Review Article

Effects of charcoal preservation methods on the biochemical parameters of three plantain (*Musa ssp*) varieties

ABSTRACT

Aims: To contribution to solve plantain post-harvest losses, six preservation methods combining charcoal and polyethylene bags were experimented on three different varieties of plantain (*SACI, Big-Ebanga and Orishele*).
Place and Duration of Study: This work was carried out at the Biocatalysis and Bioprocesses Laboratory of Nangui Abrogoua University in Abidjan and at the Food Technology Laboratory of the National Center for Agronomic Research in Côte d'Ivoire.
Methodology: Some Biochemical parameters of these fruits are monitored to know the effects of these preservation methods during storage.
Results: The outcomes indicate an average shelf green life extension up to 30 days for fruits preserved in polyethylene containing charcoal, while fruits preserved in polyethylene without charcoal have only 24 days on average. The control test (fruits stored in the open air) showed an average shelf green life of 12 days. During storage, there is an increase in contains of total carbohydrates (1.290% and 2.666%), total sugars (0.466 and 30.830 g / 100 g DM), proteins (3.016 and 5.950 g / 100 g DM), pH (4.5 and 6.5) while starch levels decrease (42.660 and 64.046 mg / 100g DM).
Conclusion: Charcoal can extend the shelf green life of plantain bananas for up to a month. These methods can be recommended to actors in the sector to reduce post-harvest losses.

Keywords: Plantain, conservation, charcoal, polyethylene

1. INTRODUCTION

Plantain is one of the main sources of staple food for more than 100 million people in sub-Saharan Africa, where it contributes significantly to food security [1]. It also represents a significant source of income for producing countries. It is the second food crop in the world after cereals and the fourth cultivated food crop in the world after rice, wheat and maize [2]. Nearly 75% of the world's plantain production is harvested in Africa [3]. In Côte d'Ivoire, with a production of around 1.9 million tones, plantain ranks fourth among foodstuff in terms of consumption after rice, cassava and yam [4].

Plantain is characterized by a high carbohydrate contents, with levels above 28 g / 100 g. These contents corresponding to values ranging from 89 to 90.52 Kcal/100 g of dry matter [5] are the main energy source for consumers. Although plantain demand is high in the Ivorian markets, its expansion faces several constraints such as the lack of improved production techniques, ineffective post-harvest processing techniques and preservation techniques, which are very expensive, therefore not accessible to every actor in the sector [6]. All these constraints lead to low yields and high losses (up to 40%) of production [7]. Facing these constraints, production with better cultivation techniques and especially preservation through inexpensive, practical and accessible techniques are necessary, for a sustainable positive impact on plantain availability all year round.

In fact, storage temperature, oxygen, carbon dioxide and ethylene contains are the main factors, which influence banana ripening process. Ethylene initiates all the processes involved in fruits ripening [8] ; for this reason preservation technics have been worked out, to slowing down ethylene production so that to extend shelf green life. Some traditional methods such as storage in pits, under foliage, under shelters [9] are commonly used. Modern or so-called improved methods of preserving plantain in a fresh state, including coating, cold, modified or controlled atmosphere, irradiation and special packaging [10], allow to store the fresh plantain for up to 60 days. A few of these methods seemed to be ineffective, difficult to implement and too expensive for common operators in the plantain sector and consumers. However, it seems easier to achieve modified atmospheres by using polyethylene bags [11]. For preservation the greatest difficulty is the too high level of chemical equipment requirement, which is very expensive and difficult to access.

Charcoal good adsorption capability is well known for very long time; it therefore has been used in many fields, in particular for water or gas purification. It could be used for ethylene absorption and slow down fruit ripening. The main objective of this work is to contribute to reduction of post-harvest losses of plantain, by developing a practical, inexpensive and accessible method of preserving plantain in a green state using charcoal.

2. MATERIAL AND METHODS

2.1 Material

The plantain were harvested at the green ripe stage in an experimental plantation of the National Center for Agronomic Research (CNRA), located in Azaguié, a village in south-east of Côte d'Ivoire, about 50 km from Abidjan. These are three cultivars, namely *Big-Ebanga*, *SACI, Orishele* (Figure 1).

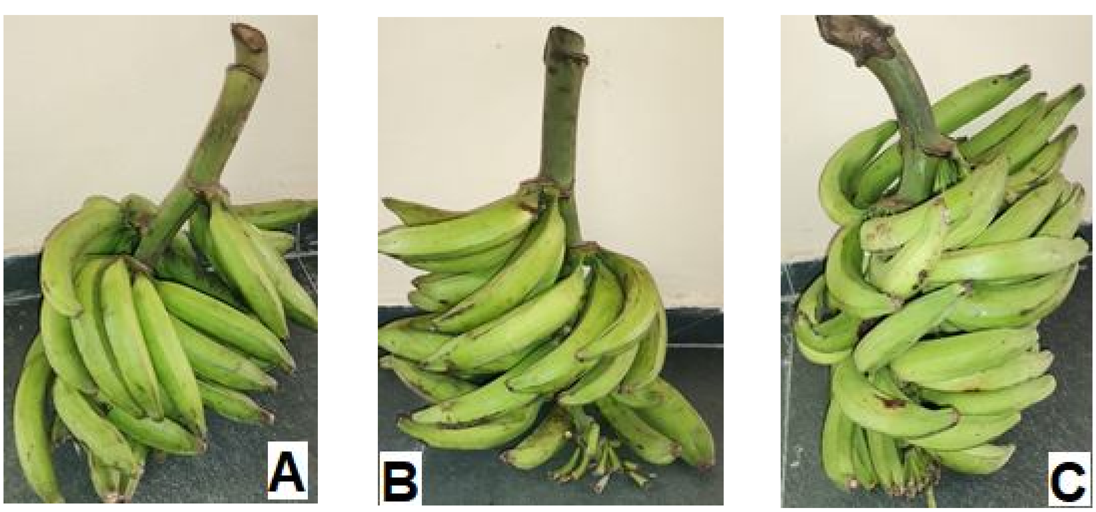

Figure 1: Plantain varieties studied at physiological maturity.

