World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Evolution of hydrosoluble vitamins and sugars contents of nine traditional plantain cultivars (*Musa sp.*) during boiling

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World Journal of Advanced Research and Reviews, 2022, 16(01), 439–448

Publication history: Received on 11 September 2022; revised on 15 October 2022; accepted on 18 October 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.16.1.1054

Abstract

Plantain is a great consumption foodstuff whose knowledge of the nutritional potential of all the cultivars is a necessity. The following research aims to highlight the nutritional value of nine local plantain cultivars grown in Côte d'Ivoire. Vitamins and ethanosoluble sugars were determined using standard methods. The outcomes indicated the existence of vitamins B1, B2, B3, B5 and C whose levels decrease during boiling. The highest thiamine levels after each cooking time (10, 15 and 20 min) were 0.071 (*Banablé*), 0.045 (*Banakpa*) and 0.023 mg/100 g DM (*Ataplègnon*). The highest riboflavin levels were observed in *Banablé* cultivars (0.051, 0.037 and 0.024 mg/100 g DM), after 10; 15 and 20 min of boiling respectively. *Banakpa* cultivar recorded the highest levels of nicotinamide at each of these three boiling times with respective values of 0.69, 0.55 and 0.33 mg/100 g DM. Pantothenic acid levels were highest in the *Banaboi* cultivar after boiling (0.048; 0.035 and 0.029 mg/100 g DM). Vitamin C levels were higher after boiling in *N'glétia* (10.02 and 8.56 mg/100 g DM) and *Banadié* (8.06 mg/100 g DM) cultivars. In addition, boiling increased the levels of total sugars and reducing sugars during cooking, thus reaching the maximum values at 15 min of cooking beyond which they decreased. The pulp being almost cooked after 15 min of boiling, it would be desirable to keep this cooking time.

Keywords: Plantain; Cultivars; Nutrients; Boiling

1. Introduction

The plantain banana is a foodstuff whose production contributes to the diversification of the actors' incomes and contributes to the improvement of the Gross Domestic Product of the producing countries [1]. In particular, it contributes to food security in both rural and urban areas. In Côte d'Ivoire, plantain production is about 1.6 million tones and consumption is estimated at nearly 64 kg/per/year [2]. Thereby, a diversity of traditional plantain cultivars is found in plantations and markets in Côte d'Ivoire. Unfortunately, apart from the reference cultivars (*Orishele, Agnrin*) which have been studied by several authors [3, 4], there is no scientific work dedicated to the fruits of many of these local cultivars. To this end, several traditional plantain cultivars have been collected from local village plantations and the evaluation of their nutritional potential is necessary for a valuation. In addition, like several starchy products, the food value of plantain is low in the raw state because it is not easily digestible by humans. Indeed, its starch is digestible by human enzymes when cooked [5]. Plantain is then eaten cooked (fried, boiled, roasted, mashed, etc.) to facilitate their digestion [6].

However, knowing that cooking can significantly influence the nutritional value of foods [7], determining the real nutritional value of these plantain cultivars after cooking is necessary for consumers. Admittedly, known for its high carbohydrate content, the plantain undoubtedly contains other nutrients. Vitamins are, for example, organic substances with no energy value, essential for the growth, reproduction, and functioning of the organism which cannot synthesize

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them itself. They must therefore be provided by food and their presence is necessary for most of the biochemical reactions responsible for cell life [8]. Even if the plantain is not known for its richness in vitamins, knowing the rate of these substances in this food is important, especially since it is consumed in large quantities by certain people. In addition, the daily doses of vitamins are minimal and represent only a tiny part of the cellular composition, unlike proteins, nucleic acids, carbohydrates, and lipids. In order to add value to traditional plantain cultivars, this work will be mainly devoted to the evaluation of the water-soluble vitamin and sugar contents of nine traditional plantain cultivars.

2. Material and methods

2.1. Vegetal Material

The vegetal material, consisting of the fruits of nine plantain cultivars (Musa spp.), comes from the experimental plot of the National Center for Agronomic Research (CNRA) located in Azaguié, about 50 km from Abidjan. The vernacular names come from localities in the east and southeast of Côte d'Ivoire, the collection area of these cultivars. They are *Afoto, Attiébana, Banakpa, Ataplègnon, Banaboi, Banadié, N'gletia, Olègna and Bana*blé.

