THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Distribution Studies of Some Secondary Metabolites in Different Parts of Four Different Cultivars of Banana Plants and Their Correlation with Antioxidant Property

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Abstract:
Introduction: Different parts of banana plants like fruits, flowers, stems are consumed in many parts of India and leaves are used as natural food wrappers. The distribution of some secondary metabolites like the extractable hydrophilic polyphenolic compounds (EHPC), total flavonoids content (TFC), total hydrolysable tannin content (HTC) as well as the DPPH free radical scavenging activity (antioxidative property) in fruit, stem, flower and leaf of four different cultivars of banana plants have been studied to have a part-wise correlation distribution picture between the above constituents and the free radical scavenging activities. Materials & Methods: Powdered and air dried parts of each of four cultivars was the sample for the entire analysis and experiment w.r.t. the above constituents. Results & Discussion; Despite of having lower polyphenolics, the Cavendish fruit revealed the best antioxidant property among all the fruits under study. The fruits of Baby/Nino banana have richer polyphenols and tannins but lesser content of flavonoids. Moreover, the higher tannin content may to some extent lessen the antioxidative efficiency of the fruits of Baby/Nino. The Plantain flowers having higher EHPC, TFC and also showing highest antioxidant property will be better to be consumed as a food. Manzano stems may be the recommended cultivar for consumption among the stems. Manzano leaves depicting a higher anti-oxidant activity than all may be recommended as an effective food wrapping material during cooking. Conclusion: Cavendish fruits, Plantain flowers, Manzano stems may be the recommended plant parts for consumption as food, whereas, Manzano leaves may be the best food wrapping material.

Keywords: *extractable hydrolysable polyphenols (EHPC), total flavonoids (TFC), total hydrolysable tannins (HTC), antioxidant property, banana plant parts, significant correlation*

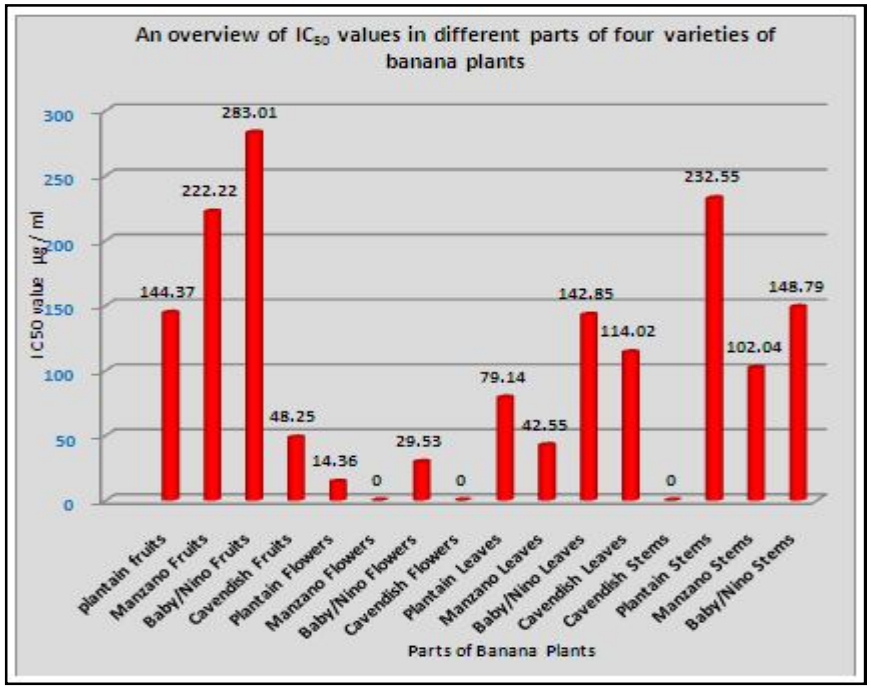

Figure 1: Graphical Abstract

1. Introduction

Banana is a unique fruit due to its high content of carbohydrate, complex fiber, micronutrient K antioxidants and flavonoids (Chang et al., 2002)[6] (Choo et al., 2010)[9] (Rajesh et al., 2012)[10] (Polshettiwar et al., 2007)[21] (Sandyarani et al., 2011)[22] (Shian et al., 2012)[23]. Its year round availability, affordability, varietal range, taste, nutritive and medicinal value makes it the favourite fruit among all classes of people. Banana (Musa sp.) (Kammoun et al., 2011)[15] (Okonogi et al., 2007)[17] is the second most important fruit crop in India next to mango. Banana evolved in the humid tropical regions of South East Asia with India as one of its centers of origin. Different cultivars of banana are available. Different parts of banana plants (Rajesh et al., 2014)[8] like fruits, flowers, stems are consumed in many parts of India and leaves are used as natural food wrappers when steaming, grilling and baking different types of food. The leaf also makes an attractive serving platter because of its size and sturdiness. The distribution of chemical constituents (Padam et al., 2012)[19] (Singleton et al., 1965)[26] responsible for antioxidative activity and anti nutritional factor in different parts of banana plants (Alothman et al., 2009)[2] (Anhwange et al., 2008)[3] (Aurore et al., 2009)[4] (Choo et al., 2010)[7] (Ganu et al., 2010)[12] (Gonzalez-Montelongo et al., 2010a)[13] (Gonzalez-Montelongo et al., 2010b)[14] (Orhan et al., 2001)[18] of Plantain, Manzano, Nino/Baby and Cavendish cultivars, those are widely found in this part of the subcontinent, have not been studied till date. Thus, the present work focused on the distribution of some secondary metabolites like. the extractable hydrophilic polyphenolic compounds (EHPC), total flavonoids content (TFC), total hydrolysable tannin content (HTC) as well as the DPPH free radical scavenging activity (antioxidative property), in different plant parts (viz., fruit, stem, flower and leaf) of four different cultivars of banana plants, so as to have an elaborate knowledge of the portion-wise distribution of the above constituents. The correlation study between free radical scavenging and EHPC, TFC and HTC were carried out separately with these four different cultivars of banana plants.

