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Effects of cultivar and harvesting conditions (age, season) on the texture and taste of boiled cassava roots

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ABSTRACT

Age of plant and environmental conditions during growing may affect texture (friability) and taste of boiled cassava roots. We investigated the quality of boiled roots of seven cultivars harvested at 10, 12 and 14 months in three different seasons.

Sensory taste (sweet or bitter) of boiled cassava root could not be correlated with sugar content and/or cyanide potential, which both interfere with taste perception; hence, bitterness is not a good indicator of the poisonous character of cassava roots. Improved cultivars generally showed lower friability scores, independently of plant age (10–14 months) or season. Rainfall before harvest directly lowers dry matter and mealiness of boiled roots. Cultivar and rainfall effects are discussed in relation to pectins (higher content for improved cultivars) that are suspected to be the major biochemical cause of vegetable mealiness.

1. Introduction

Cassava (*Manihot esculenta Crantz*) root is a very important staple food in the diet of the population of Benin and of many other countries in Africa, South America and parts of Asia. Cassava must be used immediately because of its rapid physiological and microbial deterioration after harvest. A large proportion of the roots is therefore processed into a variety of foods using various methods, including drying, roasting, frying and steaming. However, in many African countries, cassava is still mainly consumed just boiled or pounded into "fufu" (Nago & Hounhouigan, 1998; Ngeve, 2003). Cultivars are thus selected and cultivated by farmers based on consumer demand concerning quality, which is mostly governed by the final texture (particularly the friability or mealiness) and the taste of the boiled roots (Padonou, Mestres, & Nago, 2005).

Studies have shown that considerable differences, related to the taste and texture of cooked cassava roots, exist between cultivars (Charoenkul, Uttapap, Pathipanawat, & Takeda, 2006; Padonou et al., 2005). Concerning taste, cyanide content affects the bitterness of boiled roots. However, bitter cultivars often contain more soluble sugars than do sweet ones (Padonou et al., 2005), and some may thus be scored by consumers as not bitter. Concerning texture, friability or mealiness is universally cited by consumers as the most important quality attribute of boiled cassava (Asaoka, Blanchard, & Rickard, 1991; Eggleston & Asiedu, 1994; Favaro, Beleia, Junior, & Waldron, 2008; Ngeve, 2003). Several studies have shown that improved cultivars are generally not mealy and are thus considered as "non-boilable", but agro-environmental factors, during growing, and harvesting conditions can also affect this attribute (Asaoka et al., 1991; Ngeve, 2003); however, precise conditions cannot be recommended. The biochemical basis of cassava quality is still largely unknown; the physicochemical characteristics of starch do not appear to be directly linked to mealiness and ease of cooking (Asaoka et al., 1991; Charoenkul et al., 2006; Padonou et al., 2005), but the role of cell wall components and particularly of pectins and their interaction with divalent cations, has attracted attention (Eggleston & Asiedu, 1994; Favaro et al., 2008).

In parallel, several studies have been performed on the texture of boiled potato, particularly with respect to its friability (or mealiness) (Marle et al., 1997; McComber, Osman, & Lohnes, 1988; Warren & Woodman, 1974). Many attempts have been made to correlate starch content or starch properties with the friability of boiled potato. It has been reported that starch swelling during boil-

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ing induces distension of the cell walls which facilitates texture modification and softening of potato tissues (Marle et al., 1997; McComber et al., 1988). However, no clear correlation has been found between starch content or starch properties and potato friability. The role of pectic substances has also been studied (Parker, Parker, Smith, & Waldron, 2001), although there are few conclusive results (Warren & Woodman, 1974).

The current study thus aimed to evaluate the general sensorial quality of mature boiled cassava and then to focus on the effect of harvesting conditions (age of the roots and harvesting season) on the mealiness of the main traditional and improved cultivars from Benin. A method for assessing the texture of boiled cassava, calibrated with sensorial data, was used. It was shown that age at harvest (between 10 and 14 months) did not influence the texture of boiled cassava, but that a dry period before harvest had a marked impact: roots harvested under dry conditions were mealier. The role of cell walls, and particularly of pectic substances, was investigated.

