# Resistance to technological stress of yam starch gels

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## Abstract

To evaluate their aptitude to be used as functional ingredients, twenty one varieties of yam starches of Cote d'Ivoire have been submitted to different technological stress such as high temperature treatment, long term freezing and refrigeration, high speed shearing and the acid treatment, in comparison with commercial modified starches. The gel of "kangba" starch (*D. Cayenensis-rotundata* ) , is the most stable during the thermal processing. The cultivars "Daminangba" (*D. alata* ) which has the clearest gel (63 % of clarity) is also the most stable during the refrigeration with a low syneresis (26 %) at 4° C. the " Esculenta 7" cultivar ( *D. esculenta* ), is the one which shows the weakest value of syneresis at -20°C. The gel of *D. dumetorum* species is the strongest under acid condition with 8% of viscosity decrease from $pH_7$ to $pH_3$, whereas the "Bodo" cultivar (*D. alata*) gels shows good resistance to shearing with 31% fall of viscosity from 160 rpm to 900 rpm on the RVA. The "Sopèrè", "Lopka" and « Kponan » cultivars (*D. Cayenensis–rotundata*) present the strongest viscosity whatever the technological treatment.

## Introduction

In nature, starch is available in an abundance surpassed only by cellulose as natural organic compound. It is found in the roots or fruits (Duprat, 1980; Buléon et *al*., 1990). The most common sources of food starch are corn, potato, wheat, tapioca and rice (Woolfe, 1992; Alexander, 1995; Ostertag , 1996; Wheatley et al., 1996; Henry and Westby, 1998). Developed countries (Canada - USA – Europe and Japan) share between themselves 77% of the starch global deal (Sansavani & Verzoni , 1998).

The foods sector consumes 55% of that world production versus 45% in board industries, textile, adhesive, glue and pharmaceutical products (De Cock, 1996). In foods, starch is used to influence or control such characteristics as, aesthetics, moisture, consistency and shelf stability. It can be used to bind or to desire expands or to densify; to clarify or to opacify; to attract moisture or to inhibit moisture; to texture or stringy texture, smooth texture or pulpy texture, soft coatings or crisp coating, to stabilise emulsions (Luallen, 1985; Swinkels, 1985; De Cock, 1996).

Nevertheless the native starches show limit for certain industrial applications. The native starches granules hydrate with ease, swell rapidly, rupture, lose viscosity, and produce weak bodied, very stringy and cohesive pastes. Chemically modified starches have thus been designed to respond to industrial demand. The reticulation creates some decking among molecules, reinforcing the cohesion of the starch grain and rises then its resistance : to temperatures (sterilisation) to mechanical shearing (extrusion) to acidic treatment and its stability also during the freeze/ thaw cycles. The stabilisation by substitution of a chemical grouping (oxidation, esterification, etherification) avoids the resuscitation among the molecules after cooking. It then limit the risks of syneresis and delays or avoids the retrogradation .

Nowadays consumers want to see more "natural" and "healthier" industrial products manufactured "without chemical processing" on the market. Some previous works show that the native starch gels of cocoyam (*X. sagittifolium*), plantain (*M. paradisiaca*) , yam (*Dioscorea spp*) are resistant to the sterilisation (Dufour et *al*. 1996). Others natives starches are resistant to the high shearing, like maize and wheat (Howling, 1980), quinoa and amaranth (Praznick et *al*., 1999). Among the gel of starches which resist to the syneresis we can quote : tapioca (Varavinit et al. 2000), waxy maize (Yuan and Thompson, 1998), waxy sorghum (Howling, 1980). The gel of millet and quinoa's starches are described to be stable under acidic condition (Varavinit et *al*. 2000).

The publication of yam starches account is less than 1% of the total information availed of food science and technology abstracts and the food intelligence databases (Satin, 1998) . The *Dioscorea* genus with its large biological diversity including more than 600 species in the world (Hamon et *al*. 1997) and a world production with more than 37 millions Tones / year (Fao, 2000) appear nowadays as a source of native starches which functional characteristic inadequately exploited could find some application in the food ingredients industry, as reported by Amani et *al*., (2000).

