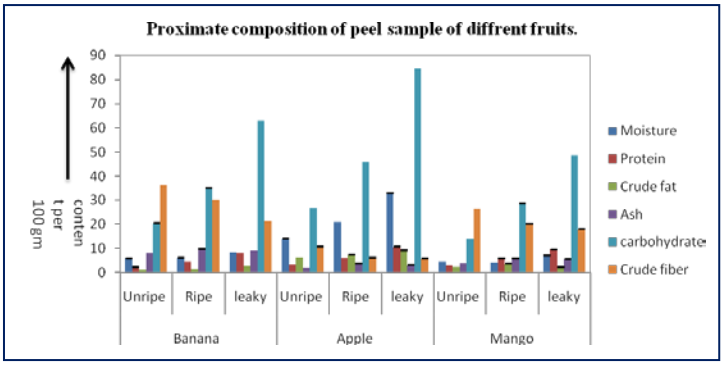


Fig. 4a: Proximate compositions of banana, apple and mango peel. The data are displayed with mean±standard deviation (bars) of three replications (sample size±9)

Fig. 4a shows the proximate content of several fruit peels (apple, banana, and mango) at various stages of ripening, which represents the nutritional components. Unripe apple peel had a moisture content of 14.1±0.12 percent, while unripe banana and mango peel had moisture contents of 5.97±0.12 percent and 4.7±0.06 percent, respectively. Fig. 4a also shows that unripe banana peel has less moisture content. As a result, it is less contaminated by bacteria and exhibits anti-microbial properties. Unripe, ripe, and overripe banana peel samples had moisture content ranging from 5.97±0.12 percent to 6.12±0.09 percent to 8.44±0.14 percent, respectively. Similarly, in apple peels, moisture content ranged from 14.1±0.12% to 20.9±0.11% to 32.9±0.16% from unripe to overripe. The result shows that as the ripening proceeds, moisture content increases. Banana peels had the highest ash level of 8.16±0.12 percent; apple peel 1.98±0.04 percent, and mango peel 3.97±0.06 percent, respectively, whereas banana peels had the highest ash content in their overripe, ripe, and unripe stages categorically, compared to apple and mango peel. As shown in table 1, the ash content rises as ripening progresses. The fat level in unripe banana peel ranged from 1.2±0.03 percent, while 2.41±0.06 percent in unripe mango peel, it was roughly 6.42±0.02 percent in unripe apple peel. The fat content in the overripe apple peel was estimated to be approximately 9.24±0.05 percent, which is quite high. The crude fat content of apple and banana peels increases as ripening progresses, as seen in table 1. When compared to other fruits, the crude fat content of unripe banana peel is lower. Unripe fruit peel had crude fiber content of 9.24±0.05 percent (banana) and 10.7±0.06 percent (apple), respectively, whereas unripe mango peel had 26.5±0.06 percent. Overripe banana peels had a high level of crude fibers (approximately 21.3±0.06%), but overripe apple and mango peels had almost 5.9±0.05 percent and 18.0±0.05 percent, respectively. Unripe banana, mango and apple peels had crude protein content ranging from 2.16±0.05 gm/100 gm to 3.34±0.02 gm/100 gm to 2.97±0.08 gm/100 gm, but overripe banana peels had 8.13±0.13 gm/100 gm, indicating that ripening has an effect on protein content. Unripe banana peel extract had a total carbohydrate content of 20.48±0.11 gm/100 gm, whereas unripe apple peel extract had a total carbohydrate content of 26.63±0.06 gm/100 gm, while unripe mango peel extracts had a total carbohydrate content of 13.95±0.09 gm/100 gm, which is approximately less.

Table 1: Standardization of the proximate composition of unripe, ripe and overripe peel samples of different fruits. The data are displayed with mean+standard deviation of three replications

Fruit sample	Ripening stage	Moisture%	Protein g/100 gram	Crude fat (%)	Ash (%)	Carbohydrate gm/100 gm	Crude fiber (%)
Banana Peel	Unripe	5.97±0.12	2.16±0.05	1.2±0.03	8.16±0.12	20.48±0.11	36.16±0.09
	Ripe	6.12±0.09	4.5±0.07	1.4±0.07	9.88±0.08	34.97±0.13	30.03±0.07
	Overripe	8.44±0.14	8.13±0.13	2.7±0.09	9.02±0.05	63.03±0.07	21.3±0.06
Apple peel	Unripe	14.1±0.12	3.34±0.02	6.42±0.02	1.98±0.04	26.63±0.06	10.7±0.06
	Ripe	20.9±0.11	5.94±0.05	7.37±0.03	3.74±0.05	45.98±0.05	6.2±0.08
	Overripe	32.9±0.16	10.79±0.08	9.24±0.05	3.06±0.07	84.63±0.08	5.9±0.05
Mango Peel	Unripe	4.7±0.06	2.97±0.08	2.41±0.06	3.97±0.06	13.95±0.09	26.5±0.06
	Ripe	4.4±0.06	5.83±0.07	3.72±0.06	5.81±0.09	28.64±0.12	20.2±0.07
	Overripe	7.1±0.08	9.59±0.08	2.20±0.05	5.54±0.08	48.57±0.07	18.0±0.05

