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Comparative characterization of some functional properties of flours of new plantain hybrids with the Orishele variety (*Musa* spp.) as control

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Abstract

Plantain hybrids CRBP 14, CRBP 39, FHIA 17 and FHIA 21 gives higher yields than traditional ones and have been conceived in response to the increasing plantain demand. The capability of these new hybrids to replace the traditional varieties was shown by the study of some functional characteristics of their native flours, in comparison with that of Orishele variety as control. Swelling power and solubility patterns of flours evolve in a homogeneous way for all cultivars, with however a particularity for hybrid FHIA 17, for which these phenomena occur earlier. This hybrid shows the lowest swelling values of its flour. Viscoamylograms indicate an earlier initial temperature of gelatinization (26th min at 74°C) for hybrids CRBP 14, FHIA 17 and FHIA 21 than for hybrid CRBP 39 and the control variety Orishele (30th min at 77°C). Hybrid FHIA 17 presents the highest values for viscosities at 95°C and at 50°C, as for the indices of gelation and instability. Plantain hybrids CRBP 14, CRBP 39 and FHIA 21 being characterized by technological aptitudes close to those of the control variety Orishele, they can thus replace it. Hybrid FHIA 17 would be a dessert type banana.

Key words: Plantain, *Musa* spp, Banana hybrids, Flours properties, Rheology

Introduction

Banana plants are monocotyledonous perennial and important crops in the tropical and subtropical world regions (Strosse et al., 2006). They include dessert banana, plantain and cooking bananas. Traded plantain (*Musa paradisiaca* AAB) and other cooking bananas (*Musa* ABB) are almost entirely derived from the AA·BB hybridization of *M. acuminata* (AA) and *M. balbisiana* (BB) (Stover and Simmonds, 1987; Robinson, 1996). Plantain and cooking bananas are very similar to unripe dessert bananas (*M. Cavendish* AAA) in exterior appearance, although often larger; the main differences in the former being that their flesh is starchy rather than sweet, they are used unripe and require cooking (Happi et al., 2007). Dessert bananas are consumed usually as ripe fruits; whereas ripe and unripe plantain fruits are usually consumed boiled or fried (Surga et al., 1998).

According to Ducroquet (2002) plantain (1 400 000 tones/year) is the third basic foodstuff produced in Côte d'Ivoire after yam (3 000 000 tones/year) and cassava (1 700 000 tones/year). Some of these cultivars are sensitive to diseases like the black *cercosporiosis*, which is prejudicial for a good return.

To reduce the incidence of this disease, the International Institute of Tropical Agriculture (IITA) in Nigeria, the Regional Research Center on Banana and Plantain (CRBP) in Cameroun and the *Fundaciòn Hondureña de Investigaciòn Agricola* (FHIA) in Honduras developed hybrids having a partial resistance to this phytopathology.

Tetraploid hybrid CRBP 14 of genomic AAAB group is at the same time tolerant to weevil and partially resistant to *cercosporiosis* and *fusariosis*. Its average weight of the bunch is 7.6 kg. Hybrid CRBP 39 a tetraploid plantain type (AAAB) is obtained by breeding the triploid plantain female (*Musa cv*. AAB, local variety "clear French") and the diploid synthetic hybrid male M23 (AA) banana. It presents an average bunch weight of 19.6 kg (Cohan et al., 2003). It is at the same time

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tolerant to weevil and partially resistant to the *cercosporiosis* and the *fusariosis*.

Hybrid FHIA 17 of genomic group AAAA is tolerant to the weevil in bananas (*Cosmopolites sordidus* Germar), resistant to fungi *Mycosphaerella fijiensis* and *Mycosphearella musicola* (Molina et al., 2003). Besides, Gonzalez et al. (2003) showed its resistance not only to the black stripes disease but also to black Sigatoka disease (caused by *M. musicola* Leach) and to *fusariosis* (caused by *Fusarium oxysporum* f. sp *cubense*). Bunches of hybrid FHIA 17 have an average weight of 43.9 kg (Gonzalez et al., 2003).

Hybrid FHIA 21 (genomic group AAAB) is a plantain type resistant to Sigatoka disease and to *fusariosis*; but it is sensitive to nematodes. It has a high output (22 to 27 kg per bunch without the rachis) and the excellent quality of its fruits confers it a privileged place for consumption as in fresh (at "green yellow" maturity stage) or in cooked form (at "green" maturity stage) (Guzmán - Piedrahita et al., 2002).

