Research Article

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Cooking mode and ripening stage influence physicochemical and nutritional properties of boiled plantain pulps

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Abstract

BACKGROUND: Plantains are of major importance in the diet of many African populations. Plantains undergo many processing techniques at different ripening stages. Boiling is the most common method of processing plantains in Cameroonian households. The present study was undertaken to evaluate the effect of cooking mode and ripening stage on the physicochemical and nutritional parameters of two *Musa* genotypes. Fruits from genotypes, *Batard* and *CARBAP K74*, at three ripening stages (unripe, semi-ripe and ripe) were studied. Physicochemical and nutritional analyses were performed on raw and cooked pulps with and without peel at different cooking times (from 10 to 60 min).

RESULTS: Significant variations ($P < 0.05$) were observed in the parameters assessed during cooking at each ripening stage according to cooking time. Plantain pulps boiled with peel exhibited high firmness (0.7–1.7 kgf), high soluble solids (7.4–22.4°Brix) and high dry matter content (29.8–38.3%) at all ripening stages. This cooking method yielded high protein (3.0–4.8%), lipid (0.2–1.8%), total starch (32–73%) and total carbohydrate (18–32%) contents. Boiling with or without peel had no significant effect ($P > 0.05$) on the pH of *Batard* pulps, nor the ash content of the pulps of both genotypes.

CONCLUSION: Irrespective of the ripening stages used, during cooking by immersion in boiling water, cooking with peel best preserves the physicochemical and nutritional parameters of the analysed genotypes.

Keywords: processing; *Musa* pulp and fruit; physicochemical criteria; nutritional properties

INTRODUCTION

The food and agriculture sectors play a key role in improving people's diets with high availability and accessibility of varied and healthy foods.[1] Plantains (*Musa paradisiaca*, AAB) account for 15% of the world's banana (*Musa* spp.) fruit production, estimated at 139 470 376 tonnes,[2] with Cameroon producing 3 940 818 tonnes in 2018.[3] Cameroon is the world's largest producer of plantain, followed by Ghana, Uganda, Colombia and Nigeria.[4] Plantains are sources of carbohydrates, phenolic compounds, minerals, vitamin C, vitamin B6 and carotenoids.[5,6] They are of major importance in the diet of many African populations. Unlike bananas that are consumed raw as a dessert, plantains are subject to many processing techniques (boiling, steaming, frying, drying and roasting)[7,8] at different stages of post-harvest maturation.[9]

Heat treatments are widely applied in food processing. Boiling in water is the most widely used cooking method in the majority of African households.[8,10] In particular, it includes the culinary techniques of simmering and blanching foods. Depending on

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the type of food, cooking with water entails two techniques, namely the immersion of the food in boiling water and the immersion of the food in cold water before bringing it to boil. The former is highly recommended because it results in less vitamin loss compared to the latter because the food is immediately seared by hot water.[11] For starchy products such as plantains, two main functions are sought during cooking: to improve digestibility by partial or total gelatinization of the starch[12] and to develop specific organoleptic properties such as texture, taste or color.[13]

Local plantain varieties (landraces) are still often preferred over new genotypes by producers, processors and consumers, mainly because of their attributes such as taste, texture, color.[14-16] Indeed, over the past decades, breeders have developed and distributed new disease-resistant and high-yielding plantain clones such as the *CARBAP K74*, a plantain-like hybrid developed by CARBAP (Centre Africain de Recherches sur Bananiers et Plantains) and CIRAD (Centre de Coopération Internationale en Recherches Agronomiques pour le Développement) breeding programs. Previous works highlighted that plantain pulps can be boiled either with or without peel.[17] In addition, some studies revealed that boiling plantain with peel should be the preferred method in domestic preparations, regardless of the cultivars since it best preserves carotenoid and secondary metabolite contents.[18,19] Nonetheless, the influence of plantain quality during boiling on its nutritional and physicochemical properties remains unclear. The present study therefore aims to evaluate the influence of the cooking method (mode and time) on the physicochemical and nutritional parameters of two plantain genotypes (a landrace and an improved hybrid) at three ripening stages.

MATERIALS AND METHODS

Plant material and sampling

The plant material (Fig. 1) consisted of bunches of *Batard* (local landrace) and *CARBAP K74* (plantain-like hybrid) harvested at optimum physiological maturity from a CARBAP experimental plot in Njombe, located in the Njombe-Penja district (Latitude: 4°34′59.99′N; Longitude: 9°39′59.99′E), Moungo Division, Littoral region of Cameroon. This plot was set up in September 2019 as part of the RTBfoods project (https://rtbfoods.cirad.fr). At harvest, fruits from the second and third hands of the bunches were selected, randomized and allowed to ripen at room temperature (27 ± 2 °C) in open boxes. Ripening stages were defined based on peel color change as recommended by Dadzie and Orchard.[20] The respective color appearance of unripe (stage 1), early ripening or semi-ripe (Stage 3) and ripe (stage 5) fruits were green, mixed green and yellow, and yellow with green tips (Fig. 2). At each ripening stage, fruits were separated into three batches: the first batch (raw) was considered as a control; the second batch was dedicated to boiling without peel; and the third batch was used for boiling with peel.

Cooking

The fruit samples described above were washed with running water and peeled when necessary with a stainless steel knife. In the present study, boiling refers to cooking by complete immersion of the pulps or whole fruits in boiling water. The cooking processes were carried out in an aluminium pot (diameter, 30 cm; height, 16 cm; thickness, 0.4 cm) burning butane as the heat source. Before boiling, the weight of plantain fruits or pulps was recorded on a precision scale (XB1200C, $d = 0.01$ g; Precisa, Dietikon, Switzerland) and they were introduced into boiling water for 10, 20, 30, 40, 50 and 60 min. Once the set boiling time was reached, the boiled fruits or pulps were drained in a strainer and allowed to cool for 5 min before any analysis.

Sample characterization

Physicochemical characteristics

Total soluble solids (TSS), total titratable acidity (TTA), pH and pulp firmness of plantain pulps were evaluated using protocols reported by Dadzie and Orchard.[20] TSS was assessed using a hand refractometer (BRIX REF113 0–32 ATC, JENWAY LEGALLAIS; Cole

(A) (B)

Figure 1. Local landrace *Batard* (A) and the plantain-like hybrid *CARBAP K74* (B) used in the present study.

Figure 2. Ripening stages of plantain fruits: unripe stage (A), half-ripe stage (B) and ripe stage (C).

Parmer, Chicago, IL, USA), TTA was determined by titration, pH was determined using a pH-meter (JENWAY LEGALLAIS; Cole Parmer, Chicago, IL, USA) and pulp firmness of plantain pulps was assessed by measuring the force required to penetrate 1 cm of pulp tissue using a crossbow-type penetrometer with a 6-mm diameter cylindrical probe.

Nutritional properties

Dry matter content (DMC) and ash content were determined using the standard methods of analysis of AOAC.[21] Crude protein determination was extrapolated from the total nitrogen content in the sample, as described in the Kjeldahl technique with a conversion factor of 6.25.[22] Crude lipid was determined by the Soxhlet extraction method using hexane as extracting solvent.[23] The carbohydrate content was obtained by difference (%carbohydrates = 100 – % moisture – % protein – % lipid – % mineral).[24] Total starch was determined using Ewers polarimetric method.[25]

Statistical analysis

The statistical analyses of results obtained from three replications were carried out using XLSTAT 2014.[26] Analysis of variance was used to compare the means using Tukey's test at $P < 0.05$. Excel 2016 (Microsoft Corp., Redmond, WA, USA) was used for data entry.

