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NUTRITIONAL ANALYSIS OF FRESH BANANA FRUITS (*MUSA* SPP.) GROWN IN SOUTH TUNISIA

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Abstract

Partial nutritional analysis including total polyphenols, vitamin C, total soluble solids (°Brix), soluble sugars and mineral constituents was evaluated for the banana fruits derived from six triploid *Musa* accessions grown in coastal oasis of south of Tunisia. Results showed that pH values ranged from 5.44 to 6.01. The °Brix values varied between 4.00 g/100 g (Fresh weight) FW in 'Arbi IRA', and 1.33 g/100 g FW in 'Lobnani'. Carbohydrates were quantified in all tested samples of the six accessions of banana fruits whereas sucrose was detected only in four accessions. The highest values of glucose, fructose and sucrose were 2.7, 3.37and 1.8 g/100 g FW, respectively. Total polyphenols content ranged from 46.0 to 55.08 mg GAE /100g FW. Vitamin C was detected in smaller quantity. Regarding the mineral composition K, P and Na were found in relatively large quantities in banana fruits whereas the levels of Mg and Ca were medium. Significant disparities were detected in mineral contents of banana samples. The micro-elements composition such as zinc, copper, iron and magnesium varied according to the tested accessions. The analysis showed a high Fe content of up to 1945 mg/100g dried matter. Therefore, banana fruits may be recommended for daily supplies of Fe, K and other mineral elements.

Introduction

The relationship between food and health has been acknowledged for thousands of years. For a healthy immune system, healthy food is essential in providing all the nutrients essential for maintaining good health. It should contain several complex chemicals: micronutrients, carbohydrates, vitamins, minerals, and proteins. Since, such food compositions have been known now, consumption of fresh fruits and natural juices have increased widely not only for those nutrients, but also for their therapeutic effects.

Recently, there is an increased interest on the part of consumers, researchers, and the food industry in determining how food products can help in maintaining good health and the importance of diet in the prevention and treatment of many illnesses (Viuda-Martos *et al.* 2010*a*). Now-a-days, considerable importance is given to useful foods that provide great physiological advantages and plays a vital role in prevention of illnesses or in slowing down the advancement of chronic ailments (Viuda-Martos *et al.* 2010*b*). Bananas provide approximately 2.7 % of the entire fiber and K eaten by a normal adult. In Africa, it was estimated that consumption of bananas provided more than 200 calories per day to nearly 60 million people (Stover and Simmonds 1987).

In Tunisia, banana has a historical importance especially during the 1990s. Throughout this time, the quantity of rains was very important especially in the southern region of Tunisia where banana grew well. Farmers have based their agronomic activities on the banana production grown

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in the coastal oasis. Consequently, banana consumption has become a pillar of the Tunisian diet. Global banana and plantain were the 4th utmost vital food produced following wheat, rice and maize relating to total worth of produce. Nearly 90 % of plantains and bananas generated worldwide (63 million tons) were consumed locally in the producing countries, the export share was only 10 % (CGIAR 1992, 1993).

Banana is extremely wholesome and simply edible as compared to various fruits. Bananas fruit are famous for their good fragrance and texture as well as being abundant in calcium and potassium content and lesser in sodium (Mohapatra *et al.* 2010). In the present study an attempt was taken to highlight the chemical profiling like vitamin C, soluble sugar, °Brix, polyphenols, acidity, and mineral configuration of the triploid *Musa* accessions cultivated in coastal oasis of South Tunisia which represents only North African maritime oasis (Chair *et al.* 2009). Their nutritional values were also discussed. It is the first work that is done on the nutritional analysis of Tunisian banana fruits.

Materials and Methods

To evaluate the triploid banana accessions origin and their growing methods, a questionnaire survey in costal oasis of South Tunisia was prepared. Six triploid *Musa* accessions were identified, the level of ploidy was ascertained by flow cytometry (unpublished data). Two accessions were harvested from the coastal oasis of Gabes and four accessions were gathered from IRA (Institute of Arid Regions).