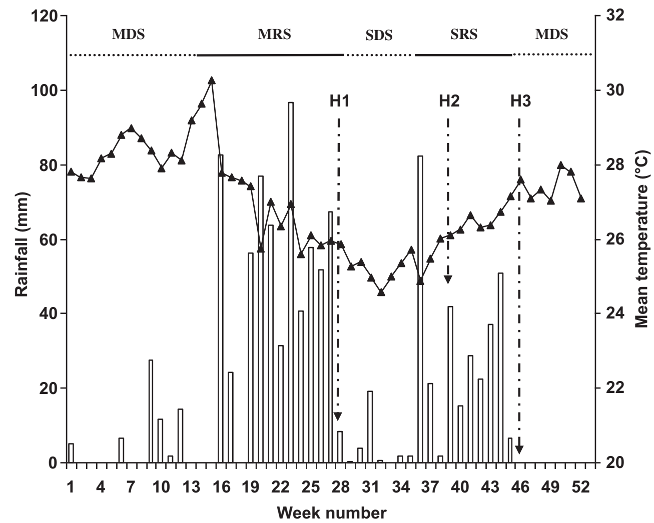

Fig. 1. Weekly rainfall (▲) and mean temperature (bars) recorded throughout the year of harvest. MDS, major dry season; MRS, major rainy season; SDS, short dry season; SRS, short rainy season.

2. Materials and methods

2.1. Materials

Seven cassava cultivars (ODOUNGBO, OLICHUTE, BEN 86052, RB 89509, TMS 30572, TMS 91/02319 and TMS 92B/057) were planted in 2005, during the main and the short rainy seasons (July and September, respectively) at the Food Plant Research Center (Benin National Institute of Agronomic Research) in Sekou; ODOUNGBO planted in July was not available in September and was replaced by OLICHUTE. The Sekou site (6°37′N, 2°14′E) is situated in the Derived Savannah (length of growing period 7–9 months) on a Rhodi-Acric Ferralsol according to the World Reference Base for Soil Resources classification (ISSS-FAO-ISRIC, 1998). The first four cultivars are considered as sweet and the three others as bitter. The first two are traditional varieties, while the others are widely distributed clones, selected for their high agronomic potential. The roots were harvested 10, 12 and 14 months after planting (Table 1). The three harvest dates were selected to enable harvesting at 2-month intervals and during three different climatic seasons (Fig. 1); the first harvest (H1) took place at the end of the main rainy season; the second harvest (H2) took place during the short rainy season, and the third harvest (H3) at the beginning of the main dry season. Samples were immediately transferred to the laboratory, where they were cleaned and stored at 4 °C, for less than 1 week, until completion of analyses. Refrigeration is a well-known technique which extends the shelf life of cassava roots beyond 10 days without any alteration of its quality (Tiky-Mpondo, 2001). Part of the sample of each cultivar was peeled, cut into thin slices (0.5 cm), freeze-dried, and then milled in a laboratory mill (Roetsch, Haan, Germany) with a 250 μm outlet sieve.

2.2. Physico-chemical analysis

The dry matter content was determined after oven-drying at 105 °C for 48 h (AACC, 1984). Total cyanide was determined, using the method described by Essers, Van der Grift, and Voragen (1996), modified by Padonou et al. (2005). Soluble sugar content was determined by HPLC using an HPX87H column (Biorad, Hercules, USA) eluted with 5 mM sulphuric acid, using a refractometric detector (Mestres, Dorthe, Akissoe, & Hounhouigan, 2004). Sugar power (SP) was calculated according to Schaafsma (Schaafsma, 2008) as follows: SP = 0.4 × [Maltose] + 0.7 × [Glucose] + 1.3 × [Fructose].

Cell walls were extracted from freeze-dried roots after removal of lipids and proteins and starch hydrolysis using the method described by Brillouet et al. (1988). Proteins were removed by hydrolysis with a protease mixture in the presence of sodium dodecyl sulphate (SDS) and β-mercapto-ethanol, followed by extensive washing with water. Starch was hydrolysed with thermostable alpha-amylase and amyloglucosidase, and the residue successively washed with 40% ethanol, pure ethanol, and then acetone. Pectin content was colorimetrically determined at 520 nm after acidic hydrolysis of the cell walls with 36 N H_2SO_4, and action of the m-phenylphenol (Blumenkrantz & Asboe-Hansen, 1973).