RESULTS

Physicochemical characteristics

pH

Unripe *Batard* pulps presented a pH of 6.58 which decreased during ripening to 5.71 at stage 5. *CARBAP K74* presented a similar trend, with values ranging from 6.53 to 5.57, respectively, at stages 1 and 5. Regardless of the cooking method, the pH consistently decreased (but not significantly at $P > 0.05$) through cooking at all ripening stages for *Batard* pulps (Table 1). On the other hand, although pH values for *CARBAP K74* pulps showed some significant differences, there was no clear pattern through cooking time, regardless of the stages of fruit ripening (Table 2).

TTA

The TTA indicates the total amount of acids present in a product. Unripe *Batard* pulps presented a value of 688.9 mEq/100 g. This value increased consistently during ripening to reach 2088.9 mEq/100 g at the ripe stage (Table 1). Unripe *CARBAP K74* pulps showed a value of 1000, increased to 1733 at Stage 3, and then decreased to 1511 mEq/100 g at stage 5 of post-harvest maturity (Table 2). In general, TTA tended to decrease with boiling, with differences reaching significance only at stage 5 for *Batard* and at stages 3 and 5 for *CARBAP K74*. Regardless of the ripening stages and the cultivars, TTA were highest when fruits were boiled with peel.

TSS

At harvest, *Batard* pulps recorded a TSS of −0.2°Brix, whereas that of *CARBAP K74* was 0.2°Brix. There was always a significant ($P < 0.05$) increase in TSS through boiling time, regardless of the genotype, cooking method or ripening stage (except for stage 5 fruits from *CARBAP K74*).

For *CARBAP K74*, changes always occurred in the first 10 min (increasing the values, often significantly) and then remained more or less constant. Occasionally, values gradually decreased from the maximum attained at 10 min of cooking. For *Batard*, on the other hand, changes often occurred more gradually within the first 20 min of boiling (except for fruits from the third and fifth stages without peel). Maximum values were generally attained 30 min after boiling.

Firmness

At harvest, *Batard* and *CARBAP K74* pulps (from stage 1 fruits) recorded a firmness value of 2.90 kgf (Tables 1 and 2). During ripening this value decreased to reach respectively 2.43 and 1.00 kgf (at Stage 3), and 2.03 and 0.70 kgf (at stage 5). Firmness therefore decreased considerably faster in *CARBAP K74* than in *Batard* (Tables 1 and 2). Irrespective of the cooking modes, the pulp firmness of these cultivars decreased significantly ($P < 0.05$) up to 60 min of boiling at all ripening stages. Higher values were recorded when pulps were boiled with peel at all ripening stages for *Batard*, but trends in *CARBAP K74* (particularly at stages 3 and 5) were not clear (Tables 1 and 2).

Nutritional properties

DMC

DMC patterns for the two genotypes were similar, with a slight increase from stages 1 and 3 of maturity followed by a sharp decrease in stage 5. In the case of *Batard* pulps, DMC decreased from 385 $g.kg^{-1}$ Fresh weight (FW) to 366 $g.kg^{-1}$ FW (Table 3), whereas for *CARBAP K74* values went from 317 $g.kg^{-1}$ FW to 282 $g.kg^{-1}$ FW at stage 5 (Table 4). A significant decrease ($P < 0.05$) in DMC was observed with increasing cooking times at stages 1 and 3 for *Batard*. However, fruits from *Batard* at Stage 3, when boiled with the peel, although showing the same pattern, failed to reach statistical significance. DMC in *Batard* fruits from stage 5 tended to decrease through boiling time, but differences were not significant. In the case of *CARBAP K74*, DMC decreased through boiling but the pattern reached statistical significance only on fruits from stage 5. Plantain pulps boiled with peels generally recorded higher DMC values compared to those boiled without peels, except for *CARBAP K74* at stage 5.