2. Materials and Methods

The following chemicals and reagents were purchased from the local supplier:

1. Folin-Ciocalteu reagent (Spectrochem, 2(N), Batch No: 2784208)
2. Sodium Carbonate (Merck, Assay - 99.5%, Batch No:-327555)
3. Potassium acetate (Merck, Assay- 99%, Batch No:-61792805001730)
4. Aluminum chloride (Merck, Assay -98%, Batch No:- 380108202501730)
5. Butylated Hydroxytoluene(Merck,Assay-99%,Batch No:-61774805001730)
6. Diphenylpicrylhydrazyl (Merck)
7. Methanol (Merck, Assay- 99.8%)
8. Gallic acid (CHD, Assay -99%, Batch No:- 050711)
9. Tannic acid (Merck, Assay-99%,Batch No.-61745877447)
10. Quercetin (SRL, Assay-99%, Batch No: -T836708)
11. DPPH (Sigma-Aldrich, Assay-99%, Lot No.-STBC5116V)
12. Distilled Water

2.1. Sample Preparation

All the parts of banana plants of each cultivar (viz. Plantain, Manzano, Nino/Baby and Cavendish) were collected locally and washed properly with water to remove the dirt. Different parts of each plant were cut to smaller fractions, air dried under normal sunlight for a few days and were grinded into fine powder with a mixer-grinder and stored in air tight containers for the experiment. The powdered mass of each part was the sample for the entire analysis and experiment (Aurore et al., 2009)[4]. 1gm of each dried mass of each part was dissolved in 10ml distilled water and was stirred in a mechanical shaker for 30 minutes. The mixture was then centrifuged for 15 minutes at 3000 rpm and the supernatant liquid was collected and used as sample solution for the experiments.

2.1.1. Methods

- Determination of DPPH free radical scavenging activity:

DPPH free radical scavenging activity (Singleton et al., 1999)[25] was determined by the method demonstrated by Karuppiah et al., 2013)[16] (Okonogi et al. 2007)[17]. 10 different concentrations (10µg-300µg) of sample solutions were taken in test tubes for carrying out the experiment. To each such solution, 3ml of DPPH reagent was added. The solutions were kept in dark for 30 minutes, after which the absorbance was measured at 517nm wavelength against a standard calibration curve. During the entire process of the experiment light was avoided as much as possible.

- Preparation of DPPH reagent:

0.004gm of DPPH was dissolved in 100ml of 80:20 methanols: water and the solution was kept in amber colored bottle, avoiding light.

- Determination of Total Flavonoids Content (TFC):

TFC has been determined by using Aluminium chloride colorimetric method (Chang et al., 2002)[6]. Each experiment was carried out in triplicate and results averaged and expressed as $\pm$ SD in µg/100g sample. 1.9ml of methanol was added to 0.1ml of sample solution (taken in test tube). 0.1ml 10% of $Alcl_3$ and 0.1ml of 1M potassium acetate were added to it successively and volume was made up to 5ml (volumetric flask) by distilled water. The solution was kept at room temperature for 30 min. Absorbance of the solution was measured at 415nm wavelength against the standard calibration curve. Quercetin was used as the standard material and the calibration curve was prepared in the range of 20µg-100µg using 20, 40, 60, 80 and 100 µg as the standard concentrations at a wavelength of 415nm (λ_{max} of quercetin).

- Determination of Total Extractable Hydophillic Phenolic Compounds Content (EHPC)

The total phenolic content of hydrophilic extracts was determined using the Folin-Ciocalteu colorimetric method. Determination of phenolic content was based on (Singhal *et al.,* 2013)[24] (Singleton *et al.,* 1999)[25] (Singleton and Rossi *et al.,* 1965)[26] (Song *et al. 2010*)[27]. Each experiment was carried out in triplicate and results averaged and expressed as $\pm$ SD in µg/100g sample. 0.1 ml of sample solution was taken into a test tube and 1ml (10 fold diluted) Folin-Ciocalteu reagent, 0.8ml 2% Na_2CO_3 were added to it and the volume was made up to 10ml (volumetric flask) by distilled water. The solution was incubated for 30mins in room temperature. Absorbance of the solution was measured at 740nm wavelength against a standard calibration curve. Gallic acid was used as a standard and the calibration curve was prepared in the range of 20µg-100µg using 20, 40, 60, 80 and 100 µg as the standard concentrations at a wavelength of 740nm (λ_{max} of gallic acid).