The purpose of this study was to estimate their aptitude to be used like foods ingredients, this account work aims at characterising the functional properties of 21 varieties of yam starches from Côte d'Ivoire. Subjected to different technological stress, like (sterilisation), refrigeration and the long-term freezing, the mechanical shearing and the acid treatment. They will be compared to natives or modified commercial starches.

## Materials and Methods

### Materials

#### Yam starch

Twenty-one natives starches were extracted from four species of yam tubers: five cultivars (cv) of *Dioscorea alata*, eleven cultivars of *Dioscorea cayenensis-rotundata* complex, one cultivar of *Dioscorea dumetorum*, and four clones selection of *Dioscorea esculenta* as described in a previous work (Amani et *al*., 2002).

#### Standards starches

To make some comparative studies, some natives starches and the commercial one have been selected.

#### Native starches

There are extracted from cassava roots (*Manihot esculenta*) and Macabo tubers (*Xanthosoma sagittifolium*) as previously described (Amani et *al*., 2002).

#### Commercial starches

-Normal maize starch (*Zea maïs*) from National starch and chemical Company (U.K)
-Potato starch (*Solanum tuberosum*) from Roquette & Frères (France)
-Colflo 67 (E1422) obtained by reticulation/ stabilisation from National starch and chemical Company (U.K)
-Purity HPC (E1422) obtained by reticulation/ stabilisation from National starch and chemical Company (U.K)
-Novation 2300 : obtained from the starches of waxy maize, modified physically (National starch and chemical Company, U.K)
-Novation 3300 : obtained from the starch of cassava modified physically (National starch and chemical Company, U.K)

## Methods

### Amylose determination

Amylose content was measured from the energy of amylose/lyso-phospholipid complex formation using differential scanning calorimeter according to Mestres et *al*. (1996). All analyses were performed in duplicate and mean values were calculated.

### Differential scanning calorimetry (DSC)

The DSC was performed on a Perkin Elmer DSC 7 device (Perkin Elmer, Norwalk, CT, USA) using hermetic inox pans. The duplicate sample pan (10-11 mg of starch and 50 µl of lyso-phospholipid 2% w/v in water) and the reference pan (50 ml of ultrapure water) were heated from 25°C to 160 °C at a scanning rate of 10 °C/min, held for 2 min at 160 °C, and cooled to 60 °C at 10 °C/min. The enthalpy of gelatinization ($\Delta H$) and the onset temperature (To) of each sample were then determined on the thermograms.

### Determination of paste clarity

The procedure of Craig et al. (1989), Zheng et *al*. (1998) was used for determination of starch paste clarity. 1% dry basis aqueous dispersions of starch were boiled at 100 °C for 30 min at constant stirring then transferred in plastic tubes that were stored at 4°C for 4 weeks. The transmittance was measured at 620 nm using spectrophotometer (spectronic 20 D+) every week on 2 tubes per sample.

### Acid resistance

The duplicate starch sample (7%, w/w, dry basis) was dispersed either in a phosphate buffer 2M ($pH_7$) or in a citrate-phosphate buffer, 2M ($pH_3$) for total amount of 28g using a Rapid Visco Analyzer model 3D (Newport Scientific, Narrabeen, Australia). Viscosity was recorded using the following temperature profile: holding at 30 °C for 1 min, heating from 30°C to 90 °C at 6 °C/min, holding at 90 °C for 5min, and then cooling to 50 °C at 6 °C/min with continuous stirring at 160 rpm. Final viscosity at $pH_3$ ($V\ pH_3$) and at $pH_7$ ($V\ pH_7$) were measured and the effect of acidity was defined as the ratio $V\ pH_3 / V\ pH_7$.

### Shear stability

Shear stability was evaluated using the RVA on 7% (db, w/w,) aqueous starch suspensions. Final viscosity was recorded following temperature profile previously described at 160 rpm ($V_{160rpm}$). Experience was repeat following the standard profile from 30°C to 90°C at 160 rpm, then held for 5 min at high shear rate (960 rpm) and cooled to 50°C at 160 rpm as the standard profile. Shear effect was calculated as the ratio of a final viscosity after shear stress ($V_{960rpm}$) to that of the standard condition: $V_{960rpm} / V_{160rpm}$. Experiences were duplicated and mean value was calculated.