A: *Orishele* variety; B: *Big-Ebanga* variety; C: *SACI* variety

2.2 METHODS

2.2.1 Sampling

The plantain bunches are harvested respectively 70 days for the *Orishele* variety and 80 days for the *SACI* and *Big-Ebanga* varieties after the inflorescence appearance, thus corresponding to the optimal maturity of the fruits according to the method of determining the cutting point described by Gnakri and Kamenan [12]. The different plantain variety fingers are packed and hermetically sealed in polyethylene plastic bags (11µm thick), containing either dry charcoal pieces or with water humidified charcoal pieces, or dry charcoal powder or with water humidified charcoal powder. The wet charcoal powder is obtained by mixing charcoal powder and water (coal/water: 1/1 ratio). Humidified charcoal pieces are obtained by immersion in water for one minute. The sizes of packaging bags and the charcoal mass are determined as follows: a 11cm long bag for a 8cm long finger and 5g of charcoal for 100g of plantain. The fruits are stored at room temperature (28°C). The different preservation batches are constituted as follows:

- Batch 1 or control batch: plantain samples preserved with no packaging.
- Batch 2: plantain samples preserved in packaging without charcoal.
- Batch 3: plantain samples preserved in packages with dry charcoal powder.
- Batch 4: plantain samples preserved in packages with humidified charcoal powder.
- Batch 5: plantain samples preserved in packages with dry charcoal pieces.
- Batch 6: plantain samples preserved in packages with humidified charcoal pieces.
- The batches 2, 3, 4, 5 and 6 contained 40 bags each. The sampling was carried out during the storage process for the determination of physicochemical parameters.

2.2.2 Determination of green lifetime

The green lifetime is determined according to the colorimetric scale defined by Wainwright and Hughes [13]. It consisted in examining visually plantain's skin color. For each sample, the green lifetime corresponds to the elapsed time between harvested plantain at mature green stage and ripening start, when the color of the skin changes to the yellow-green.

2.2.3 Determination of starch levels

The starch content is determined according to Faithful [17] method modified by Abu et al. [18]. A quantity of 1 g of dried plantain flour is dispersed in 10 mL ethanol (10% v/v). After stirring for 30 min using a stirrer (J.P. SELECTA), the mixture is centrifuged at 3000 rpm for 5 min. The supernatant is decanted and the paste is washed with 10 ml, sulfuric acid solution (1 M) and centrifuged during 5 min. The paste is dispersed in 50 ml sulfuric acid (1 M) and heated in a boiling water bath during 45 min. After 10 min cooling, the liquids are poured into a 100 ml flask and completed with distilled. Then 10 ml of this solution is poured into a flask and completed to 100 ml with distilled water. The glucose in the hydrolysate is quantified according to the method of Dubois et al. [16] for total sugars. The starch content is calculated with following formula:

Starch content (%) = 0.9 × glucose level

2.2.4 Determination of total carbohydrate content

Total carbohydrates are measured according to the method of Dubois et al. [16]. A quantity of 2 g of plantain flour is poured into a 250 ml flask. 40 ml of lukewarm distilled water is then added. After stirring for solution homogenization, 3 ml of concentrated hydrochloric acid (12 N) are added to the mixture, which is then boiled during 3 h. The solution is cooled and neutralized with 6 N sodium hydroxide, when the color of 3 phenolphthalein drops change to pink. The obtained solution is centrifuged at 3000 rpm for 15 min. The supernatant is transferred to a 200 ml flask and the volume is completed with distilled water. 0.2 ml of this extract is mixed with 1.8 ml distilled water and 1 ml DNS. The whole was incubated for 10 min in a boiling water bath. Finally, 17 ml of distilled water are added to it. The tubes are smoothly agitated and cooled down to room temperature. The optical density is determined on a spectrophotometer (Thermo Fisher scientific, Madison WI 53711 USA) at 546 nm against a control containing no sugar extract.

2.2.5 Extraction and determination of ethanosoluble sugars

2.2.5.1 Extraction of ethanosoluble sugars

Plantain sugars are extracted according to the method described by Martinez-Herrera et al. [15]. One gram of dried plantain pulp is ground in 10 ml ethanol (80% v/v). The grinding obtained is centrifuged for 30 minutes at 3000 rpm. The supernatant is collected in a graduated cylinder. The pellet is taken up with 10 ml ethanol and centrifuged twice. The supernatant is then added to the first part. The whole supernatant is the extract which is used for the determination of total sugars.

2.2.5.2 Determination of total sugar

Total sugars are determined according Dubois et al. [16] method using phenol. A volume of 0.1 mL of extract is diluted in 0.9 mL distilled water, then 1 mL phenol (5% w/v) is added to the mixture. The mixture is homogenized and put in a boiling water bath, after adding 2 mL concentrated sulfuric acid, then cooled for 5 minutes at room temperature. The Optical Density (O.D) is determined at 490 nm on a spectrophotometer (PG INSTRUMENTS, England) versus a control containing all products, except the extract. The indicated D.O is converted into total sugars by using the calibration curve obtained from a glucose solution (1 mg/mL).

2.2.6 Determination of protein content

Crude proteins are determined from the total nitrogen assay according to Kjeldhal method [19]. It includes a mineralization phase, followed by a distillation phase and a sulfuric acid titration phase. First, a mass of 0.5 g of each dried sample is weighed in a digestion tube to which are successively added 0.5 g of the catalyst (selenium, copper sulphate ($CuSO_4$) and potassium sulphate (K_2SO_4) and 20 mL of concentrated sulfuric acid. Mineralization is carried out at 400°C for 2 h in a digester (BUCHI, France). After cooling the tube to room temperature, the mineralize is transferred into a 100 mL volumetric flask and distilled water is added up to the gauge line. Then 10 mL of NaOH 40% (w/v) is added to 10 mL of the mineralize and the mixture is poured in the distiller reservoir. The distiller's condenser extension is then immersed in a beaker containing 20 mL boric acid 5% (w/v) to which a mixed indicator (methyl red + bromocresol green) is added. The distillation is carried out for 10 minutes until a green or blue distillate is obtained. Finally, the distillate is dosed with a 0.1 N sulfuric acid solution until it turns green. A blank is made with distilled water. The total protein rate is expressed as a percentage of mass by the following formula:

$$\text{Protein content} = \frac{(VH2SO4) \times N(H2SO4) \times 14 \times 6{,}25}{me \times 10}$$

V H2SO4: Volume of H2SO4 used
N(H2SO4): Normality of sulfuric acid used for titration (0.1N)
14: Atomic mass of nitrogen
me: flour sample mass (g)
6.25: Total nitrogen to protein conversion factor

2.2.7 Statistical analysis

Statistical analysis of the data are performed using IBM SPSS Statistics 21.0 software. The averages of biochemical parameters data undergo a variance analysis (ANOVA) in order to know the effects of preservation methods on the properties. Tukey's test is used to compare parameter values that differ significantly from each other at the threshold of 5%.

