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Evolution of phytochemicals compounds of three plantain cultivars (*Musa* sp.) preserved by a method involving charcoal

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Abstract

Despite the good nutritional qualities and large production areas of plantain bananas, their production is subject to a lack of inexpensive conservation techniques that are accessible to everyone. For this, a conservation study combining charcoal and polyethylene bags was carried out. For this work, the fruits of the plantain varieties Saci, Big-Ebanga and Orishélé harvested at the mature stage were preserved in six different storage media. Some physicochemical and antinutritional parameters such as polyphenols, flavonoids and phytates of the pulps of the three varieties of plantain bananas were determined according to standard methods. The results obtained indicate that the storage time in the media containing charcoal exceeded 30 days, unlike the control media where the storage times were 12 and 24 days. of polyphenols between 120.66 and 1961.10mg/100g DM and finally of flavonoids between 0.76 and 7.23mg/100g DM. Regarding the antinutritional parameters, the phytate levels vary between 42.66 and 64.05mg / 100g DM.

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Introduction

The plantain banana is a fruit which, in addition to contributing to food security, is an excellent source of carbohydrates for its high content of complex carbohydrates (starch), thus providing consumers with the bulk of total energy with rates varying from 89 to 90.52 Kcal per 100g of dry matter (FAO, 2003). Apart from carbohydrate parameters, plantain also contains phytochemicals. Indeed, they are natural and biologically active chemical compounds in plants. They act as a natural defense system for host plants and provide color, aroma and flavor. They are localized on fruits, seeds, stem epidermis, flower and other peripheral surfaces of plants. They are a group of bioactive substances inherent in plants and are responsible for protecting these plants against environmental stress, microbial attacks, insects and other external aggressions (Daramola and Adegoke, 2011). The consumption of foods rich in phytochemical compounds such as carotenoids, polyphenols, isoprenoids, phytosterols, saponins, dietary fibers, polysaccharides, etc., allows, on a curative or preventive basis, to spare consumers from diseases such as diabetes, obesity, cancer, cardiovascular diseases, etc. (Ashwani *et al.*, 2023). In addition, the plantain (Musa spp), like most tropical fruits and vegetables, is highly perishable. Given its perishable nature, a practical, accessible and inexpensive method of preservation, unlike known methods, has been tested with the aim of contributing sustainably to food security by reducing post-harvest losses. The interest of this work is then to evaluate the impact of this charcoal-based preservation method on some phytochemical parameters of these plantain fruits during storage.

Materials and methods

Plant material

The plants of plantains of the SACI, Big-Ebanga and Orishelé varieties were identified and controlled during their development. The different harvest dates corresponding to optimum maturity were 70 days for the Orishélé variety and 80 days for those of SACI and Big-Ebanga. These dates were chosen according to the method of determining the cutting point described by Gnakri and Kamenan. (1990) and Kouadio *et al.* (2013) corresponding to the day of optimization of biochemical indices such as starch, water and total sugar contents are optimal. The harvested samples were detached from the bunches and transported to the conservation site while minimizing shocks and injuries.

Fig. 1. Plantain fruits at the stage of physiological maturity (Absence of fingers turning yellow on the bunch before harvest).

Extraction of phenolic compounds

The phenolic compounds were extracted with methanol according to the method of Singleton *et al.* (1999). A quantity of 1g of the dried and ground sample was homogenized in 10mL of 70% (v/v) methanol. The mixture obtained was centrifuged at 1000 rpm for 10 minutes. The pellet was recovered in 10mL of 70% (v/v) methanol and centrifuged again. The supernatants were combined in a 50mL flask and constituted the extract used for the determination of total phenols.

Dosage of total phenols

Total polyphenols were assayed according to the method described by Singleton *et al.* (1999). A volume of 1mL of methanolic extract was introduced into a test tube. To the contents of the tube was added 1mL of Folin-ciocalteu's reagent. The whole was left to stand for 3 minutes then 1mL of the 20% (v/v) sodium carbonate solution was added. The contents of the tube were completed to 10mL with distilled water and the whole was placed in the dark for 30 minutes. Absorbance was read at 725nm. The blank was prepared for each test tube, replacing Folin-ciocalteu's reagent with 70% (v/v) methanol. A standard range established from a stock solution of gallic acid (1mg/mL) under the same conditions as the test makes it possible to determine the quantity of phenols in the sample. The results obtained were expressed in equivalentmg of gallic acid per 100g of DM.

Determination of flavonoids level

Flavonoids were determined according to the method of Meda *et al.* (2005). The flavonoids react with aluminum chloride in the presence of sodium acetate to give a yellow-colored complex whose intensity is proportional to the quantity of flavonoids present in the medium. A volume of 0.5mL of the supernatant resulting from the extraction of the polyphenols was withdrawn and successively added thereto 0.5mL of distilled water, 0.5mL of aluminum chloride (10%, wp), 0.5mL of sodium acetate (1 M) and 2mL of distilled water.

The mixture was allowed to stand for 30 minutes at room temperature. Absorbance was read by spectrophotometer at 451 nm against blank. The optical densities were converted intomg of flavonoids using a calibration line (0.03-0.30mg/ml) prepared under the same conditions as the test from a quercetin standard solution at 0. 1mg/ml. The results obtained were expressed in equivalentmg of quercetin per 100g of DM.

Determination of phytates content

Phytates were determined according to the technique of Mohammed *et al.* (1986). About 5g of banana flour was weighed and 25mL of 3% trichloroacetic acid was added to it and then the mixture was gently stirred for 45 minutes at room temperature.