Table 1. Physicochemical characteristics of *Batard* pulps at two cooking modes and three ripening stages

Ripening stages	Cooking modes	Cooking times (min)	pH	TTA (mEq/100 g)	TSS (°Brix)	Firmness (kgf)
ST1	**With peel**	**0**	6.6 ± 0.2 a	688.9 ± 214.3 a	−0.2 ± 0.6 c	2.9 ± 0.8 a
		10	6.6 ± 0.1 a	666.7 ± 115.5 a	7.4 ± 3.4 bc	1.3 ± 0.3 b
		20	6.4 ± 0.0 a	755.6 ± 167.8 a	19.4 ± 1.9 a	1.0 ± 0.4 b
		30	6.3 ± 0.1 a	644.4 ± 101.8 a	21.2 ± 1.7 a	0.9 ± 0.3 b
		40	6.3 ± 0.1 a	644.4 ± 138.8 a	19.0 ± 1.6 a	0.9 ± 0.3 b
		50	6.3 ± 0.3 a	600.0 ± 66.7 a	18.8 ± 1.4 a	0.7 ± 0.2 b
		60	6.2 ± 0.3 a	733.3 ± 230.9 a	19.0 ± 1.0 a	0.7 ± 0.2 b
		Average	6.4 ± 0.2	676.2 ± 148.0	14.9 ± 1.7	1.2 ± 0.0
	Without peel	**0**	6.6 ± 0.21 a	688.9 ± 214.3 a	−0.2 ± 0.6 c	2.9 ± 0.8 a
		10	6.4 ± 0.1 a	666.7 ± 133.3 a	14.0 ± 5.0 ab	1.1 ± 0.3 b
		20	6.4 ± 0.0 a	666.7 ± 115.5 a	18.2 ± 3.5 a	0.9 ± 0.3 b
		30	6.4 ± 0.3 a	644.4 ± 77.0 a	17.8 ± 3.1 a	0.8 ± 0.3 b
		40	6.3 ± 0.2 a	577.8 ± 8.5 a	16.8 ± 5.0 a	0.7 ± 0.2 b
		50	6.3 ± 0.2 a	555.6 ± 138.8 a	17.8 ± 3.3 a	0.7 ± 0.2 b
		60	6.2 ± 0.2 a	511.1 ± 101.8 a	18.0 ± 1.5 a	0.6 ± 0.1 b
		Average	6.4 ± 0.4	615.9 ± 112.6	14.6 ± 3.1	1.1 ± 0.3
ST3	**With peel**	**0**	5.9 ± 0.2 a	1377.8 ± 269.4 a	5.4 ± 0.4 c	2.4 ± 0.7 a
		10	5.7 ± 0.2 a	1444.4 ± 234.1 a	12.0 ± 4.9 bc	1.0 ± 0.3 b
		20	5.7 ± 0.2 a	1444.4 ± 203.7 a	18.4 ± 4.3 ab	0.8 ± 0.3 b
		30	5.7 ± 0.1 a	1422.2 ± 138.8 a	20.2 ± 3.0 a	0.7 ± 0.2 b
		40	5.6 ± 0.1 a	1444.4 ± 167.8 a	20.8 ± 1.6 a	0.6 ± 0.2 b
		50	5.6 ± 0.1 a	1377.8 ± 214.3 a	20.0 ± 0.4 a	0.6 ± 0.3 b
		60	5.6 ± 0.1 a	1311.1 ± 167.8 a	19.0 ± 1.6 ab	0.5 ± 0.2 b
		Average	5.7 ± 0.0	1217.4 ± 179.6	16.5 ± 2.3	0.9 ± 0.3
	Without peel	**0**	5.9 ± 0.2 a	1377.8 ± 269.4 a	5.4 ± 0.4 c	2.4 ± 0.7 a
		10	5.7 ± 0.1 a	1288.9 ± 252.4 a	20.8 ± 3.3 a	0.9 ± 0.3 b
		20	5.7 ± 0.2 a	1200.0 ± 66.7 a	22.2 ± 3.5 a	0.8 ± 0.2 b
		30	5.6 ± 0.1 a	1288.9 ± 101.8 a	22.2 ± 1.7 a	0.6 ± 0.1 b
		40	5.6 ± 0.1 a	1200.0 ± 176.4 a	20.0 ± 0.9 a	0.6 ± 0.2 b
		50	5.6 ± 0.2 a	1177.8 ± 38.5 a	19.8 ± 0.7 a	0.5 ± 0.1 b
		60	5.6 ± 0.1 a	1155.6 ± 154.0 a	19.4 ± 0.9 a	0.4 ± 0.2 b
		Average	5.7 ± 0.1	1241.3 ± 151.3	15.4 ± 1.6	0.9 ± 0.3
ST5	**With peel**	**0**	5.7 ± 0.5 a	2088.9 ± 315.1 a	13.6 ± 2.2 b	2.0 ± 0.4 a
		10	5.7 ± 0.5 a	1800.0 ± 176.4 ab	13.6 ± 1.0 b	0.7 ± 0.2 b
		20	5.5 ± 0.1 a	1800.0 ± 115.5 ab	22.4 ± 1.3 a	0.7 ± 0.3 b
		30	5.5 ± 0.1 a	1644.4 ± 192.5 ab	20.8 ± 0.6 a	0.6 ± 0.2 b
		40	5.4 ± 0.1 a	1666.7 ± 176.4 ab	22.0 ± 1.6 a	0.5 ± 0.2 b
		50	5.4 ± 0.1 a	1533.3 ± 115.5 ab	21.2 ± 1.7 a	0.5 ± 0.1 b
		60	5.4 ± 0.1 a	1600.0 ± 133.3 ab	21.8 ± 0.9 a	0.4 ± 0.2 b
		Average	5.5 ± 0.2	1733.3 ± 175.0	19.3 ± 1.3	0.8 ± 0.2
	Without peel	**0**	5.7 ± 0.5 a	2088.9 ± 315.1 a	13.6 ± 2.2 b	2.0 ± 0.6 a
		10	5.5 ± 0.1 a	1622.2 ± 269.4 ab	21.2 ± 2.5 a	0.7 ± 0.4 b
		20	5.4 ± 0.1 a	1488.9 ± 214.3 ab	21.8 ± 1.5 a	0.6 ± 0.3 b
		30	5.4 ± 0.1 a	1400.0 ± 200.0 b	19.8 ± 0.7 a	0.5 ± 0.2 b
		40	5.4 ± 0.1 a	1400.0 ± 176.4 b	20.0 ± 1.5 a	0.5 ± 0.2 b
		50	5.4 ± 0.1 a	1355.6 ± 252.4 b	20.2 ± 0.0 a	0.4 ± 0.1 b
		60	5.4 ± 0.0 a	1244.4 ± 214.3 b	19.2 ± 1.7 a	0.3 ± 0.1 b
		Average	5.5 ± 0.1	1514.3 ± 234.6	19.4 ± 1.4	0.7 ± 0.3