3. RESULTS AND DISCUSSION

3.1 Starch

The starch content of the three plantain varieties fruits *SACI* (Table 1), *Big-Ebanga* (Table 2), and *Orishele* (Table 3) decreased significantly ($p \leq 0.05$) during storage in all preservation environments. The results also indicate a significant difference ($p \leq 0.5$) between the starch values of the fruits from one storage environment to another.

The starch rate of *SACI* variety recorded on day 0 is 77.310%. This rate decreases to 37.064% for SACSS, 39.710% for SACSH, 36.393% for SACPS and 34.517% for SACPH, respectively, after 30 days of storage. Fruits from SSC have a starch content of 48.523% after 24 days of storage, which corresponds to the end of green life. The highest starch rate of the *SACI* variety, after 30 days of storage, are obtained by SACSM (39.710%) and SACSS (37.064%). Fruits from SSC (33.052%) and SACPH (34.517%) had the lowest starch rate.

The starch rate of the *Big-Ebanga* variety decreased from 81.349% on day 0 to 40.203%, after 30 days of storage, for BCSS, 42.450% for BCSH, 40.044% for BCPS and 39.728% for BCPH. At the end of their green life, after 24 days of storage, the BSC have a starch content of 47.240%. The highest starch rate in 30 days of storage was obtained by BCSH (42.450%) and the lowest rate is obtained by BCPH (39.728%).

The starch content of the *Orishele* variety is 78.664% on day 0. After 30 days of storage, the starch content of the fruit is 51.140% for OCSS, 50.260% for OCSH, 51.067% for OCPS and

50.660% for OCPH respectively. OSC have 58.842% of starch rate at the end of green life (24 days). Fruits from OCSS (51.140%) and OSC (52.318%) had the highest starch rate in 30 days of storage, while the lowest rate is obtained by OCSH (50.318%).

The decrease in starch content during ripening is also observed by Belalcázar et al. [20] on the fruits of plantain “Dominico harton” clone (80% to 69%) and also by Assemand et al., [21]on *Orishele* (79.63% to 59.13%) and *Agnrin* (80.85% to 56.92%) varieties fruits. This decrease in starch content is due to its conversion in soluble sugars during the ripening process of the fruit ([22];[23]). Indeed, during ripening, α and β-amylases catalyze starch degradation, thus releasing glucose, maltose and maltodextrins [24].

Table 1: Evolution of the starch content of *SACI* variety fruits in six different storage environment

Green life (Day)	Starch of SA (%)	Starch of SACSS (%)	Starch of SACSH (%)	Starch of SACPS (%)	Starch of SACPH (%)	Starch of SSC (%)
0	77.310 ± 0.002^{aA}					
4	72.89 ± 0.011^{bA}	77.302 ± 0.006^{aE}	77.117 ± 0.004^{aC}	77.050 ± 0.003^{aB}	77.181 ± 0.054^{aD}	77.268 ± 0.002^{aE}
8	59.568 ± 0.002^{cA}	72.392 ± 0.003^{bE}	71.730 ± 0.003^{bD}	71.212 ± 0.003^{bC}	70.143 ± 0.002^{bB}	72.748 ± 0.001^{bF}
12	37.688 ± 0.002^{dA}	70.812 ± 0.003^{cD}	71.171 ± 0.005^{cE}	70.090 ± 0.100^{cB}	70.141 ± 0.002^{bB}	70.458 ± 0.002^{cC}
16		65.669 ± 0.364^{dAB}	66.456 ± 0.558^{dB}	65.309 ± 0.859^{dAB}	63.281 ± 1.781^{cAB}	62.518 ± 0.002^{dA}
20		60.209 ± 0.002^{eC}	61.072 ± 0.002^{eE}	60.648 ± 0.004^{eD}	58.867 ± 0.003^{dB}	58.213 ± 0.002^{eA}
24		51.488 ± 0.002^{fC}	55.790 ± 0.002^{fE}	51.614 ± 0.004^{fD}	49.600 ± 0.004^{eB}	48.523 ± 0.002^{fA}
28		45.250 ± 0.003^{gC}	48.098 ± 0.002^{gE}	47.510 ± 0.003^{gD}	43.514 ± 0.004^{fA}	
30		37.064 ± 0.003^{hD}	39.710 ± 0.005^{hE}	36.393 ± 0.002^{hC}	34.517 ± 0.003^{gA}	

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

SA: SACI no packaging; SACSS: SACI packed in polythene bags containing dry solid charcoal; SACSH: SACI packed in polythene bags containing wet solid charcoal; SACPS: SACI packed in polythene bags containing dry powdered charcoal; SACPH: SACI packed in polythene bags containing wet charcoal powder; SSC: SACI packed in polythene bags without charcoal.

Table 2: Evolution of the starch content of the *Big-Ebanga* variety fruits in six different storage environment

Green life (Day)	Starch of B (%)	Starch of BCSS (%)	Starch of BCSH (%)	Starch of BCPS (%)	Starch of BCPH (%)	Starch of BSC (%)
0	81.349 ± 0.001^{aA}					
4	78.101 ± 0.003^{bA}	79.905 ± 0.003^{aF}	79.348 ± 0.002^{aE}	79.025 ± 0.003^{aB}	79.252 ± 0.003^{aD}	79.107 ± 0.002^{aC}
8	69.57 ± 0.002^{cA}	72.152 ± 0.003^{bE}	71.145 ± 0.003^{bD}	71.080 ± 0.002^{bC}	71.033 ± 0.002^{bB}	73.115 ± 0.001^{bF}
12	41.942 ± 0.002^{dA}	64.557 ± 0.002^{cF}	63.514 ± 0.003^{cE}	61.499 ± 0.003^{cC}	61.066 ± 0.002^{cB}	62.480 ± 0.002^{cD}
16		58.600 ± 0.002^{dE}	56.425 ± 0.176^{dC}	53.365 ± 0.002^{dB}	51.180 ± 0.002^{dA}	57.066 ± 0.002^{dD}
20		53.200 ± 0.002^{eE}	51.810 ± 0.002^{eD}	49.198 ± 0.002^{eB}	49.170 ± 0.003^{eA}	51.320 ± 0.002^{eC}
24		49.158 ± 0.002^{fE}	47.151 ± 0.003^{fC}	45.531 ± 0.003^{fB}	45.445 ± 0.002^{fA}	47.240 ± 0.001^{fD}
28		44.184 ± 2.88^{gAB}	43.179 ± 0.002^{gAB}	41.170 ± 0.002^{gAB}	41.019 ± 0.002^{gA}	
30		40.203 ± 0.007^{hC}	42.450 ± 0.002^{hD}	40.044 ± 0.002^{hB}	39.728 ± 0.002^{hA}	

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

B: Big-Ebanga no packaging; BCSS: Big-Ebanga packed in polythene bags containing dry solid charcoal; BCSH: Big-Ebanga packed in polythene bags containing wet solid charcoal; BCSP: Big-Ebanga packed in polythene bags containing dry powdered charcoal; BCPH: Big-Ebanga packed in polythene bags containing wet charcoal powder; BSC: Big-Ebanga packed in polythene bags without charcoal.