2.3. Appearance of boiled roots

The appearance of boiled roots was assessed using the method described by Charoenkul et al. (2006), slightly modified, with two replications. Cassava roots of approximately the same size from each cultivar were washed, peeled and transversally cut into successive slices 5 cm in length. They were boiled in distilled water for 30 min and cooled to room temperature (about 30 °C). Boiled roots were cut crosswise and pictures taken with a digital camera (Olympus C-2000 Zoom). Friability was visually scored using a four point scale by comparison with standard pictures (Fig. 2): 1, very

Table 1
Planting and harvesting schedule of cassava samples.

Cassava plantation	1st planting		2nd planting		
Planting date	July 2005		September 2005		
Planting season	Main rainy season		Short rainy season		
Harvest date	July 2006	September 2006	July 2006	September 2006	November 2006
Harvest season	Main rainy season	Short rainy season	Main rainy season	Short rainy season	Main dry season
Age of cassava	12 months	14 months	10 months	12 months	14 months

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cohesive, without any cracks; 2, cohesive, centre is cracked; 3, friable, centre is cracked and surface is partly cracked; 4, very friable, centre and surface are largely cracked.

2.4. Instrumental firmness analysis

A puncture test was performed to determine the firmness of the boiled roots (Padonou et al., 2005). Two roots of each cultivar were peeled and four 2.5 mm thick slices were cut from each root and steamed for 45 min. Firmness was assessed, using a Texture Analyser (Stevens-LFR) equipped with a cone penetrator moving at 2 mm s^{-1} to a final penetration depth of 3 mm. Twelve measurements were made on each slice (four different readings for the outer, the middle and the inner part of the slice) and mean value (in Newtons) of 60 readings was calculated by the general linear model (GLM) method.

2.5. Sensory evaluation

The panel was composed of 15 ordinary consumers of boiled cassava. Taste and friability were considered by the panel to be the most important attributes to describe the quality of boiled cassava. The panel had been previously trained for taste attributes of yam thick paste (Mestres et al., 2004). The panel was additionally trained for texture attributes by chewing the following references: uncooked cassava (cohesive), boiled friable yam, cultivar laboko (friable) and boiled sweet potato (very friable). In this way, the assessors were trained to quantify these attributes on a semi-structural scale (1–10) by tasting and chewing six samples of boiled cassava with two replications. The scale was fitted by consensus for both attributes: from cohesive (1) to very friable (10) for friability and from not sweet/bitter (1) to sweet (10) for taste. After training, the assessors tested each cultivar twice. Cassava roots were peeled, cut into pieces, washed and boiled for 45 min. Three samples were prepared simultaneously for each test and rapidly assessed by the panel.

2.6. Statistical analyses

The statistical analyses were performed on duplicate data with Statistica 7 (StatSoft, Tulsa, USA), using ANOVA and general linear model (GLM) procedures, Newman-Keuls mean comparison tests, correlation and linear multiple regression models.

3. Results and discussion

3.1. Texture of boiled mature cassava roots

Sensory evaluation of the friability of 14 month-old cassava roots showed a significant effect of the panel; but a very good consensus was observed between the assessors; the correlation coefficients between mean panel score and individual scores ranged between 0.96 and 1. Mean sensory friability scores of boiled cassava ranged between 1.5 for TMS 91/02319 and 8.6 for the traditional cultivar OLICHUTE (Table 2). Among the improved cultivars, only a sweet one, BEN 86052, had a friability score above 5. Safo-Kantanka & Owusu-Nipah (1992) also found that two local varieties from Nigeria were more mealy than 12 improved cultivars. This confirmed consumer preferences and explained why farmers continued planting them to the detriment of improved cultivars (Ngeve, 2003).