Orishele is a cultivated variety of Medium False horn type; it belongs to the *Musa* genus, EUMUSA Section, AAB Species/Groups, Plantain Subgroup/subspecies. This variety is regularly used as control for agronomic trials by the researchers in the 13 African countries members of *Musa* network for West and Central Africa (MUSACO) (Anonym, 2002). Moreover, it belongs to the 13 cultivars (among 1177 currently existing accessions) stored for long period safety in cryoconservation suspension, by the World Consortium on *Musa* Genomic (INIBAP, 2004).

In addition to agronomic works, researchers in post-harvest technology did investigations on physicochemical, biochemical properties and nutritional values of many banana cultivars. Thus Orishele variety was studied by Gnakri and Kamenan (1994). Their results indicated the optimal date of harvesting it at the 72nd day after flowering. This result confirms that of Collin and Dalnic (1991).

Other works concerning the chemical composition of some varieties of Nigeria, Ghana and Côte d'Ivoire were completed by Burdon et al. (1991), Amankwah et al. (2011) and by Aboua (1991) respectively.

Coulibaly et al. (2006, 2007) extracted and characterized starches, then determined the chemical composition, the nutritional values and energy of banana hybrids CRBP 14, CRBP 39, FHIA 17 and FHIA 21 and that of Orishele. These hybrids, which can be considered as a good progress in the agronomy, have not benefits enough post-harvest investigations. With the objective of contributing to the knowledge of their technological aptitudes, our study aims to compare some flour functional properties such as swelling power, solubility patterns and viscosity with those of the Orishele variety as control. That will make it possible to determine their potential use as cooking (standard Orishele) or as dessert banana.

Material and Methods

Row material

Banana hybrids CRBP 14, CRBP 39, FHIA 17, FHIA 21 and Orishele variety were obtained from the Research Station on Fruits and Citrus Fruits of National Center of Agronomic research (CNRA), located 20 kilometers East of Abidjan (5° 38 ' N, 4° 05' W). They were all harvested at the stage of maximal maturity, when at least one ripe fruit appears on the bunch. Starting from the date of flowering, this stage corresponds to 67, 92, 78 and 82 days for the 4 hybrids CRBP 14, CRBP 39, FHIA 17 and FHIA 21 respectively. The control variety Orishele was harvested after 70 days.

Processing method of raw banana flour

The fruits of the 4 four banana hybrids (CRBP 14, CRBP 39, FHIA 17 and FHIA 21) and of the control variety Orishele were initially peeled using a stainless steel knife, washed then cut to chips. The chips were dried in a ventilated drying oven (MEMMERT, 854 Scwachbach, West Germany) at 45°C during 48 hours. The dried chips were crushed (Crushing machine model 14680, Glen Creston Ltd, Great Britain). The flower was then sieved in a 250 µm mesh sieve.

Swelling power and solubility patterns studies

These parameters were measured at treatment temperatures from 65, to 95°C using 10g db L^{-1} flour dispersion as described previously (Mestres and Rouan, 1997).

The tubes were placed in a shaking heating block and the temperature increased at 5°C/min from 50 to 95°C. After 1 hour at 95°C, the tubes were cooled at 5°C/min to 25°C and then centrifuged (Laborfuge A, Heraeus CHRIST GMBH OSTERODE, West Germany) for 15 min at 5000 x g. Supernatants and sediments were then collected and weighed (W_{su} and W_{se}, respectively). They were then dried at 105°C for 24 hours for the supernatant and 48 hours for the sediment. Their dry matter weight was then determined (D_{su} and D_{se}, respectively). The swelling power and solubility patterns were then calculated as following:

Swelling power (g/g) = $(W_{se} - D_{se}) / D_{se}$

Solubility (%) = $D_{su} / (W_{su} - D_{su})$

All measurements were performed in triplicate.

Viscosity studies of flours

The viscosity characteristics of each sample were studied using a Brabender bunchl N8025 viscoamylograph, (Duisburg, West Germany) at a fixed starch concentration of 6% db (w/w) and constant speed of 75 x g using Standard I profile as described by Garcia and Walter (1998)**.** The temperature profile employed was as follows: heating range 25 to 95°C at a rate of 5°C/min, holding at 95°C for 15 min, cooling to 50°C at the same speed and holding at 50°C for 2 min. The scale of sensitivity (torsion) used for the recording is 250 Centimorgans. The viscosity profile recorded by the Brabender reflects the peak, trough and final viscosity, pasting temperature and peak time for each sample.