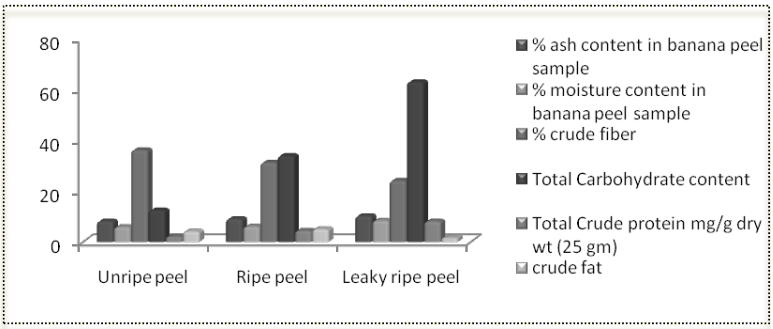


Fig. 4b: Proximate composition of peel at three different stages of ripening. The data are displayed with mean±standard deviation (bars) of three replications (sample size±3)

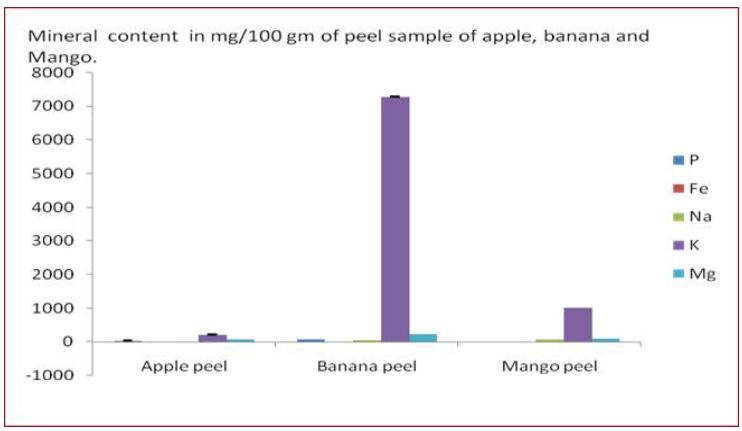


Fig. 5(a): Mineral contents (mg/100 gm) in apple, banana and mango peels. The data are displayed with mean±standard deviation (bars) of three replications (sample size±3)

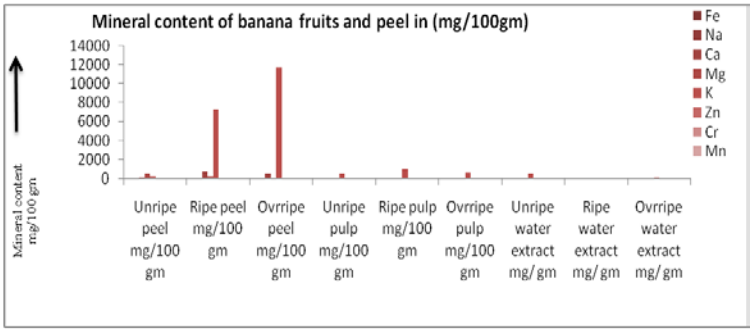


Fig. 5(b): Determination of mineral content (mg/100 gm) in banana pulp and peel at three different stages of ripening (sample size±9)

Fig. 5(a) depicts the mineral content of different fruit peels (apple, banana, and mango) at various phases of ripening. Potassium content was found to be high in banana peels at 7288±.0.06 mg/100 gm, compared to mango peel at 1026±2.2 mg/100 gm and apple peel at almost 216.05±1.5 mg/100 gm, Similarly Mg content was found to be high in banana peel at approximately 234.91±0.078 mg/100 g, whereas 98.2±1.6 mg/100 gm in mango peel, while 75.05±0.03 mg/100 gm in apple peel. Compared to other fruits peels the results show that Na is found to be more banana peel. The banana peel has a high phosphorus level (74.5±0.19 mg/100 g), whereas mango and apple peel extracts have a low phosphorus content (63.2±0.17 mg/100 g to75.05±0.03 mg/100 gm). Iron content ranged from 7.02+0.05 mg/100 gm in mango peel to 8.23±0.03 mg/100 gm in apple peel, where, as in banana peel, the iron content is approximately 11.05±0.09 mg/100 gm. While the iron content of banana peels was roughly 11.05±0.09 mg/100 gm. The iron level in banana peels is high, whereas it is low in other fruit samples. In graph 5(b), potassium was found to be abundant in banana peel when compared to other minerals. It also contains a certain amount of magnesium (234.91±0.078 mg/100 gm) and phosphorus (74.5±0.19 mg/100 gm). While unripe banana peel shows the anti-diabetic properties with low K (245.1±0.07 mg/100 gm) and high magnesium (566.61±0.07 mg/100 gm) ratio, furthermore, banana peel is good source of iron content too.