The firmness of boiled cassava was measured in parallel. Slice position (from head to tip) and puncture position (from centre to periphery) had a highly significant effect. Mean values of the 60 measurements for each cultivar were thus calculated by GLM; standard error of the mean value was of the order of 0.2 N. Mean

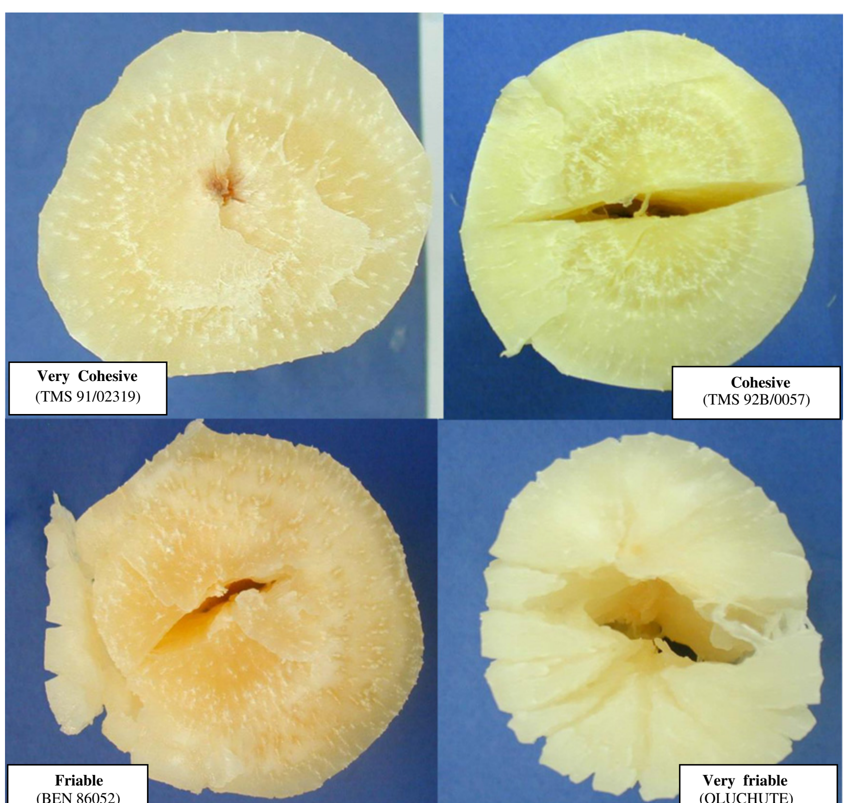

Fig. 2. Scoring scale for texture appearance of boiled roots.

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Table 2
Global characterisation of six cassava cultivars harvested 14 months after planting.

Cultivars	Dry matter (%, wb)	Total cyanide (mg/kg, db)	Cell walls (%, db)	Pectin (%, db)	Firmness (*N*)	Sugary power (mg/g, db)	Sensory analysis	
							Friability score	Taste score
Sweet cultivars								
OLICHUTE	28.8 a	107 a	3.1	0.35 a	1.1 a	28.6 c	8.6 f	6.4 d
BEN 86052	40.2 b	79.1 a	2.6	0.38 ab	1.3 a	35.0 d	6.2 e	7.5 e
RB 89509	39.9 b	94.7 a	3.7	0.48 b	2.5 c	25.6 b	2.5 b	5.3 c
Bitter cultivars								
TMS 30572	39.5 b	162 b	4.0	0.50 b	1.8 b	41.2 f	4.2 c	3.4 a
TMS 91/02319	41.1 bc	189 c	4.0	0.46 c	3.9 d	38.4 e	1.5 a	4.0 b
TMS 92B/0057	40.8 b	91.6 a	3.8	0.41 a	1.8 b	21.6 a	4.9 d	3.1 a
SDR	1.5	8.4	0.3	0.1	0.2	0.2	0.1	0.2

SDR = standard deviation of the residual; values in the same column not followed by the same letter are significantly different ($p < 0.05$).