- Determination of Total Hydrolysable Tannin Content (HTC):

Content of tannins was determined by Folin-Denis reagent (Parimala *et al.,* 2013)[20] based on colorimetric estimation of tannins (measurement of blue colour formed by the reduction of phosphotungstomolybdic acid by tannins in alkaline medium 0.5gm of dry sample was added to 75ml of distilled water, heated gently at first and then boiled for 30 minutes. Then it was centrifuged at 2000 rpm for 20 minutes. The supernatant liquid was collected and made up to the volume of 100ml (volumetric flask) by distilled water. After that 0.1ml of this solution was taken in a test tube and 7.5ml of water, 0.5ml of Folin-Denis reagent and 1ml of 35% Na_2CO_3 were added to it. The volume was made up to 10ml (volumetric flask) by using distilled water and shaked well. The test tubes were incubated for 30 minutes at room temperature and the absorbance of the solution was measured at 700nm wavelength against a standard calibration curve. Each experiment was carried out in triplicate and results averaged and expressed as $\pm$ SD in µg/100g sample. Tannic acid was used as a standard and the calibration curve was prepared in the range of 20µg-100µg using 20, 40, 60, 80 and 100 µg as the standard concentrations at a wavelength of 700nm (λ_{max} of tannic acid).

3. Results & Discussion

BANANA VARIETY	PARTS OF BANANA PLANT	POLYPHENOLS (EHPC) µg/100g				FLAVONOIDS (TFC) µg/100g				TANNINS (HTC) µg/100g			
		VALUE	MEAN	SD	SE	VALUE	MEAN	SD	SE	VALUE	MEAN	SD	SE
PLANTAIN BANANA	FRUIT	220	220	0.6	0.3	132	130	2.1	1.2	78	80	2	1.2
		221				129				82			
		220				128				80			
	LEAF	741	740	0.6	0.3	710	710	0.6	0.3	21	20	0.6	0.3
		740				710				20			
		740				709				20			
	FLOWER	562	560	2.1	1.2	112	110	1.5	0.9	38	40	1.5	0.9
		561				110				41			
		558				109				40			
	STEAM	11	10	1.7	1.0	58	60	1.5	0.9	24	25	1.2	0.7
		11				60				24			
		8				61				26			
MANZANO BANANA	FRUIT	18	20	2.0	1.2	55	55	0.0	0.0	30	30	2.5	1.5
		22				55				33			
		20				55				28			
	LEAF	490	490	0.6	0.3	821	820	2.1	1.2	80	80	0.6	0.3
		490				822				80			
		491				818				79			
	FLOWER	552	550	1.5	0.9	101	100	1.2	0.7	32	30	1.5	0.9
		549				101				30			
		550				99				29			
	STEAM	28	30	2.0	1.2	79	80	2.1	1.2	18	20	2.1	1.2
		32				78				19			
		30				82				22			
BABY/ NINO BANANA	FRUIT	439	440	1.5	0.9	20	20	2.0	1.2	109	108	1.2	0.7
		442				22				109			
		440				18				107			
	LEAF	428	430	1.5	0.9	38	40	1.7	1.0	122	120	1.5	0.9
		431				41				119			
		430				41				120			
	FLOWER	508	510	2.0	1.2	48	50	2.1	1.2	83	85	2.1	1.2
		512				49				84			
		510				52				87			
	STEAM	88	90	1.5	0.9	63	60	2.9	1.7	28	30	2.1	1.2
		90				58				32			
		91				58				29			
CAVENDISH BANANA	FRUIT	28	30	2.9	1.7	32	30	2.9	1.7	42	40	2.0	1.2
		28				32				40			
		33				27				38			
	LEAF	471	470	2.1	1.2	321	320	1.0	0.6	101	100	2.1	1.2
		472				320				98			
		468				319				102			
	FLOWER	210	210	3.0	1.7	8	10	3.8	2.2	69	65	4.0	2.3
		207				7				61			
		213				14				65			
	STEAM	20	20	1.5	0.9	17	20	3.1	1.8	24	20	4.0	2.3
		18				19				21			
		21				23				16			

Table 1: Distribution of polyphenols, flavonoids & tannins in each part of Banana Plants (4 varieties)