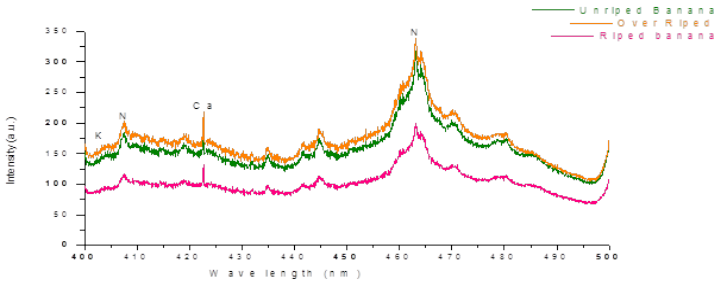


Fig. 6(a): Comparative study for Ca and K content in banana peel at different stage of ripening (sample size±3)

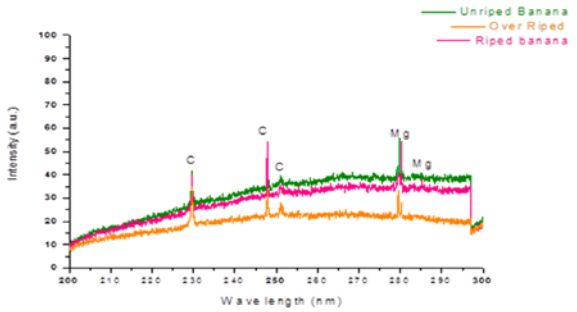


Fig. 6(b): Comparative studies for Mg content in banana peel at different stage of ripening (sample size±3)

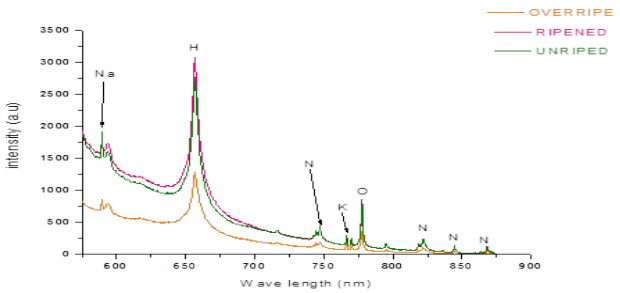
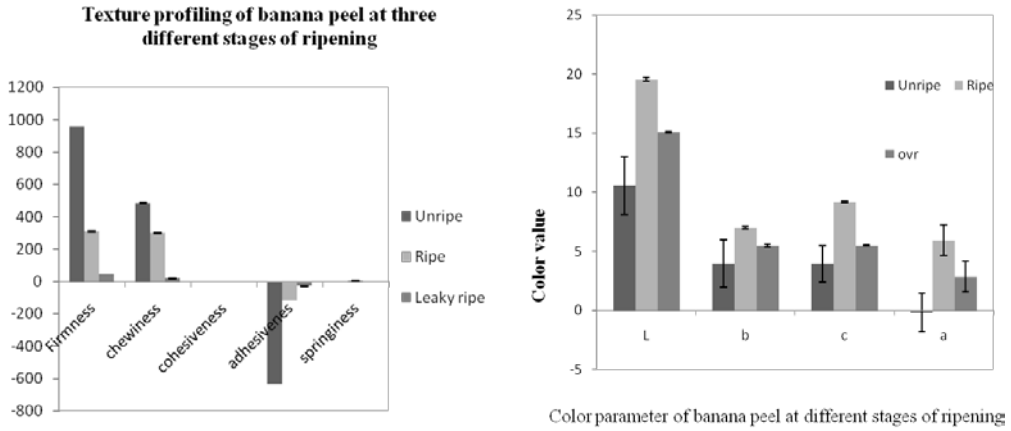


Fig. 6(c): Comparative studies for K, Na and N content in banana peel at different stage of ripening (sample size+3)