A sample of 8mL of the mixture was centrifuged at 3000 rpm for 15 minutes. Then, 5mL of the supernatant obtained was mixed with 3mL of a solution of ferric chloride hexahydrate ($FeCl_3.6H_2O$ 1% (v/v)) prepared in 1 N HCl, heated in a boiling water bath for 45 minutes, cooled, and then centrifuged at 3000 rpm for 10 min in a centrifuge. The resulting pellet was incubated with 1mL of 0.5 N HCl at room temperature for 2 h. Then, a volume of 7mL of water and 3mL of 1.5 N NaOH were added to it and then the mixture was heated in a boiling water bath for 15 minutes. Once cooled, the mixture was centrifuged at 3000 rpm for 10 min. Finally, 0.2mL of the supernatant was mixed with 4.6mL of water and 2mL of a chromogenic solution (0.03% $FeCl_3.6H_2O$ and 0.3% sulfosalicylic acid) then the mixture was heated at 95°C for 30 min.

After cooling, absorbance was read at 830 nm against a blank. A standard curve was established by treating 0.58 g of phytic acid as the sample and the phytate content of the plantain flour sample was expressed asmg of phytates per 100g of dry matter.

Statistical analysis

Statistical analysis of the data was carried out using the IBM SPSS STATISTICS 21 software. The comparison of the means was made according to the Tukey test at the 5% threshold.

Results

Total polyphenols

The total polyphenol contents of the fruits of the three varieties of plantain, namely, SACI (Table 1), Big-Ebanga (Table 2), and Orishélé (Table 3) increased significantly ($p \leq 0.05$) during storage with a significant difference ($p \leq 0.5$) between total polyphenol levels of the fruit during storage.

The rate of total polyphenols of the SACI variety was 205.88mg/100g DM on day 0. Concerning the SACI without packaging (SA), the rate was 1541.66mg/100g DM at the end of storage (day 12) and 1864.49mg/100g DM for SACI stored in carbon-free polyethylene bags (SSC), at the end of storage (day 24).

After 30 days of storage (end of green life), the total polyphenol contents were respectively 1821.64mg/100g DM for SACI stored in polyethylene bags containing dry solid carbon (SACSS), 1961.10mg/100g DM for SACI in polythene bags containing humidified solid carbon (SACSH), 1781.68mg/100g DM for SACI in polythene bag containing dry powdered carbon (SACPS) and 1754.87mg/100g DM for SACI in polyethylene bags containing humidified carbon powder (SACPH).

Table 1. Evolution of the total polyphenol level of the SACI variety in six storage environments.

Shelf life (days)	Total polyphenols of SA (mg/100g DM)	Total polyphenols of SACSS (mg/100g DM)	Total polyphenols of SACSH (mg/100g DM)	Total polyphenols of SACPS (mg/100g DM)	Total polyphenols of SACPH (mg/100g DM)	Total polyphenols of SSC (mg/100g DM)
0	205.88 ± 0.01^{aA}					
4	206.64 ± 0.14^{bA}	246.65 ± 0.02^{aB}	273.92 ± 0.02^{aD}	294.75 ± 0.05^{aE}	276.19 ± 0.03^{aD}	265.09 ± 0.10^{aC}
8	619.15 ± 0.04^{cF}	321.15 ± 0.06^{bA}	329.47 ± 0.02^{bB}	376.05 ± 0.03^{bE}	361.31 ± 0.07^{bD}	343.85 ± 0.04^{bC}
12	1541.66 ± 0.05^{dF}	364.45 ± 0.04^{cA}	398.73 ± 0.03^{cC}	417.74 ± 0.03^{cD}	393.32 ± 0.03^{cB}	433.84 ± 0.03^{cE}
16		456.93 ± 0.03^{dA}	478.16 ± 0.05^{dB}	529.65 ± 0.04^{dC}	632.29 ± 0.12^{dD}	755.40 ± 0.08^{dE}
20		659.82 ± 0.03^{eA}	724.95 ± 0.57^{eA}	714.58 ± 0.26^{eA}	731.46 ± 0.39^{eA}	1373.58 ± 0.25^{eB}
24		819.58 ± 0.05^{fA}	977.58 ± 0.41^{fB}	1041.13 ± 0.04^{fD}	997.56 ± 0.27^{fC}	1864.49 ± 0.11^{fE}
28		1218.23 ± 0.12^{gB}	1297.73 ± 0.19^{gD}	1125.20 ± 0.15^{gA}	1234.33 ± 0.05^{gC}	
30		1821.64 ± 0.05^{hC}	1961.10 ± 0.08^{hD}	1781.68 ± 0.32^{hB}	1754.87 ± 2.31^{hA}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

SA: SACI without packaging; SACSS: SACI in polythene bags containing dry solid charcoal; SACSH: SACI in polythene bags containing moistened solid charcoal; SACPS: SACI in polythene bags containing dry powdered charcoal; SACPH: SACI in polyethylene bags containing moistened powdered charcoal; SSC: SACI in polythene bags without charcoal.

Table 2. Evolution of the total polyphenol level of the *Big-Ebanga* variety in six storage environments.