Statistical analysis

The significance level of differences observed in the case of the small samples was determined with the Student t-test (Snedecor and Cochran, 1984) using the SPSS software (10th version).

Results

Evolution of flours swelling power and solubility patterns

The swelling and solubility of the 5 banana cultivars' flours according to the temperature (Figures 1 and 2) are given in the range of temperatures going from 65 to 95°C.

Concerning the flour of hybrid CRBP 14, a notable swelling (8.6 g water/g flour) is recorded only at 75°C, at this temperature hybrid CRBP 39 records the same swelling. The flour of hybrid FHIA 17 starts to swell significantly with 5.2 g water/g flour at 70°C as for hybrid FHIA 21 and the control variety Orishele. The process of notable swelling of their flour starts at 80°C with 8.3 and 8.8g water/g flour respectively.

For the 5 banana cultivars the highest swelling was reached at 95°C. It varied from 12.3 to 17.8 g water/g flour, for the flours of hybrids FHIA 17 and CRBP 14 respectively. The flour of the control variety Orishele presented at that temperature a low swelling (13.7g water/g flour).

The solubility curves (Figure 2) of the flours of the 5 banana cultivars presented in general an increasing solubility according to temperature from 4.8% (at 65°C for the control variety Orishele) to 22.3% (at 95°C for hybrid CRBP 14). The growth of this solubility was not homogeneous for all flours. It presented 3 phases:

The first phase of low solubility for the flours of all cultivars, besides hybrid FHIA 17 ranged from 65 to 70°C with solubility rates varying between 4.8% (for the control variety Orishele) and 8.7% (for hybrid CRBP 14).

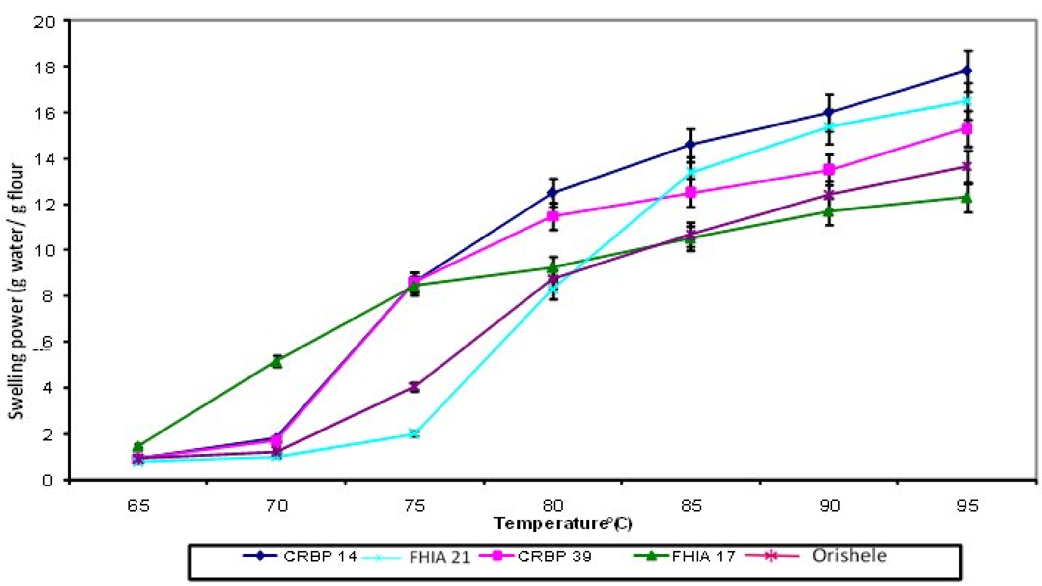

Figure 1. Flour swelling according to temperature carried out using 1% db (w/w) flour dispersion of the 5 banana cultivars (the flours was heated from 65 to 95°C in 45 min and then cooled at 5°C/min to 5°C).