Samples were collected during the period of peak production (April to July 2018). One hundred and twenty samples were collected randomly throughout the two selected regions.

The banana juice was prepared according to the protocol described by Cano *et al.* (1997) and preserved at -20°C until required. The resulting juice was centrifuged for 10 min at 2,500 rpm. The supernatants from the centrifugation step of the banana juice extract were recovered, filtered prior to experimentation. Acidity of banana juice was calculated as a percentage of citric acid by titrating 10 ml of banana juice with NaOH 0.1N solution until pH 8.1 using a Sartorius PB-10 pH meter (Sartorius, Germany). The pH was measured by a pH meter (InoLab, Germany). The quantity of sugars was calculated by a digital refractometer as °Brix (Cambridge Instruments Inc, Models 10430, 0- 30° Brix).

The fresh banana fruit (30g) was blended and homogenized with an extracting solution containing orthophosphoric acid (20ml). The mixture was kept in a conical bottle covered by aluminium foil and agitated at 9000 rpm at 20°C for 20 min. Samples were taken out in triplicates. Ascorbic acid analysis was done on a Bechman M332 HPLC system. The chromatographic split was attained on a RP-HPLC column, by isocratic release of a mobile stage (A/B 33/67): A: 0.1 M potassium acetate (pH= 4.9), B: acetonitrile-water (80:20) at a rate of flow of 1.2 ml/mn. UV absorbance was recorded at 254 nm at room temperature. Ascorbic acid identification was achieved by comparing the retention time of L-ascorbic acid purchased from Sigma Co. Ascorbic acid standard was made in metaphosphoric acid (0.3 M) acetic acid (1.4 M) solution by dissipating 100 mg of L-ascorbic acid at the concentration of 0.1 mg/ml. The calibration line was divided into linear range based on four concentration levels. Each point was the average of three peak area measurements.

The nonreducing and reducing sugars from banana fruit juice were determined (Elfalleh *et al.* 2009) by high-pressure liquid chromatography (HPLC) (Knauer Wellchrom model, Germany). Twenty five ml of pure water was added to 3g of each fruit samples. The mixture was centrifuged at 9000 rpm for 15 min and then filtrated by a 0.45 μm membrane filter. Separation was done on Eurospher NH_2 column, 100 Å pore size, 7 μm particles size, 250 mm 4.6 mm at room temperature (Knauer, Germany). The integrator was calibrated with external standards consisting of solutions of glucose (20 g/l), fructose (20 g/l) and sucrose (10 g/l). Every sample was examined in triplicate and quantification was done from integrated pick of the sample in contrast to the matching standard graph. The highest surfaces were ascertained by the Eurochrome 2000 software.

Fresh banana (0.5 g) pulp from each accession was extracted and stirred with 100 ml of MeOH. Aascorbic acid (80 mg) was dissolved in 15 ml of distilled water and added to the flask. 10 ml/ (6M) of hydrochloric acid was inserted in the mixture. The flask was well shaken and placed in the dark. After 16 hrs, the extract was filtered by Whatman no.1 filter paper and ready for assay. Entire phenols were assessed by the Folin-Ciocalteu method. The 25 µl from each sample was diluted with 10 ml of distilled water and 50 µl of Folin-Ciocalteu (Prolabo) reagent was added. After 3 min, 4 ml of Na_2CO_3 (1M) was also added. Then, tubes were placed for 30 minutes in dark. The reading of the absorbance was done at 765/nm applying a Shimadzu 1600-UV spectrophotometer (Elfalleh *et al*. 2009). Total phenolic components of every fraction were changed in mg equivalents of gallic acid per g fresh weight (mg GAE/g FW).