Shelf life (days)	Total polyphenols of B (mg/100g DM)	Total polyphenols of BCSS (mg/100g DM)	Total polyphenols of BCSH (mg/100g DM)	Total polyphenols of BCPS (mg/100g DM)	Total polyphenols of BCPH (mg/100g DM)	Total polyphenols of BSC (mg/100g DM)
0	401.97 ± 0.02^{aA}					
4	574.34 ± 0.29^{bC}	413.50 ± 0.36^{aA}	421.36 ± 0.05^{aA}	461.33 ± 0.17^{aB}	453.12 ± 0.05^{aB}	447.17 ± 0.07^{aB}
8	834.94 ± 0.04^{cF}	458.22 ± 0.03^{bA}	472.26 ± 0.05^{bB}	507.46 ± 0.07^{bE}	492.16 ± 0.06^{bC}	501.15 ± 0.04^{bD}
12	1231.62 ± 0.03^{dF}	531.22 ± 0.02^{cB}	539.65 ± 0.05^{cC}	547.15 ± 0.06^{cD}	524.77 ± 0.02^{cA}	568.15 ± 0.03^{cE}
16		611.34 ± 0.05^{dB}	631.85 ± 0.04^{dC}	683.08 ± 0.03^{dE}	641.39 ± 0.07^{dD}	607.33 ± 0.04^{dA}
20		674.13 ± 0.03^{eB}	662.84 ± 0.03^{eA}	704.36 ± 0.04^{eD}	768.72 ± 0.02^{eE}	681.14 ± 0.02^{eC}
24		881.35 ± 0.04^{fA}	898.66 ± 0.05^{fB}	921.18 ± 0.04^{fC}	923.16 ± 0.02^{fD}	1001.27 ± 0.02^{fE}
28		969.16 ± 0.04^{gC}	1071.93 ± 0.04^{gD}	937.44 ± 0.04^{gA}	951.13 ± 0.02^{gB}	
30		1137.18 ± 0.06^{hD}	1114.35 ± 2.21^{hC}	998.26 ± 0.08^{hB}	981.33 ± 0.03^{hA}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

B: Big Ebanga without packaging; BCSS: Big Ebanga in polyethylene bags containing dry solid charcoal; BCSH: Big Ebanga in polyethylene bags containing humidified solid charcoal; BCPS: Big Ebanga in polyethylene bags containing dry powder charcoal; BCPH: Big Ebanga in polyethylene bags containing humidified powder charcoal; BSC: Big Ebanga in polyethylene bags without charcoal.

Table 3. Evolution of the total polyphenol level of the *Orishélé* variety in six storage environments.

Shelf life (days)	Total polyphenols of O (mg/100g DM)	Total polyphenols of OCSS (mg/100g DM)	Total polyphenols of OCSH (mg/100g DM)	Total polyphenols of OCPS (mg/100g DM)	Total polyphenols of OCPH (mg/100g DM)	Total polyphenols of OSC (mg/100g DM)
0	120.66 ± 0.22^{aA}					
4	122.04 ± 01.69^{bB}	119.52 ± 0.13^{aA}	131.17 ± 0.08^{aD}	137.17 ± 0.09^{aE}	120.44 ± 0.04^{aAB}	127.40 ± 0.12^{aC}
8	408.81 ± 0.09^{cF}	139.43 ± 0.04^{bA}	145.86 ± 0.10^{bB}	161.38 ± 0.21^{bD}	173.71 ± 0.13^{bE}	151.26 ± 0.05^{bC}
12	958.73 ± 0.04^{dE}	255.62 ± 0.42^{cA}	256.88 ± 0.15^{cB}	255.46 ± 0.02^{cA}	275.21 ± 0.07^{cC}	281.31 ± 0.17^{cD}
16		422.33 ± 0.03^{dB}	399.38 ± 0.20^{dA}	451.96 ± 0.05^{dD}	433.28 ± 0.11^{dC}	434.59 ± 0.46^{eC}
20		461.26 ± 0.08^{eC}	468.49 ± 0.25^{eD}	452.20 ± 0.14^{eB}	469.58 ± 0.49^{eE}	673.74 ± 0.47^{fE}
24		511.45 ± 0.03^{fA}	561.27 ± 0.12^{fC}	533.74 ± 0.03^{eB}	575.54 ± 0.25^{fD}	981.24 ± 0.19^{gE}
28		858.16 ± 0.08^{gA}	903.35 ± 0.24^{gD}	881.36 ± 0.08^{fB}	885.43 ± 0.04^{gC}	
30		991.39 ± 0.28^{hD}	943.43 ± 0.37^{hA}	961.27 ± 0.06^{gB}	973.59 ± 0.34^{hC}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

O: Orishélé without packaging; OCSS: Orishele in polythene bags containing dry solid charcoal; OCSH: Orishélé in polythene bags containing moistened solid charcoal; OCPS: Orishélé in polythene bags containing dry powdered charcoal; OCPH: Orishélé in polyethylene bags containing moistened charcoal powder; CSO: Orishélé in polythene bags without charcoal.

With regard to the Big-Ebanga variety, the rate of total polyphenols on day 0 was 401.97mg/100g DM. This rate evolved to reach on day 12 (end of storage) 1231.62mg/100g DM for the Big-Ebanga without packaging (B) and 1001.27mg/100g DM Big-Ebanga in polythene bags without carbon (BSC), after 24 days of storage (end of storage). On day 30, the levels recorded were 1137.18mg/100g DM for Big-Ebanga in polythene bags containing dry solid carbon (BCSS), 1114.35mg/100g DM for Big-Ebanga in polythene bags containing humidified solid carbon (BCSH), 998.26mg/100g DM for Big-Ebanga in polythene bags containing dry powdered carbon (BCPS) and 981.33mg/100g DM for Big-Ebanga in polyethylene bags containing humidified charcoal powder (BCPH).