Note: Mean ± SD values with the same lowercase letters in the same columns for each ripening stage are not significantly different ($P < 0.05$, Tukey's test). ST1, unripe stage; ST3, half-ripe stage; ST5, ripe stage; TTA, total titratable acidity; TSS, total soluble solids.

Crude protein

Crude protein contents were low at harvest (approximately 26 $g.kg^{-1}$ FW) for both cultivars. This value increased to 35 $g.kg^{-1}$ FW for *Batard* and 46 $g.kg^{-1}$ FW for *CARBAP K74* at the ripe stage. The crude protein contents significantly decreased ($P < 0.05$) with cooking times for *Batard* at the unripe stage, while a significant increase was noted at the half-ripe stage. Finally, a non-significant decrease in crude protein content was observed at the ripe stage (Table 3).

Table 2. Physicochemical characteristics of *CARBAP K74* pulps at two cooking modes and three ripening stages

Ripening stages	Cooking modes	Cooking times (min)	pH	TTA (mEq/100 g)	TSS (°Brix)	Firmness (kgf)
ST1	**With peel**	**0**	6.5 ± 0.1 a	1000.0 ± 66.7 a	0.2 ± 1.3 b	2.9 ± 0.7 a
		10	6.1 ± 0.3 b	1244.4 ± 401.9 a	18.8 ± 1.5 a	1.7 ± 0.6 b
		20	6.1 ± 0.1 ab	1244.4 ± 269.4 a	17.6 ± 1.5 a	1.0 ± 0.3 bc
		30	6.1 ± 0.1 ab	1244.4 ± 203.7 a	18.2 ± 0.9 a	0.8 ± 0.2 bc
		40	6.1 ± 0.1 b	1200.0 ± 133.3 a	18.2 ± 0.4 a	0.7 ± 0.2 bc
		50	6.0 ± 0.2 b	1266.7 ± 176.4 a	18.8 ± 0.9 a	0.6 ± 0.2 c
		60	6.0 ± 0.2 b	1066.7 ± 176.4 a	18.2 ± 1.3 a	0.5 ± 0.1 c
		Average	6.1 ± 0.2	1180.9 ± 204.0	13.3 ± 0.9	1.2 ± 0.3
	Without peel	**0**	6.5 ± 0.1 a	1000.0 ± 66.7 a	0.2 ± 1.3 b	2.9 ± 0.7 a
		10	6.2 ± 0.1 ab	1022.2 ± 154.0 a	16.2 ± 0.9 a	1.4 ± 0.4 bc
		20	6.1 ± 0.1 ab	977.8 ± 101.9 a	17.2 ± 0.6 a	0.8 ± 0.2 bc
		30	6.2 ± 0.1 ab	911.1 ± 252.4 a	16.4 ± 2.4 a	0.6 ± 0.1 c
		40	6.0 ± 0.2 b	1111.1 ± 335.6 a	17.8 ± 1.2 a	0.6 ± 0.1 c
		50	6.1 ± 0.1 ab	977.8 ± 214.3 a	16.4 ± 1.9 a	0.5 ± 0.1 c
		60	6.2 ± 0.1 ab	933.3 ± 133.3 a	17.0 ± 0.4 a	0.4 ± 0.1 c
		Average	6.2 ± 0.1	990.5 ± 179.7	14.5 ± 1.2	1.0 ± 0.2
ST3	**With peel**	**0**	5.6 ± 0.1 a	1733.3 ± 115.5 a	9.4 ± 0.0 b	1.0 ± 0.3 a
		10	5.6 ± 0.0 a	1577.8 ± 214.3 ab	15.6 ± 1.9 ab	0.6 ± 0.1 b
		20	5.5 ± 0.1 a	955.6 ± 712.9 b	14.4 ± 3.3 ab	0.5 ± 0.1 b
		30	5.6 ± 0.0 a	1422.2 ± 154.0 ab	16.6 ± 2.2 a	0.4 ± 0.0 b
		40	5.5 ± 0.0 a	1466.7 ± 240.4 ab	15.0 ± 3.3 ab	0.3 ± 0.0 b
		50	5.6 ± 0.1 a	1488.9 ± 192.5 ab	16.8 ± 1.5 a	0.3 ± 0.0 b
		60	5.6 ± 0.1 a	1466.7 ± 115.5 ab	15.8 ± 1.5 ab	0.3 ± 0.0 b
		Average	5.6 ± 0.1	1441.6 ± 249.3	14.8 ± 1.96	0.4 ± 0.1
	Without peel	**0**	5.6 ± 0.1 a	1733.3 ± 115.5 a	9.4 ± 0.0 b	1.0 ± 0.3 a
		10	5.5 ± 0.1 a	1422.2 ± 101.8 ab	17.0 ± 2.7 a	0.6 ± 0.1 b
		20	5.5 ± 0.0 a	1266.7 ± 176.4 ab	14.0 ± 2.7 ab	0.5 ± 0.1 b
		30	5.5 ± 0.0 a	1155.6 ± 101.8 ab	14.8 ± 2.2 ab	0.4 ± 0.1 b
		40	5.5 ± 0.1 a	1355.6 ± 38.5 ab	15.8 ± 2.4 ab	0.4 ± 0.0 b
		50	5.5 ± 0.0 a	1133.3 ± 115.5 ab	12.8 ± 2.4 ab	0.3 ± 0.0 b
		60	5.5 ± 0.1 a	1200.0 ± 24.4 ab	12.4 ± 2.1 ab	0.3 ± 0.3 b
		Average	5.5 ± 0.1	1323.8 ± 96.3	13.7 ± 1.8	0.4 ± 0.1
ST5	**With peel**	**0**	5.6 ± 0.1 a	1511.1 ± 214.3 ab	11.6 ± 0.4 ab	0.7 ± 0.1 a
		10	5.6 ± 0.1 a	1666.7 ± 231.0 a	16.8 ± 1.8 a	0.4 ± 0.0 b
		20	5.5 ± 0.1 a	1600.0 ± 133.3 ab	14.4 ± 0.9 ab	0.4 ± 0.0 bc
		30	5.5 ± 0.1 a	1244.4 ± 77.0 ab	12.4 ± 2.1 ab	0.3 ± 0.0 bcdef
		40	5.5 ± 0.0 a	1311.1 ± 342.1 ab	13.8 ± 4.9 ab	0.3 ± 0.1 cdef
		50	6.0 ± 0.7 a	933.3 ± 437.2 b	10.2 ± 4.2 ab	0.2 ± 0.0 def
		60	5.6 ± 0.0 a	1088.9 ± 234.1 ab	11.4 ± 3.0 ab	0.2 ± 0.1 ef
		Average	5.6 ± 0.2	1336.5 ± 238.4	12.9 ± 2.5	0.4 ± 0.0
	Without peel	**0**	5.6 ± 0.1 a	1511.1 ± 214.3 ab	11.6 ± 0.4 ab	0.7 ± 0.1 a
		10	5.6 ± 0.1 a	1355.6 ± 101.9 ab	15.8 ± 0.7 ab	0.4 ± 0.1 b
		20	5.5 ± 0.0 a	1177.8 ± 234.1 ab	12.4 ± 3.1 ab	0.4 ± 0.1 bcd
		30	5.5 ± 0.1 a	1311.1 ± 214.3 ab	13.4 ± 1.9 ab	0.3 ± 0.0 bcde
		40	5.5 ± 0.0 a	1133.3 ± 290.6 ab	12.4 ± 4.2 ab	0.3 ± 0.0 bcdef
		50	5.6 ± 0.1 a	1044.4 ± 101.8 ab	11.0 ± 0.4 ab	0.2 ± 0.1 cdef
		60	5.6 ± 0.1 a	1000.0 ± 94.3 b	9.7 ± 2.1 b	0.2 ± 0.1 f
		Average	5.6 ± 0.1	1057.1 ± 178.8	12.3 ± 1.8	0.4 ± 0.1

Note: Mean ± SD values with the same lowercase letters in the same columns for each ripening stage are not significantly different ($P < 0.05$, Tukey;s test). ST1, unripe stage; ST3, half-ripe stage; ST5, ripe stage; TTA, total titratable acidity; TSS, total soluble solids.

CARBAP K74 pulps showed a contrasting trend, with a non-significant increase ($P > 0.05$) in crude protein content with cooking times at all ripening stages (Table 4). With few exceptions (particularly for *Batard* fruits at stage 5), when boiled with peels, plantain pulps displayed higher crude protein contents than when boiled without peels.

Table 3. Nutritional characteristics of *Batard* pulps at two cooking modes and three ripening stages