2.2. Sampling

The fruits of the nine plantain cultivars were harvested at the traditional cutting stage, that is, when the fingers of the first hand of the bunch show signs of ripening or when their apex turns black [9]. 10 fingers used by cultivar were washed and peeled using a stainless steel knife. The pulps obtained were boiled (100°C) in water for 10, 15, and 20 min. The cooked pulps were sliced and dried in a ventilated oven (Mem-mert, Model 854, Scwachbach, Germany) at 45°C for 72 h. Dehydrated boiled pulps obtained were ground and the precooked flours obtained were used for the analyses.

2.3. Determination of ethanosoluble sugars levels

2.3.1. Extraction of ethanosoluble sugars

The sugars were extracted from the flours using the technique described by Martinez-Herrera et al. [10]. 1 g of plantain flour was weighed and put in a centrifuge tube. A volume of 10 mL of ethanol (80%, v/v) was added thereto. The mixture was homogenized and centrifuged at 6000 rpm for 10 min in a centrifuge (JOUAN, BR4i multifunction, St Nerblain, France). The collected supernatant was stored in a 50 mL Erlenmeyer flask. The pellet was taken up in 10 mL of ethanol (80%, v/v), homogenized and centrifuged under the same conditions as above. The new supernatant was added to the first content in the 50 mL Erlenmeyer flask. The ethanol contained in this mixture was evaporated to the maximum in a sand bath. The sugar deposit obtained was used to assay the ethanosoluble sugars.

2.3.2. Determination of total sugars levels

Total sugars were determined according to the method described by Dubois et al. [11] using phenol and concentrated sulfuric acid. This dosage is based on the following principle: in the presence of phenol and concentrated sulfuric acid, the sugars give a yellow-orange color whose intensity is proportional to the concentration of carbohydrates. The optical density is determined between 490 nm.

2.3.3. Determination of reducing sugars levels

Reducing sugars were determined according to the method of Bernfeld [12] using 3.5 dinitrosalycilic acid (DNS). 3,5-DNS (3,5-dinitrosalicylic acid) forms quantitatively, when hot, with reducing sugars, an orange-red derivative whose absorbance is measured at 540 nm.

2.4. Determination of vitamins B levels

The vitamins B (B1, B2, B3 and B5) were determined by HPLC according to the method described by Aslam et al. [13]. 10 g of flour from the plantain cultivars was dissolved in 250 mL of an extraction solution (composed of 50 mL of acetonitrile, 10 mL of glacial acetic acid and made up to 1 L with l bi-distilled water). The mixture obtained was stirred in a water bath at 70°C for 40 min. After cooling, the mixture is filtered through Whatman No. 4 paper and then through a 0.45 µm Millipore filter (Sartorius, AG, Goëttingen, Germany). The volume of the collected solution was completed at 50 mL with the extraction solution. 10 µL of the sample/standard is injected into a 250 nm UV monitor. The standards are filtered and injected separately. All standards were prepared from pure powders of the primary reference substances. The qualitative analysis at the level of the different samples was obtained by comparing the retention time

of the eluted compounds with the retention times of the reference solutions. Concentrations were obtained from the average of the peaks of the reference solutions. The analyzes are carried out in triplicate.

2.5. Determination of vitamin C levels

The ascorbic acid content (vitamin C) was determined according to the method described by Pongracz [14], using 2,6-dichlorophenol indophenol.

2.6. Statistical analysis

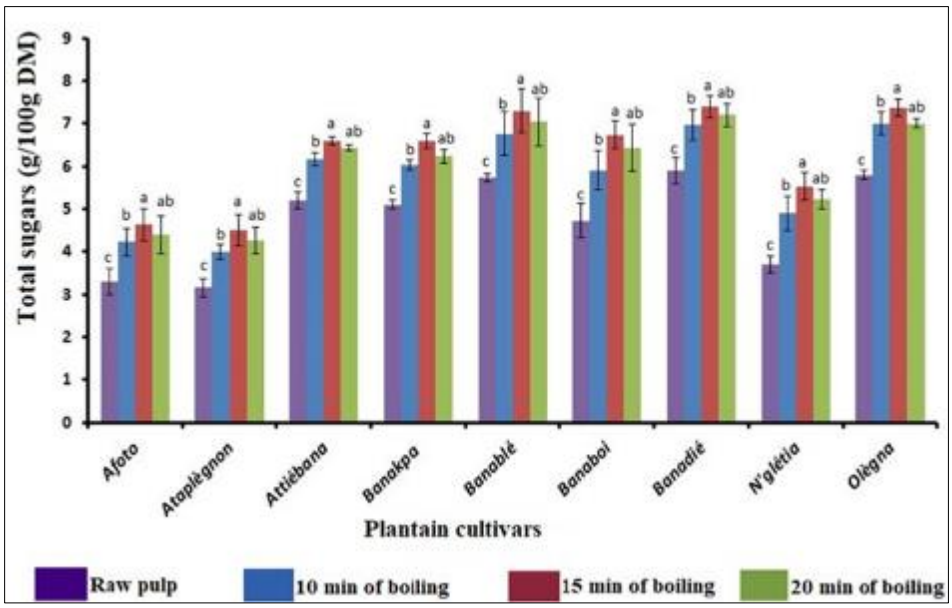
Analysis of the results was performed using Statistica 7.1 software. Tukey's test at the 5 % threshold was used to classify the means of experimental factors fruits. The difference between two data is significant when the level of significance is less than 5 %.