### Resistance to temperature

28 g of gel sample were prepared at 4% (db, w/w, $pH_7$) using RVA. The experiment was stopped after 12 min at 90°C according to the profile previously described. Viscosity was measured ($V_{30}$) once the gel was cooled at 30°C, using Haake viscotester VT550 (Germany) at 140 $s^{-1}$ shear rates. The experiment is took back on the same sample after the sterilisation at 121°C during an hour, then the gel was cooled at 30°and the viscosity was measured in the same conditions than previously ($V_{121}$). The temperature effect was calculated according to the formula : $V_{121}/ V_{30}$

### Freezing and cold stability

Pastes were prepared by cooking starch slurries (4% db, w/w) in water. 10 g of starch paste sample were frozen in a plastic tube at –20°C; when another was held at 4°C, two tubes per sample. All tubes were stored for 8 weeks. Freeze and cold stabilities were evaluated by measuring the percentage of syneresis by centrifugation at 2660 *g* for 30 minutes after thawing in water bath at 50°C for 90 min for frozen sample and storage at ambient temperature for 60 min for refrigerated sample respectively, according to Eliasson and Kim (1992).

## Results

### Characterisation of standard starches .

The standard starches are grouped together in natural, theses ones with are high amylose content (around 26%) except the waxy maize (0%) and the tapioca (19%); and in modified, those ones are zero amylose content except the <<novation 3300 >> (table 1). They are distinguished by an uniform enthalpy of gelatinization near 15 $J.g^{-1}$ and a gelatinization temperature of 62°C except the macabo (76°C). The natural gel starches of the potato, of the waxy maize and the cassava are very clear (96.1; 60.0 and 54.1% of transmittance respectively) although the starch gels of maize and macabo are less clear with around 26% of transmittance. The modified starches get a bad clarity according to their transmittance range from 16.8 to 20.2% (table 1).

## Table 1: Physico-chemical properties of standard starches

| Samples | Botanical name | Amylose (%) | Gelatinization Temperature (°C) | Enthalpy of Gelatinization ($Joule. g^{-1}$) | Clarity (%) |
|---|---|---|---|---|---|
| **Native starches** | | | | | |
| Maize | *Z. mais* | 27.2 | 65.3 | 11.9 | 27.0 |
| Waxy maize | *Z. mais* | 0.0 | 61.6 | 16.0 | 60.0 |
| Potato | *S. tuberosum* | 23.1 | 60.0 | 16.3 | 96.1 |
| Cassava | *M. esculenta* | 19.5 | 64.3 | 16.2 | 54.1 |
| Macabo | *X. Sagittifolium* | 26.6 | 76.5 | 15.3 | 26.2 |
| **Modified starches** | | | | | |
| Colflo67 | ******** | 0.0 | 62.4 | 15.0 | 21.0 |
| Purity HPC | ******** | 0.0 | 64.0 | 15.5 | 16.8 |
| novation2300 | ******** | 0.0 | 60.3 | 15.5 | 19.2 |
| novation3300 | ******** | 21.4 | 62.3 | 14.0 | 20.2 |

### Resistance to syneresis

The syneresis is very great between zero and one week and besides becomes stabilised from the first to the eighth week, which lead us to calculate the syneresis average between one and eight weeks (table 2). The natural standard starches with low content in amylose (cassava and waxy maize) appear as most resistant to the syneresis after refrigeration or freezing with values varying between 0 to 4% of syneresis whereas the macabo starch with high amylose content get a syneresis of 38% (table 2) . The two chemically modified starches (Colflo 67 and Purity HPC) show less syneresis with respectively average of 20% and 35%. Among commercial standards, the physically modified starches (Novation 2300 and Novation 3300) are both high syneresis after refrigeration and freezing – thawing (~ 44% of syneresis) (table 2).