The total polyphenol levels of the Orishélé variety also increased from 120.66mg/100g DM on day 0 to respectively reach, after 30 days of storage, the values of 991.39mg/100g DM for the Orishélé stored in polythene bags containing dry solid carbon (OCSS), 943.43mg/100g DM for Orishele stored in polyethylene bags containing humidified solid carbon (OCSH), 961.27mg/100g DM for Orishele stored in polyethylene bags containing dry powdered charcoal (OCPS) and 973.59mg/100g DM for Orishélé stored in polyethylene bags containing humidified powdered charcoal (OCPH).

Flavonoids

The flavonoid levels of plantain banana varieties such as SACI (Table 4), Big-Ebanga (Table 5), and Orishélé (Table 6) increased significantly ($p \leq 0.05$) during storage.

The flavonoid levels of the fruits of the SACI variety evolved from the day of harvest (day 0) to the last day of storage (day 30) from 2.29mg/100g DM to 4.73mg/100g DM for the SACSS, 4.86mg/100g MS for SACH, 4.52mg/100g MS for SACPS and 4.81mg/100g MS for SACPH. As for AS, they recorded an average flavonoid level of 4.66mg/100g DM on day 12 and that of SSC was 4.52mg/100g DM on day 24.

The fruits of the Big-Ebanga variety recorded flavonoid levels during storage, changing from 0.76mg/100g DM on the day of harvest to 4.91mg/100g DM at the end of storage (day 30) for BCSS, 5.22mg/100g DM for BCSH, 5.04mg/100g DM for BCPS, 5.25mg/100g DM for BCPH. Concerning B, the average of the levels obtained was 5.20mg/100g DM on day 12 and that of BSC was 4.96mg/100g DM on day 24.

Table 4. Evolution of the flavonoid rate of the SACI variety in six storage environments.

Shelf life (days)	Flavonoids of SA (mg/100g DM)	Flavonoids of SACSS (mg/100g DM)	Flavonoids of SACSH (mg/100g DM)	Flavonoids of SACPS (mg/100g DM)	Flavonoids of SACPH (mg/100g DM)	Flavonoids of SSC (mg/100g DM)
0	2.29 ± 0.07^{aA}					
4	3.64 ± 0.03^{bD}	$3.51 \pm 0{,}45^{aC}$	3.39 ± 0.02^{aB}	3.18 ± 0.01^{aA}	3.24 ± 0.03^{aA}	3.61 ± 0.01^{aB}
8	4.14 ± 0.05^{cE}	$3.54 \pm 0{,}02^{aC}$	3.45 ± 0.03^{bB}	3.39 ± 0.02^{bA}	3.36 ± 0.05^{bA}	3.72 ± 0.01^{bD}
12	4.66 ± 0.03^{dD}	$3.73 \pm 0{,}02^{bB}$	3.80 ± 0.05^{cC}	3.58 ± 0.03^{cA}	3.53 ± 0.01^{cA}	3.77 ± 0.02^{cBC}
16		$4.04 \pm 0{,}05^{cC}$	3.90 ± 0.01^{dB}	3.79 ± 0.02^{dA}	3.94 ± 0.03^{dB}	3.82 ± 0.03^{dA}
20		$4.23 \pm 0{,}02^{dB}$	4.17 ± 0.03^{eA}	4.24 ± 0.02^{eB}	4.345 ± 0.03^{eC}	4.28 ± 0.05^{eB}
24		$4.42 \pm 0{,}02^{eC}$	4.31 ± 0.02^{fA}	4.39 ± 0.01^{fBC}	4.50 ± 0.02^{fD}	4.52 ± 0.01^{fE}
28		$4.57 \pm 0{,}02^{fB}$	4.76 ± 0.02^{gD}	4.41 ± 0.01^{fA}	4.67 ± 0.02^{gC}	
30		$4.73 \pm 0{,}02^{gB}$	4.86 ± 0.01^{hD}	4.52 ± 0.05^{gA}	4.81 ± 0.05^{hC}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

SA: SACI without packaging; SACSS: SACI in polythene bags containing dry solid charcoal; SACSH: SACI in polythene bags containing moistened solid charcoal; SACPS: SACI in polythene bags containing dry powdered charcoal; SACPH: SACI in polyethylene bags containing moistened powdered charcoal; SSC: SACI in polythene bags without charcoal.

Table 5. Evolution of the flavonoid rate of the *Big-Ebanga* variety in six storage environments.