Ripening stages	Cooking modes	Cooking times (minutes)	Dry matter content ($g\ kg^{-1}$ FW)	Crude protein ($g\ kg^{-1}$ FW)	Crude lipid ($g\ kg^{-1}$ FW)	Total starch ($g\ kg^{-1}$ DW)	Ash content ($g\ kg^{-1}$FW)	Total carbohydrates ($g\ kg^{-1}$ FW)
ST1	**With peel**	**0**	385.0 ± 14.0 a	26.0 ± 3.0 a	19.0 ± 6.0 a	773.0 ± 23.0 a	31.0 ± 7.0 a	309.0 ± 16.0 a
		10	383.0 ± 13.0 ab	20.0 ± 4.0 ab	18.0 ± 1.0 a	713.0 ± 17.0 ab	28.0 ± 6.0 a	317.0 ± 12.0 a
		20	377.0 ± 15.0 abc	19.0 ± 1.0 ab	17.0 ± 3.0 a	698.0 ± 41.0 ab	21.0 ± 5.0 a	321.0 ± 8.0 a
		30	368.0 ± 12.0 abc	18.0 ± 2.0 ab	15.0 ± 4.0 a	726.0 ± 5.0 ab	23.0 ± 3.0 a	311.0 ± 12.0 a
		40	359.0 ± 10.0 abc	15.0 ± 1.0 b	13.0 ± 1.0 a	710.0 ± 4.0 ab	28.0 ± 4.0 a	303.0 ± 13.0 a
		50	351.0 ± 11.0 bc	14.0 ± 2.0 b	11.0 ± 4.0 a	719.0 ± 13.0 ab	24.0 ± 7.0 a	302.0 ± 21.0 a
		60	345.0 ± 15.0 c	14.0 ± 1.0 b	10.0 ± 2.0 a	686.0 ± 53.0 b	23.0 ± 2.0 a	298.0 ± 16.0 a
		Average	367.0 ± 13.0	18.0 ± 2.0	15.0 ± 3.0	718.0 ± 22.0	25.0 ± 5.0	309.0 ± 14.0
	Without peel	**0**	385.0 ± 14.0 a	26.0 ± 3.0 a	19.0 ± 6.0 a	773.0 ± 23.0 a	31.0 ± 7.0 a	309.0 ± 16.0 a
		10	362.0 ± 12.0 abc	19.0 ± 4.0 ab	18.0 ± 4.0 a	686.0 ± 26.0 b	30.0 ± 10.0 a	295.0 ± 20.0 a
		20	363.0 ± 4.0 abc	16.0 ± 2.0 ab	15.0 ± 2.0 a	686.0 ± 35.0 b	22.0 ± 9.0 a	311.0 ± 12.0 a
		30	355.0 ± 4.0 abc	16.0 ± 2.0 ab	15.0 ± 1.0 a	698.0 ± 19.0 ab	17.0 ± 10.0 a	307.0 ± 11.0 a
		40	353.0 ± 7.0 abc	15.0 ± 5.0 b	13.0 ± 1.0 a	689.0 ± 19.0 b	23.0 ± 2.0 a	303.0 ± 13.0 a
		50	347.0 ± 1.0 c	15.0 ± 4.0 b	11.0 ± 6.0 a	716.0 ± 18.0 ab	24.0 ± 10.0 a	297.0 ± 11.0 a
		60	345.0 ± 11.0 c	16.0 ± 6.0 ab	9.0 ± 5.0 a	721.0 ± 3.0 ab	19.0 ± 3.0 a	300.0 ± 13.0 a
		Average	359.0 ± 8.0	18.0 ± 4.0	14.0 ± 4.0	710.0 ± 20.0	24.0 ± 7.0	303.0 ± 14.0
ST3	**With peel**	**0**	388.0 ± 18.0 a	17.0 ± 2.0d	13.0 ± 1.0 a	592.0 ± 62.0 a	21.0 ± 6.0 a	337.0 ± 19.0 a
		10	388.0 ± 19.0 a	25.0 ± 2.0 abc	11.0 ± 1.0 a	598.0 ± 91.0 a	24.0 ± 5.0 a	328.0 ± 20.0 a
		20	383.0 ± 7.0 ab	25.0 ± 3.0 abc	12.0 ± 3.0 a	588.0 ± 24.0 a	34.0 ± 10.0 a	312.0 ± 4.0 ab
		30	383.0 ± 22.0 ab	29.0 ± 3.0 abc	9.0 ± 4.0 a	562.0 ± 22.0 a	38.0 ± 11.0 a	307.0 ± 16.0 ab
		40	386.0 ± 7.0 ab	29.0 ± 5.0 abc	9.0 ± 1.0 a	610.0 ± 10.0 a	26.0 ± 3.0 a	322.0 ± 6.0 ab
		50	373.0 ± 6.0 ab	30.0 ± 3.0 ab	9.0 ± 6.0 a	611.0 ± 22.0 a	24.0 ± 13.0 a	310.0 ± 12.0 ab
		60	359.0 ± 17.0 ab	32.0 ± 2.0 a	8.0 ± 5.0 a	588.0 ± 15.0 a	23.0 ± 12.0 a	296.0 ± 24.0 ab
		Average	380.0 ± 14.0	27.0 ± 3.0	10.0 ± 3.0	593.0 ± 3.5.0	27.0 ± 9.0	316.0 ± 14.0
	Without peel	**0**	388.0 ± 18.0 a	17.0 ± 2.0d	13.0 ± 1.0 a	592.0 ± 62.0 a	21.0 ± 6.0 a	337.0 ± 19.0 a
		10	383.0 ± 13.0 ab	22.0 ± 2.0 cd	9.0 ± 4.0 a	577.0 ± 49.0 a	26.0 ± 5.0 a	325.0 ± 13.0 ab
		20	372.0 ± 14.0 ab	24.0 ± 4.0 bcd	9.0 ± 1.0 a	581.0 ± 63.0 a	27.0 ± 6.0 a	312.0 ± 11.0 ab
		30	363.0 ± 8.0 ab	27.0 ± 3.0 abc	9.0 ± 4.0 a	554.0 ± 81.0 a	30.0 ± 11.0 a	297.0 ± 20.0 ab
		40	361.0 ± 3.0 ab	26.0 ± 1.0 abc	8.0 ± 2.0 a	545.0 ± 53.0 a	28.0 ± 6.0 a	298.0 ± 7.0 ab
		50	361.0 ± 10.0 ab	26.0 ± 2.0 abc	8.0 ± 2.0 a	576.0 ± 21.0 a	27.0 ± 5.0 a	300.0 ± 12.0 ab
		60	347.0 ± 13.0 b	28.0 ± 2.0 abc	8.0 ± 2.0 a	600.0 ± 23.0 a	28.0 ± 8.0 a	284.0 ± 7.0 b
		Average	368.0 ± 11.0	24.0 ± 2.0	9.0 ± 2.0	575.0 ± 50.0	27.0 ± 7.0	308.0 ± 13.0
ST5	**With peel**	**0**	366.0 ± 32.0 a	35.0 ± 0.0 a	25.0 ± 17.0 a	406.0 ± 85.0 a	26.0 ± 2.0 a	280.0 ± 44.0 a
		10	376.0 ± 15.0 a	28.0 ± 12.0 a	7.0 ± 1.0 ab	387.0 ± 38.0 a	22.0 ± 5.0 a	320.0 ± 12.0 a
		20	360.0 ± 41.0 a	30.0 ± 8.0 a	7.0 ± 3.0 ab	428.0 ± 17.0 a	28.0 ± 12.0 a	295.0 ± 35.0 a
		30	371.0 ± 13.0 a	33.0 ± 7.0 a	6.0 ± 2.0 ab	408.0 ± 38.0 a	21.0 ± 4.0 a	312.0 ± 17.0 a
		40	367.0 ± 7.0 a	35.0 ± 7.0 a	7.0 ± 4.0 ab	421.0 ± 69.0 a	26.0 ± 10.0 a	299.0 ± 11.0 a
		50	367.0 ± 11.0 a	36.0 ± 5.0 a	7.0 ± 1.0 ab	486.0 ± 30.0 a	34.0 ± 31.0 a	290.0 ± 17.0 a
		60	358.0 ± 15.0 a	39.0 ± 5.0 a	6.0 ± 0.0 ab	486.0 ± 42.0 a	22.0 ± 4.0 a	291.0 ± 17.0 a
		Average	366.0 ± 19.0	34.0 ± 6.0	9.0 ± 4.0	432.0 ± 46.0	26.0 ± 10.0	298.0 ± 22.0
	Without peel	**0**	366.0 ± 32.0 a	35.0 ± 0.0 a	25.0 ± 17.0 a	406.0 ± 85.0 a	26.0 ± 2.0 a	280.0 ± 44.0 a
		10	377.0 ± 19.0 a	30.0 ± 16.0 a	3.0 ± 1.0 b	454.0 ± 107.0 a	39.0 ± 4.0 a	306.0 ± 34.0 a
		20	357.0 ± 3.0 a	33.0 ± 12.0 a	3.0 ± 1.0 b	460.0 ± 48.0 a	27.0 ± 5.0 a	295.0 ± 19.0 a
		30	350.0 ± 9.0 a	36.0 ± 13.0 a	3.0 ± 2.0 b	436.0 ± 28.0 a	27.0 ± 5.0 a	284.0 ± 22.0 a
		40	349.0 ± 10.0 a	36.0 ± 11.0 a	4.0 ± 2.0 b	479.0 ± 67.0 a	22.0 ± 5.0 a	287.0 ± 25.0 a
		50	342.0 ± 12.0 a	37.0 ± 12.0 a	3.0 ± 1.0 b	473.0 ± 71.0 a	20.0 ± 10.0 a	282.0 ± 22.0 a
		60	342.0 ± 18.0 a	38.0 ± 11.0 a	4.0 ± 0.0 b	494.0 ± 57.0 a	24.0 ± 2.0 a	276.0 ± 26.0 a
		Average	355.0 ± 15.0	35.0 ± 11.0	6.0 ± 3.0	457.0 ± 66.0	26.4 ± 5.0	287.0 ± 27.0

Note: Mean ± SD values with the same lowercase letters in the same columns for each ripening stage are not significantly different ($P < 0.05$, Tukey's test). FW, fresh weight; DW, dry weight; ST1, unripe stage; ST3, half-ripe stage; ST5, ripe stage.