The yam starch gels get a behaviour lightly different between the refrigeration and the freezing. When storage at 4°C they show a mean rate of syneresis of 41 ± 11% (table 2) . The analysis of the variance doesn't show any significant difference between yam specie. However we notice gaps rather quite significant between cultivars. The starch of cultivar << damingba >> of *D. alata* is the most resistant at the refrigeration (26% of syneresis ) whereas those of cultivar << kangba >> and << frou >> which belong to *D. Cayenensis-rotundata* complex show highest rates of syneresis ( 59% ), at the refrigeration (Table 2).

After freezing (-21°C, 4 weeks), the yam starch gels present a syneresis which rises the most than at the refrigeration (51 ± 10%). The analysis of the variance gives two homogeneous groups significantly different at $P< 0.05$. The group of high syneresis (~54%) make up by the starch of *D. dumetorum*, *D. alata* et *D. cayenensis-rotundata* and the group of syneresis which raise the less (~ 39%), represented by the starch of *D. esculenta* cultivar's. The << kangba >> starch (*D. cayenensis-rotundata*) is the less resistant at the freezing (65% of syneresis) while the cultivar << esculenta 7 >> (*D. esculenta*) distinguish itself as the most resistant of yam starch at freezing with 30% of syneresis (Table 2).

**Table 2: Effect of pH, shearing, sterilization and freezing, on starch gels.**

| Samples | Botanical name | Vf RVA pH7 (RVU) | Vf RVA pH3 (RVU) | pH Effect | Vf RVA Shearing (RVU) | Shear effect | Viscosity before sterilization (mPa. S) | Viscosity after sterilization (mPa. S) | Heat effect | Syneresis after freezing (%v/v) | Syneresis after refrigeration (%v/v) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Bodo* | | 210 | 150 | 0.72 | 144 | 0.69 | 328 | 265 | 0.81 | 37 | 35 |
| *Daminangba* | | 207 | 132 | 0.64 | 102 | 0.49 | 219 | 272 | 1.24 | 57 | 26 |
| *Florido* | *D. alata* | 163 | 126 | 0.78 | 100 | 0.62 | 318 | 273 | 0.86 | 62 | 28 |
| *Soglan* | | 218 | 134 | 0.62 | 85 | 0.39 | 234 | 242 | 1.03 | 58 | 38 |
| *Suidié* | | 198 | 126 | 0.64 | 75 | 0.38 | 364 | 263 | 0.72 | 53 | 36 |
| ***Mean value ± SDT*** | ***D. alat*** | **199$^{a}$±21** | **134$^{a}$±10** | **0,68$^{b}$±0,07** | **101$^{a}$±26** | **0,51$^{a}$±014** | **293$^{a}$±63** | **263$^{a}$±13** | **0,93$^{ab}$±0,21** | **53$^{a}$±10** | **32$^{a}$±5** |
| *Assawa* | | 224 | 155 | 0.69 | 102 | 0.45 | 197 | 292 | 1.49 | 55 | 28 |
| *assobayérè* | | 171 | 109 | 0.64 | 56 | 0.33 | 99 | 275 | 2.77 | 61 | 55 |
| *Frou* | | 251 | 154 | 0.61 | 90 | 0.36 | 208 | 253 | 1.21 | 58 | 59 |
| *Kangba* | | 112 | 95 | 0.84 | 75 | 0.67 | 50 | 288 | 5.75 | 65 | 59 |
| *Kouba* | | 196 | 135 | 0.69 | 110 | 0.56 | 172 | 261 | 1.52 | 58 | 48 |
| *Kpassadjo* | *D. cayener* | 183 | 127 | 0.70 | 119 | 0.65 | 148 | 298 | 2.01 | 52 | 32 |
| *kpokpokpo* | *rotundata* | 240 | 159 | 0.66 | 79 | 0.33 | 242 | 202 | 0.83 | 53 | 57 |
| *Kponan* | | 289 | 191 | 0.66 | 107 | 0.37 | 232 | 341 | 1.47 | 45 | 34 |