Fig. 6(a) and 6(b) and 6(c) show LIBS spectra of banana peel samples at various stages of ripening, which clearly demonstrate the presence of atomic lines of numerous minerals such as calcium (Ca), magnesium (Mg), carbon (C), phosphorous (P), potassium (K), nitrogen (N), sodium (Na), chromium (Cr), sodium (Na), and potassium (K) (K). The existence of the above minerals in these food supplements is clearly demonstrated by these data. In overripe banana peel, K and Ca were detected at wavelengths of 400 nm and 420 nm, respectively, as shown in fig. 6(a), whereas N was detected at wavelengths of 420 and 465 nm in overripe banana peel. Overripe banana peels had higher levels of calcium and potassium. At wavelength 280, an intense Mg peak was detected. Fig. 6(b) demonstrates that unripe banana peels have a higher Mg concentration than ripe and leaky ripe banana peels. Fig. 6(c) shows the potassium content of an unripe banana peel measured at a wavelength of 765 nm. While, a sharp intensity peak of Na was noticed at a wavelength of 580 nm. Fig. 6(c) shows an intense peak of N at wavelengths of 750 nm, 830 nm, 850 nm, and 870 nm.



a **b**

Fig. 7: Standardization of three different stages of banana sample by (a) Determining textural parameter (b) Determining color parameter of unripe, ripe and overripe banana peel (Sample size+3)

Unripe banana peel has a firmness of 956±2.12 mm, whereas leaky ripe banana peel has a firmness of 32±0.042 mm, as shown in fig. 7(a). Unripe banana peel had a chewiness of 484.84±1.63 mm, whereas leaky ripe banana peel had a chewiness of 17.23±1.28 mm, which grew and subsequently dropped as ripening progressed. Springiness (1.002±1.53 to 1.05+0.017) and cohesiveness (0.582±0.003 to 0.509±0.01), however, showed the least significant variation (P 0.05) when compared to other characteristics. These factors were used to optimize banana peel samples for further investigation. Brightness (a*) increased from-0.1866±1.63 (green) to 2.875±1.28 (yellow) during the first eight days of storage, as illustrated in fig. 7(b) Further, the color decreased steadily at the constant rate of over 2.87±1.28 (black). Whereas Lightness (L*) value increased gradually from 10.57±2.45 to 19.57±0.169 after 7 d of storage without ethylene treatment. This value slightly decreased after 15 d of storage.

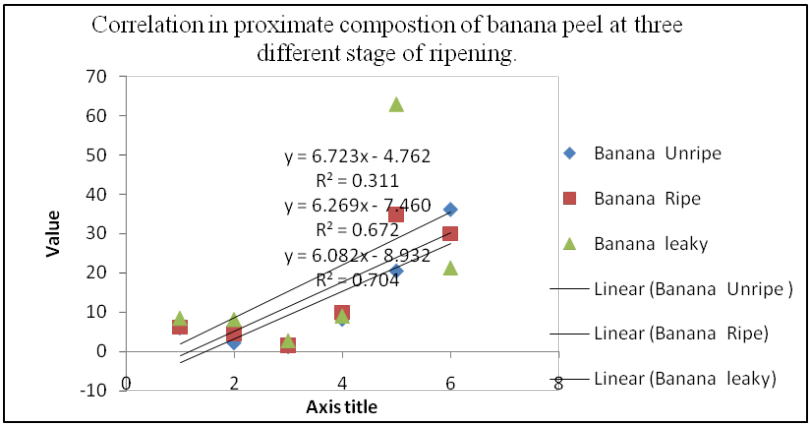


Fig. 8: Determination of proximate composition of banana peel at three different stages of ripening

Fig. 8 depicts the linear correlation between nutrient content at different stages of banana peel. Highest correlation was observed in leaky stage of banana peel. Significant difference ($P<0.001$) was found in leaky ripe banana peel. Highest correlation in minerals was oserved in leakyripe banana peel ($R^2= 0.7041$). where, as unripe sample shows correlation ($R^2= 0.311$), which is less.

Moisture, ash, crude protein-carbohydrate, and crude fat increase as ripening proceed, whereas crude fiber is found high in the unripe stage.

Fig. 9 shows a positive correlation among fruits (apple, mango, and banana) peels, as the ripening progresses. Linera correaltion was found in banana peel samples for their mineral composition, according to the findings. The banana peel had a R^2 of 0.2755, while the mango and apple peels had R^2 of 0.1577 and 0.1393, respectively. This means that bananas are a rich source of minerals. High magnesium 566.61±0.07 mg/100 gm and low potassium 245.1±0.07 mg/100 gm in unripe banana peel could be an use as an anti-diabetic source (Pandhija and Rai, 2008) [17]. In comparison

to other minerals, banana peel has the highest potassium content. Potassium levels rise as the fruit ripens. Whereas magnesium decreases. The correlation of Ca with Mg was 0.15 as the ripening progressed, whereas the correlation of Mg with K was-0.2044. The strongest correlation between Fe and Mn was 0.9091, while the correlations of Fe with Mg, K, and Zn were 0.776, 0.404, and-0.189, respectively. Unripe banana peels had the highest manganese content (566.61±0.07 mg/100 gm) compared to leaky ripe banana peels (105.22±0.067 mg/100 gm). A positive correlation demonstrated that as membrane-bound minerals are released during the ripening process, they display the highest intensity in the leaky stage. The above results clearly show that banana peels in the overripe or leaky stage could be a good source of bio-fertilizer. It could be recycled for organic farming purposes.