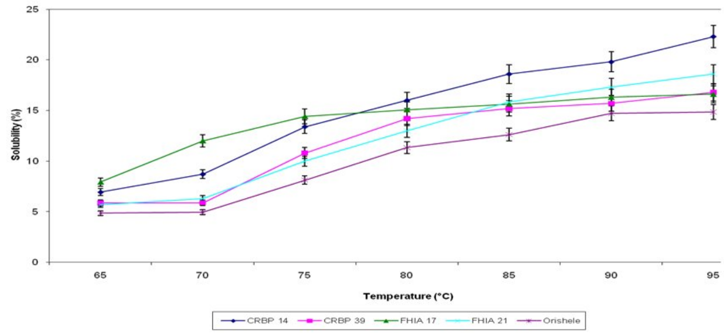

Figure 2. Flour solubility according to temperature carried out using 1% db (w/w) flour dispersion of the 5 banana cultivars (the flours was heated from 65 to 95°C in 45 min and then cooled at 5°C/min to 50°C).

The second phase was characterized by a significant solubility increase of the flours of all cultivars besides hybrid FHIA 17. It ranged from 70 to 80°C, with a flour solubility varying from 5.0 to 16.0%.

In the third phase (from 80 to 95°C), flours solubility remains low: from 13.0 (for hybrid FHIA 21) to 22.3% (for hybrid CRBP 14).

Hybrid FHIA 17 is unique with the solubility growth of its flour in 2 phases. The first one, high (from 7.9 to 12%) for temperatures ranging from 65 to 70°C; and the second one low (12.0 to 16.6%) on the last range of temperatures.

Flours pasting properties

The pasting curve of the five banana cultivars flours (Figure 3) showed some homogeneity. Flours of hybrids CRBP 14, FHIA 17, and FHIA 21 present an earlier (at the 26th minute, 74°C) increase in their viscosity, than that the flours of hybrid CRBP 39 and the control variety Orishele, whose viscosities started increasing at the 30th minute, at 77°C. For the 5 cultivars flours, the most significant increase in their viscosity was noted between the 26th and 30th minute, which corresponds to the range of temperatures between 74 and 77°C. At 77°C the highest viscosity (950 UB) and lowest viscosity (300 UB) are noted at for hybrid FHIA 21 and the control variety Orishele respectively. For all flours, maximum viscosities were reached between the 38th and 40th minute, at 95°C. Hybrid FHIA 17 and the control variety Orishele present highest (1150 UB) and lowest (770 UB) viscosity respectively.

In general, a stabilization of all viscosities was noted, between temperatures ranging from 92 to 93°C while passing by the maximum temperature 95°C.

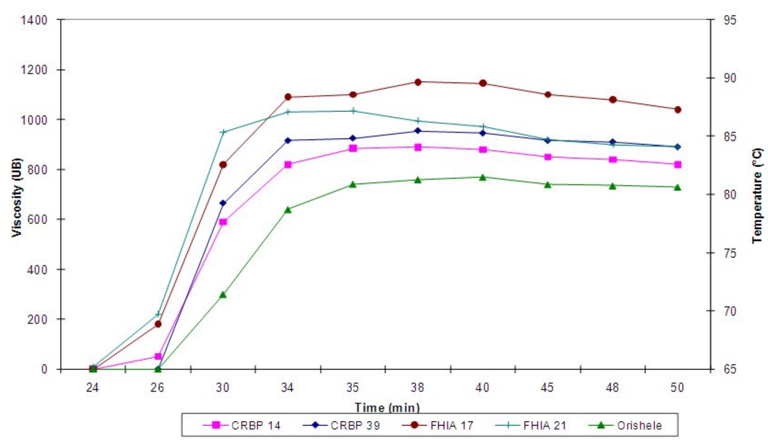

Figure 3. Viscoamylograms of the 5 banana cultivar flours according to the temperature and heating time. Flours were heated from 65 to 95°C in 45 min and then cooled at 5°C/min to 50°C).

Table 1. Viscoamylograms characteristics of the 5 banana cultivar flours.