values for the six cultivars investigated ranged between 1.1 and 3.9 N (Table 2). A similar range (1.3–3.8 N) has been previously reported for 20 cultivars from Benin (Padonou et al., 2005). One improved cultivar BEN 86052 and, as expected, the traditional cultivar, OLICHUTE, showed the lowest firmness values (1.3 and 1.1 N, respectively), while the highest firmness value (3.9 N) was measured for TMS 91/02319. The firmness of boiled cassava was significantly and negatively correlated with the sensory friability score ($r = -0.98$; Fig. 3). The friability of boiled cassava could thus be predicted from the instrumental firmness according to the formula:

$$\text{Sensory friability score} = -1.1 \times \text{Instrumental firmness}(N) + 5.4$$

Similarly, a negative correlation was found between the mealiness of cooked potato and the energy required to shear mashed potato (Unrau & Nylund, 1957). It is generally accepted that friability (or mealiness) is due to cell rupture on chewing and mealy cultivars display more "cell disorganisation" than do non-mealy ones (Safo-Kantanka & Owusu-Nipah, 1992). Accordingly, the higher the instrumental cohesive force between cells, the lower the cell disintegration (Eggleston & Asiedu, 1994) and the lower the sensory friability.

The appearance of boiled cassava was evaluated in parallel in 12- and 14 month-old cassava roots. OLICHUTE and BEN 86052 had the highest mean score (4), followed by TMS92B/0057 (3.5) and TMS 30572 (3). RB 89509 and TMS 91/02319 had the lowest scores (2 and 1, respectively). The appearance of boiled roots was negatively correlated with instrumental firmness ($r = -0.96$; Fig. 3). This confirmed firmness as a good measure of friability (either assessed by texture sensorial analysis or by visual appearance). Based on these results, the texture of boiled cassava can be classified into four groups as follows:

Group 1. Very cohesive: firmness value above 3 N (TMS 91/02319).
Group 2. Cohesive: firmness ranges from 2.5 to 3 N (RB 89509).
Group 3. Friable: firmness ranges from 1.5 to 2.5 N (TMS 30572 and TMS 92B/0057).
Group 4. Very friable: firmness value lower than 1.5 N (OLICHUTE and BEN 86052).

The traditional cultivar, OLICHUTE, had the lowest dry matter contents (28.8%, wet basis, wb), while the improved cultivars had similar dry matter contents (about 40%). There was no correlation between water content and mealiness. Cell walls were isolated from 14 month-old cassava roots. Yields were between 3.1% and 4.0%, db. This is consistent with cell wall extraction yields measured by Favaro et al. (2008) (3.3–3.5%, dry basis, db). We could not demonstrate any significant difference in cell wall contents between cultivars, even though the yield range was quite large. This may be partly due to the relatively low repeatability of the extraction procedure: standard deviation of the residual (SDR) was 0.3, and the coefficient of variation 8%. Indeed, any very slight variation in the efficiency of starch removal (starch represents around 90% of initial dry matter) or in cell wall precipitation and recovery after sedimentation and filtration has a direct impact on cell wall yield.

Pectin level was assessed on cell wall extracts and was 10–15% of the extracted cell wall. By comparison, Favaro et al. (2008) found 14–22% uronic acids (the main constituent of pectin) in extracted cassava root cell walls. In our study, calculated on a dry basis in fresh roots, pectin content ranged from 0.35% to 0.38% for OLICHUTE and BEN 86052 and 0.50% db for TMS 30572 (Table 2). Very friable cultivars thus had the lowest pectin contents. Pectin is the main component of middle lamella and is indeed widely recognised as being responsible for cell–cell adhesion, and hence for the crispness or mealiness of vegetables and fruits (Parker et al., 2001), even though few results directly and quantitatively support this idea (Warren & Woodman, 1974). However, in agreement with our results, Favaro et al. (2008) found a much higher uronic acid level in cell walls extracted from a long-cooking cassava cultivar than in two fast-cooking cultivars (21% vs. 14%). Furthermore, specific pectin fractions appear to be more likely linked to vegetable and fruit crispness and mealiness. Recent works showed that harder cassava root or fruits and/or ripe fruits (compared to unripe ones) have lower chelate-soluble pectin levels (CSP), but higher chelate-insoluble pectin level, and a particularly higher sodium carbonate-soluble pectin (SSP) level (Favaro et al., 2008; Xin et al., 2010; Zhang et al., 2008). In addition, it has been demonstrated that the rate of cooking, cell disruption level and firmness of cassava root are also directly linked to divalent cations that promote pectin gelation and cross-linking (Eggleston & Asiedu, 1994; Favaro et al., 2008). By contrast, addition of chelating agents (imidazole, CDTA) or sodium carbonate dramatically favours cell disruption, whereas natural chelating agents, such as phytic acid, also seem to contribute to this effect (Favaro et al., 2008). This confirms that pectins, and particularly chelate- and sodium carbonate-soluble ones, have a direct impact on cassava mealiness. The different components of pectins (in particular CSP and SSP), and cations and phytic acid levels, should be thus evaluated to understand and predict cassava mealiness.