Crude lipids

At harvest, crude lipid contents were 2% for both cultivars. Lipid performance during ripening, however, was different in the two genotypes. In the case of *Batard*, lipid contents went down to 13 $g\ kg^{-1}$ FW at Stage 3 and then went up to 25 $g\ kg^{-1}$ FW at stage 5. On the other hand, *CARBAP K74* showed a consistent gain

Table 4. Nutritional characteristics of *CARBAP K74* pulps at two cooking modes and three ripening stages

Ripening stages	Cooking modes	Cooking times (minutes)	Dry matter content (g kg^{-1} FW)	Crude protein (g kg^{-1} FW)	Crude lipid (g.kg^{-1} FW)	Total starch (g kg^{-1} DW)	Ash content (g kg^{-1} FW)	Total carbohydrates (g kg^{-1} FW)
ST1	**With peel**	**0**	316.0 ± 13.0 ab	26.0 ± 5.0 a	20.0 ± 5.0 a	727.0 ± 8.0 a	34.0 ± 5.0 a	236.0 ± 22.0 a
		10	326.0 ± 9.0 a	33.0 ± 9.0 a	19.0 ± 3.0 a	631.0 ± 79.0 a	29.0 ± 5.0 a	246.0 ± 13.0 a
		20	323.0 ± 14.0 ab	33.0 ± 7.0 a	17.0 ± 5.0 a	646.0 ± 64.0 a	30.0 ± 6.0 a	244.0 ± 12.0 a
		30	302.0 ± 18.0 ab	36.0 ± 7.0 a	16.0 ± 8.0 a	680.0 ± 14.0 a	31.0 ± 5.0 a	219.0 ± 26.0 a
		40	299.0 ± 12.0 ab	36.0 ± 8.0 a	13.0 ± 8.0 a	678.0 ± 32.0 a	29.0 ± 9.0 a	221.0 ± 04.0 a
		50	293.0 ± 17.0 ab	36.0 ± 6.0 a	12.0 ± 2.0 a	680.0 ± 22.0 a	34.0 ± 3.0 a	212.0 ± 19.0 a
		60	299.0 ± 2.0 ab	36.0 ± 8.0 a	11.0 ± 3.0 a	674.0 ± 27.0 a	33.0 ± 13.0 a	218.0 ± 8.0 a
		Average	308.0 ± 72.0	34.0 ± 7.0	15.0 ± 5.0	674.0 ± 27.0	31.0 ± 7.0	228.0 ± 15.0
	Without peel	**0**	316.0 ± 13.0 ab	26.0 ± 5.0 a	20.0 ± 5.0 a	727.0 ± 8.0 a	34.0 ± 5.0 a	237.0 ± 22.0 a
		10	310.0 ± 6.0 ab	22.0 ± 2.0 a	18.0 ± 5.0 a	685.0 ± 40.0 a	28.0 ± 4.0 a	242.0 ± 12.0 a
		20	306.0 ± 7.0 ab	24.0 ± 4.0 a	16.0 ± 5.0 a	671.0 ± 32.0 a	25.0 ± 41.0 a	211.0 ± 44.0 a
		30	294.0 ± 10.0 ab	29.0 ± 4.0 a	13.0 ± 2.0 a	669.0 ± 39.0 a	30.0 ± 4.0 a	222.0 ± 13.0 a
		40	289.0 ± 7.0 b	29.0 ± 3.0 a	11.0 ± 5.0 a	633.0 ± 65.0 a	35.0 ± 3.0 a	214.0 ± 15.0 a
		50	299.0 ± 14.0 ab	30.0 ± 7.0 a	10.0 ± 3.0 a	614.0 ± 87.0 a	27.0 ± 6.0 a	232.0 ± 16.0 a
		60	296.0 ± 13.0 ab	31.0 ± 7.0 a	9.0 ± 3.0 a	698.0 ± 31.0 a	21.0 ± 8.0 a	236.0 ± 17.0 a
		Average	301.0 ± 10.0	27.0 ± 5.0	14.0 ± 4.0	671.0 ± 65.0	29.0 ± 8.0	228.0 ± 20.0
ST3	**With peel**	**0**	318.0 ± 37.0 a	28.0 ± 2.0 a	39.0 ± 4.0 a	398.0 ± 45.0 ab	38.0 ± 6.0 a	214.0 ± 42.0 a
		10	298.0 ± 11.0 a	38.0 ± 8.0 a	13.0 ± 7.0 b	424.0 ± 50.0 ab	38.0 ± 12.0 a	209.0 ± 9.0 a
		20	298.0 ± 1.0 a	42.0 ± 10.0 a	13.0 ± 5.0 b	363.0 ± 34.0 b	38.0 ± 1.0 a	205.0 ± 14.0 a
		30	287.0 ± 16.0 a	44.0 ± 8.0 a	14.0 ± 7.0 b	426.0 ± 23.0 ab	34.0 ± 11.0 a	195.0 ± 13.0 a
		40	278.0 ± 10.0 a	44.0 ± 8.0 a	11.0 ± 5.0 b	441.0 ± 39.0 ab	44.0 ± 13.0 a	180.0 ± 18.0 a
		50	287.0 ± 2.0 a	47.0 ± 9.0 a	10.0 ± 7.0 b	462.0 ± 27.0 ab	35.0 ± 8.0 a	195.0 ± 16.0 a
		60	279.0 ± 28.0 a	47.0 ± 9.0 a	13.0 ± 10.0 b	488.0 ± 27.0 a	33.0 ± 5.0 a	187.0 ± 10.0 a
		Average	292.0 ± 15.0	41.0 ± 8.0	16.0 ± 6.0	429.0 ± 35.0	36.0 ± 8.0	198.0 ± 17.0
	Without peel	**0**	318.0 ± 37.0 a	28.0 ± 2.0 a	39.0 ± 4.0 a	398.0 ± 45.0 ab	38.0 ± 6.0 a	214.0 ± 42.0 a
		10	284.0 ± 12.0 a	37.0 ± 11.0 a	11.0 ± 1.0 b	395.0 ± 26.0 ab	27.0 ± 10.0 a	210.0 ± 17.0 a
		20	282.0 ± 4.0 a	38.0 ± 12.0 a	13.0 ± 1.0 b	455.0 ± 8.0 ab	27.0 ± 11.0 a	205.0 ± 10.0 a
		30	292.0 ± 7.0 a	40.0 ± 9.0 a	11.0 ± 2.0 b	450.0 ± 23.0 ab	28.0 ± 10.0 a	213.0 ± 8.0 a
		40	281.0 ± 21.0 a	42.0 ± 10.0 a	12.0 ± 9.0 b	402.0 ± 76.0 ab	31.0 ± 23.0 a	197.0 ± 36.0 a
		50	286.0 ± 6.0 a	43.0 ± 10.0 a	13.0 ± 6.0 b	423.0 ± 12.0 ab	37.0 ± 3.0 a	193.0 ± 23.0 a
		60	275.0 ± 11.0 a	44.0 ± 10.0 a	13.0 ± 6.0 b	429.0 ± 62.0 ab	33.0 ± 15.0 a	186.0 ± 40.0 a
		Average	300.0 ± 14.0	39.0 ± 9.0	16.0 ± 4.0	422.0 ± 36.0	32.0 ± 11.0	203.0 ± 25.0
ST5	**With peel**	**0**	282.0 ± 6.0 abc	46.0 ± 4.0 a	44.0 ± 3.0 a	289.0 ± 87.0 abc	44.0 ± 4.0 a	148.0 ± 12.0 bc
		10	298.0 ± 9.0 a	38.0 ± 9.0 a	4.0 ± 2.0 b	187.0 ± 19.0 bc	32.0 ± 10.0 a	225.0 ± 14.0 a
		20	287.0 ± 10.0 ab	41.0 ± 9.0 a	5.0 ± 1.0 b	255.0 ± 15.0 abc	28.0 ± 15.0 a	213.0 ± 16.0 ab
		30	263.0 ± 18.0 abc	43.0 ± 9.0 a	4.0 ± 2.0 b	206.0 ± 1.0 bc	31.0 ± 8.0 a	185.0 ± 32.0 abc
		40	268.0 ± 4.0 abc	44.0 ± 10.0 a	2.0 ± 1.0 b	209.0 ± 14.0 bc	42.0 ± 6.0 a	181.0 ± 9.0 abc
		50	232.0 ± 43.0 bc	46.0 ± 9.0 a	3.0 ± 1.0 b	280.0 ± 47.0 abc	33.0 ± 6.0 a	150.0 ± 55.0 bc
		60	235.0 ± 21.0 bc	48.0 ± 7.0 a	4.0 ± 2.0 b	322.0 ± 78.0 ab	34.0 ± 10.0 a	149.0 ± 3.0 bc
		Average	238.0 ± 16.0	44.0 ± 8.0	9.0 ± 2.0	250.0 ± 37.0	35.0 ± 8.0	179.0 ± 20.0
	Without peel	**0**	282.0 ± 6.0 abc	46.0 ± 4.0 a	44.0 ± 3.0 a	289.0 ± 87.0 abc	44.0 ± 4.0 a	148.0 ± 12.0 bc
		10	265.0 ± 17.0 abc	37.0 ± 11.0 a	7.0 ± 3.0 b	162.0 ± 47.0 c	42.0 ± 10.0 a	179.0 ± 22.0 abc
		20	268.0 ± 11.0 abc	41.0 ± 13.0 a	5.0 ± 1.0 b	209.0 ± 27.0 bc	35.0 ± 19.0 a	188.0 ± 16.0 abc
		30	273.0 ± 6.0 abc	42.0 ± 13.0 a	6.0 ± 2.0 b	316.0 ± 58.0 abc	42.0 ± 5.0 a	183.0 ± 13.0 abc
		40	274.0 ± 14.0 abc	44.0 ± 11.0 a	5.0 ± 1.0 b	380.0 ± 81.0 a	38.0 ± 12.0 a	187.0 ± 37.0 abc
		50	261.0 ± 8.0 abc	46.0 ± 10.0 a	5.0 ± 1.0 b	317.0 ± 08.0 abc	39.0 ± 2.0 a	171.0 ± 14.0 abc
		60	251.0 ± 0.0 c	45.0 ± 12.0 a	9.0 ± 1.0 b	315.0 ± 30.0 abc	42.0 ± 5.0 a	135.0 ± 36.0 c
		Average	268.0 ± 9.0	43.0 ± 11.0	12.0 ± 2.0	258.0 ± 48.0	40.0 ± 8.0	170.0 ± 21.0