| *Krenglé* | | 246 | 166 | 0.68 | 94 | 0.38 | 311 | 261 | 0.84 | 32 | 51 |
| *Lokpa* | | 258 | 162 | 0.63 | 118 | 0.45 | 142 | 348 | 2.44 | 57 | 30 |
| *sopèrè* | | 307 | 208 | 0.68 | 105 | 0.34 | 301 | 378 | 1.26 | 55 | 44 |
| ***Mean value ± SDT*** | ***D. ca*** | **225$^{a}$±56** | **151$^{a}$±33** | **0,68$^{b}$±0,06** | **96$^{a}$±19** | **0,45$^{a}$±0,13** | **191$^{b}$±80** | **291$^{a}$±50** | **1,96$^{a}$±1,40** | **54$^{a}$±9** | **45$^{a}$±12** |
| ***Dumetorum*** | ***D. dumetc*** | **75$^{b}$** | **69$^{b}$** | **0,92$^{a}$** | **25$^{b}$** | **0,34$^{a}$** | **61$^{b}$** | **115$^{b}$** | **1,88$^{a}$** | **56$^{a}$** | **51$^{a}$** |
| *Esculenta 154* | | 102 | 93 | 0.91 | 48 | 0.47 | 167 | 55 | 0.33 | 43 | 36 |
| *Esculenta 5* | *D. esculen* | 119 | 82 | 0.69 | 53 | 0.44 | 178 | 70 | 0.39 | 45 | 44 |
| *Esculenta 6* | | 130 | 103 | 0.79 | 79 | 0.61 | 76 | 85 | 1.12 | 39 | 31 |
| *Esculenta 7* | | 90 | 75 | 0.84 | 45 | 0.50 | 113 | 42 | 0.37 | 30 | 40 |
| ***Mean value ± SDT*** | ***D. esc*** | **110$^{b}$±18** | **88$^{b}$±12** | **0,81$^{a}$±0,09** | **56$^{b}$±16** | **0,51$^{a}$±0,07** | **133$^{b}$±48** | **63$^{b}$±18** | **0,55$^{b}$±0,38** | **39$^{b}$±7** | **38$^{a}$±6** |
| *Mean value ± SDT all yam* | | 190±66 | 131±37 | 0,71±0,09 | 86±29 | 0,47±0,12 | 198±92 | 232±99 | 1,44±1,18 | 51±10 | 41±11 |
| **Maize** | *Z. mais* | 96 | 77 | 0.81 | 89 | 0.93 | 88 | 222 | 2.53 | 36 | 48 |
| **Waxy maize** | *Z. mais* | 84 | 60 | 0.71 | 42 | 0.50 | 300 | 60 | 0.20 | 0 | 4 |
| **Potato** | *S. tuberosı* | 205 | 137 | 0.67 | 126 | 0.61 | 851 | 324 | 0.38 | 65* | 30* |
| **Cassava** | *M. esculen* | 125 | 96 | 0.77 | 100 | 0.80 | 363 | 214 | 0.59 | 4 | 0 |
| **Macabo** | *X. Sagittifo* | 130 | 83 | 0.64 | 67 | 0.52 | 274 | 116 | 0.42 | 38 | 38 |
| **colflo67** | ******** | 284 | 251 | 0.88 | 245 | 0.86 | 219 | 274 | 1.25 | 20 | 21 |
| **Purity HPC** | ******** | 259 | 218 | 0.84 | 245 | 0.95 | 103 | 305 | 2.98 | 31 | 39 |
| **novation2300** | ******** | 211 | 156 | 0.74 | 179 | 0.85 | 36 | 170 | 4.70 | 42 | 48 |
| **novation3300** | ******** | 51 | 72 | 1.41 | 49 | 0.96 | 11 | 100 | 9.11 | 41 | 45 |

Value not signficantly different ($p < 0,05$) share the same following letter. Statistical differences must be read within the same column.

* Dufour et *al*.(1996)

## Gel clarity behaviour during storage at 4°C

Stocked at 4°C, the clarity of all species of yam starch gels decreases significantly during the first week then slowly beyond; the transmittance is lower at 10% after the second week of storage (Figure 1). On the other hand the clarity of cassava starch gel initially rised (54% of transmittance) falls slowly until the third week (50% of transmittance), then rapidly until reaching a value lower than 40% after 4 weeks conservation at 4°C. the natural waxy maize or chemically modified (purity HPC) presents kinetic of darkening identical to the yam starches at the first week, but this clarity is more stable beyond the first week.