Shelf life (days)	Flavonoids of B (mg/100g DM)	Flavonoids of BCSS (mg/100g DM)	Flavonoids of BCSH (mg/100g DM)	Flavonoids of BCPS (mg/100g DM)	Flavonoids of BCPH (mg/100g DM)	Flavonoids of BSC (mg/100g DM)
0	0.76 ± 0.02^{aA}					
4	0.88 ± 0.00^{bD}	0.79 ± 0.02^{aC}	0.77 ± 0.01^{aBC}	0.75 ± 0.04^{aBC}	0.69 ± 0.01^{aA}	0.73 ± 0.05^{aAB}
8	2.18 ± 0.06^{cD}	0.84 ± 0.01^{bAB}	0.80 ± 0.02^{aA}	0.89 ± 0.02^{bB}	0.83 ± 0.02^{bAB}	1.02 ± 0.15^{bC}
12	5.20 ± 0.11^{dD}	1.77 ± 0.01^{cC}	1.33 ± 0.02^{bA}	1.49 ± 0.02^{cB}	1.35 ± 0.02^{cA}	1.41 ± 0.02^{cAB}
16		2.01 ± 0.02^{dA}	2.06 ± 0.01^{cA}	2.11 ± 0.02^{dC}	1.99 ± 0.02^{dA}	2.19 ± 0.02^{dD}
20		2.76 ± 0.05^{eC}	2.75 ± 0.01^{dC}	2.53 ± 0.01^{eB}	2.23 ± 0.04^{eA}	3.83 ± 0.03^{eD}
24		3.15 ± 0.03^{fA}	3.29 ± 0.02^{eB}	3.61 ± 0.02^{fD}	3.43 ± 0.01^{fC}	4.96 ± 0.02^{fE}
28		4.22 ± 0.01^{gB}	4.16 ± 0.02^{fA}	4.19 ± 0.01^{gB}	4.59 ± 0.02^{gC}	
30		4.91 ± 0.05^{hA}	5.22 ± 0.02^{gC}	5.04 ± 0.03^{hB}	5.25 ± 0.02^{hC}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

B: Big Ebanga without packaging; BCSS: Big Ebanga in polyethylene bags containing dry solid charcoal; BCSH: Big Ebanga in polyethylene bags containing humidified solid charcoal; BCPS: Big Ebanga in polyethylene bags containing dry powder charcoal; BCPH: Big Ebanga in polyethylene bags containing humidified powder charcoal; BSC: Big Ebanga in polyethylene bags without charcoal.

Table 6. Evolution of the flavonoid rate of the *Orishélé* variety in six storage environments.

Shelf life (days)	Flavonoids of O (mg/100g DM)	Flavonoids of OCSS (mg/100g DM)	Flavonoids of OCSH (mg/100g DM)	Flavonoids of OCPS (mg/100g DM)	Flavonoids of OCPH (mg/100g DM)	Flavonoids of OSC (mg/100g DM)
0	1.08 ± 0.03^{aA}					
4	1.42 ± 0.03^{bA}	1.17 ± 0.02^{aA}	1.22 ± 0.05^{aA}	1.13 ±0.02^{aA}	1.27 ±0.02^{aA}	1.10 ± 0.02^{aA}
8	3.44 ± 0.05^{cE}	1.42 ±0.01^{bAB}	1.48 ±0.02^{bBC}	1.53 ±0.02^{bCD}	1.37 ±0.02^{bA}	1.59 ±0.03^{bD}
12	7.09 ± 0.03^{dE}	2.56 ± 0.01^{cC}	2.39 ± 0.07^{cB}	2.23 ± 0.02^{cA}	2.67 ± 0.02^{cD}	2.29 ± 0.02^{cA}
16		3.83 ± 0.02^{dC}	3.26 ± 0.02^{dA}	3.93 ± 0.02^{dD}	3.32 ± 0.06^{dA}	3.44 ± 0.03^{dB}
20		5.85 ± 0.03^{eD}	5.51 ± 0.02^{eA}	5.88 ± 0.01^{eD}	5.62 ± 0.03^{eB}	5.77 ± 0.02^{eC}
24		6.35 ± 0.02^{fB}	6.17 ± 0.04^{fA}	6.58 ± 0.03^{fD}	6.47 ± 0.03^{fC}	6.99 ± 0.05^{fE}
28		6.81 ± 0.03^{gD}	6.57 ± 0.02^{gB}	6.33 ± 0.02^{gA}	6.76 ± 0.02^{gC}	
30		7.15 ± 0.02^{hC}	7.05 ± 0.04^{hB}	6.95 ± 0.03^{hA}	7.23 ± 0.02^{hD}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

O: Orishélé without packaging; OCSS: Orishele in polythene bags containing dry solid charcoal; OCSH: Orishélé in polythene bags containing moistened solid charcoal; OCPS: Orishélé in polythene bags containing dry powdered charcoal; OCPH: Orishélé in polyethylene bags containing moistened charcoal powder; CSO: Orishélé in polythene bags without charcoal.

With regard to the fruits of the Orishélé variety, the flavonoid levels obtained varied, from day 0 to day 30, from 1.08mg/100g DM to 7.15mg/100g DM for the OCSS, 7.05mg/100g DM for OCSH, 6.95mg/100g DM for OCPS and 7.23mg/100g DM for OCPH. Unwrapped Orishele (O) recorded a level of 7.09mg/100g DM on day 12 while CSOs achieved a level of 6.99mg/100g DM on day 24.

Phytates

The results revealed a significant increase ($p \leq 0.05$) in the phytate content of the fruits of the three varieties of plantain studied, namely, SACI (Table 7), Big-Ebanga (Table 8), and Orishélé (Table 9) depending on the storage time. The Phytate level of the SACI variety, recorded on day 0, was 42.66mg/100g DM. The SA and the SSC were recorded at the end of storage (day 12 for the SA and day 24 for the SSC) the respective levels of 51.35mg/100g DM and 51.78mg/100g DM. After 30 days of storage, the phytate levels increased respectively to 51.42mg/100g DM for SACSS, 51.24mg/100g DM for SACSH, 51.46mg/100g DM for SACPS, and 51.84mg/100g DM for SACPHs.