3.1. Percentage Wise Distribution of EHPC, TFC & HTC in Each Part of Different Banana Plants

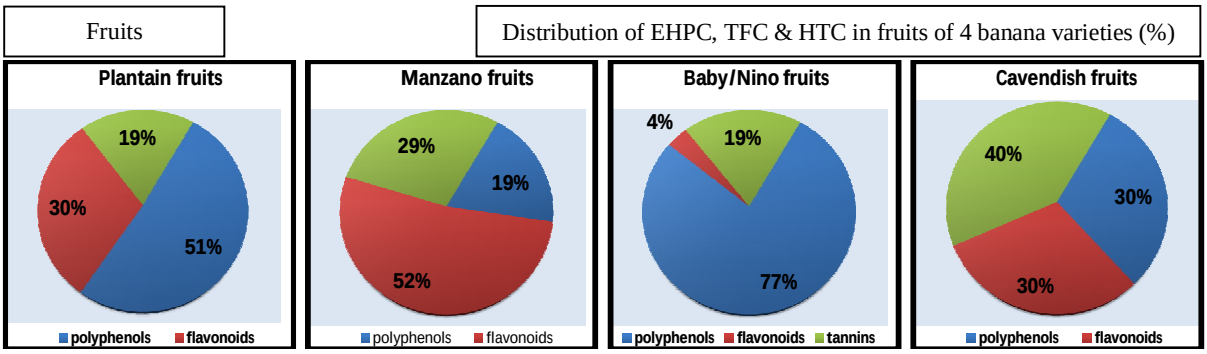

Figure 1

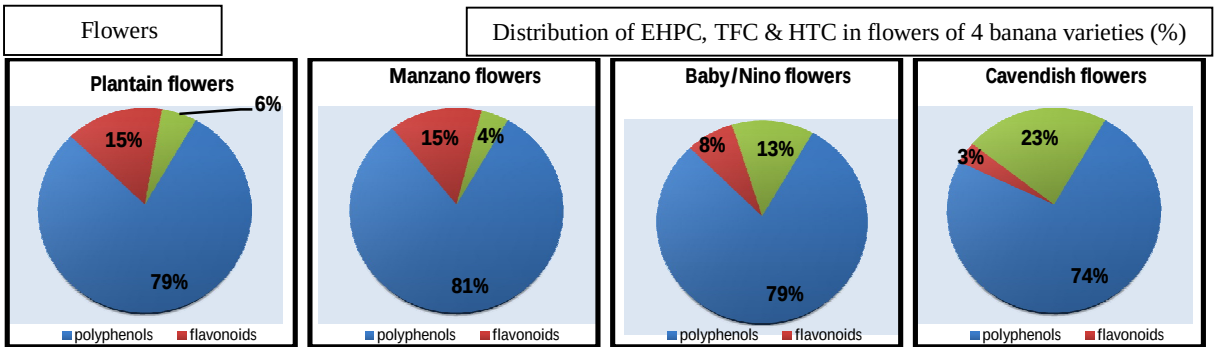

Figure 2

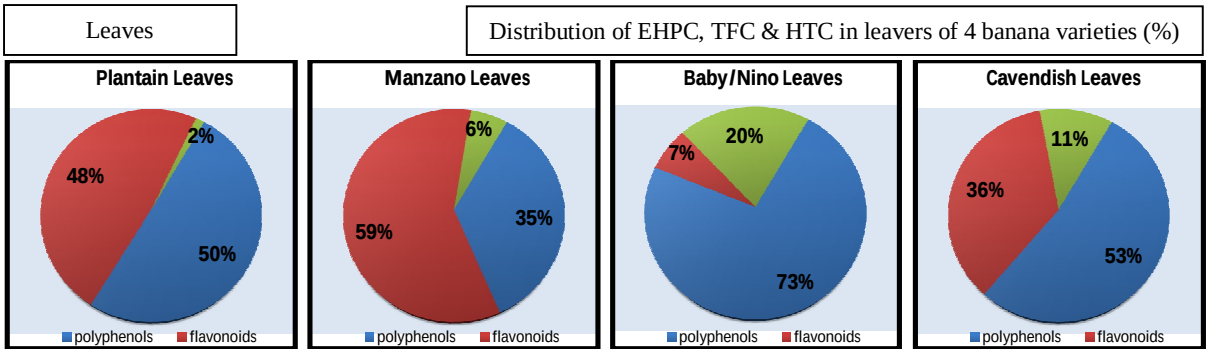

Figure 3

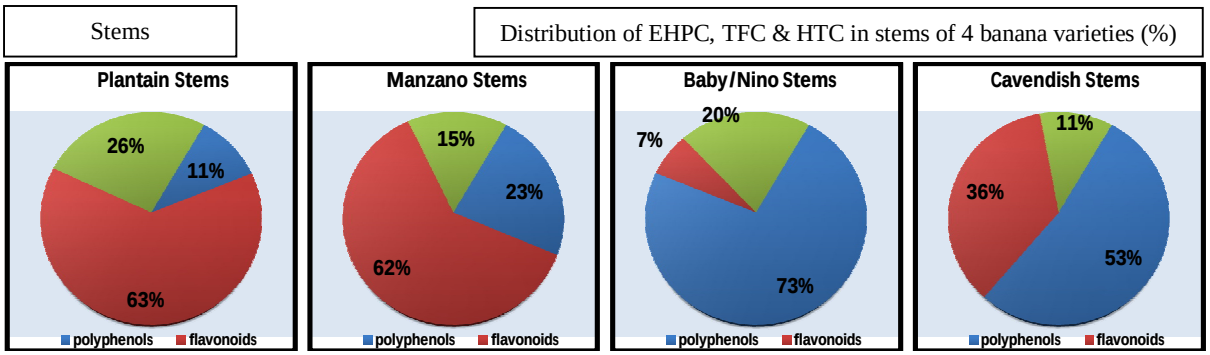

Figure 4