The high Mg and low K content of unripe banana peel boost its potential as an anti-diabetic source. Bananas are a good source of protein and minerals, including calcium and potassium. As a result, it can be used as a dietary supplement, particularly in countries where the majority of people eat starchy foods and cereals.

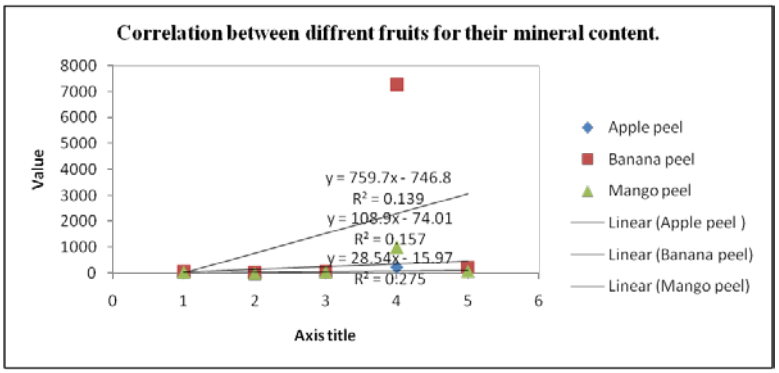


Fig. 9: Correlation between mineral content of apple, banana and mango

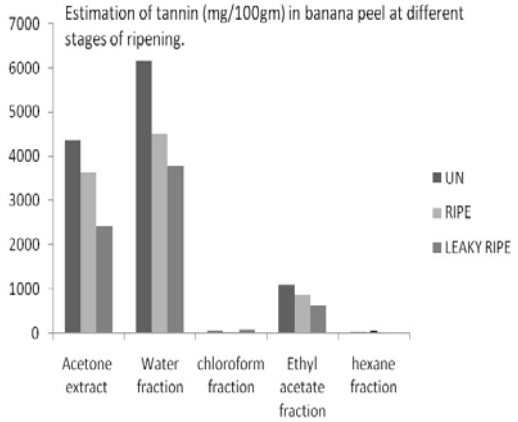


Fig. 10: Estimation of tannin mg/100 gm in banana peel at different stages of ripening. The data are displayed with mean±standard deviation (Sample size+15)

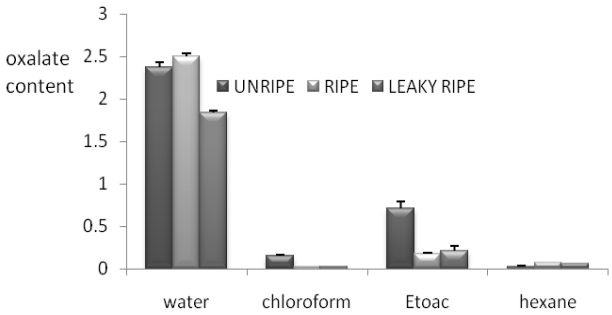


Fig. 11: Estimation of oxalate content in banana peel at different stages of ripening. The data are displayed with mean±standard deviation ((Sample size+12)

Unripe water fractionate had the highest tannin content in contrast to 70 percent acetone extracts, ranging from 6160±0.12 to 4360±0.057 mg/100 gm, as shown in fig. 10. Tannin was found to be high in the unripe stage of banana peel. The largest concentration of tannin is found in a water extract of banana peel. The aforementioned result demonstrates that tannin is polar in nature, allowing for the most extraction in a water solvent.

Fig. 11 shows that the oxalate concentration in the unripe water fraction was determined to be (2.37±0.061 mg/100 gm), but it was found to be 1.84±0.018 mg/100 gm in the leaky stage.

We might deduce from the aforementioned observations that as ripening progresses, certain antinutrional factors decline. The oxalate level of banana peels decreased significantly (P<0.05) as ripening progressed, which was recorded (-0.872 correlation with oxalate oxidase), Oxalates can bind to calcium in food, thereby rendering calcium inaccessible for ordinary physiological processes. Ripening is an oxidative phenomenon, the decrease in antinutritional factors like oxalate content (-0.872 correlation with oxalate oxidase) and tannin content (-0.999 correlation with oxalate oxidase) with the advancement of ripening indicated the physiological role of oxalate oxidase in fruit ripening as shown in table 2, These antinutritional factor decreases the bioavailability of nutrients like Ca, Fe and protein. So a decrease in anti-nutritional factor is a good indicator that banana is useful for human health.