The phytate levels of the Big-Ebanga variety evolved from 44.98mg/100g DM on day 0 to 66.86mg/100g DM in B after 12 days and to 63.78mg/100g DM in the BSC on day 24. After 30 days of storage, the levels were respectively 63.15mg/100g DM for the BCSS, 63.94mg/100g DM for the BCSH, 64.05mg/100g DM for BCPS, and 63.29mg/100g DM for BCPH. Concerning the Orishélé variety, the level of phytates was 47.54mg/100g DM on day 0. It then reached 63.17mg/100g DM for O, after 12 days and 65.56mg/100g DM for OSC on day 24. After 30 days of storage, phytate levels were 63.37mg/100g DM for OCSS, 63.54mg/100g DM for OCSH, 63.92mg/100g DM for OCPS, and, 63.46mg/100g DM for OCPH, respectively.

Table 7. Evolution of the phytate level of the SACI variety in six storage environments.

Shelf life (days)	Phytates of AS (mg/100g DM)	Phytates of SACSS (mg/100g DM)	Phytates of SACSH (mg/100g DM)	Phytates of SACPS (mg/100g DM)	Phytates of SACPH (mg/100g DM)	Phytates of SSC (mg/100g DM)
0	42.66 ± 0.03^{aA}					
4	46.08 ± 0.03^{bE}	42.49 ± 0.02^{aB}	42.83 ± 0.02^{aD}	42.56 ± 0.02^{aBC}	42.15 ± 0.04^{aA}	42.63 ± 0.06^{aC}
8	50.69 ± 0.020^{cE}	43.67 ± 0.02^{bD}	43.23 ± 0.02^{bA}	43.57 ± 0.02^{bC}	43.38 ± 0.03^{bB}	43.34 ± 0.04^{bB}
12	51.35 ± 0.03^{dF}	44.84 ± 0.03^{cC}	45.46 ± 0.05^{cE}	45.27 ± 0.03^{cD}	44.54 ± 0.03^{cB}	44.02 ± 0.04^{cA}
16		45.38 ± 0.01^{dA}	46.13 ± 0.03^{dB}	46.22 ± 0.09^{dB}	45.31 ± 0.01^{dA}	46.67 ± 0.16^{dC}
20		49.26 ± 0.02^{eB}	49.74 ± 0.02^{eD}	49.61 ± 0.02^{eC}	50.11 ± 0.02^{eE}	48.46 ± 0.03^{eA}
24		50.14 ± 0.03^{fA}	50.84 ± 0.03^{fB}	51.21 ± 0.03^{fC}	50.90 ± 0.03^{fB}	51.78 ± 0.03^{fD}
28		51.40 ± 0.04^{gBC}	51.09 ± 0.02^{gA}	51.28 ± 0.02^{fB}	51.44 ± 0.12^{gC}	
30		51.42 ± 0.02^{gB}	51.24 ± 0.03^{hA}	51.46 ± 0.02^{gB}	51.84 ± 0.04^{hC}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

SA: SACI without packaging; SACSS: SACI in polythene bags containing dry solid charcoal; SACSH: SACI in polythene bags containing moistened solid charcoal; SACPS: SACI in polythene bags containing dry powdered charcoal; SACPH: SACI in polyethylene bags containing moistened powdered charcoal; SSC: SACI in polythene bags without charcoal.

Table 8. Evolution of the phytate level of the *Big-Ebanga* variety in six storage environments.

Shelf life (days)	Phytates of B (mg/100g DM)	Phytates of BCSS (mg/100g DM)	Phytates of BCSH (mg/100g DM)	Phytates of BCPS (mg/100g DM)	Phytates of BCPH (mg/100g DM)	Phytates of BSC (mg/100g DM)
0	44.90 ± 0.20^{aA}					
4	45.82 ± 0.03^{bD}	45.15 ± 0.03^{aBC}	45.06 ± 0.06^{aB}	44.93 ± 0.03^{aA}	45.08 ± 0.01^{aB}	45.22 ± 0.04^{aC}
8	57.24 ± 0.03^{cF}	46.03 ± 0.02^{bE}	45.86 ± 0.00^{bC}	45.74 ± 0.03^{bB}	45.39 ± 0.02^{bA}	45.93 ± 0.02^{bD}
12	62.86 ± 0.03^{dE}	46.35 ± 0.01^{cB}	46.19 ± 0.02^{cA}	46.67 ± 0.02^{cD}	46.12 ± 0.01^{cA}	46.57 ± 0.02^{cC}
16		57.83 ± 0.05^{dB}	57.93 ± 0.02^{dC}	57.45 ± 0.05^{dA}	57.92 ± 0.08^{dB}	58.20 ± 0.04^{dB}
20		59.66 ± 0.02^{eB}	59.64 ± 0.03^{eB}	59.75 ± 0.03^{eC}	59.56 ± 0.01^{eA}	60.33 ± 0.01^{eD}
24		60.95 ± 0.15^{fB}	61.04 ± 0.03^{fBC}	60.96 ± 0.01^{fB}	60.72 ± 0.03^{fA}	63.78 ± 0.02^{fD}
28		61.82 ± 0.03^{gA}	62.23 ± 0.02^{gB}	62.43 ± 0.02^{gC}	62.92 ± 0.02^{gD}	
30		63.15 ± 0.02^{hA}	63.94 ± 0.03^{hC}	64.05 ± 0.03^{hD}	63.29 ± 0.02^{hB}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

B: Big Ebanga without packaging; BCSS: Big Ebanga in polyethylene bags containing dry solid charcoal; BCSH: Big Ebanga in polyethylene bags containing humidified solid charcoal; BCPS: Big Ebanga in polyethylene bags containing dry powder charcoal; BCPH: Big Ebanga in polyethylene bags containing humidified powder charcoal; BSC: Big Ebanga in polyethylene bags without charcoal.