3.2. DPPH Free Radical Scavenging Activities of Different Parts of Banana Plants (IC_{50})

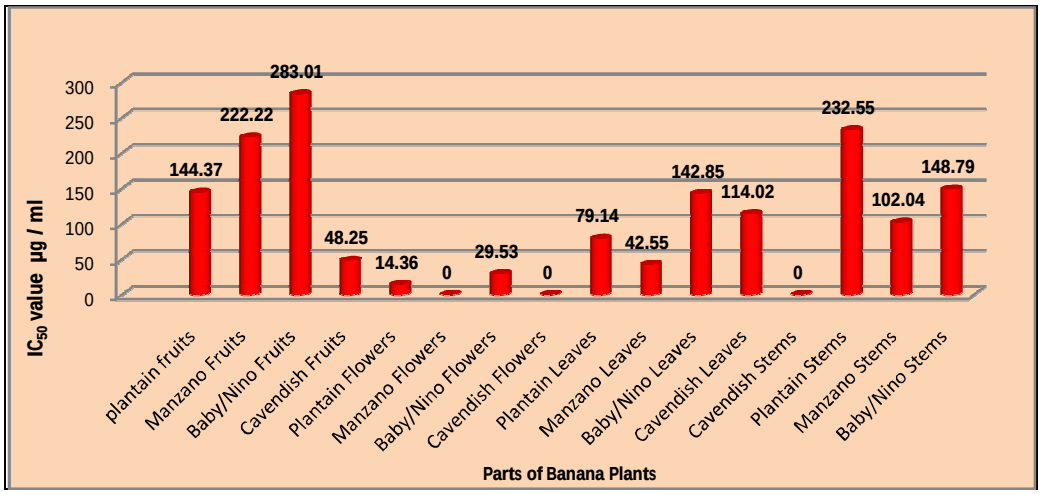

*Figure 5: An overview of IC_{50} values in different parts of four varieties of banana plants (based on 10 different conc. from 10-300 **µg**) *results averaged (triplicate data) and expressed as ± SD*