3. Results and discussion

3.1. Evolution of total sugars and reducing sugars content

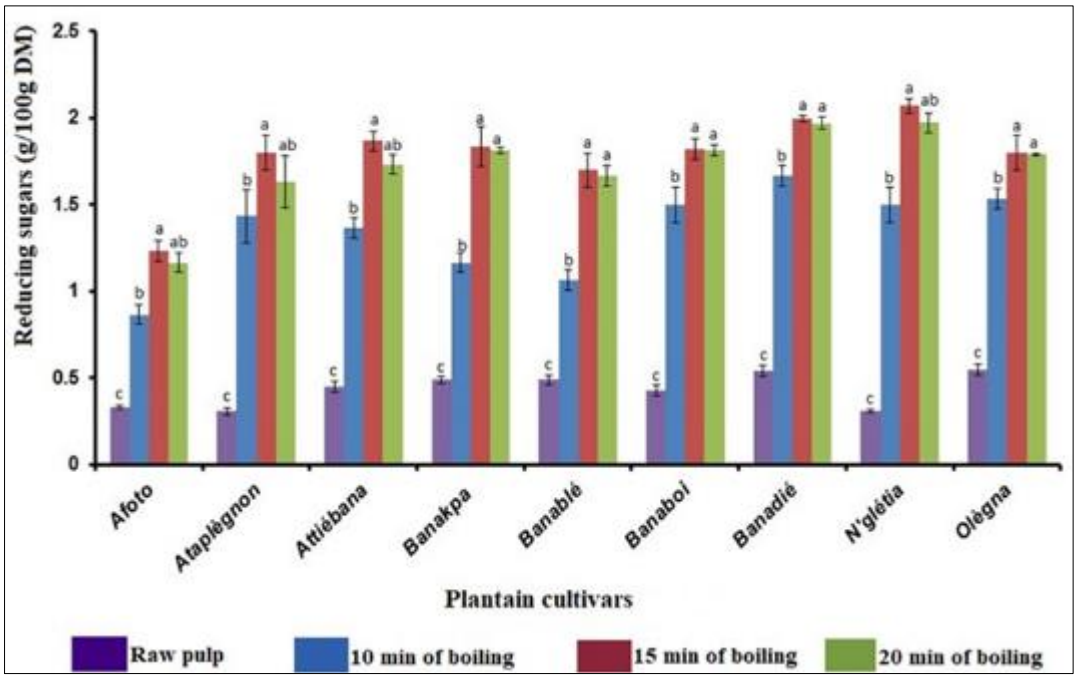
Variation in the total sugars content of the pulps of the different plantain cultivars during boiling are shown in Figure 1. There is a significant increase ($p < 0.05$) in the total sugars during boiling in the pulps of all cultivars. Thus, the total sugars content which were between 3.16 g/100 g DM (*Ataplègnon*) and 5.90 g/100 g DM (*Banadié*) before cooking reached levels between 4.00 g/100 g MS (*Ataplègnon*) and 6.98 g/100 g MS (*Olègna*) after 10 min of cooking. At 15 min of cooking, these contents increase further to reach levels varying between 4.50 g/100 g DM (*Ataplègnon*) and 7.37 g/100 g DM (*Olègna*). In contrast, when the pulps are boiled for up to 20 min, total sugars levels begin to decrease, but not significantly ($p \geq 0.05$) and reach values between 4.27 g/100 g MS (*Ataplègnon*) and 7.01 g/100 g DM (*Olègna*).