Note: Mean ± SD values with the same lowercase letters in the same columns for each ripening stage are not significantly different ($P < 0.05$, Tukey's test). FW, fresh weight; DW, dry weight; ST1, unripe stage; ST3, half-ripe stage; ST5, ripe stage.

in lipid contents through maturity from 20 g kg^{-1} FW to 40 and 44 g kg^{-1} FW, respectively, for stages 1, 3 and 5. Boiling always reduced lipid contents. However, these reductions reached statistical significance ($P > 0.05$) only for *Batard* (stage 5, non-peeled) and *CARBAP K74* in stages 3 and 5, regardless of the cooking method. Boiling plantain pulps with peels preserved better the crude lipid contents as they portrayed the highest values compared to pulps boiled without peels (Tables 3 and 4), with some exceptions, particularly for *CARBAP K74* at stage 5 of maturity.

Total starch content

Total starch content was highest for both cultivars when unripe: 773 and 737 g kg^{-1} DW respectively, for *Batard* and *CARBAP K74*. These contents decreased consistently with ripening to reach values as low as 406 and 289 g kg^{-1} DW, respectively, for *Batard* and *CARBAP K74* at the ripe stage. The total starch content of unripe pulps significantly decreased ($P < 0.05$) with cooking times against a non-significant increase ($P > 0.05$) at the half-ripe and ripe stages for *Batard* pulps (Table 3). *CARBAP K74* instead displayed an up-and-down trend in total starch content, which significantly increased ($P < 0.05$) with cooking times at the half-ripe and ripe stages, against a non-significant decrease ($P > 0.05$) at the unripe stage (Table 4). There was no clear pattern regarding starch retention when the two boiling methods were compared (Tables 3 and 4).

Ash content

The ash content for both cultivars was low at harvest (< 35 g kg^{-1} FW). This ash content increased with the ripening process for *CARBAP K74* against a reduction observed for *Batard* (particularly at Stage 3). In addition, a non-significant decrease ($P > 0.05$) in ash content with cooking times was observed in both cultivars at all ripening stages (Tables 3 and 4). There were no clear patterns when comparing contents for both boiling methods across genotypes or maturity status.

Total carbohydrate content

The total carbohydrate content at harvest was high for both cultivars (309 g kg^{-1} FW for *Batard* and 237 g kg^{-1} FW for *CARBAP K74*) and decreased during the ripening process (except for *Batard* at Stage 3) to 280 g kg^{-1} FW and 148 g kg^{-1} FW, respectively, at the ripe stage. A significant decrease ($P < 0.05$) was observed with cooking times only at the half-ripe stage for *Batard*. For other genotype-by-maturity combinations no clear pattern could be identified. (Tables 3 and 4).

DISCUSSION

Firmness, which provides information on the degree of consistency of food, was high when the pulps of both plantain genotypes were still in the raw state and decreased with the ripening stage as a result of starch conversion into simple sugars. Our results are similar to those obtained by Ngoh Newilah *et al.*[27] and Gibert *et al.*[13] on raw banana and plantain pulps. Moreover, these results reveal a decrease in firmness after cooking at all ripening stages. This could be a result of pectic changes in the middle lamella layer or to the absorption of water by the pulp which increases as cooking intensifies, leading to a softening, caused by the degradation of the starch. Indeed, the hydration of starch granules under the effect of heat (increasing the cooking temperature) causes them to swell and, consequently, the starch is gelatinized, whereas the pectic substances are solubilized.[13,28] Moreover, whatever the ripening stage, the firmness was mostly higher when the pulps were cooked with peel. The peel may constitute a barrier limiting the penetration of water into the pulp. Furthermore, Toro *et al.*[29] demonstrated that at higher steeping temperatures (75 °C and 100 °C), apparent water diffusivity was mainly in the diffusional domain, as starch gelatinizes at high temperatures. In the case of *CARBAP K74*, however, firmness was lower at stages 3 and 5.