An atomic absorption spectrophotometer (SHIMADZU AA, model 6800) was used to quantify the minerals content (Na, K, Cu, Fe, Ca, Mg, Zn and Mn). The solution used for the analysis was prepared as follows: after the calcination of 4 g dried plant material (pre-drying oven) in oven at 550 °C for 4 hrs, the ashes were treated by 5 ml of conc. hydrochloric acid and 5 ml of ultra-pure water and then boiled. The mixture was double filtered and the filtrate was recovered in a graduated flask of 100 ml and then supplemented by ultra-pure water.

The phosphorus quantification was performed using a UV spectrophotometer previously calibrated with known concentration solutions 0, 2, 4, 6, 8 and 10 mg/l. In test tubes, 1 ml of the solution, 4 ml of ultra-pure water and 5 ml of the reagent vanado-molybdic were added. The tubes were kept in darkness and in ambient temperature for 15 min approximately in order to develop yellow coloration. The reading of the absorption followed by the samples concentration was carried out with a wavelength of 430 nm.

Results of compound contents were reported as mean values of three replicates (mean ± standard deviation, n = 3). Data were compared based on standard deviation of the mean values. Differences between mean values were assessed using a one-way analysis of variance (ANOVA) with a post-hoc determination using Duncan's multiple range tests. The amount of significance was finalised at $p < 0.05$. The principal component analysis (PCA) was applied on all studied chemical parameters using XLSTAT.

Results and Discussion

The titrable acidity ranged from 0.64 (Gabssi khchin) to 1.28 (Arbi IRA) and the pH values ranged from 5.44 (Arbi IRA) to 6.01 (Gabssi khchin). Significant differences were observed in pH values between studied banana accessions (Table 1). Arbi IRA had the highest total soluble solids (4°Brix) and Lobnani had the lowest one (1.33°Brix). Three soluble sugars were identified as glucose, fructose and sucrose in studied banana fruits. Glucose and fructose were the major soluble sugars whereas sucrose was detected only in four banana accessions (Table 1). According to Table 1, Gabssi jwaid banana accession had the highest value of glucose and Arbi IRA had the highest fructose, 2.7 and 3.37 g/100g FW, respectively. 'Lobnani' accession had the lowest glucose and fructose proportions (1.16 and 1.35 g/100 g FW) (Table 1).

Quantitatively vitamin C content in all studied banana accessions ranged from 0.5 to 0.9 mg/100g MF and were statistically significant (Table 2). Banana fruits have ascorbic acid content higher than that of palm date fruit with an average of 0.4 mg/100 g FW (USDA 2015).

The quantity of entire phenolics (Table 2) was found to range from 46.00 to 55.08 mg GAE/g based on the fresh weight (mg GAE/g FW) and were statistically significant More than 8,000 phenolic compounds encompass an extensive variety of secondary metabolites in plants (Pietta 2000). They play a significant function in plant metabolism, but also protect the plant against stresses.

Dicko *et al.* (2005) showed that plant resistance to both biotic and abiotic stresses was associated with phenolic compounds (. A higher number of reactive oxygen species such as singlet oxygen ($^1O_2$), superoxide anion radical (O_2•-), hydroxyl radical (OH•), nitric oxide radical (NO•) and alkyl peroxyl (ROO•) are regularly produced in the human body (Langseth 1995). Phenolic compounds jointly with additional natural compounds (vitamins C, E, and carotenoids) provide resistance by scavenging free radicals, inhibiting oxidative enzymes such as lipoxygenase, cyclooxygenase and chelating metal ions (Shi *et al.* 2001).