Like total sugars, the reducing sugars content of the pulps of each plantain cultivar increases significantly ($p < 0.05$) during boiling (Figure 2). In fact, when the pulps are boiled for 10 min, the reducing sugars content passes values between 0.31 g/100 g DM (*Ataplègnon*, *N'glétia*) and 0.55 g/100 g DM (*Olègna*) before the boiling at values between 0.87 g/100 g DM (*Afoto*) and 1.67 g/100 g DM (*Banadié*). Pulps of these plantain record higher levels of reducing sugars when boiled for 15 min with contents between 1.23 g/100 g DM (*Afoto*) and 2.07 g/100 g DM (N' *glétia*). These reducing sugars levels show a decrease, but not significant ($p \geq 0.05$) after 20 min. The values obtained are between 1.17 g/100 g DM (*Afoto*) and 1.97 g/100 g DM (*N'glétia*).



The means, represented by the bands ± standard deviation (I) assigned different letters at the cultivar level, indicate a significant difference at $p < 0.05$ according to the Tukey test.

Figure 1 Evolution of the total sugars content of the pulps of the nine plantain cultivars boiled



The means, represented by the bands ± standard deviation (I) assigned different letters at the cultivar level, indicate a significant difference at $p < 0.05$ according to the Tukey test.

Figure 2 Evolution of the reducing sugars content of the pulps of the nine plantain cultivars boiled

Increase in total and reducing sugars contents would be due to the simultaneous phenomena of hydrolysis and gelatinization that occur in the pulp during cooking. Indeed, under the effect of heat, starch grains swell and burst to release their contents, which are essentially composed of amylose and amylopectin [15, 16]. These molecules are then degraded to produce total sugars and reducing sugars. The results obtained are in agreement with those of Tsamo et al. [17] who observed the increase in soluble sugars during the cooking of the fruits of plantain cultivars Moto Ebanga (39.1 to 40.9 g/100 g DM) and Mbouroukou N°1 (52.2 to 53, 4g/100g DM). Adeniji et al. [18] also found the same results in plantain hybrids with rates ranging from 1.43 to 1.55%. Furthermore, since these sugars are now accumulated in the pulp, they can pass into the cooking water by leaching if the pulp is boiled for long periods [19]. This would explain the reduction of these sugars beyond 15 min of cooking.

3.2. Evolution of vitamin B1, B2, B3, B5 and vitamin C content

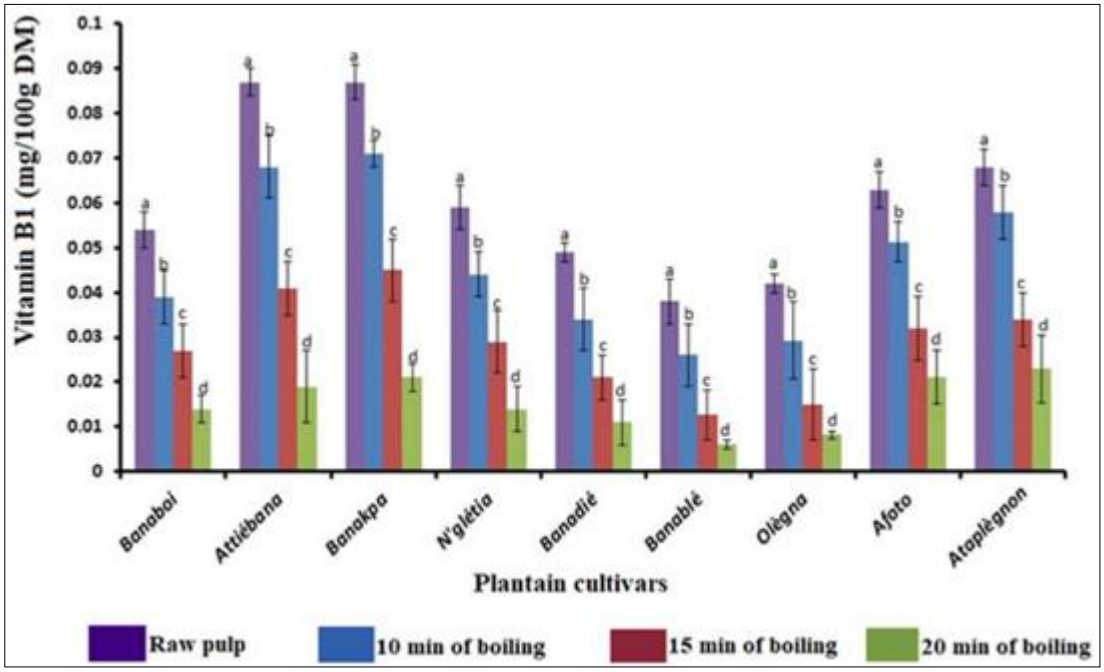
Vitamin B1 levels in plantain pulps decreases significantly ($p < 0.05$) during boiling (Figure 3). This decrease is accentuated when the boiling time is prolonged. Plantain pulps boiled for 10 min show vitamin B1 contents between 0.071 mg/100 g DM and 0.026 mg/100 g DM, respectively for the *Banablé* and *Banakpa* cultivars. After 15 min of cooking, the vitamin B1 content decreases and reach levels varying between 0.045 mg/100 g DM (*Banakpa*) and 0.013 mg/100 g DM (*Banablé*). These vitamin B1 contents are lower in the pulps boiled for 20 min and the values obtained are between 0.023 mg/100 g DM (*Ataplègnon*) and 0.006 mg/100 g DM (*Banablé*).