	Tg (°C)	$V_{95\,°C\,(d)}$ (UB)	$V_{95\,°C\,(f)}$ (UB)	V_e (UB)	t_g(min)	t_m(min)	T_c(min)	$\frac{V_e - V_{95\,°C\,(f)}}{V_e}$	$\frac{V_{95\,°C\,(d)} - V_{95\,°C\,(f)}}{15\ min}$	$\frac{V_e - V_{95\,°C\,(d)}}{V_e}$
CRBP 14	74.4[a]	890±45	850±40	860±43	25±1	39±2	14±1	-0.85 ±0.1	2.7±0.3	-0.94±0.1
CRBP 39	77.2[a]	955±48	915±41	925±41	27±1	38±2	12±1	-0.74±0.1	2.7±0.2	-0.82±0.2
FHIA 17	74.5[a]	1150±60	1100±56	990±42	25±1	38±2	14±1	-0.59±0.1	3.3±0.4	-0.67±0.1
FHIA 21	74.3[a]	1035±55	920±45	955±42	24±1	34±1	10±0.5	-0.66± 0.1	7.7±0.6	-0.86±0.2
Orishele	77.1[a]	770±23	740±17	760±20	27±1	40±2	14±1	-1.06±0.1	2.0±0.1	-1.11±0.3

Values affected by the same letter in the same column are not significantly different at p = 0.05

Tg : pasting beginning temperature
Tc : Time of cooking (Time necessary to reach maximum viscosity starting from viscosity increasing)
V95 °C (d): Viscosity at 95 °C (beginning)
V95 °C (f): Viscosity after 15 min at 95 °C
Ve : Viscosity at 50 °C after cooling
tg : time of pasting beginning
tm : Time to reach maximum of viscosity
Ve-V95 °C (f) / Ve : Gelation index
V95 °C (d) –V95 °C (f) / 15 min: Viscosity drop
Ve-V95 °C (d) / Ve : Gel instability index

A drop of viscosities is recorded for all the flours, from the 45[th] to the 70[th] minute, where temperatures dropped from 95 to 50°C. The highest value (690 UB) at 50°C was noted for hybrid FHIA 17 and the lowest (360 UB) for the control variety Orishele.

Average viscosities of all cultivars varied between 519 UB (for the control variety Orishele) and 823 UB (for hybrid FHIA 17).

The starching beginning temperatures (Tg) of the flours of the 5 banana cultivars are roughly the same (Table I); they are around 75°C; the lowest (74.3°C) is noted for hybrid the FHIA 21 and the highest (77.2°C) is recorded for hybrid CRBP 39.

Hybrid FHIA 17 which has a middle starching beginning temperature (74.5°C), has with 1150 UB the highest maximum viscosity ($V_{95°C(d)}$). It is followed by hybrid FHIA 21 with 995 UB and that of hybrid CRBP 39 with 955 UB. The lowest maximum viscosity (770 UB) is recorded for the control variety Orishele.

This ranging remained the same, concerning the viscosity reached after 15 minutes at 95°C ($V_{95°C(f)}$); but an average reduction of these viscosities of 5% is noted, compared to maximum viscosities.

The viscosity drops ($V_{95°C(d)}$ - $V_{95°C(f)}$ / 15 min) noted for hybrids CRBP 14, CRBP 39 and FHIA 17 are roughly the same; it is around 3.0. The highest and the lowest viscosity drop (7.7 and 2.0) were recorded for hybrid FHIA 21 and for the control variety Orishele respectively.

After cooling at 50°C, viscosities drops (V_e) compared to maximum viscosities ($V_{95°C\ (d)}$) are noted. The highest variation (14%) was noted for hybrid FHIA 17 and the lowest (1.3%) for the control variety Orishele.

For all 5 cultivars, times of beginning of the pasting (tg) were rather close to each other (only 3 minutes between the extreme values). It was the same on the level for times necessary (MT) to obtain maximum viscosity: these times vary between 38 and 40 minutes, with however an exception at the hybrid FHIA 21, which requires only 34 minutes. This hybrid presents besides starting from the appearance of an increase in viscosity, shortest time (10 minutes) necessary to reach maximum viscosity ($V_{95°C\ (d)}$). For all the others cultivars, this time is approximately 14 minutes. The index of gelation (V_e - $V_{95°C\ (f)}$ / V_e) varies from -0.59 for hybrid FHIA 17 to -1.06 for the control variety Orishele. All of the instability index (V_e - $V_{95°C\ (d)}$ / V_e) of the 5 banana cultivars flours gel is negative and very close to 0. They vary from -0.67 for hybrid FHIA 17 to -1.11 for the control variety Orishele.