Table 2: Determination of effect of ripening and correlation between oxalate content, tannin content, oxalate oxidase activity and superoxide dismutase activity of banana peel at three different stages of ripening

Variation in ripening stages (Crude extracts of banana peel)		
Correlation	**R**	**R^2 (%)**
Oxalate vs. Tannin	0.855	73.10
Oxalate vs. Oxalate oxidase activity	*0.872	70.22*
protein vs. oxalate oxidase activity	0.999	99.8
Oxalate oxidase vs. Tannin	-0.999	99.8*

DISCUSSION

The work was started with three different fruits: banana, mango and apple, because all these are tropical fruits and readily available thoughout the year. In the initial stage, the nutritive values of different fruit samples were analyzed. Fig. 1 shows the experimental setup of Laser-induced breakdown spectroscopy (LIBS) for the determination of mineral content and for nutritional properties of fruit peel**s.**

The chemical composition and mineral concentration of these fruits' crude extracts were determined. Moisture, ash, crude fat, crude protein, crude fiber, and carbohydrate content were found to differ significantly (P 0.05) among different fruits, as shown in fig. 2. According to this, apple has a high moisture level, whereas banana and mango have low moisture content. Previous studies have shown that a low moisture content value in fruit is a good indication of fruit preservation, keeping them for a long time without growing moldy. The crude protein content of banana fruit was 1.1±0.05 g/100 gram shown in fig. 2. High protein content of banana compared to mango (0.5±0.03 gm/100 gm) and apple (0.3±0.05 gm/100 gm) could be due to the fact that, more protein being extracted during the extraction process. Proteins are essential components of diet, needed for the survival of living beings and the basic function in nutrition is to supply an adequate amount of amino acids [20]. Bananas are an alternative source of protein as a dietary supplement, especially in areas where the majority of the population lives on starchy foods and cereals. The above results also revealed that crude fat was high in banana fruit pulp (0.9±0.08 gm/100 gm) compared to other fruits due to the high content of polyunsaturated fatty acid, particularly linoleic acid and α-linolenic acid. When compared to other fruits, banana pulp has high carbohydrate content (24.5±0.06 gm/100 gm). Because bananas are a non-climatic fruit, they produce a lot of ethylene, which increases the breakdown of starch to sugar in the presence of ethylene. Variety, harvesting year, weather conditions, and latitude are all factors that determine the chemical composition of fruits [21]. Fig. 3 shows the mineral content of different fruits. Banana pulp shows high Fe (22.4±0.04 mg/100 gm), Na (454.0±0.06 mg/100 gm) and K (236.0±0.07 mg/100 gm) and Mg (22.0±0.05 mg/100 gm) content with significant difference (σ2= 36347.63). Results demonstrate the view of previous studies that high concentrations of K with a low concentration of Mg were found to be responsible for the regulation of body fluids, maintaining normal blood pressure, controlling kidney failure, heart oddities and respiratory flow [22]. Furthermore, banana have a good Fe content compared to other fruits shown in fig. 3, which could be helpful for treating anemia and other disorders [4]. Iron transports oxygen to the cells and is necessary for the production of energy, synthesis of collagen and in the proper functioning of the immune system. The moderate concentration of iron in banana peel makes it an ideal source for its use in any form since excess iron causes abnormal functioning of the immune system, cell growth and functioning of heart [22].

Banana peels, like the rest of the banana, are high in nutrients. In fig. 4a, the moisture contents of banana, mango and apple peel at different stages of ripening were examined. It was estimated in the range of 5.97±0.12, 4.7±0.06 and 14.1±0.12 g/100 gm categorically, compared to ripe 6.12±0.09, 4.4±0.06, 20.9+0.11 gm/100 gm and overripe 8.44±0.14, 7.1±0.08 and 32.9±0.16 gm/100 gm peels. It has been found that banana peels at immature stages have low moisture percent, which prevents bananas from frequent microbial spoilage and promotes long time storage and transportation. The ash content of unripe to overripe banana peel was in range of 8.16±0.12 to 9.02±0.05 gm/100 gm and for apple peel, 1.98±0.04 to 3.06±0.07 gm/100 gm whereas 3.97±0.06 to 5.54±0.08 gm/100 gm for mango peels. High ash content in banana (tropical fruit peel) indicates that it is a good source of minerals.