## Resistance to sterilisation

In general, yam starch gels present a viscosity rise during the sterilisation which goes on average from 198 m Pa.s to 232 mPa.s after sterilisation, either a rise factor of 1.4. the variance analysis among yam species show no revealing difference as for temperature effect. Nevertheless the most thermostable cultivar's belong to the *D. cayenensis-rotundata* and the *D. dumetorum* species (table 2). The cultivar <<kangba>> from the complex *D. Cayenensis-rotundata* is the one which is the most stable to the autoclaving (rise rate~6) whereas <<esculenta 154 >> belonging to *D. esculenta* is the culivar which resists the less with a rise rate of 0,33 (table 2)

Among the natural standard starches, the one which is the most stable to the temperature is the maize starch (rise rate of 1.53 ) whereas on the opposite side the waxy maize falls of five times of viscosity (from 300 m Pa.s to 60 mPa.s ) after thermic treatment (table 2). all the modified starches are resistant to the temperature. the << Novation 3300>> comes in first position followed by the << Novation 2300 >> and the << purity HPC>> (table 2) . But the gel which keep a strong viscosity after thermal treatment come first the yam starches from *D. cayenensis-rotundata* complex, notably the cultivars << Sopèrè >>, << Lokpa>> and << kponan>> ( 378, 348 et 341 mPa.s respectively ); then come the potato starch among the natural standard starches,( 324 mPa.s ) and <<purity HPC >> ( 305 mPa.s ) among the modified starches.

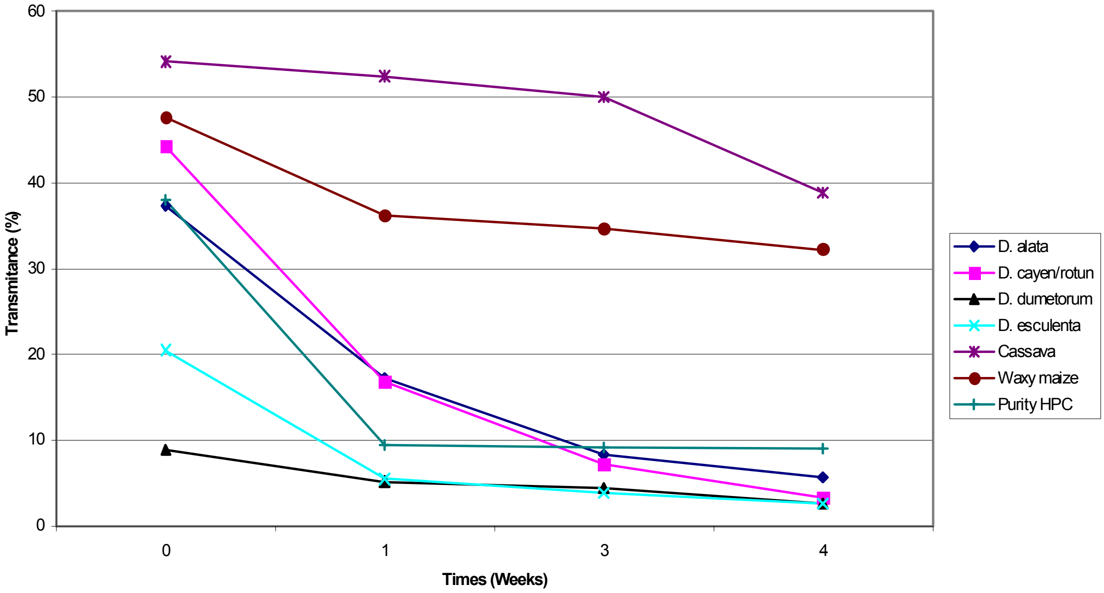

**Figure 1 : Evolution of clarity of starch gel during storage at 4°C**

## The pH effect

The yam starches gels are sensitive to the acidic condition. The fall of viscosity at pH3 is of the order of 31% on average . we distinguish two homogeneous group at $P< 0.05$. The starch gel with a strong stability in acid area (~85% of stability) summing the species of *D. dumetorum* and *D. esculenta* and the gels less resistant. (68% of stability ) which are the *D. alata* and the *D. cayenensis-rotundata* species together (table 2). Among the natural standard starches, the maize starch is the one which resist the most to the acid condition with a stability rate of 0.81% that is to say 19% of viscosity fall in acid area. On the other hand, among the modified starches, all resistant to the acidic, we note specially the increase of viscosity in acid area of the order of 41% to the Novation 3300 (Table 2).