Discussion

The representation of swelling rate according to heating temperature going from 65 to 95°C shows a hydration speed for the 5 banana cultivars flours. All the curves present a regular increase, with a homogeneous slope starting from 85°C and the maximum swelling at 95°C going form 12.3 and 17.8 g water/g flour for hybrids FHIA 17 and CRBP 14 respectively. Our results corroborate those of Coulibaly et al. (2006), which indicated for starches of the same banana cultivars, a regular increase of swelling with a homogeneous slope starting at 85°C. These authors present maximum swellings at 95°C between 16.1 and 35.6 g water/g starch recorded for the same hybrids (FHIA 17 and CRBP 14). These results were also in the same order of those obtained by Delahaye et al. (2008) with unirape plantain flour in chamber dryer conditions. Dadier et al. (1998) noted a regular swelling for the flours of 2 sweet potato (*Ipomea batatas*) varieties (red skin white flesh and yellow skin yellow flesh) between 65°C and 95°C. By considering initial swelling temperatures, Tetchi et al. (2007) noted on starches of various products, different ranges of swellings temperatures (from 55°C to 65°C, from 65°C to 75°C and from 75°C to 85°C). The swellings values recorded at 95°C by Dadier et al. (1998) located around 20 g water/g flour, were higher than the present one (12.3 and 17.8 g water/g flour). The present results however were close on one hand to 16 g water/g starch obtained by Amani et al. (2004) at 95°C on ginger starch, and on the other hand to 12.9g water/g starch obtained by Tetchi et al. (2007) on corn starch.

Solubility according to temperature (from 4.8 to 22.3%) of the tested bananas flours are quit the same with those (from 0.9 to 28.2%) obtained by Coulibaly et al. (2006) on the bananas starches. At low temperatures (from 65 to 75°C), average flours solubility (4.8%) are higher than those of starches (0.9%). That was due to the low solubility of starches because of homogeneous cohesion forces, which maintain the starch granule matrix (Reyes et al., 1983). Flours solubility rates of the tested bananas correspond to those obtained by Dadier et al. (1998), who recorded on flours of 2 sweet potato (*Ipomoea batatas*) (red skin yellow flesh and yellow skin yellow flesh) solubility rates varying between 5% (at 65°C) and 23% (at 80%). These values corroborate our results (4.5% and 16%). On the other hand for temperatures ranging from 80 to 95°C, our values (from 11.3 to 22.3%), remain lower than those given by Dadier et al. (1998) on sweet potato flours (from 23 and 34%), and those (from 23.0 to 31.7%) obtained by Amani et al. (1997) on cocoyam flours.

There is proportionality between solubility and swelling power of the flours (Figure 4).

The curves of tendencies are lines whose equations are y = ax + B, with 0.7909 ≤ a ≤ 0.8825 and 4.4545≤ B ≤ 7.1486. The value of R^2 for the different lines varies from 0.9532 for hybrid FHIA 17 to 0.9902 for hybrid CRBP 14. These values very close to 1 indicate a very close correlation between the solubility and the swelling power of the flours. This result confirms former work of Coulibaly et al. (2006), who on the same banana starches noted a very strong correlation between solubility and swelling power, with values of R^2 varying between 0.9837 and 1.

The study of solubility according to swelling power generally showed a linear relation between the two phenomena. Thus, a swelling increase was accompanied by a high solubility. This phenomenon was observed by several authors (Amani et al, 1997; Delpeuch and Favier, 1980; bertolini et al., 2010).

The pasting curve of the 5 banana flours has the same shape. For hybrids CRBP 14, FHIA 17 and FHIA 21 the first notable viscosity increase was recorded after 26 minutes at 74°C. For hybrid CRBP 39 and the control variety Orishele the significant viscosity variation occurs at the 30th minute at 77°C. These 2 temperatures (74 and 77°C) are those of the beginning of flour gelatinization of these 2 banana groups. The flours swelling evolution according to temperature corresponds to the initial pasting temperature (Tg) of these flours. Comparatively, low swellings were observed at 70°C for the flours of hybrid CRBP 39 and the control variety Orishele; that is coherent with their relatively high initial pasting temperature. Temperature of 78°C was reported for the beginning of gelatinization for *Xanthosoma sagittifolium* (red and white *cv.*) native starches Amani et al. (1997).