3.2. Sweetness and bitterness of mature cassava roots

The sensory sweetness scores of boiled cassava ranged between 3.1 for TMS 92B/0057 and 7.5 for BEN 86052 samples. As expected, the sweet cultivars had higher sweetness scores (over 5.3) than had the bitter ones (equal to or less than 4; Table 2). As for mealiness, the traditional cultivars, OLICHUTE and BEN 86052, were

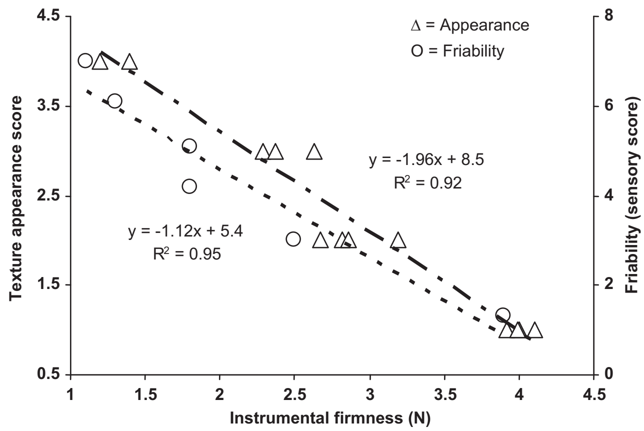

Fig. 3. Relationships between firmness and texture appearance or friability of boiled cassava.

considered superior, based on their higher sweetness scores (6.4 and 7.5, respectively). These results are in accordance with the classification used by Beninese farmers (Hongbété, Mestres, Akissoé, & Nago, 2009; Nago & Hounhouigan, 1998).

The major sugar determined by HPLC was maltose (66%). The other sugars were fructose (18 %) and glucose (16%). The values obtained for these sugars ranged between 30.5 and 51.4 mg g^{-1}, db (mean of 38.4 mg g^{-1}) for maltose, 4.6 and 17.6 mg g^{-1}, db (mean of 10.4 mg/g) for fructose and between 5.4 and 14.3 mg/g^{-1}, db (mean of 9.4 mg g^{-1}) for glucose. The sugary power of cassava ranged between 24.7 mg g^{-1} for TMS 92B/0057 and 45.1 mg g^{-1}, db for TMS 30572, with significant differences between cultivars. The sugary power of bitter cultivars was generally higher than that of the sweet cultivars (Table 2). These results are in agreement with those of Padonou et al. (2005) who reported that bitter cultivars had higher soluble sugar contents than had sweet ones. Bitter cultivars from Amazonia have also been found to give sweeter products (Wilson & Dufour, 2002).

The total cyanide contents of cassava roots ranged between 79.1 and 189 mg/kg, db (Table 2). This range is within a previous range of 22–244 mg/kg reported for 57 cultivars from Tanzania (Oluwole, Onabolu, Mtunda, & Mlingi, 2007). The bitter cultivars, TMS 91/02319 and TMS 30572, had the highest total cyanide contents (189 and 162 mg/kg, respectively). However TMS 92B/0057, classified as bitter by breeders and by farmers, had a total cyanide content (91.6 mg/kg) in the same range as that of sweet cultivars (Hongbété et al., 2009). This cultivar, with a low cyanide content, also had the lowest sugar content and, despite its low cyanide content, was scored as the most bitter. This observation is in agreement with that of Oluwole et al. (2007), who reported overlapping in cyanide contents between bitter and sweet cultivars. This result points to the discrepancy between cultivar classifications based on their cyanide content and their sensorial bitterness; the term ‘bitter’ should be thus avoided when classifying cyanide-rich cultivars and should be replaced by ‘poisonous’.