Tableau 9. Evolution of the phytate level of the *Orishélé* variety in six storage environments.

Shelf life (days)	Phytates of O (mg/100g DM)	Phytates of OCSS (mg/100g DM)	Phytates of OCSH (mg/100g DM)	Phytates of OCPS (mg/100g DM)	Phytates of OCPH (mg/100g DM)	Phytates of OSC (mg/100g DM)
0	47.54 ± 0.03^{aA}					
4	48.17 ± 0.02^{bE}	47.66 ± 0.03^{aA}	47.75 ± 0.04^{aB}	47.92 ± 0.03^{aD}	47.84 ± 0.03^{aC}	47.95 ± 0.02^{aD}
8	54.93 ± 0.03^{cD}	48.24 ± 0.03^{bB}	48.63 ± 0.07^{bC}	48.74 ± 0.03^{bC}	48.04 ± 0.03^{bA}	48.33 ± 0.08^{bB}
12	63.17 ± 0.03^{dF}	49.24 ± 0.03^{cB}	49.32 ± 0.01^{cC}	49.40 ± 0.03^{cD}	49.61 ± 0.02^{cE}	49.13 ± 0.02^{cA}
16		53.73 ± 0.03^{dA}	54.84 ± 0.03^{dE}	54.73 ± 0.03^{dD}	54.60 ± 0.03^{dC}	54.37 ± 0.02^{dB}
20		55.59 ± 0.09^{eA}	55.80 ± 0.07^{eB}	56.30 ± 0.03^{eC}	56.71 ± 0.02^{eD}	58.06 ± 0.02^{eE}
24		56.45 ± 0.02^{fC}	56.25 ± 0.04^{fA}	56.35 ± 0.03^{eB}	56.93 ± 0.03^{fD}	63.56 ± 0.12^{fE}
28		60.24 ± 0.03^{gA}	60.83 ± 0.02^{gC}	60.33 ± 0.08^{fB}	60.71 ± 0.07^{gC}	
30		63.37 ± 0.02^{hA}	63.54 ± 0.03^{hB}	63.92 ± 0.03^{gC}	63.46 ± 0.01^{hAB}	

These values are the means of 3 determinations for each parameter. Means ± standard deviation, assigned different lowercase letters in the same column indicate a significant difference ($p < 0.05$) between days of storage according to Tukey. Means ± standard deviation with different capital letters in the same line indicate a significant difference between storage media according to Tukey.

O: Orishélé without packaging; OCSS: Orishele in polythene bags containing dry solid charcoal; OCSH: Orishélé in polythene bags containing moistened solid charcoal; OCPS: Orishélé in polythene bags containing dry powdered charcoal; OCPH: Orishélé in polyethylene bags containing moistened charcoal powder; CSO: Orishélé in polythene bags without charcoal.

Discussion

Unlike fruits stored in the control environment, the evolution of polyphenols, flavonoids, and phytates was slower for fruits stored in packaging containing charcoal. These results indicate a positive influence of charcoal on the green life of fruits. The increase in total polyphenol content during the ripening of plantain fruits was also observed by N'goh Neewilah *et al.* (2005) on fruits of hybrids CRBP 39 (665.38 to 2652.75 ppm EAG/ms), CRBP 755 (907.13 to 2488.06 ppm EAG/ms), FHIA 17 (569.83 to 1556.84 ppm EAG/ms) and also on the cultivars "French Clair" (440.55 to 1397.69 ppm EAG/ms), "French Sombre" (451.57 to 2958.76 ppm EAG/ms), Pita 3 (540.31 to 3613.45 ppm EAG/ms). According to Pedneault *et al.* (2001), then Aganga and Mosase (2003), extrinsic factors (geographical and climatic), genetic factors, and the degree of maturation have a strong influence on the polyphenol content. The evolution of these rates testifies to the continuity of the metabolic and/or physiological activities of banana fruits after harvest. These natural antioxidants such as polyphenols help to fight against the attacks caused by oxygen in the consumer's body, which are the cause of a large number of pathologies such as cancer (Siddhuraju and Becker, 2003) , inflammatory (Aruoma, 1994), cardiovascular (Leifert and Abeywardena, 2008) and neurodegenerative (Ramassamy, 2006) diseases. This is why their high levels in food would constitute a nutritional advantage. The flavonoid contents recorded are lower than those obtained by Viera *et al.* (2003) during the maturation of *Ocinum américanum* (L) cultivars, whose levels varied from 10 to 749mg CA / 100g DM. The increase in flavonoid levels can be attributed to the synergy of phenolic compounds (phenolic acids, tannins, and flavonoids) whose increase leads to that of flavonoids (Rice-Evans *et al.*, 1997). Note that flavonoids also have the ability to inhibit and/or reduce the production of reactive oxygen species (ROS) by neutrophils (Limasset *et al.*, 1993). The increase in phytate levels observed during storage would be linked to inhibition by the accumulation of phosphate (Sung *et al.*, 2005) or degradation of the enzyme (phytase) by active proteases (Azeke *et al.*, 2011). Indeed, phytates accumulate in plants during the maturation period in the form of phosphate and inositol (Loewus, 2002). This increase in the level of phytates in plants could be explained by the accumulation of phytates in the form of phosphorus which can evolve up to 80% of the total phosphorus content (Raboy, 1990).