Plants require nutrients to survive. Nitrogen, phosphorus, and potassium are the most important nutrients, while calcium, manganese, sodium, and sulphur are only needed in small amounts. Banana peels, which are high in nutrients, might be widely employed in gardening to boost soil fertility. It's suitable for organic farming. Potassium aids in the transport of water and nutrients within cells. It also strengthens stems and protects plants from disease. Due to its high potassium, banana is a better counterpart to other organic substances. Banana peels are 74.5±0.19 mg/100 gm of phosphorus, one of the other major nutrients that plants need to grow, shown in fig. 5a. Phosphorus helps rooting, improves winter hardiness and speeds up flowering and fruiting. Patricia H. 2019 reported that banana peels inserted in the soil near the roots are an effective way to get phosphorus to your plants because the peels break down quickly in the soil. This immediacy is helpful because phosphorus is not mobile in the soil. The peels also contain magnesium (234.91±0.078 mg/100 gm) and iron (11.05±0.09 mg/100 gm), both important in the formation of chlorophyll and aids in photosynthesis and the formation of some enzymes and plant pigments [23]. Sodium, concentrated at (54±1.5 mg/100 gm) is involved in the movement of water and ions between cells. Though, banana, apple, and mango have good nutritional value. The nutritive values of all selected fruit peels at different ripening stages were estimated. But keeping in mind the concept of environmental sustainability, the work was only carried out on peels of these fruits.

In terms of mineral content, banana peel has the highest potassium level (7288±.2.6 mg/100 gm), followed by mango (1026±2.2 mg/100 gm) and apple peel (216.05±1.5 mg/100 gm). Oshodi and Adeladun (1993) [24] reported similar findings on banana peel. In fig. 5a Iron, magnesium, phosphorous, potassium, and sodium concentrations (mg/100g) in banana peel were 11.05±0.09, 234.91±0.078, 74.5±0.19, 7288±2.6, and 54±1.5, respectively. Bananas had a moderate level of iron content (11.05±0.09 mg/100 gm), whereas apple (8.23±0.03 mg/100 gm) and mango (7.02±0.05 mg/100 gm) had significantly lower levels (P<0.05).

Furthermore, the research work was focused on banana peel, because it is more nutritious, cheap, and easily available throughout

the year. So peel samples of different ripening stages of banana were standardized by using X-rite LAB colorimeter (USA) and TAXT2i texture analyzer (Stable Microsystems, USA). Standardized samples of banana peel at three different stages of ripening were selected for further work. In terms of texture, the variation in work applied and distance (s) versus time (t) were reported in fig. 7(a). Textural characteristics viz. hardness/firmness, cohesiveness, springiness and chewiness of banana peel changed as the ripening proceeded. Fig. 7(a) shows that firmness (956±2.12 mm to 32±0.042 mm) and chewiness (484.84±1.63 mm to 17.23±1.28 mm) initially increased and then gradually decreased as the ripening proceeds. But significant variation ($P<0.05$) in springiness (1.002±1.53 mm to 1.05±0.017 mm) and cohesiveness (0.582±0.003 mm to 0.509±0.01 mm) was least as compared to other factors. These parameters were taken for the optimization of banana peel samples for further study. Color measured by colorimeter, brightness (a*) increased-0.1866±1.63 (green) to 2.875±1.28 (yellow) during the first eight days of storage, as shown in fig. 7(b). Further, the color decreased steadily at the constant rate of over 2.87±1.28 (black). Whereas Lightness (L*) value increased gradually from 10.57±2.45 to 19.57±0.169 after 7 d of storage without ethylene treatment. This value slightly decreased after 15 d of storage. The color of the banana peel changed from yellowish green to yellow as it ripened, and the brightness of the color increased due to the carotenoids. Ripe stage of banana peel showed more brightness compared to unripe and overripe samples of banana peel.

During the analysis, the concentration of Mg and Fe was found higher in unripe than in the ripe and overripe fruit peel, whereas the concentration of K was found lower, as shown in fig. 5(b). These results reinstate the view of earlier studies that high concentrations of Mg with a low concentration of K were found responsible for the anti-diabetic effect [17]. Fig. 5b shows that, as the ripening proceeded, the correlation of Ca with Mg was found to be 0.15, whereas correlation of Mg with K was-0.2044 and the highest correlation among Fe and Mn was 0.9091, whereas, the correlation of Fe with Mg, K and Zn was 0.776, 0.404 and-0.189, respectively. Highest level of manganese was found in leaky stage (6.8±0.088 mg/100 gm) compared to unripe stage (5.6±0.067 mg/100 gm) of banana peel. Manganese, known to aid formation of skeleton and cartilage, was also found to be high (76.20 mg/100g) in *Musa sapientum* as reported by Anhwange *et al.* (2009) Manganese dearth could affect glucose tolerance, normal reproductive, skeleton and cartilage formation [25].

In fig. 5(b), the concentrations of the non-essential minerals zinc and chromium were found to be in the range of 2.53±0.09 to 88.4±0.07. The result implied that banana peel was containing very low concentrations of non-essential minerals. Fig. 6(a) of LIBS spectrum shows that overripe banana peels has intense peaks of N, Ca and K; so, it could be used as organic fertilizer, especially if your plants are heavy nitrogen feeders. An unripe sample of banana peel shows the intense peaks of Na as shown in fig. 6c. From iron to phosphorus to calcium, to Na and K, there are many valuable vitamins and minerals in peels that can help to enrich soil and encourage healthy plant growth. It helps to enrich soil and encourage healthy plant growth. One of the benefits of fertilizing with banana peels is that they break down quickly–either in the soil or in compost–making those nutrients available to plants sooner than nutrients from other organic materials.