The average values of studied minerals (P, Na, K, Cu, Fe, Ca, Mg, Zn and Mn) of different *Musa* accessions are presented in Table 3. The level of mineral elements varied depending on accessions (Table 3). Potassium is the major element having the highest rate with an average of 1211.68 mg/100 g DM. The 'AIcv' is characterized by the highest levels of potassium by 1542 mg/100 g DM), while the 'Scv' is considered the poorest one by an average of 961 mg/100 g DM). K, P and Na were found in relatively large quantities in banana fruits whereas the levels of Mg and Ca are medium. 'Gchcv' is characterized by higher proportion of Cu with an average of 17.5 mg/100 g DM, while the lowest was given by the 'Scv' (10.4 mg/100 g DM). Concerning P content, the highest level was recorded in AIcv (47.2 mg/100 g DM) whereas the lowest quantity was identified in 'Lcv' (23 mg/100 g DM). Potassium ranked well ahead. The average of K content was about 1542 mg/100 g DM registered in samples of the 'AI' accession, which was considered as the richest banana fruits in mineral elements in the present study. Banana brought much more potassium than lemon (53 mg/100 g), fisheries (150 mg/100 g) and apple (120 mg/100 g) (Favier *et al.* 1995). It had been stated that the potassium content varied from 350 to760 mg/100 g DM in banana fruits (*Musa acuminata*. var Cavendisch Dwarf) from the Tenerife and Canary Islands, respectively (Hardisson *et al.* 2001). In the present study, it was found high potassium content in studied banana fruit ranging from 961 to 1542 mg/100 g DM. Potassium represented the major macro element of table fruits (Jimenez *et al.* 1997).

Table 1. Names, origin, and chemical properties of Tunisian bananas fruits.

Accession	Origin		pH	Acidity (%)	Total soluble solids (°Brix)	Soluble sugars (g/100g FM)		
						Glucose	Fructose	Sucrose
"Arbi IRA"	IRA* Medenine	AGcv	5.44 ± 0.52^a	1.28 ± 0.32^a	4.00 ± 0.2	2.53 ± 0.017	3.37 ± 0.016	0.01 ± 0.0015
"Gabssi jwaid"	IRA* Medenine	Scv	5.57 ± 0.15^{ab}	0.85 ± 0.18^a	2.00 ± 0.4	2.70 ± 0.0075	3.25 ± 0.002	00±00
"Gabssi khchin"	IRA* Medenine	AIcv	6.01 ± 0.35c	0.64 ± 0.55^a	3.2 ± 0.2	1.3 ± 0.0001	1.60 ± 0.0005	1.80 ± 0.001
"Lobnani"	IRA* Medenine	GJcv	5.67 ± 0.04^{bc}	1.17 ± 0.37^a	1.33 ± 0.76	1.16 ± 0.004	1.35 ± 0.005	00±00
"Arbi Gabes"	Gabes	Gchcv	5.76 ± 0.03^c	0.85 ± 0.18^a	1.93 ± 0.41	1.51 ± 0.01	1.83 ± 0.014	0.87 ± 0.025
"Spani"	Gabes	Lcv	5.58 ± 0.25^{ab}	1.07 ± 0.18^a	2.06 ± 1.02	2.05 ± 0.004	2.30 ± 0.002	1.00 ± 0.011

*Institute of Arid Areas. $^c p < 0.05$; $^b p < 0.01$; $^a p < 0.001$ compared compared to control; Data are mean of three replicates ± SD.

Table 2. Total phenols and vitamin C contents of fruit extracts of Tunisian *Musa* accessions.

Accessions	Vitamin C (g/100g MF)	Total polyphenols (mg GAE /100g MF)
AGcv	0.008 ± 3.6 E-05^{b}	55.08 ± 1.35^{b}
Scv	0.009 ± 2.2 E-04^{a}	46.00 ± 1.8^{a}
AIcv	0.0065 ± 6 E-06 ^{c}	53.83 ± 3.76 ^{bc}
GJcv	0^{e}	47.80 ± 3.9 ^{ab}
Gchcv	0.007 ± 3.7 E-04^{b}	48.20 ± 2.73 ^{ab}
Lcv	0.005 ± 1.1 E-04^{d}	49.12 ± 4.3 ^{ab}

$^{c}p < 0.05$; $^{b}p < 0.01$; $^{a}p < 0.001$ compared compared to control; Data are mean of three replicates ± SD.