Table 3: Evolution of the starch content of the *Orishele* variety fruits in six different storage environment

Green life (Day)	Starch of O (%)	Starch of OCSS (%)	Starch of OCSH (%)	Starch of OCPS (%)	Starch of OCPH (%)	Starch of OSC (%)
0	78.564 ± 0.003^{aA}					
4	77.683 ± 0.003^{bF}	76.840 ± 0.001^{aD}	76.255± 0.003^{aC}	75.059 ± 0.003^{aA}	76.030 ± 0.002^{aB}	76.940 ± 0.002^{aE}
8	65.780 ± 0.002^{cA}	71.842 ± 0.003^{bF}	71.583± 0.003^{bE}	70.721 ± 0.003^{bC}	70.209 ± 0.002^{bB}	71.559 ± 0.004^{bD}
12	54.688 ± 0.003^{dA}	68.540 ± 0.003^{cE}	68.540± 0.003^{cE}	67.570 ± 0.053^{cD}	65.280 ± 0.003^{cB}	67.294 ± 0.004^{cC}
16		64.478 ± 0.003^{dD}	64.515± 0.003^{dE}	63.869 ± 0.002^{dA}	64.110 ± 0.003^{dB}	64.279 ± 0.001^{dC}
20		61.507 ± 0.002^{eB}	61.431± 0.003^{eB}	61.238 ± 0.003^{eB}	60.217 ± 0.003^{eA}	60.859 ± 0.579^{eAB}
24		58.139 ± 0.002^{fD}	57.145± 0.002^{fC}	57.020 ± 0.002^{fB}	56.428 ± 0.002^{fA}	58.842 ± 0.003^{fE}
28		54.431 ± 0.003^{gD}	54.008± 0.002^{gB}	54.127 ± 0.003^{gC}	52.607 ± 0.005^{gA}	
30		51.140 ± 0.007^{hD}	50.260± 0.002^{hA}	51.067 ± 0.002^{hC}	50.660 ± 0.002^{hB}	

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

O: Orishele no packaging; OCSS: Orishele packed in polythene bags containing dry solid charcoal; OCSH: Orishele packed in polythene bags containing wet solid charcoal; OCPS: Orishele packed in polythene bags containing dry powdered charcoal; OCPH: Orishele packed in polythene bags containing wet charcoal powder; OSC: Orishele packed in polythene bags without charcoal.

3.2 Total carbohydrates

The total carbohydrate content of plantains *SACI* (Table 4), *Big-Ebanga* (Table 5) and *Orishele* (Table 6) varieties fruits decreased significantly ($p \leq 0.5$) during storage for each storage environment. The results also indicate a significant difference ($p \leq 0.5$) between the total carbohydrate values of these fruits from one storage environment to another.

The total carbohydrate content of the *SACI* variety fruits on day 0 is 89.414%. This value decreases during storage to 73.553% for SACSS, 73.362% for SACSH, 73.196% for SACPS and 73.244% for SACPH at the end of storage (30 days). The green life of SSC is 24 days and the total carbohydrate content recorded for this period is 76.682% for SSC.

The total carbohydrate content of the *Big-E*banga variety fruits also decreases from day 0 to day 30 from 92.496% to 74.511% for BCSS, 74.412% for BCSH, 74.210% for BCPS and 74.312% for BCPH. At the end of green life, after 24 days, the BSC have a rate of 76.203%. Fruits from BSC (74.567%) and BCSS (74.511%) had the highest total carbohydrate rate and the lowest level are obtained by BCPS (74.210%) in 30 days of storage.

Total carbohydrate rate of fruits of the *Orishele* fruit ranges from day 0 to day 30 from 91.431% to 71.179% for OCSS, 71.152% for OCSH, 70.047% for OCPS and 71.113% for OCPH. OSC have a rate of 75.272% at the end of green life (24 days). At the 30 day of storage, OSC (71.266%) and OCSS (71.179) had the highest rate while those of OCPS (70.047%) have the lowest value of total carbohydrates.

Authors such as Assemand et al. [21] also observed decreases in total carbohydrate contents of plantain varieties such as *Orishele* (93.41% to 91.95%) and *Agnrin* (94.96% to 93.22%) during storage. This decrease in total carbohydrate content is due to starch conversion in sugars under the action of some enzymes such as endo-1,4-ß-D-glucanases, polygalacturonases , pectate lyases and pectin esterases and expansins [25] which degrade the cell wall [26], during ripening.

Table 4: Evolution of the carbohydrates content of the *SACI* variety fruits in six different storage environment

Green life (Day)	Carbohydrates of SA (%)	Carbohydrates of SACSS (%)	Carbohydrates of SACSH (%)	Carbohydrates of SACPS (%)	Carbohydrates of SACPH (%)	Carbohydrates of SSC (%)
0	89.414 ± 0.790^{aA}					
4	85.697 ± 2.780^{aA}	88.921± 0.675^{aA}	88.610 ± 1.037^{aA}	88.475± 1.148^{aA}	88.394 ± 1.146^{aA}	88.623± 0.967^{aA}
8	78.874 ± 3.890^{bA}	87.195± 0.344^{abB}	87.040 ± 0.354^{abB}	86.842± 0.467^{abB}	87.052 ± 0.013^{abB}	87.390± 0.213^{abB}
12	73.263 ± 0.11^{bA}	85.004± 1.827^{bB}	83.948 ± 3.250^{bB}	85.818± 0.614^{bB}	83.847 ± 3.210^{bB}	84.676± 1.948^{bB}
16		79.669± 1.011^{cA}	79.184 ± 0.997^{cA}	79.380± 1.280^{cA}	78.318 ± 1.513^{cA}	79.572± 1.017^{cA}
20		78.102± 0.441^{deA}	77.399 ± 1.042^{dfA}	77.566± 0.420^{deA}	77.363± 0.609^{cA}	78.490± 0.347^{deA}
24		76.911± 0.818^{efA}	77.058 ± 0.240^{efgA}	76.734± 0.479^{eA}	76.025 ± 0.757^{cdA}	76.682± 0.873^{efA}
28		74.586± 1.007^{fgA}	74.440 ± 1.068^{fgA}	74.229± 0.948^{fA}	74.385 ± 0.927^{cdA}	
30		73.553± 0.072^{gB}	73.362 ± 0.132^{gAB}	73.196± 0.068^{gA}	73.244 ± 0.060^{dA}	

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

SA: SACI no packaging; SACSS: SACI packed in polythene bags containing dry solid charcoal; SACSH: SACI packed in polythene bags containing wet solid charcoal; SACPS: SACI packed in polythene bags containing dry powdered charcoal; SACPH: SACI packed in polythene bags containing wet charcoal powder; SSC: SACI packed in polythene bags without charcoal.