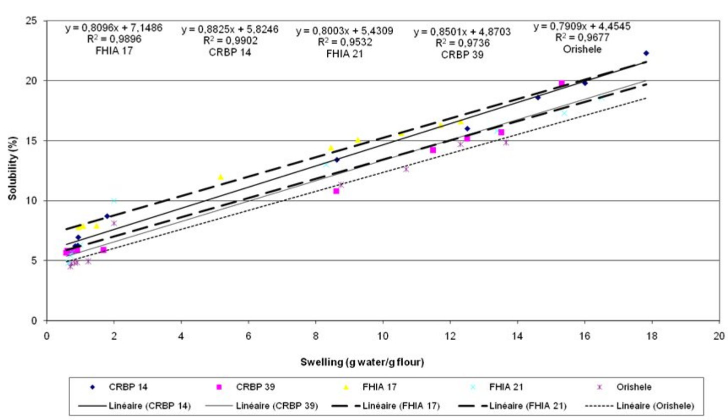

Figure 4. Straight lines of flour solubilisation according to flour swelling of the 5 banana cultivars.

On the starches of various products, Tetchi et al. (2007) noted initial temperatures of gelatinization varying between 70°C for rice and 90°C for ginger. Gnakri (1993) indicated the gelatinization beginning at 74°C for the starch of the Orishele variety. For the starch of the banana *Musa paradisiaca*, Núňez-Santiago et al. (2004) noted the beginning of gelatinization at 75°C. The viscosity increase at the beginning of gelatinization is due to starch solubility between 70 and 95°C, corresponding to starch paste formation. It follows a second phase during which the gel formation occurs (Leach, 1965; Duprat et al., 1980; Adunni and Olaposi, 2010).

After cooling at 50°C, the gelation index (V_e – $V_{95°C\ (f)}$ / V_e) of all flours remain negative (from -1.06 for the control variety Orishele to -0.59 for hybrid FHIA 17). Therefore, they do not have any reconstitution capacity of their starch macromolecular network. According to Leach (1965) and Duprat et al. (1980), when the temperature is lowered gradually until 50°C, there is retrogradation by a partial reconstitution of the macromolecular network of the starch in the flour. This reconstitution determines the final consistency of the product after cooling. It is a function of amylopectin and amylose concentrations in the flour. Instability index of gel (varying from -1.11 to -0.67) are very close to 0. That implies good gel stability. This result confirms those of Eggleston et al. (1992) that indicated a great stability and a negligible retrogradation on several plantain (*Musa* spp., AAB group) starches. The gel instability Index of hybrids CRBP 14, CRBP 36 and FHIA 21 (-0.94; -0.82 and -0. 86 respectively) are very close to that of the control variety Orishele (-1.11); that augurs them an identical aptitude of cooking in water. Hybrid FHIA 17 with -0.67 as instability index, produces the least stable gel; the control variety Orishele with -1.11 has the most stable gel. The flour of hybrid FHIA 17 has moreover the highest viscosities at 95°C as well as at 50°C (after cooling).

Conclusion

This study was carried out to determine some functional properties of banana hybrids CRBP 14, CRBP 39, FHIA 17 and FHIA 21, in comparison with those of the control variety Orishele.

The swelling power and the solubility patterns of flours according to temperature progressed homogeneously for all bananas, with however a particularity for hybrid FHIA 17, for which these phenomena occurred earlier.

The flours viscoamylogramms indicate an earlier initial pasting temperature for hybrids CRBP 14, FHIA 17 and FHIA 21, than that of hybrid CRBP 39 and the control variety Orishele. Hybrid FHIA 17 shows the most stable gel and the control variety Orishele, least stable.

Hybrid FHIA 21 is characterized by the shortest times for beginning of empesage and for cooking. The control variety Orishele presented average values for all characteristics.

Looking at the results, the banana hybrids CRBP 14, CRBP 39 and FHIA 21 are similar to the control variety Orishele. Moreover, Hybrid FHIA 17 is significantly different from the other hybrids and the control variety Orishele. These result made CRBP 14, CRBP 39 and FHIA 21 able to replace the control variety Orishele, as regards the culinary preparations in vegetable oil. And Hybrid FHIA 17 could be classified among dessert bananas.

Complementary work in vivo should determine nutritional qualities of these new banana hybrids, as well as their aptitudes for the preparation of local dishes of high consumption such as "Foutou"(water boiled and pounded bananas), "Foufou" (water boiled and crushed bananas) and "Concondé" (banana stew). That will open ways for popularizing these hybrids in farming system at rural level.

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