The decrease in pH recorded in the present study during the ripening of *Batard* and *CARBAP K74* fruits was greater than the values presented by Ngoh Newilah *et al.*[17] (from 6.2 to 5.8) and Falade *et al.*[30] (from 5.77 to 4.67) from stage 1 to stage 5 of post-harvest maturity. Despite the non-significant decrease in pH during cooking, the pH was higher when the pulps were boiled with peel, as also observed in other studies.[6] The peel limits the absorption of water by the pulp. The difference in pH observed between fruits boiled with peels and those boiled without peels could be attributed to depolymerization caused by heat treatment, producing acidic thermal residues in the starch molecules.[30]

TTA influences plantain taste and is a function of the stage of ripening.[17] The TTA of our cultivars increased with the ripening stage. These results are similar to those obtained by Ngoh Newilah *et al.*[27] but contradict those observed by Falade *et al.*[30] where a decrease in total titratable acidity was observed with increasing ripening stage. The TTA values during boiling without peel reported for *CARBAP K74* at the unripe stage after 50 min corroborate our results.[17] The significant change in TTA during cooking at stages 3 and 5 is a result of the increase in sugar content, which consequently leads to an increase in the acids contained in the plantain pulp. Cooking is known to release organic acids from the cell walls into the cytoplasm.[31]

The increase in TSS with the ripening stage is assumed to be result of the breakdown of starch stored in the pulp into simpler sugars. This phenomenon is the origin of the increase in the sweetness of the fruit as it ripens, during pulp storage, with values between 2 and 13°Brix.[32] These values, however, were lower compared to those obtained in the present study. Our values agree with those obtained for the cultivar *Agbagba*, but are lower than that of the cultivar *Obino l'Ewai*, which ranged from 2.6°Brix at stage 1 to 20.2°Brix at stage 5 in previous reports.[30] However, the soluble solids content increased significantly during cooking with and without peel for both genotypes, but this increase was more pronounced in pulps cooked with peel as observed elsewhere.[6,33] The variations in TSS with cooking time at stages 3 and 5 could be explained by the non-uniformity of the ripening stages, which occurs progressively and is characterized by the change in coloration of the plantain's peel observed by the naked eye (an indicator of the evolution of its ripeness).

The DMC is an indicator of better cooking and storage quality. At each ripening stage, the DMC of *Batard* pulp was higher than that of *CARBAP K74*. Studies have pointed out that the DMC of local cultivars is generally higher than that of plantain-like hybrids and dessert bananas.[30,34] The decrease in DMC during ripening could be a result of the increase in water content, which could be promoted through the migration of water from the peel to the pulp because of the high sugar concentration of the latter.[35] The higher DMC tendency observed during the cooking of pulp with peel compared to the cooking of pulp without peel can be explained by the low leaching of certain compounds during cooking because the peel acts as a barrier, thereby limiting exchanges with the heat transfer fluid. During cooking unripe pulp without peel, *Batard* and *CARBAP K74* dry matter values were similar to those obtained by Ngoh Newilah *et al.*,[17] which varied between 27.9% and 39.6%.

Protein contents (before cooking) increased with the ripening stage. However, they were higher in the pulps of *CARBAP K74* compared to those of *Batard*. The increase in protein content with ripening could be a result of the migration of these elements from the peel to the pulp.[36] The large difference in protein content between the two cultivars with the ripening stage could be explained by the genetic factors attributed to each cultivar. Our results on raw plantains are similar to those obtained in Cameroon on the fresh pulp of the plantain cultivar *French sombre* at stages 1, 3 and 5 of post-harvest maturity.[37] In addition, another conducted in Ghana showed that protein content increased with the ripening stage.[7]

Crude lipid content increased with the ripening stage and was higher in the pulps of *CARBAP K74* than those of *Batard* when raw. Cooking the plantain pulps with and without peel resulted in a decrease in lipid content, with the decrease being more pronounced when cooked without peel. This could be a result of the leaching of fat by the heat treatment in the cooking water. However, Adepoju[38] showed an increase in lipids after 10 min of boiling plantain pulps without peels ranging from 1.5% to 3.8%.

The decrease in total starch content with the ripening stage of *Batard* and *CARBAP K74* raw pulps is a result of the degradation of starch into simple sugars during ripening. According to previous studies, the decrease in starch content during the ripening stage is a result of the hydrolysis of starch by α- and β-amylases present in plantain that catalyse its degradation by releasing glucose, maltose and maltodextrins during cooking.[39–42] The α-1,4 and α-1,6-glucosidases present in plantain will subsequently intervene to degrade maltose and maltodextrins, yielding glucose. The decreases in starch content obtained by Assemand *et al*.[35] at stages 1, 3 and 5 of post-harvest maturity for the *Agnrin* (80.85% to 56.92%) and *Orishele* (79.63% to 59.13%) varieties are higher than our results. During heat treatments, the behaviour of starch depends on the proportion of amylose, amylopectin and the size of the starch granules.[12] For this reason, the starch content of pulps is specific to each fruit and therefore varies with cooking time. During gelatinization, the starch granules absorb water and swell, causing them to burst and consequently leach amylose into the cooking water.[43] Xiaowen *et al*.[44] found that, when water is bound to starch, as a result of gelatinization, it is less mobile than water in contact with native starch. Starch gelatinization depends on the botanical species and genotype studied.[45] Future studies must focus on starch characteristics (amylose/amylopectin ratio and granule size) as predictors of sweetness after cooking.

The ash content of food indicates its mineral composition. The high levels of ash recorded during ripening were also observed with the ripening of plantain pulps analysed by Agbemafle *et al*.[7] Similarly, studies by Assemand *et al*.[35] on the *Agnrin* and *Orishele* varieties revealed that ash contents ranged, respectively, from 1.47% to 2.18% and from 1.82% to 2.40% between stages 1, 3 and 5 of post-harvest maturity. However, despite this increase, these results were different from those obtained in the current study.

A decrease in total carbohydrate content was observed during the ripening of the pulps of *Batard* and *CARBAP K74*, as also reported elsewhere.[7] The carbohydrate content of raw plantain pulps of approximately 24.4% obtained by Adepoju[38] is similar to that of *CARBAP K74* pulps at the unripe stage. The decrease in total carbohydrate content after 10 min of cooking could be a result of the diffusion of free sugars from food to water.[46]

The present study aimed to evaluate the effect of cooking modes on the physicochemical and nutritional parameters of two plantain genotypes at three ripening stages. Boiling plantain with peel, in general, better preserved both physicochemical and nutritional parameters. In addition, irrespective of the cooking mode and ripening stage, *Batard* pulps had better physicochemical properties and high starch content, while *CARBAP K74* exhibited high protein, lipid and ash contents. Moreover, for both genotypes, boiling considerably affected all the nutritional parameters assessed, but with no significant effect on the ash content.

Depending on the type of plantain, be it bred hybrid or hybrid, based on their dry matter content, it is advised to boil pulps with peels from clones with high DMC for a longer time, unlike clones with low dry matter contents. However, sensory evaluation, coupled with quantitative descriptive analyses and textural measurements, should be carried out to have an idea of the Target Food Product Profile of boiled plantain. This research highlights the complexity of processing plantains into food products. There is a need for a better understanding and distinction between traits whose trends can be generalized and easier to predict from those that cannot.

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AUTHOR CONTRIBUTIONS

GNN and AB were responsible for conceptualization. CKV was responsible for data curation. GNN and CKV were responsible for formal analysis. GNN and DD were responsible for funding acquisition. CKV, ATN and DFK were responsible for investigations. GNN, AB, CKV and DFK were responsible for methodology. GNN and DD were responsible for project administration. GNN was responsible for resources. GNN and M-JM were responsible for supervision. CKV, GNN and DFK were responsible for writing the original draft. CKV, GNN, AB, DD and IG were responsible for reviewing and editing.

ETHICAL STATEMENT

The research described in this manuscript did not require an approval from the National Ethics Committee for Human Health Research in Cameroon'

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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