3.3. Correlation Study

3.3.1. Plantain -- Correlation between EHPC, TFC, HTC distributed in different parts & IC_{50}

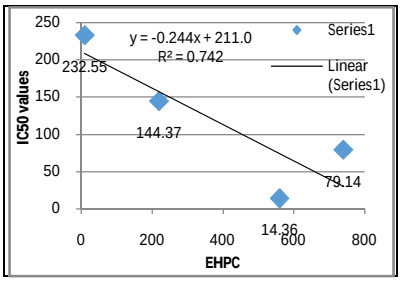

Figure 6

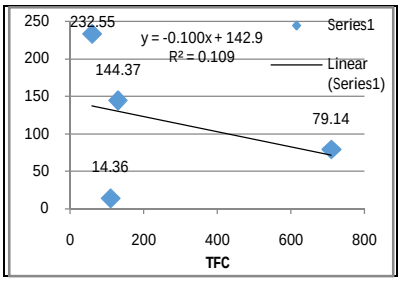

Figure 7

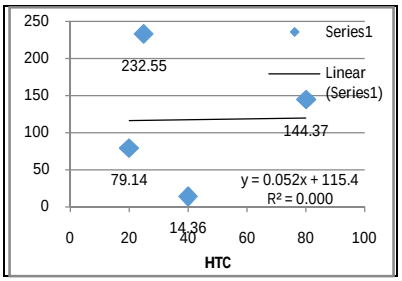

Figure 8

3.3.2. Manzano -- Correlation between EHPC, TFC, HTC distributed in different parts & IC_{50}

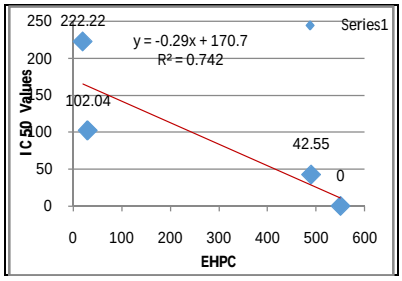

Figure 9

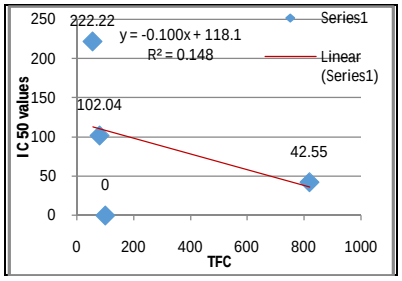

Figure 10

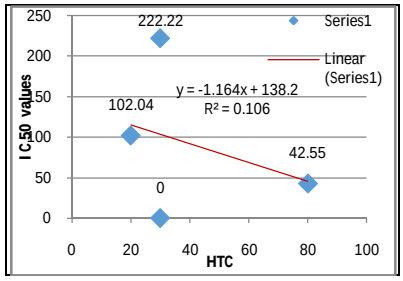

Figure 11

3.3.3. Baby / Nino -- Correlation between EHPC, TFC, HTC distributed in different parts & IC_{50}

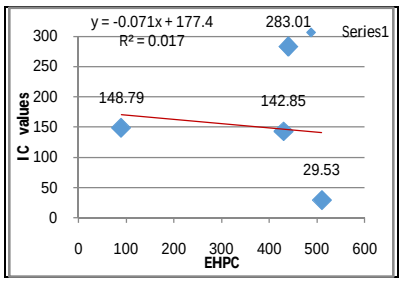

Figure 12

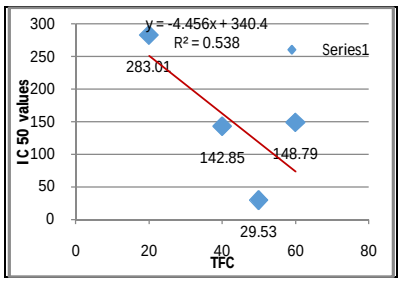

Figure 13

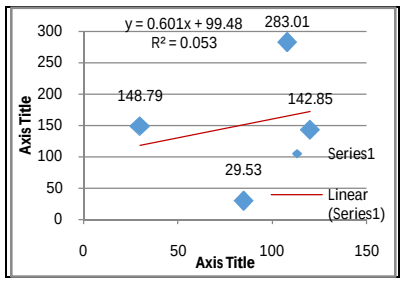

Figure 14

3.3.4. Cavendish -- Correlation between EHPC, TFC, HTC distributed in different parts & IC_{50}

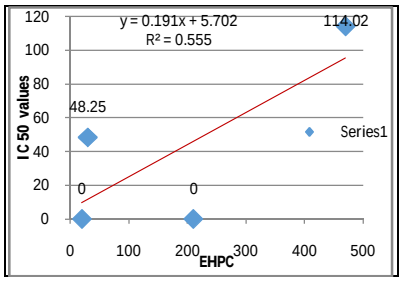

Figure 15

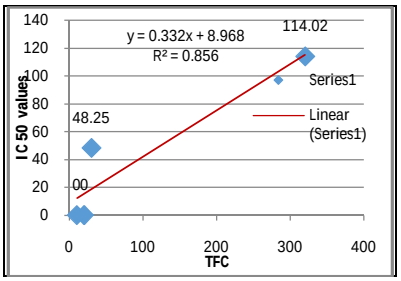

Figure 16

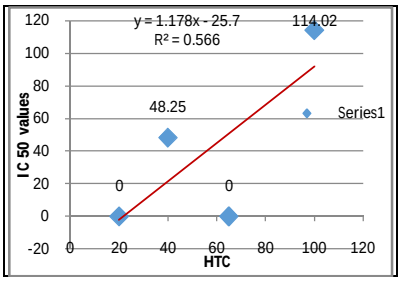

Figure 17

The total extractable hydrophilic polyphenolic compounds (EHPC) (Agarwal et al., 2012)[1] (Barros et al., 2007)[5] total flavonoid content (TFC) (Padam et al., 2012)[19] (Sultana et al., 2008)[28] total hydrolysable tannin content (HTC) (Padam et al., 2012)[19] (Sultana et al., 2008)[28] as well as the DPPH Free Radical Scavenging Activities have been ascertained with respect to the different parts namely, fruits, leaves, flowers and stems of the four different cultivars (Plantain, Manzano, Cavendish & Baby/Nino) of banana plants collected locally.

3.4. Distribution of Total Extractable Hydophilic Polyphenolic Compounds (EHPC)

3.4.1. Inter Cultivars

From this study, it is revealed that, the leaves of the two cultivars (Plantain-740µg/100g & Cavendish-470µg/100g) of banana plants are the richest source of Total Extractable Hydrophilic Polyphenolic Compounds (EHPC), while the flowers of other two cultivars (Manzano-550µg/100g & Baby/Nino-510µg/100g) had served the same purpose, among the plant parts under study. On the contrary, the lowest values of EHPC have been depicted by the stems of Plantain, Cavendish & Baby banana plants (10, 20 & 90µg/100g respectively) and by the Manzano fruits (20µg/100g).