References

Aganga AA, Mosase KW. 2003. Tannins content, nutritive value and dry matter digestibility of *Lonchocarpus capassa, Ziziphus mucronata, Sclerocarya birrea, Kirkia acuminata* and *Rhus lanceaseeds*. Animal Feed Science and Technology **91,** 107-113.

Aruoma OI. 1994. Nutrition and health aspects of free radicals and antioxidants. Food and chemical toxicology **32(7),** 671-683.

Ashwani K, Nirmal P, Mukul K, Anina J, Vidisha T, Emel O, Charalampos P, Maomao Z, Tahra E, Sneha K, Fatih O. 2003. Major Phytochemicals: Recent Advances in Health Benefits and Extraction Method. Molecules **28(2),** 887. DOI: 10.3390/molecules28020887

Azeke MA, Egielewa SJ, Eigbogbo MU, Ihimire IG. 2011. Effect of germination on the phytase activity, phytates and total phosphorus contents of rice (*Oryza sativa*), maize (*Zea mays*), millet (*Panicum miliaceum*), sorghum (*Sorghum bicolor*) and wheat (*Triticum aestivum*). Journal of Food Science and Technology **48(6),** 724-729.

Daramola B, Adegoke GO. 2011. Bitter kola (*Garcinia kola*) seeds and health management potential, In Preedy VR, Watson RR, Patel VB, (Editors). Nuts and Seeds in Health and disease prevention (1st edition) Academic press (imprint of Elsevier) Vurlington, San diego 213-220.

Gnakri D, Kamenan A. 1990. Degré de maturité et conservation de la banane plantain (*Musa* sp.). Qualité physicochimique de l'amidon. Cahiers des industries Agroalimentaires, Cahier Scientifique et Technique **107(4),** 251-256.

Kouadio KA, Coulibaly S, Soro LC, Ocho-Anin AL. 2013. Determination of the optimal point of cut fruit of plantain hybrids PITA 3, PITA 8 and varieties of plantain Lorougnon and Horn 1. International Journal of Agriculture and Food Science **3,** 16-21.

Leifert WR, Abeywardena MY. 2008. Cardioprotective actions of grape polyphenols. Nutrition Research **28(11),** 729-737.

Limasset B, Le Doucen C, Dore JC, Ojasoo T, Damon M, Crastes de Paulet A. 1993. Effects of flavonoids on the release of reactive oxygen species by stimulated human neutrophils. Multivariate analysis of structure-activity relationships (SAR). Biochemical Pharmacological **46,** 1257-1271.

Loewus F. 2002. Biosynthesis of Phytate in Food Grains and Seeds. In: Food Phytates (Eds.) Reddy NR, Sathe SK, CRC Press. Florida, USA p. 53-61.

Meda A, Lamien CE, Romito M, Millogo J, Nacoulma OG. 2005. Determination of the total phenolic, flavonoid and proline contents in Burkina Faso honey, as well as their radical scavenging activity. Food Chemistry **91,** 571-577.

Mohammed AI, Ponnamperuma AJ, Youssep SH. 1986. New chromophore for phytic acid determination. Cereal Chemistry **63,** 475-478.

Ngoh NG, Brat P, Tchango TJ, Tomekpe K, Alter P, Fokou E, Etoa FX. 2005. Effet de la cuisson sur la teneur en polyphenols totaux de quelques cultivars de bananiers (*Musa* sp.) au Cameroun. Maîtrise des Procédés en vue d'améliorer la qualité et la sécurité des aliments, Utilisation des OGM, Analyse des risques en agroalimentaire, Ouagadougou, 8-11 Novembre 2005.

Pedneault K, Leonharts A, Gosselin A, Ramputh A, Arnason JT. 2001. Influence de laculture hydroponique de quelques plantes médicinales sur la croissance et la concentration encomposés secondaires des organes végétaux. Texte de conférence. Canada p. 1-5.

Raboy V. 1990. The biochemistry and genetics of phytic acid synthesis in higher plants. In: Morre, EJ; Boss, Loewus WS, FA Inositol metabolism in plants. New York: John Wiley and Sons **1,** 55-76.

Ramassamy C. 2006. Emerging role of polyphenol compounds in the treatment of neurodegenerative deseases a review of their intracellular targets. European Journal of Pharmacology **545(1),** 51-64.

Rice-Evans C, Miller N, Paganga G. 1997. Antioxydant properties of phenolic compounds. Triends in plant science **2(4),** 152-159.

Siddhuraju P, Becker K. 2003. Antioxidant properties of various solvent extracts of total phenolic constituents from 3 different agroclimatic origins of drumstick tree (*Moringa oleifera* Lam). Journal Agricultural Food Chemistry **51(8),** 2144-2155.

Singleton VL, Orthofer R, Lamuela-Raventos RM. 1999. Analysis of total phenols and other oxydant substrates and antioxydants by means of Folin-ciocalteu reagent. Methods in Enzymology **299,** 152-178.

Sung HG, Shin HT, Ha JK, Lai HL, Cheng KJ, Lee JH. 2005. Effect of germination temperature on characteristics of phytase production from barley. Bioresource Technology **96(11),** 1297-1303.

Viera RF, Grayer RJ, Paton AJ. 2003. Chemical profiling of *Ocimum americanum* using external flavonoids. Phytochemistry **63,** 555-67.