Vitamin B2 content of boiled plantain pulp decreases significantly ($p < 0.05$) with boiling time (Figure 4). Results show vitamin B2 levels varying between 0.069 mg/100 g DM (*Banablé*) and 0.041 mg/100 g DM (*Olègna*) before cooking. These levels decrease after 10 min of boiling to reach values of between 0.051 mg/100 g DM (*Banablé*) and 0.019 mg/100 g DM (*Olègna*). Plantain pulp boiled for 15 min still loses vitamin B2 and the values obtained vary between 0.037 mg/100 g DM (*Banablé*) and 0.010 mg/100 g DM (*Olègna*). The loss of vitamin B2 from the pulp continues when the boiling time is 20 min. The contents recorded for this boiling time (20 min) vary from 0.024 mg/100 g DM (*Banablé*) to 0.005 mg/100 g DM (*Olègna*).

Vitamin B3 levels in boiled pulps from plantain cultivars decreased significantly ($p < 0.05$) with boiling time (Figure 5). These vitamin B3 levels in plantain pulps range from 0.80 mg/100 g DM (*Banadié*) to 0.71 mg/100 g DM (*Banablé*) before cooking at levels between 0.69 mg/100 g DM (*Banakpa*) and 0.61 mg/100 g DM (*Attiébana*) when boiled for 10 min. After 15 min of cooking, the reduction in vitamin B3 contents of plantain pulps is still significant ($p < 0.05$) and the rates obtained are between 0.29 mg/100 g DM (*Ataplègnon*) and 0.55 mg/100 g DM (*Banakpa*). Finally, pulp boiled for 20 min has the lowest vitamin B3 levels. These levels range from 0.11 mg/100 g DM (*Ataplègnon*) to 0.33 mg/100 g DM (*Banakpa*).

Vitamin B5 levels, like those of other B vitamins, drop significantly ($p < 0.05$) as a function of boiling time (Figure 6). Vitamin B5 content of the pulps before cooking varies from 0.065 mg/100 g DM (*Banaboi*) to 0.041 mg/100 g DM (*Attiébana*). After 10 min of cooking, the levels vary from 0.048 mg/100 g DM (*Banaboi*) to 0.021 mg/100 g DM (*Banablé*). These vitamin B5 levels again when the pulps are boiled for 15 min and the values obtained vary from 0.035 mg/100 g DM (*Banaboi*) to 0.016 mg/100 g DM (*Attiébana*). Pulps boiled for 20 min have the lowest levels of vitamin B5. These contents are arranged between 0.029 mg/100 g DM (*Banaboi*) and 0.010 mg/100 g DM (*Banablé*).

As with vitamins B, the vitamin C content of the plantain pulps decreases significantly ($p < 0.05$) depending on the boiling time (Figure 7). Before boiling the pulp, the vitamin C content is between 25.56 mg/100 g DM (*N'gletia*) and 16.72 mg/100 g DM (*Banablé*). However, after cooking for 10 min of boiling, vitamin C content of the pulps is between 10.02 mg/100 g DM (*N'gletia*) and 4.16 mg/100 g DM (*Afoto*). Then, when the pulp boiling time reaches 15 min, vitamin C levels drop significantly ($p < 0.05$) and vary from 8.56 mg/100 g DM (*N'gletia*) to 2.34 mg/100 g MS (*Banablé*). Extending the pulp boilng time to 20 min accentuates the reduction in vitamin C levels and reaches values between 8.06 mg/100 g DM (*Banadié*) and 0.99 mg/100 g DM (*Banablé*).