Table 3. **Mineral composition of the Tunisian Musa accessions (mg/100 g DM).**

Accessions	Na	K	Cu	Fe	Ca	Mg	Zn	Mn	P
AGcv	6.54^{b}	1050^{b}	15.3^{b}	0.155^{a}	0.15^{e}	0.59^{a}	0.15^{a}	0.15^{a}	29.8^{c}
Scv	4.77^{a}	961^{a}	10.4^{c}	0.193^{b}	0.15^{a}	0.58^{a}	0.20^{b}	0.20^{b}	26.6^{b}
AIcv	11.3^{b}	1542^{c}	15^{b}	1.945^{b}	0.16^{b}	0.53^{b}	2^{b}	0.22^{c}	47.2^{c}
GJcv	10 ^{a}	1330^{b}	14^{c}	0.827^{e}	0.15^{c}	0.48^{b}	0.83^{a}	0.22^{c}	32.5^{b}
Gchcv	9.05^{c}	1174^{c}	17.5^{c}	0.245^{c}	0.48^{c}	0.68^{a}	0.24^{c}	0.24^{e}	42.7^{a}
Lcv	10.2^{c}	1212^{b}	14^{a}	0.302^{b}	0.13^{b}	0.53^{c}	0.30^{c}	0.30^{a}	23^{a}
Mean ± SD	9.24 ± 2.51	1211.68± 206	0.24 ± 0.14	0.61 ± 0.7	14.45 ± 2.4	70.78 ± 18.5	0.56 ± 0.07	0.22 ± 0.05	33.6 ± 9.45

$^{c}p < 0.05$; $^{b}p < 0.01$; $^{a}p < 0.001$ compared compared to control; Data are mean of three replicates ± SD.

Hardisson *et al.* (2001) found that the levels of sodium for the *Musa acuminata* cultivars varied between 9 to 24 mg/100 g edible portion. It had been stated that the Na value varies between 9 to 10 mg/100 g in edible portion of 68 tropical fruits (Leterme *et al.* 2006). Bananas had low sodium levels when compared with other tropical fruits. The highest Ca content was found in Gchcv by 0.48mg/100 g DM. Calcium was an essential element for the cohesion of cells and had an important role in the conservation of fruits (Fallahi *et al.*1985). Leterme *et al.* (2006) had highlighted the valuable role of various tropical fruits as a major source of mineral elements and their usefulness in the daily diet of adults supported by the data provided by USDA/HHS (2015) which insisted about the importance of sodium intake of bananas especially during the breakfast.

In the present study, the magnesium content was found to range from 0.68 to 0.48 mg/100 g DM indicating a higher content of magnesium levels when compared with other tropical fruits such as papaya, pineapple and palm fishing having a mean value of 29 mg/100 g (Leterme *et al.* 2006). The phosphorus content ranged from 23.0 to 47.2 mg/100 g DM. These levels were lower than other fruits such as dates that have levels of 226 to 247 mg/100 g (Ercisli and Orhan 2007) and 57.4 to 91.6 mg/100 g (El'Mrabet 2005), respectively. The quantitative analysis of micro-elements composition showed high Fe content of up to 1.95 mg/100 g DM recorded with the 'AIcv'; the lowest was recorded in the 'AG' accession (0.16). Regarding other trace elements, the highest content of Mn was found in 'Lcv' (0.303 mg/100 g DM). The lowest amount was recorded in the 'AGcv' (0.155 mg/100 g DM). The maximum level of Cu and Zn was recorded in 'Gchcv' (17.5 mg/100g DM) and in 'Lcv' (0.30 mg/100g DM), respectively (Table 3). Results of quantitative analysis showed that banana fruits were richer in minerals and had a heterogeneous composition of macro and micro-elements. Duncan's test showed a significant difference in the mineral ingredients of banana fruits (Table 3). It had been stated that the variation in the mineral content in leguminous plants could be correlated to genetic origin, geographical sources, and the level of soil fertility (Apata and Ologhobo 1994). The studied banana fruits had high levels of micronutrients as for the Fe having a mean value of 0.61 mg/ g DM, which was higher than the banana varieties studied by El Mrabet (2005) who noted an 18.7 µg/100 g concentration of Fe.