Table 5: Evolution of the carbohydrates content of the *Big-Ebanga* variety fruits in six different storage environment

Green life (Day)	Carbohydrates of B (%)	Carbohydrates of BCSS (%)	Carbohydrates of BCSH (%)	Carbohydrates of BCPS (%)	Carbohydrates of BCPH (%)	Carbohydrates of BSC (%)
0	92.496 ± 1.734^{aA}					
4	89.259 ± 1.195^{aA}	89.962 ± 1.350^{aA}	89.962 ± 1.400^{aA}	89.962 ± 0.006^{aA}	91.015 ± 0.003^{aA}	91.015 ± 0.141^{aA}
8	80.938 ± 5.535^{bA}	87.320 ± 1.220^{abAB}	87.965 ± 0.717^{abB}	88.206 ± 0.011^{bB}	88.120 ± 0.004^{bB}	88.380 ± 0.054^{bB}
12	74.634 ± 0.005^{bA}	85.975 ± 0.570^{bB}	85.316 ± 1.040^{bB}	86.027 ± 0.009^{cB}	85.417 ± 0.098^{cB}	86.435 ± 0.096^{cB}
16		81.607 ± 1.883^{cA}	81.817 ± 1.488^{cA}	83.087 ± 0.010^{dA}	83.015 ± 0.002^{dA}	83.125 ± 0.011^{dA}
20		77.967 ± 1.657^{dA}	78.052 ± 1.292^{dA}	79.047 ± 0.011^{eA}	78.565 ± 0.144^{eA}	79.460 ± 0.138^{eA}
24		76.135 ± 0.300^{deB}	76.072 ± 0.054^{deB}	75.654 ± 0.073^{fA}	75.583 ± 0.056^{fA}	76.203 ± 0.010^{fB}
28		75.332 ± 0.583^{deA}	75.076 ± 0.485^{eA}	75.309 ± 0.003^{gA}	75.011 ± 0.008^{gA}	
30		74.511 ± 0.001^{eD}	74.412 ± 0.008^{eC}	74.210 ± 0.004^{hA}	74.312 ± 0.013^{hB}	

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

B: Big-Ebanga no packaging; BCSS: Big-Ebanga packed in polythene bags containing dry solid charcoal; BCSH: Big-Ebanga packed in polythene bags containing wet solid charcoal; BCSP: Big-Ebanga packed in polythene bags containing dry powdered charcoal; BCPH: Big-Ebanga packed in polythene bags containing wet charcoal powder; BSC: Big-Ebanga packed in polythene bags without charcoal

Table 6: Evolution of the carbohydrates content of the *Orishele* variety fruits in six different storage environment

Green life (Day)	**Carbohydrates of O (%)**	**Carbohydrates of OCSS (%)**	**Carbohydrates of OCSM (%)**	**Carbohydrates of OCPS (%)**	**Carbohydrates of OCPM (%)**	**Carbohydrates of OCEM (%)**
0	91.431 ± 1.165^{aA}					
4	89.018 ± 0.524^{bA}	90.234 ± 0.021^{aA}	89.490± 1.152^{aA}	89.363 ± 1.265^{aA}	90.140± 0.046^{aA}	89.625± 1.053^{aA}
8	82.851 ± 0.645^{cA}	86.538 ± 1.012^{bB}	87.240± 0.814^{aB}	86.212 ± 0.954^{bB}	86.228± 0.937^{bB}	86.218± 1.057^{bB}
12	71.406 ± 0.046^{dA}	84.370 ± 1.157^{bB}	84.414± 1.221^{bB}	83.336 ± 1.123^{bB}	83.933± 0.705^{cB}	83.966± 2.364^{bB}
16		81.004 ± 0.379^{cA}	80.530± 0.702^{cA}	79.797 ± 1.401^{cA}	79.693± 1.340^{dA}	80.088± 1.059^{cA}
20		77.627 ± 1.052^{dA}	77.249± 0.880^{dA}	76.909 ± 0.785^{cdA}	76.196± 0.910^{eA}	77.515± 0.764^{cdA}
24		75.142 ± 0.985^{eA}	75.141± 0.645^{dA}	74.331 ± 0.622^{deA}	73.558± 0.723^{fA}	75.272± 0.744^{deA}
28		73.114 ± 0.955^{efA}	72.245± 1.114^{eA}	71.918 ± 1.631^{efA}	72.007± 0.850^{fgA}	
30		71.179 ± 0.097^{fC}	71.152± 0.016^{eBC}	70.047 ± 0.033^{fA}	71.113± 0.003^{gB}	

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

O: Orishele no packaging; OCSS: Orishele packed in polythene bags containing dry solid charcoal; OCSH: Orishele packed in polythene bags containing wet solid charcoal; OCPS: Orishele packed in polythene bags containing dry powdered charcoal; OCPH: Orishele packed in polythene bags containing wet charcoal powder; OSC: Orishele packed in polythene bags without charcoal

3.3 Total sugars

The total sugars contents of following plantain varieties fruits: *SACI* fruits (Table 7), *Big-Ebanga* fruits (Table 8) and *Orishele* fruits (Table 9) increase significantly ($p \leq 0.05$) depending on the days of storage for each storage environment.

Concerning *SACI* variety, the total sugars rate observed on day 0 is 0.736 g/100 g DM. This value changes during storage to reach, at 30 days of storage, 27.910 g / 100 g DM for SACSS, 27.796 g / 100 g DM for SACSH, 27.700 g / 100 g DM for SACPS and 28.163 g / 100 g MS for SACPH. The SSC record a rate of 21.333 g / 100 g DM on day 24 which marks the end of their green life.

The total sugars content of *Big-Ebanga* variety also increases from day 0 to day 30 from 0.623 g / 100 g DM to 29.820 g / 100 g DM for BCSS, 30.130 g / 100 g DM for BCSH, 30.830 g/100 g DM for BCPS and 30.840 g/100 g DM for BCPH. Those of BSC at the end of green life (24 days) is 31.433 g / 100 g. At 30 days of storage, the fruits of BCSS (29.820 g / 100 g DM) and BCSH (30.130 g / 100 g DM) record the lowest total sugar rate while the highest is that of BCPS (30.830 g / 100 g DM).