3.3. Effect of harvesting age and season on dry matter content and on firmness of boiled cassava

Firmness and dry matter contents of 10-, 12- and 14 month-old boiled cassava roots were measured for both planting dates (Table 3). Firmness did not vary significantly with the age of cassava plant. Mean firmness values ranged between 2.3 N for 10-month old roots and 2.4 N for 14-month old roots. Only ODOHOUNGBO exhibited differences in firmness between 12 months (value of 1.8 N) and 14 months (value of 3.2 N). Our data thus indicate that the age of the cassava plant had no (or only a slight) influence on the firmness of the boiled roots of mature plants (10–14 months old). Previous studies have indeed evidenced a rapid decrease in mealiness from 6 to 10 months, with no further variation thereafter (Ngeve, 2003) (Wheatley & Gomez, 1985). The dry matter content of cassava roots did not vary significantly with the age of the cassava plant. Mean values were 38.5%, 39.1% and 39.4% (wb) at 10, 12 and 14 months, respectively.

As far as the harvesting season is concerned, there were significant differences in the firmness values of boiled roots and dry matter contents. However, the variation (2.8 %) was much lower than that due to cultivar (28.8–41.1% wb, Table 2). Mean dry matter ranged between 37.5% for samples harvested during the short rainy season (H2) and 39.9% and 40.3% for samples harvested at the end of the main rainy season (H1) and at the beginning of the main dry season (H3), respectively. Dry matter was expected to be low in roots harvested during the short rainy season, but the relatively high value for roots in the main rainy season was puzzling. This may be due to the relatively dry period recorded at the end of this season, just before harvesting (end of week 28, Fig. 1).

Firmness values of boiled cassava harvested at three different seasons are given in Table 4. Roots harvested at the beginning of the main dry season (H3) had lower firmness values (mean value of 2.0 N) than had those harvested at the end of the main rainy season and during the short rainy seasons (2.3 N and 2.8 N, H1 and H2, respectively). An interaction between cultivar and season (or antecedent dry period) was, however, evidenced and OLICHUTE (the most friable cultivar) and TMS 91/02319 (the firmest and the most cohesive cultivar) showed constant firmness at all three harvesting seasons. This means that cultivars with intermediate friability were improved when harvested in the dry season, whereas extreme ones remain unchanged. This ties in with what farmers and consumers report. The main period for harvesting cassava is the dry season, as processing often requires sun-drying. The increase in dry matter content and in the friability of boiled roots, during this period, is thus an advantage for both processors and consumers. Previous studies did not evidence a clear relationship between the harvest period and the texture of boiled cassava (Asaoka, Blanchard, & Rickard, 1992; Asaoka et al., 1991); an increase in the glassy/hard texture of boiled roots has, however, been reported when harvesting took place in the rainy season. This has been tentatively linked to an increase in soil temperature, as starch physicochemical properties (amylose content, gelatinization properties) are influenced by plant growth temperature (Sriroth, Piya-

Table 3
Firmness (Newtons) of boiled cassava from seven cultivars harvested at different ages.

Age of roots in months (season at harvest)	BEN 86052	RB 89509	ODOHOUNGBO[a]	OLICHUTE	TMS 30572	TMS 91/02319	TMS 92B/0057	Mean[a]
10 (MRS)	1.7	2.7	ND	1.2	2.6	4.0	1.9	2.3 ± 0.3
12 (MRS + SRS)	1.8	3.2	1.8	1.2	2.1	4.0	2.4	2.4 ± 0.2
14 (SRS + MDS)	2.0	3.2	3.2	1.1	2.1	4.0	2.3	2.4 ± 02

MDS = main dry season; MRS = main rainy season; SRS = short rainy season; ND = data not determined.
Values in the same column not followed by the same letter are significantly different ($p < 0.05$).
[a] ODOHOUNGBO not involved in ANOVA and mean calculation.