Table 4. Variability percentages and loadings of original set of variables associated with principal components from chemical characterization of Tunisian banana fruits.

		F1	F2
	Variability (%)	45.168	22.172
	Cumulative (%)	45.168	67.340
Correlations			
pH		0.926	0.080
Acidity (%)		-0.557	-0.227
°Brix		-0.033	0.840
Glucose		-0.885	0.325
Fructose		-0.860	0.446
Sucrose		0.809	0.210
VitaminC		-0.358	0.784
Total polyphenols		0.273	0.671
Na		0.882	-0.291
K		0.948	-0.140
Cu		0.538	0.357
Fe		0.761	0.615
Ca		0.243	0.266
Mg		-0.181	0.617
Zn		0.842	0.053
Mn		0.329	-0.587
P		0.821	0.429

The Principal Component Analysis (PCA) was conducted on studied banana accessions using all chemical parameters. . Only the two calculations for extracting PC (PC1 and PC2) explaining 67.34% of the sample variability were used. The loading values of the variables associated with each PC are presented in Table 4. The examination of the loadings associated with each variable for the PC1 and PC2 singles out the variables most influencing these PC (Table 4). In the present case, the PC1 loadings are high and positive for pH, Na, K, Fe, Zn, and P contents and negative for glucose, fructose contents. °Brix, vitamin C and total polyphenols had high loadings on PC2 (Table 4 and Figure 1A). The PC1 and PC2 were applied for the score plot of variables and banana accessions in Fig. 1A and 1B. The clustering of the fruit samples according to their chemical profiling showed the clusters of Arbi Gabes and Gabssi khchin, of Arbi IRA and Gabssi jwaid and of Spani and Lobnani. The present investigation showed the richness of banana fruits from South Tunisia on TPC, soluble sugar and minerals contents. Therefore, consumption of foods produced with natural compound extracts (functional foods) were expected to prevent the risk of free radical dependent diseases. On the other hand, it may be suggested that banana are a useful source of K and Mg in the diet. A high level of potassium was detected in most of the studied accessions. Consequently, Tunisian triploid *Musa* accessions would be highly useful in providing health benefits beyond those provided by basic nutrients.

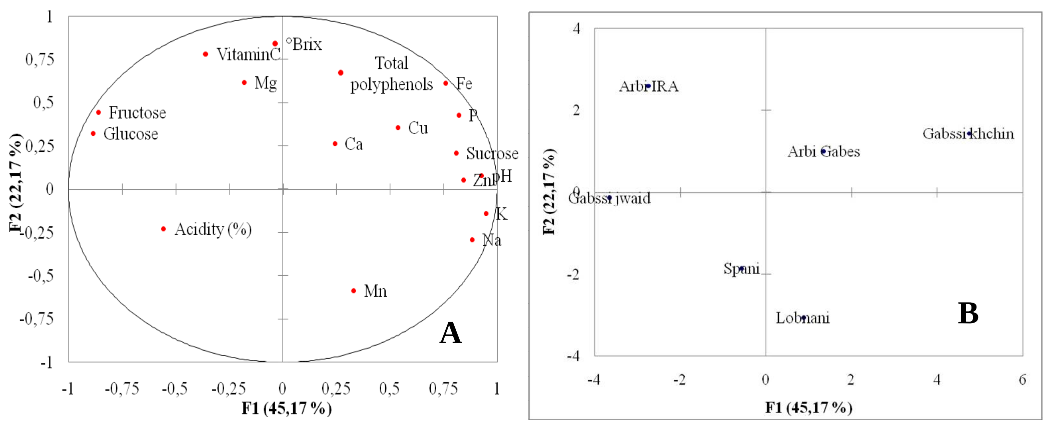

Fig. 1. Scatter plot of chemical data (**A**) banana sample scores (**B**) from first two principal components (PC1 and PC2) of the principal component analysis (PCA) based on the chemical data.

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