3.4.2. Intra Cultivars

Among the fruits of all the four types of banana plants, Baby fruits (440µg/100g) showed the highest EHPC, followed by Plantain fruits (220µg/100g), whereas, the other two fruits depicted considerably lower values (Manzano fruits-20 µg & Cavendish fruits-30µg/100g). The leaves of all the types contained moderate to higher EHPC, where comparable data have been observed in case of three cultivars of banana leaves, viz. Manzano, Cavendish & Baby leaves (430-490µg/100g), the highest EHPC value being represented by the Plantain leaves (740µg/100g). Likewise, the flowers of three cultivars (Plantain-560, Manzano-550 & Baby-510µg/100g) depicted comparable data w.r.t EHPC, leaving the Cavendish flowers with a lower EHPC value (210µg/100g). The stems of all the four types had generally a lower EHPC (10-90µg/100g). Thus, the data revealed that w.r.t. the total extractable hydrophilic polyphenols, the Plantain banana plant was much richer than the other three cultivars of banana plants. All the data are being tabulated in Table 1.

3.5. Distribution of the Total Flavonoids Contents (TFC)

3.5.1. Inter Cultivars

Generally, the leaves of the banana plants showed rich TFC contents. For Manzano, Plantain & Cavendish cultivars, leaves have been the richest sources (820, 710 & 320µg/100g respectively) of TFC, but in case of Baby plants, stems have been associated with highest value (60µg/100g) of TFC. On the contrary, the poorest values of TFC have been represented by the fruits of Manzano & Baby banana 55 & 20µg/100g respectively, whereas, by the flowers of Cavendish & stems of Plantain banana showed 10 & 60 µg/100g respectively.

3.5.2. Intra Cultivars

As evident from Table 1, the richest source of TFC in banana plants have been the leaves, except the Baby cultivar, which had the lowest TFC content among the leaves (40µg/100g); TFC values of other cultivars being: Plantain-710, Cavendish-320 & Manzano-820µg/100g; the latter being the richest source of TFC among all the plant parts under study. With respect to the banana flowers, while the Plantain & Manzano have been associated with comparable figures (110 & 100 µg/100g respectively), Baby & Cavendish flowers showed lower values (50 & 10µg/100g respectively). Only the Plantain fruits have had a moderate TFC content (130 µg/100g); other fruits being represented with lower TFC contents (55, 30 & 20µg/100g by Manzano, Cavendish & Baby fruits respectively). Moreover, the stems of all the types also depicted a lower TFC values, ranging from 20-80µg/100g (vide Table 1).

3.6. Distribution of the Total Hydrolysable Tannin Contents (HTC)

3.6.1. Inter Cultivars

In case of Hydrolysable Tannin Content (HTC), believed to have some general antimicrobial and antioxidant activities (Padam et al., 2012)[19] (Sultana et al., 2008)[28] the highest value (being represented by the Baby leaves) among all the four plants have not crossed the 120µg/100g (ranging from 20-120µg/100g). It is established in the Table 1, that generally the leaves had highest HTC, except the Plantain leaves, which showed the lowest value of HTC, being 20µg/100g. Only the fruits of Baby/Nino had the richest HTC of 108µg/100g, other fruits resulted in lower values (<80µg/100g). Both, the flowers (30-85µg/100g) & stems (20-30µg/100g) have had generally lower HTC.

3.6.2. Intra Cultivars

The hydrolysable tannin content in the banana plants had low to moderate values (20-120µg/100g) when all the parts of the four types have been compared. Among the fruits, while Plantain & Baby cultivars showed moderate HTC (80 & 108µg/100g respectively), the Manzano & Cavendish fruits depicted lower values (30 & 40µg/100g respectively). In case of stems all the varieties have been associated with low and almost same HTC (20-30µg/100g). Among the leaves, three cultivars, namely, Manzano, Cavendish & Baby leaves have had moderate and comparable HTC (80, 100 & 120µg/100g respectively), leaving the Plantain leaves with low HTC value (20µg/100g). The flowers of all the cultivars also showed generally low values of HTC ranging from 30-85µg/100g.

Percent-wise distribution of EHPC, TFC & HTC in the fruits of the four different banana plants was depicted in Fig.-1. Moreover, percentage-wise distribution of EHPC, TFC & HTC in the flowers, leaves and stems of these four different banana plants has been showed in Fig.-2, Fig.-3 and Fig.-4 respectively.

Fig.-5 is a graphical elaboration of the overview of DPPH free radical scavenging activities of different parts of four different cultivars of Banana Plants and Prediction of Inhibitory Concentration values at 50% Inhibition (IC_{50}). The

results have been averaged (triplicate data) and expressed as $\pm$ SD in µg/ml of sample required, to inhibit 50% DPPH free radicals, with showed a lower value associated with higher antioxidant property, resembles with the previous work (Alothman et al., 2009)[2] (Karuppiah et al., 2013)[16].