In fig. 4(b), the ash content was found to be 8.16%. This value is analogous to other staples measured as good sources of minerals [4]. The organic matter was found to be 91.50%. Organic matter measures the nutritional value (lipids, proteins, and carbohydrates) of a plant material. The high value indicates that banana peels are good sources of nutrients [4]. The content of protein, lipid, carbohydrates and crude fiber (fig. 4b) was found to be 2.16±0.05g/100 gm, 1.2±0.03%, 20.48±0.11 gm/100 gm and 36.16±0.09% respectively, which indicates that the peel could be a good source of carbohydrates and fiber. The high fiber content also indicates that the peels could be helpful in treating constipation and improving general health and well-being. Singh*, et al.* 2015 reported that fiber-rich diets have a positive effect on health. Their investigation has been related to a decrease prevalence of several diseases [26]. The increase in moisture content of the peel during the ripening process is due to respiratory breakdown of starches into sugar and migration of moisture from pulp to peel [27]. During the ripening process, starch is converted into sugar through an enzymatic breakdown process. Banana protein, depending on the genome, type variety, altitude and climate, increases the ripening process. In the unripe stage of banana peel, fat content was found to be high as compared to ripe and overripe, due to richness of polyunsaturated fatty acids, particularly linoleic acid and α-linolenic acid. Tanin and oxalate content was found to be low, as the ripening proceeds. These are anti-nutritional factors, which impact on the bioavailability of nutrients. Tannin is a high molecular weight phenolic compound, which is present in many plants including fruit pericarp. They inhibit bacterial growth and protease activity by damaging its cell wall and cytoplasm (Sundaram S *et al.* (2007) [7]. Tannins bind to proteins through hydrogen binding and hydrophobic interactions, thereby reducing their nutritional quality, and combine with digestive enzymes, thereby making them unavailable for digestion [28]. Tannins prevent minerals like iron from being absorbed, which can lead to anemia if left untreated.

Decrease in anti-nutritional factor is an indicator that banana is useful for human health and may pose negative effect by reducing protein digestibility and mineral bioavailability. Banana peel contains a low amount of anti-nutritional factors, where it is noted that the content of oxalate in the peels is 1.84 mg/100g. Oxalate consumption has been related to kidney diseases, which can lead to mortality. Oxalates can bind to calcium in the diet, making it unavailable for normal physiological functions [28]. As a result of the findings, we may conclude that unripe banana peels have superior nutritional properties than ripe and overripe as it contains high dietary fiber and certain nutraceutical components. The high protein and mineral content in overripe banana peel makes it equally nutritionally important. Therefore, these results could be used to formulate banana peel powder which could be used for medicinal purpose, bio-fertilizer and as concentrate for livestock feed.

The results were in line with the suggested dosage (18–32g) for an average man per day. Banana (Musa paradisiaca) is one such medicinal plant believed to have multi-faceted health benefits and its health benefits extend to different countries of the world. It is a stable crop found in Asia, Africa, and Central and South America, commonly consumed as energy-yielding food but with many medicinal values aswell [29]. Thus, if the peels are properly handled, they could be a useful forsocio-economic benefit.

It has the potential to reach the majority of the Indian market.

CONCLUSION

Banana peels are important sources of nutrients: protein, fat, crude fiber and total carbohydrates, minerals and anti-nutrients (tannin and oxalates). These components are considered to be within safe limits. Therefore, banana peels can be used as good ingredients for their health benefits in food products. Compared to ripe and leaky-ripe, unripe banana peels have a high Mg and less K content, which increases its potential as an antidiabetic source. Bananas are an alternative source of protein and minerals. So it can be used as a dietary supplement, especially in areas where the majority of the population live on starchy foods and cereals. The low value of moisture content and high ash content make it useful for various medicinal purposes. All stages of banana peel are equally important; even the leaky stages of banana peel contains the fullest of mineral and nutrients, which, we throw without knowing its nutritional values. Banana peels are an alternative source for the cosmetic and clinical industries. Banana peels can be used as organic fertilizer in ecofriendly ways to save time and money. These peels otherwise can be used as potential sources of antioxidants for industrial applications. Because of its diverse nature, banana could capture most of the Indian industry if it is properly processed.

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ETHICAL APPROVAL

Not required

AUTHORS CONTRIBUTIONS

All authors have equally participated in the designing and drafting of the article.

CONFLICT OF INTERESTS

All other authors declare no competing interests.

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