The total sugars content of fruits of *Orishele* variety varies from day 0 to day 30 from 0.466 g / 100 g DM to 25.656 g / 100 g DM for OCSS, 25.240 g / 100 g DM for OCSH, 25.543 g / 100 g DM for OCPS and 25.865 g / 100 g DM for OCPH. This rate is 20.256 g/100 g DM for OSC after 24 days of storage (end of green life). On day 30, the fruits of OCSH (25.240 g / 100 g DM) and OCPS (25.543 g / 100 g DM) have the lowest total sugar rate while that of OCPH (25.865 g / 100 g DM) is the highest.

The total sugars rate of these plantain varieties vary significantly ($P \leq 0.05$) during storage from one conservation environment to another. Collin and Dalnic [27] also observed the increase in total sugar levels (0.466 to 30.830 g / 100 g DM) during plantain storage, but these levels are slightly higher than those of *Orishele* variety (0. 5% to 22.56%). Belalcázar et al. [20] also observed the same evolution in plantain “Dominico harton” clone (0.75% 23.70%). Similar to total carbohydrates, the increase in total sugars is due to starch degradation during storage by the same process. Furthermore, according to Dorais et al. [28] factors such as mineral content water availability, irrigation, fertilization and climatic conditions con influence fruit sugar levels.

Table 7: Evolution of the total sugars content of the *SACI* variety fruits in six different storage environment

Green life (Day)	Total sugars of SA (g / 100 g DM)	Total sugars of SACSS (g / 100 g DM)	Total sugars of SACSH (g / 100 g DM)	Total sugars of SACPS (g / 100 g MD)	Total sugars of SACPH (g / 100 g DM)	Total sugars of SSC (g / 100 g DM)
0	0.736 ± 0.035^{aA}					
4	7.256 ± 0.030^{bB}	1.663 ± 0.025^{aA}	1.700 ± 0.200^{aA}	2.433 ± 0.305^{aA}	2.633 ± 0.251^{aA}	1.850 ± 0.036^{aA}
8	16.053 ± 0.035^{cB}	5.873 ± 0.030^{bA}	5.926 ± 0.020^{bA}	6.333 ± 0.251^{bA}	6.243 ± 0.025^{bA}	6.253 ± 0.315^{bA}
12	27.160 ± 0.036^{dD}	11.956 ± 0.035^{cA}	11.960 ± 0.026^{cAB}	11.813 ± 0.015^{cC}	12.080 ± 0.010^{cB}	12.103 ± 1.826^{cAB}
16		16.240 ± 0.030^{dAB}	16.116 ± 0.030^{dBC}	17.153 ± 0.035^{dAB}	16.566 ± 0.251^{dC}	17.226 ± 0.030^{dA}
20		19.316 ± 0.030^{eAB}	19.663 ± 0.030^{eBC}	20.133 ± 0.025^{eA}	19.840 ± 0.030^{eCD}	20.130 ± 0.043^{eD}
24		21.330 ± 0.030^{fA}	21.226 ± 0.020^{fA}	21.540 ± 0.030^{fA}	20.790 ± 0.020^{fB}	21.333 ± 0.251^{fA}
28		25.123 ± 0.020^{gA}	25.416 ± 0.030^{gA}	25.356 ± 0.025^{gA}	26.026 ± 0.020^{gA}	
30		27.910 ± 0.052^{hB}	27.796 ± 0.240^{hA}	27.700 ± 0.253^{hB}	28.163 ± 0.030^{hB}	

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

SA: SACI no packaging; SACSS: SACI packed in polythene bags containing dry solid charcoal; SACSH: SACI packed in polythene bags containing wet solid charcoal; SACPS: SACI packed in polythene bags containing dry powdered charcoal; SACPH: SACI packed in polythene bags containing wet charcoal powder; SSC: SACI packed in polythene bags without charcoal

Table 8: Evolution of the total sugars content of the *Big-Ebanga* variety fruits in six different storage environment

Green life (Day)	Total sugars of B (g / 100 g DM)	Total sugars of BCSS (g / 100 g DM)	Total sugars of BCSH (g / 100 g DM)	Total sugars of BCPS (g / 100 g DM)	Total sugars of BCPH (g / 100 g DM)	Total sugars of BSC (g / 100 g DM)
0	0.623 ± 0.025^{aA}					
4	7.240 ± 0.020^{bB}	2.143 ± 0.035^{aA}	3.230 ± 0.036^{aA}	2.813 ± 0.035^{aA}	2.563 ± 0.030^{aA}	2.316 ± 0.011^{aA}
8	18.063 ± 0.020^{cD}	6.230 ± 0.030^{bA}	7.146 ± 0.035^{bC}	8.036 ± 0.030^{bC}	8.600 ± 0.300^{bAB}	7.250 ± 0.030^{bBC}
12	29.630 ± 0.020^{dD}	10.653 ± 0.030^{cA}	11.153 ± 0.035^{cC}	10.856 ± 0.030^{cA}	11.653 ± 0.025^{cBC}	11.623 ± 0.041^{cAB}
16		15.246 ± 0.040^{dB}	16.040 ± 0.026^{dD}	16.340 ± 0.036^{dC}	16.593 ± 57.700^{dA}	16.240 ± 0.036^{dB}
20		18.356 ± 0.025^{eA}	17.880 ± 0.030^{eA}	18.333 ± 0.035^{eA}	18.733 ± 0.035^{eA}	19,.56 ± 0.025^{eA}
24		23.520 ± 0.036^{fAB}	24.163 ± 0.011^{fA}	23.750 ± 0.030^{fB}	23.583 ± 0.025^{fB}	24.116 ± 0.030^{fB}
28		25.133 ± 0.025^{gB}	26.216 ± 0.030^{gA}	26.763 ± 0.025^{gC}	25.830 ± 0.036^{gD}	
30		29.820 ± 0.036^{hA}	30.130 ± 0.036^{hA}	30.830 ± 0.036^{hB}	30.340 ± 0.036^{hB}	

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

B: Big-Ebanga no packaging; BCSS: Big-Ebanga packed in polythene bags containing dry solid charcoal; BCSH: Big-Ebanga packed in polythene bags containing wet solid charcoal; BCSP: Big-Ebanga packed in polythene bags containing dry powdered charcoal; BCPH: Big-Ebanga packed in polythene bags containing wet charcoal powder; BSC: Big-Ebanga packed in polythene bags without chacoal