From this graph it is clear that the lowest antioxidative effect being represented by Baby/Nino fruits (283.01µg/ml) among all the plant parts of the four different cultivars under study. Among the four different cultivars of banana fruits analysed, the Cavendish fruits have expressed the highest antioxidant property (48.25µg/ml), followed by Plantain (144.37µg/ml) & Manzano fruits (222.22µg/ml). In continuation of the work with the different flowers of the banana plants, it has been revealed that, both the Manzano & Cavendish cultivars did not produce any significant results, while the Plantain flowers emerged out to be the strongest antioxidant, having the IC_{50} value of only 14.36µg/ml. The Baby/Nino flowers also possessed a stronger antioxidant action, IC_{50} being 29.53µg/ml. The leaves of Manzano had the highest antioxidative property (42.55µg/ml), followed by Plantain (79.14µg/ml), Cavendish (114.02µg/ml) & Baby leaves (142.85µg/ml). Among the stems, as the Cavendish stems did not produce any significant data, the Manzano stems depicted the highest antioxidant action (102.04µg/ml). While the stems of the Plantain banana (232.55µg/ml), being the weakest in action to quench the free DPPH radicals, Baby/Nino stems showing a moderate action (148.79µg/ml).

Thus, the most effective antioxidant effect (Rajesh et al., 2014)[8] (Ebrahimzadeh et al., 2010)[11] was exhibited by the Plantain flowers, having IC_{50} value of 14.3655µg/ml, which means that to inhibit or destroy the 50% free radical of DPPH, only 14.36µg/ml of flower extract in 80:20 methanol:water was required. The Manzano flowers did not show any representable antioxidant property. This result was in concurrence with the values, which showed that Plantain flowers represented high proportion of chemical constituents w.r.t. total EHPC, TFC and total HTC contents, when compared to Manzano flowers. Thus, it may be concluded that, the total EHPC, TFC and total HTC of the Plantain flowers in congruence, would have been effective and efficient to demonstrate the inhibitory action towards quenching of the free radicals of DPPH to a better extent. Manzano leaves (IC_{50} - 42.55µg/ml.), being the next higher in antioxidant property. Among the fruits, the Plantain variety showed higher antioxidant property (144.37µg/ml) than the Manzano fruits (222.22µg/ml). On the contrary, the stems of Manzano showed more than two-fold higher antioxidant property (102.04µg/ml) than that showed by the Plantain stems (232.55µg/ml).

The correlation between free radical scavenging and total phenol content (Polshettiwar et al. 2007)[21] of Manzano and Plantain cultivars of banana plants had a significant correlation coefficient of R^2=0.742, whereas in case of baby and Cavendish cultivars correlation coefficient is R^2=0.017 and R^2=0.555 respectively. It suggests that 74% of the free radical scavenging of these two cultivars (Plantain, Manzano) is contributed by phenolic compounds. The antioxidative activity of polyphenols is generally ascribed to their hydroxyl groups (Rajesh et al., 2014)[8]. The remaining 25% of free radical scavenging activity may come from the presence of other active components like vitamins, carotenoids and other carbohydrates. The correlation between flavonoids with free radical scavenging activity is found to have a correlation coefficient of R^2=0.109, 0.148, 0.538 and 0.036 for Plantain, Manzano, Baby and Cavendish cultivars respectively suggested that Baby cultivars only have the significant correlation and in case of correlation between tannins and free radical scavenging activity, significant correlation is showed by Cavendish cultivar. All the correlation graphs are depicted by Fig-6 to Fig-17.

4. Conclusion

In this study, the distribution of extractable hydrophilic polyphenolic compounds (EHPC), total flavonoids content (TFC), total hydrolysable tannin content (HTC) and the DPPH free radical scavenging activity (IC_{50}) in different parts of four cultivars of banana

plants have been ascertained. Correlation studies were carried out between IC_{50} and EHPC, TFC, HTC respectively. After analysing all the results it can be concluded in a nut shell that:

Plantain fruits having richer constituents of polyphenols, flavonoids and tannins (which are hydrolysable chemically) and also have higher antioxidant property. Despite of having lower polyphenolics, the Cavendish fruit revealed the best antioxidant property among all the fruits under study. The fruits of Baby/Nino banana have richer polyphenols and tannins but lesser content of flavonoids. Moreover, the higher tannin content may to some extent lessen the antioxidative efficiency of the fruits of Baby/Nino. Thus the Cavendish fruits may be the better option to consume as food in addition to the Plantain fruits.

The Plantain flowers having higher EHPC, TFC and also showing highest antioxidant property will be better to be consumed as a food.

The stems of the Baby/Nino cultivar have higher percentage of polyphenols than the stems of the Manzano banana plants, but the later is richer w.r.t. the TFC than its counterpart. Moreover, the IC_{50} value of Manzano stems suggests it is to be the best cultivar as far as the antioxidant activity is considered. Thus, Manzano stems may be the recommended cultivar for consumption.

The leaves of Manzano, Cavendish & Plantain cultivars show comparable phenolics but the Manzano leaves depicting a two-fold efficient anti-oxidant activity may be recommended as an effective wrapping material to be used during cooking of foods.

5. Acknowledgements

Research conducted with contribution from: Dept. of Home Science,, University of Calcutta, West Bengal, India, for funding and infrastructural support.

6. References

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