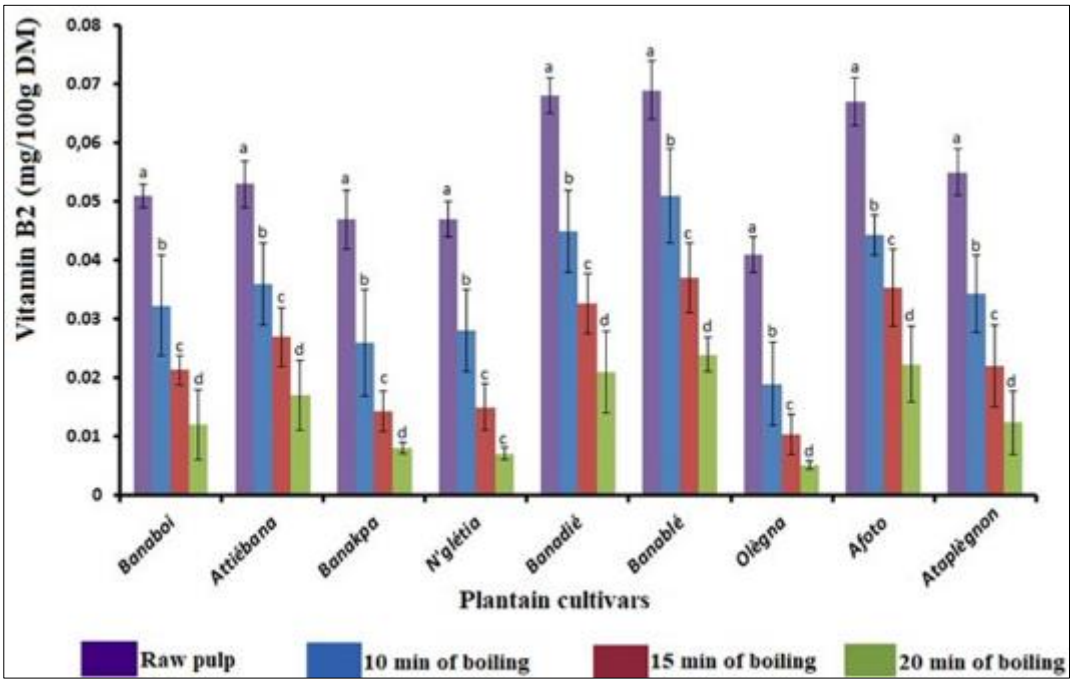


The means, represented by the bands ± standard deviation (I) assigned different letters at the cultivar level, indicate a significant difference at $p < 0.05$ according to the Tukey test.

Figure 3 Evolution of the vitamin B1 content of the pulps of the nine plantain cultivars boiled

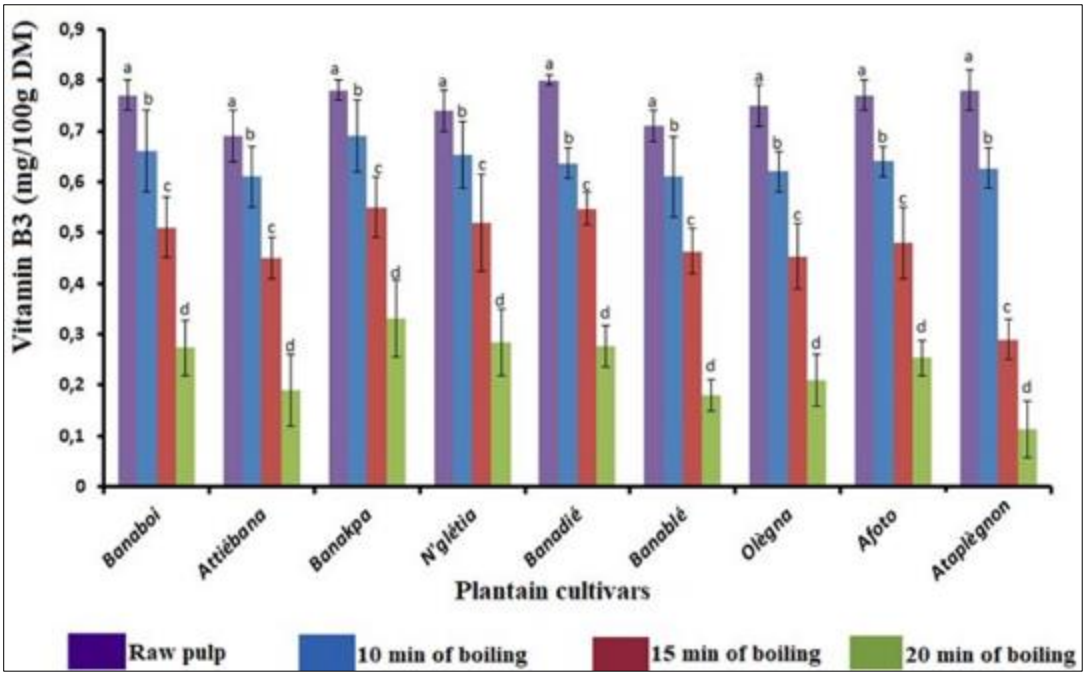
These results are in agreement with those of Preeti et al. [20] who observed a significant decrease in vitamins B1, B2, and B3 in boiled green peas. Similarly, Gahler et al. [21] noted in their study that the best way to take advantage of vitamin C from vegetables is to eat them fresh with minimal cooking, to avoid losing this vitamin. Indeed, the loss of water-soluble vitamins in food is due to several factors, including the time it takes to heat during cooking [22]. However, taking account the daily requirements of vitamins B, the different levels obtained after plantain pulp cooking are certainly low but not negligible for consumers. Indeed, the needs of thiamine correlated with energy metabolism are 0.5 mg / l000 kcal in men and women, 0.6 mg / l000 kcal in pregnant women and lactating women and between 0.4 and 0.5 mg / l 000 kcal depending on age, in children [23, 24]. Concerning riboflavin, the recommended nutritional intakes are 1.8 mg / d in adult men, 1.4 mg / d in adult women, 1.6 and 1.8 mg / d respectively in pregnant women and breastfeeding women and 0.4 to 1.2 mg/d in children depending on age [25, 26]. According to Mourey A. [27], the reference intake of niacin for a population is around 6.7 mg/1000 kcal. It is clear from these daily intakes that plantain bananas can help meet the vitamin needs of the major consumers of this commodity. Deficiency of these vitamins is responsible for several neurological, neuropsychological, dermatological, and hematological signs for thiamine, skin lesions, mucous membranes (stomatitis, cheilitis, glossitis, and seborrheic dermatitis), ocular, as well as hypochromic anemia for riboflavin and even a series of symptoms typical of pellagra, which is fatal if not treated rapidly in the event of niacin deficiency [27]. For these reasons, their presence in these plantain cultivars is a real asset for consumers. For average vitamin C requirements of around 30 mg/d, 55 mg/d for pregnant women, and 70 mg/g for breastfeeding