Table 9: Evolution of the total sugars content of the *Orishele* variety fruits in six different storage environment

Green life (Day)	Total sugars of O (g / 100 g DM)	Total sugars of OCSS (g / 100 g DM)	Total sugars of OCSH (g / 100 g DM)	Total sugars of OCPS (g / 100 g DM)	Total sugars of OCPH (g / 100 g DM)	Total sugars of OSC (g / 100 g DM)
0	0.466 ± 0.025^{aA}					
4	6.280 ± 0.045^{bB}	2.043 ± 0.025^{aA}	1.853 ± 0.035^{aA}	2.226 ± 0.160^{aA}	1.850 ± 0.036^{aA}	2.050 ± 0.040^{aA}
8	9.556 ± 0.025^{cE}	4.736 ± 0.030^{bA}	4.953 ± 0.025^{bD}	4.860 ± 0.026^{bBC}	5.050 ± 0.030^{bAB}	4.550 ± 0.020^{bC}
12	25.133 ± 0.025^{dC}	10.140 ± 0.036^{cA}	9.946 ± 0.025^{cAB}	10.233 ± 0.025^{cB}	10.576 ± 0.015^{cB}	10.746 ± 0.030^{cB}
16		15.140 ± 1.706^{dAB}	14.533 ± 0.025^{dC}	13.950 ± 0.030^{dBC}	14.643 ± 0.041^{dA}	14.246 ± 0.025^{dAB}
20		18.560 ± 0.026^{eAB}	17.963 ± 0.025^{eBC}	18.116 ± 0.015^{eA}	18.850 ± 0.036^{eC}	18.443 ± 0.030^{eAB}
24		20.170 ± 0.020^{eA}	19.656 ± 0.035^{fB}	20.230 ± 0.020^{fA}	20.343 ± 0.030^{fB}	20.256 ± 0.025^{fB}
28		22.340 ± 0.156^{fAB}	22.150 ± 0.020^{gB}	22.460 ± 0.026^{gA}	23.163 ± 0.025^{gB}	
30		25.656 ± 0.020^{gA}	25.240 ± 0.030^{hA}	25.543 ± 0.030^{hA}	25.863 ± 0.030^{hA}	

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

O: Orishele no packaging; OCSS: Orishele packed in polythene bags containing dry solid charcoal; OCSH: Orishele packed in polythene bags containing wet solid charcoal; OCPS: Orishele packed in polythene bags containing dry powdered charcoal; OCPH: Orishele packed in polythene bags containing wet charcoal powder; OSC: Orishele in polythene bags without charcoal

3.4 Proteins

The proteins contents of following plantain varieties fruits: *SACI* (Table 10), *Big-Ebanga* (Table 11), *Orishele* (Table 12) increase significantly ($p \leq 0.05$) during storage in each conservation environment.

The proteins rate on day 0 of *SACI* variety is 3.016 g/100 g DM. It evolves, after 30 days of storage, to reach 5.880 g / 100 g DM for SACSS, 5.803 g / 100 g DM for SACSH, 5.796 g / 100 g DM for SACPS and 5.630 g / 100 g DM for SACPH. The green life of SSC ends after 24 days of storage with a proteins content of 5.520 g / 100 g DM. The fruits of SACSS (5.880 g / 100 g DM) record the highest proteins content at 30 days while that of SACPH (5.630 g / 100 g DM) is the lowest.

Concerning the *Big-Ebanga* variety, the proteins content on day 0 is 3.1 g / 100 g DM. It varies and reaches, after 30 days of storage, levels of 5.243 g / 100 g DM for BCSS, 5.213 g / 100 g DM for BCSH, 5.096 g / 100 g DM for BCPS and 5.197 g / 100 g DM for BCPH. The BSC have a green life of 24 days and the proteins level obtained is 4.893 g / 100 g DM. The highest values of proteins content are obtained by BCSS (5.243 g / 100 g DM) while the lowest value is that of BCPS (5.096 g / 100 g DM).

The proteins contents of the *Orishele* variety increased from 3.250 g / 100 g DM on day 0 to 5.080 g / 100 g DM for OCSS, 5.016 g / 100 g DM for OCSH, 4.983 g / 100 g DM for OCPS and 4.956 g / 100 g DM for OCPH, on day 30. As for OSC, they have a storage time of 24 days and end up with a protein rate of 4.630 g / 100 g DM. The OCSS (5.080 g / 100 g DM) have the highest protein content while those of the OCPH (4.956 g / 100 g DM) have the lowest content at the end of 30 days of storage. Similar results are observed by Assemand et al. [21] on *Orishele* (4.15% to 5.01%) and *Agnrin* (3.27% to 4.27%) varieties. These low protein levels are consistent with those of nine plantain cultivars studied by Maniga et al. [29], who obtained rates ranging from 3.02 to 4.71 g / 100 g DM. The low protein content observed in the pulp of mature plantains is due to their degradation during ripening. The resulting amino acids are used in gluconeogenesis [30]. However, the increase of the proteins content of the pulp during ripening would be due to specific activities of expansins (enzymes) involved in the modification and/or in the hydrolysis of the wall components [31]. In addition, it is possible that a proportion of these elements (proteins, lipids and mineral salts) migrates with the water towards the pulp in the ripening process of fruits [32].

Table 10: Evolution of the proteins content of the *SACI* variety fruits in six different storage environment

Green life (Day)	Proteins of SA (g / 100 g DM)	Proteins of SACSS (g / 100 g DM)	Proteins of SACSH (g / 100 g DM)	Proteins of SACPS (g / 100 g DM)	Proteins of SACPH (g / 100 g DM)	Proteins of SSC (g / 100 g DM)
0	3.016 ± 0.015^{aA}					
4	4.626 ± 0.025^{bF}	3.713 ± 0.015^{aD}	3.120 ± 0.020^{aB}	3.546 ± 0.015^{aC}	3.086 ± 0.015^{aA}	4.003 ± 0.015^{aE}
8	5.013 ± 0.015^{cE}	3.873 ± 0.015^{bC}	3.596 ± 0.025^{bB}	3.896 ± 0.015^{bC}	3.323 ± 0.025^{bA}	4.220 ± 0.020^{bD}
12	5.943 ± 0.020^{dF}	4.510 ± 0.020^{cD}	4.220 ± 0.020^{cB}	4.296 ± 0.015^{cC}	3.776 ± 0.015^{cA}	4.546 ± 0.015^{cE}
16		4.666 ± 0.015^{dC}	4.696 ± 0.015^{dC}	4.313 ± 0.015^{cB}	4.020 ± 0.010^{dA}	4.720 ± 0.020^{dD}
20		5.203 ± 0.025^{eD}	5.103 ± 0.025^{eC}	4.713 ± 0.015^{dA}	4.893 ± 0.015^{eB}	5.330 ± 0.020^{eE}
24		5.413 ± 0.015^{fD}	5.388 ± 0.025^{fC}	5.306 ± 0.020^{eB}	4.940 ± 0.036^{fA}	5.520 ± 0.020^{fE}
28		5.613 ± 0.015^{gD}	5.496 ± 0.015^{gB}	5.533 ± 0.020^{fC}	5.070 ± 0.020^{gA}	
30		5.880 ± 0.026^{hD}	5.803 ± 0.015^{hC}	5.796 ± 0.025^{gB}	5.630 ± 0.020^{hA}	