## Effect of shear stress

The chemically modified starch gels (Purity HPC and Colflo 67) and those physically modified (Novation 3300 and 2300 ) are those which are the most resistant to high shear treatment (table 2). Among the natural standard starches, only the maize starch resists to the shear effect with only 7% of viscosity fall while the waxy maize is the less stable to the shearing off (50% of viscosity fall). The yam starches are also sensitive to shearing off (table2). The shear stress (47±12% of stability) is very less variable significantly among the different yam species. The gel starch of *D. dumertorum* is the most sensitive (66% of viscosity fall after shearing off 960 tr/min), whereas the cultivar « bodo » is the yam which resist the most to shear stress with 31% of viscosity fall. These values are higher than those of the modified standards which are more stable to the shear stress (table 2).

## Discussion

## Principal component analysis

The realised PCA on the 21 yam cultivars from 10 variables (physico-chemical and functional properties) gives 3 principal components. The principal component one (44%) represents the high viscosity axis, opposed to the pH effect. The principal component 2 (21%) is defined as to be stable to the autoclaving and high syneresis after freezing. The last one (17%) represents the stability to shearing off, opposed to high syneresis after cooling. The two last principal components lead us to put in evidence the unity of gels starch functional characteristics and their stability during the technological treatments except for the pH (figure 2).

The projection of samples (yam starches) and further samples (natives or modified standards starches) on the axis 2 and 3 previously defined lead to free 4 homogeneous clusters with identical properties (figure 3). The first group contains the starches chemically modified (colflo 67 and purity HPC), situated in the forefront of axis 3. This group of starch is stable to shear stress and to the syneresis. The second group represented by the starches physically modified (novation 2300 and novation 3300). This one is at the middle of axis 2 and 3, they are resistant to heat treatment, to acid treatment and to shear stress, then unstable to the syneresis. The third group (cassava ,waxy maize and potato) gathers together some natural standard starches presenting a gel of good clarity, stable to the syneresis and unstable to heat treatment. These results are in harmony with a previous works of Hoover and Manuel (1996 ) on the waxy maize starch syneresis and Vanavinit and *al.* (2000), on the cassava starches. The group of yam starches, gathered together at the centre of axis 2 and 3. They are characterised by their weak stability to the technological stress (figure 3).