women [27], the levels recorded at plantain cultivars studied (10.02 and 8.06 mg/100 g DM) are not negligible, given the quantity of plantain frequently consumed by certain peoples.



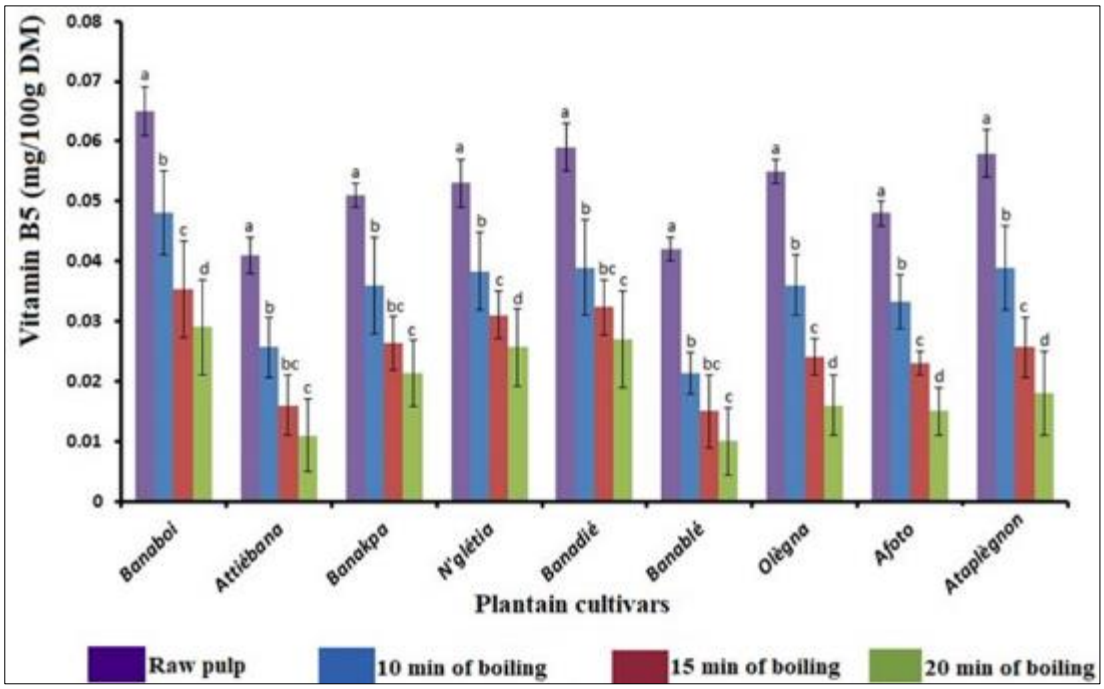
The means, represented by the bands ± standard deviation (I) assigned different letters at the cultivar level, indicate a significant difference at $p < 0.05$ according to the Tukey test.