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

SA: SACI no packaging; SACSS: SACI packed in polythene bags containing dry solid charcoal; SACSH: SACI packed in polythene bags containing wet solid charcoal; SACPS: SACI packed in polythene bags containing dry powdered charcoal; SACPH: SACI packed in polythene bags containing wet charcoal powder; SSC: SACI in polythene bags without charcoal

Table 11: Evolution of the proteins content of the *Big-Ebanga* variety fruits in six different storage environment

Green life (Day)	Proteins of B (g / 100 g DM)	Proteins of BCSS (g / 100 g DM)	Proteins of BCSH (g / 100 g DM)	Proteins of BCPS (g / 100 g DM)	Proteins of BCPH (g / 100 g DM)	Proteins of BSC (g / 100 g DM)
0	3.100 ± 0.010^{aA}					
4	3.673 ± 0.015^{bC}	3.263 ± 0.015^{aAB}	3.266 ± 0.015^{aB}	3.216 ± 0.015^{aAB}	3.176 ± 0.015^{aA}	3.373 ± 0.136^{aB}
8	4.836 ± 0.025^{cD}	3.546 ± 0.015^{bA}	3.723 ± 0.025^{bB}	3.756 ± 0.025^{bB}	3.886 ± 0.015^{bC}	3.626 ± 0.015^{bA}
12	5.116 ± 0.056^{dD}	3.866 ± 0.015^{cA}	4.046 ± 0.025^{cB}	3.896 ± 0.025^{cA}	4.103 ± 0.015^{cB}	4.196 ± 0.015^{cC}
16		4.206 ± 0.025^{dA}	4.453 ± 0.015^{dC}	4.303 ± 0.020^{dB}	4.316 ± 0.025^{dB}	4.486 ± 0.015^{dC}
20		4.630 ± 0.036^{eC}	4.753 ± 0.015^{eD}	4.590 ± 0.020^{eB}	4.400 ± 0.085^{dA}	4.773 ± 0.025^{dD}
24		4.816 ± 0.015^{fC}	4.866 ± 0.025^{fD}	4.700 ± 0.020^{fB}	4.566 ± 0.020^{eA}	4.893 ± 0.015^{eE}
28		5.103 ± 0.015^{gC}	5.126 ± 0.015^{gD}	5.023 ± 0.025^{gA}	5.083 ± 0.020^{fB}	
30		5.243 ± 0.025^{hD}	5.213 ± 0.015^{hC}	5.096 ± 0.025^{hB}	5.187 ± 0.025^{gA}	

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

B: Big-Ebanga no packaging; BCSS: Big-Ebanga packed in polythene bags containing dry solid charcoal; BCSH: Big-Ebanga packed in polythene bags containing wet solid charcoal; BCSP: Big-Ebanga packed in polythene bags containing dry powdered charcoal; BCPH: Big-Ebanga packed in polythene bags containing wet charcoal powder; BSC: Big-Ebanga in polythene bags without charcoal.

Table 12: Evolution of the proteins content of the *Orishele* variety fruits in six storage different environment

Green life (Day)	Proteins of O (g / 100 g DM)	Proteins of OCSS (g / 100 g DM)	Proteins of OCSH (g / 100 g DM)	Proteins of OCPS (g / 100 g DM)	Proteins of OCPH (g / 100 g DM)	Proteins of OSC (g / 100 g DM)
0	3.250 ± 0.020^{aA}					
4	3.806 ± 0.015^{bC}	3.546 ± 0.015^{aAB}	3.526 ± 0.025^{aA}	3.530 ± 0.020^{aA}	3.506 ± 0.015^{aA}	3.596 ± 0.025^{aB}
8	4.293 ± 0.025^{cF}	3.613 ± 0.015^{bA}	3.796 ± 0.015^{bD}	3.683 ± 0.015^{bB}	3.766 ± 0.015^{bC}	3.803 ± 0.020^{bE}
12	5.106 ± 0.025^{dF}	3.880 ± 0.010^{cB}	3.940 ± 0.020^{cD}	3.856 ± 0.015^{cA}	3.913 ± 0.015^{cC}	3.973 ± 0.020^{cE}
16		4.356 ± 0.015^{dE}	4.290 ± 0.020^{dC}	4.143 ± 0.015^{dB}	4.123 ± 0.025^{dA}	4.336 ± 0.015^{dD}
20		4.381 ± 0.015^{eC}	4.393 ± 0.015^{eD}	4.356 ± 0.025^{eB}	4.320 ± 0.020^{eA}	4.410 ± 0.020^{eE}
24		4.673 ± 0.020^{fD}	4.590 ± 0.020^{fB}	4.483 ± 0.025^{fA}	4.586 ± 0.015^{fB}	4.630 ± 0.020^{fC}
28		4.736 ± 0.025^{gC}	4.686 ± 0.015^{gB}	4.523 ± 0.025^{gA}	4.594 ± 0.015^{gA}	
30		5.080 ± 0.036^{hC}	5.016 ± 0.030^{hB}	4.983 ± 0.015^{hA}	4.956 ± 0.015^{hA}	

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

O: Orishele no packaging; OCSS: Orishele packed in polythene bags containing dry solid charcoal; OCSH: Orishele packed in polythene bags containing wet solid charcoal; OCPS: Orishele packed in polythene bags containing dry powdered charcoal; OCPH: Orishele packed in polythene bags containing wet charcoal powder; OSC: Orishele in polythene bags without charcoal.

4. CONCLUSION

The different charcoal preservation methods used in this study allow an extension of the green life of the plantain until 30 days. Better still, these preservation methods have no negative impact on plantain biochemical composition. Overall, there is a significant increase of some biochemical parameters during the preservation of these fruits in these different storage environments. These preservation methods could be recommended to reduce post-harvest losses of plantain, especially since they are less expensive.

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