Table 4
Firmness (Newtons) of boiled cassava from seven cultivars harvested at different seasons.

Harvest seasons (age of plant)	BEN 86052	RB 89509	ODOHOUNGBO[a]	OLICHUTE	TMS 30572	TMS 91/02319	TMS 92B/0057	Mean[a]
Main dry season (14 months)	1.2 a	2.4 a	ND	1.1	1.7 a	3.7	1.7 a	2.0 ± 0.2 a
Short rainy season (12 and 14 months)	2.4 c	2.5 a	3.2	1.2	2.4 b	3.9	2.7 b	2.8 ± 0.1 c
Main rainy season (10 and 12 months)	1.5 b	3.8 b	1.8	1.2	1.9 ab	3.8	1.9 ab	2.3 ± 0.1 b

Values in the same column not followed by the same letter are significantly different ($p < 0.05$).
[a] ODOHOUNGBO not involved in ANOVA and mean calculation; ND = data not determined.

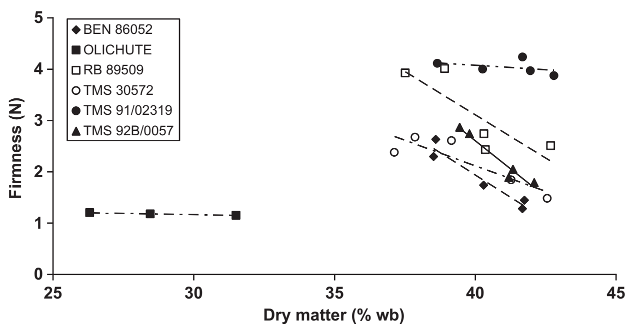

Fig. 4. Relationship between dry matter of raw root and firmness of boiled root.

chomkwan, Santisopasri, & Oates, 2001). However, no physico-chemical characteristic of starch has yet been directly correlated with boiled cassava texture and mealiness (Asaoka et al., 1991; Charoenkul et al., 2006; Padonou et al., 2005). In our case, the mean temperature was almost constant (25–28 °C) during plant growth (Fig. 1), but rainfall resulted in marked variations, particularly when rain fell some weeks before harvest. Variation in friability appeared to mirror variation in rainfall 1 or 2 weeks before harvest and negative significant correlations (0.88–0.98) were evidenced between root dry matter and boiled firmness in most cultivars (Fig. 4). Bibliographic data are confusing on this subject; in agreement with our results, mealiness has been shown to increase with dry matter (Safo-Kantanka & Owusu-Nipah, 1992), whereas not any or a reversed relationship has been reported (Ngeve, 2003). In the case of potato, in agreement with our results, mealiness has been associated with high solid matter content and high starch content (Warren & Woodman, 1974). Incidentally, the negative relationship between dry matter and firmness indicates that, even if water does have an influence on texture, it does not act as a solvent; otherwise the relationship would be reversed. It may act indirectly, with pectins, which are suspected to be the major biochemical cause of vegetable mealiness (Eggleston & Asiedu, 1994; Favaro et al., 2008; Parker et al., 2001; Warren & Woodman, 1974). It should also be noted that dry matter is not the most important factor, as traditional cultivars have the lowest dry matter content but are the mealiest. It may only, but significantly, affect mealiness, depending on weather conditions, and particularly the occurrence of a dry period preceding harvest. The possible links between antecedent dry period, drought and variations in cations (mono and divalent) for osmotic adjustment remain to be investigated.

4. Conclusion

A puncture test can confidently be used for evaluating cassava friability; it correlates with both texture sensorial evaluation and disintegration visual appearance. One traditional cultivar, OLICHUTE, and one improved cultivar, BEN 86052, proved superior in sweetness and friability, the latter being tentatively associated with lower pectin content. Plant age (10–14 months) did not have a significant effect on root quality. More than the harvesting season, rainfall before harvest directly lowers mealiness of boiled roots, perhaps through interaction with pectins, which are suspected to be the major biochemical cause of vegetable mealiness.

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