Figure 4 Evolution of the vitamin B2 content of the pulps of the nine plantain cultivars boiled



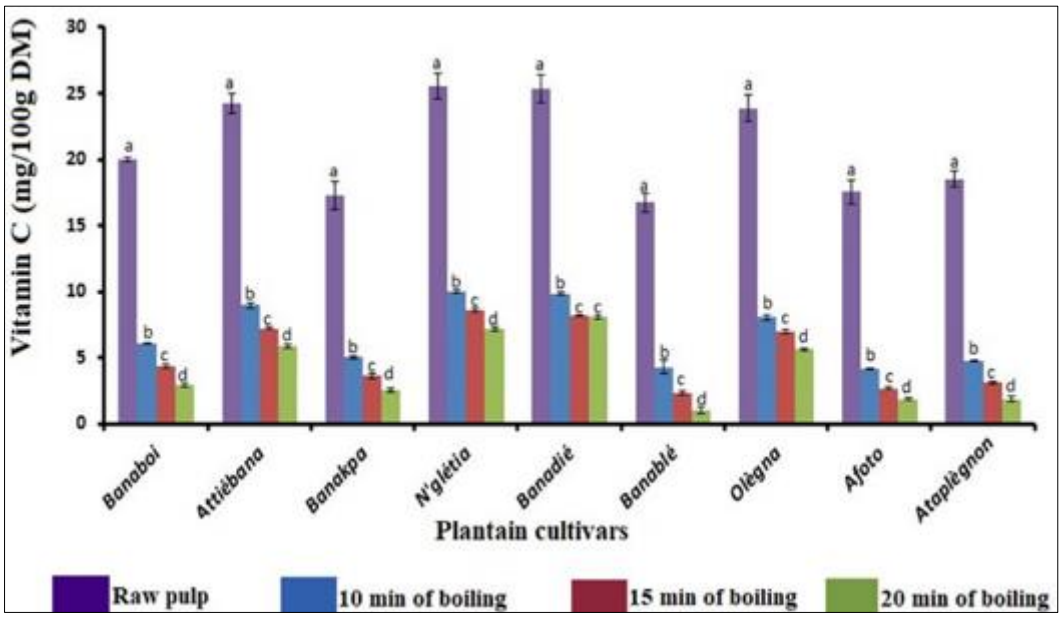
The means, represented by the bands ± standard deviation (I) assigned different letters at the cultivar level, indicate a significant difference at $p < 0.05$ according to the Tukey test.

Figure 5 Evolution of the vitamin B3 content of the pulps of the nine plantain cultivars boiled



The means, represented by the bands ± standard deviation (I) assigned different letters at the cultivar level, indicate a significant difference at $p < 0.05$ according to the Tukey test.

Figure 6 Evolution of the vitamin B5 content of the pulps of the nine plantain cultivars boiled



The means, represented by the bands ± standard deviation (I) assigned different letters at the cultivar level, indicate a significant difference at $p < 0.05$ according to the Tukey test.

Figure 7 Evolution of the vitamin C content of the pulps of the nine plantain cultivars boiled

4. Conclusion

Although the results of boiling the pulps of the nine plantain cultivars show the reduction of vitamin levels, it is necessary to ensure good digestion of plantains. On the other hand, it favors an increase in the levels of ethanosoluble sugars. Cooking the pulps for 20 min further affects the nutritional quality of the pulps. It would be ideal to boil the pulps for 15 min to avoid losing more nutrients.

Compliance with ethical standards

Acknowledgments

The authors would like to thank the National Center for Agronomic Research for their support in the development of this work.

Approval of Conflict of interest

The authors declare that they have no competing interests.

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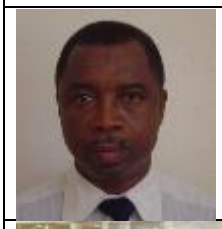	**Authors Name: Coulibaly Souleymane** Coulibaly Soulemane was a researcher, then a research master and then a research director at the National Center for Agricultural Research (CNRA). He is a specialist in banana plantain and has coordinated several projects in this field at the CNRA. He has received several fellowships and has participated in several food-related seminars and symposia. He is the author of several publications.
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