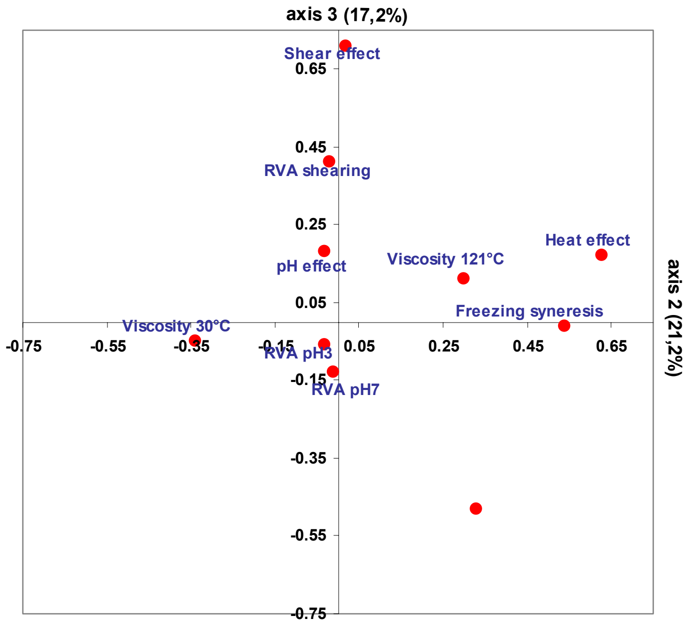

**Figure 2: Circle of correlation of the functional properties of starch on axis 2 and 3**

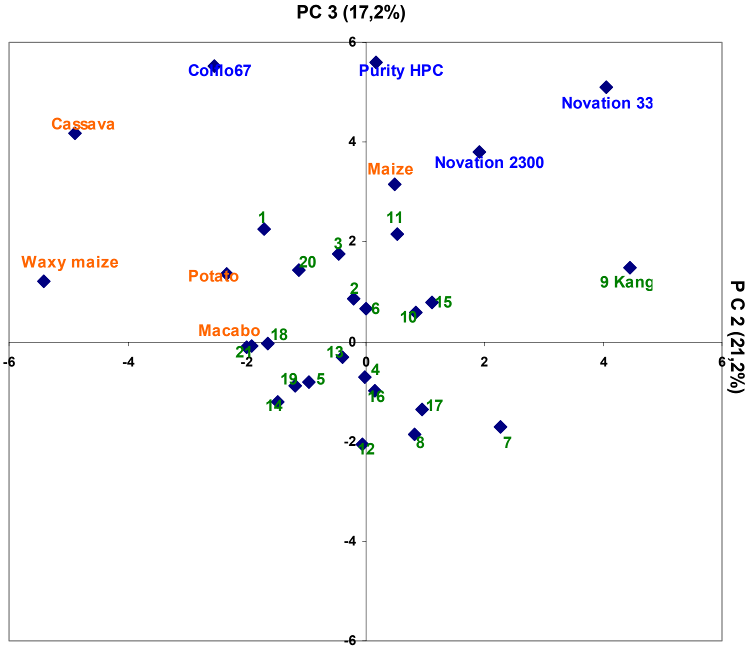

**Figure 3: Sample plot of principal components 2 and 3 of yam starch and others starches**
from 1 to 5 :*D. alata*; 6 to 16: *D. cayenensis-rotundata*; 17: *D . dumetorum*; 18 to 21: *D. esculenta*

The maize starch is the only natural standard close to the modified starches because of its stability to shearing off , to acid condition and to sterilisation. Our result confirm those of Howling (1980) then Khun and Schlauch (1994) , which had previously put in evidence the stability of maize to mechanical shearing off. Among yam starches, only the cultivar « kangba » starch is close to the physically modified starches (Novation 2300 and 3300), because of its stability to sterilisation, to shearing off and to acid treatment. Cultivar « kangba », in addition with cultivar "assobayérè" and << lokpa >> are also resistant to the temperature whereas the species of *D. dumetorum* and of *D. esculenta* show also a strong stability in acid condition.

## Relationships between physico-chemical properties and functional properties.

The yam starches are less resistant to the syneresis phenomenon after long-term freezing or refrigeration . The mean value of syneresis at 4°C and -21°C is negatively correlated ($r = -0.47$) with the enthalpy of gelatinization, and positively correlated ($r = +0.59$) to the temperature effect. This indicates that the yam starch gels which are the less stable to the syneresis are the most stable to the thermal treatment. On the other hand, there were no correlation between syneresis and amylose content; contrary to the previous works (Zheng et Sosulski, 1998 ; Dufour et *al*. 2000 et Varavinit et *al*. 2002). But when we add more native starches, we notice a tendency to the rise of the syneresis ($R^2 = 0.63$) according to the amylose content until to 21%. This one confirms the literature results. Beyond 20%, the amylose has no significant effect on the syneresis (figure 4). This would probably shows that other phenomenon could occur in the syneresis phenomenon. The high content in amylose is also linked to the phenomenon of starch retrogradation (Ortega-Ojeda et Eliasson 2001). so the high content in amylose of yam starches would then be at the origin of their instability to the long-term freezing or refrigeration. This result is confirmed by the darkest of the gel during the storage at 4°C of yam starches in comparison with starches having low or none amylose content like cassava, waxy maize or purity HPC. In fact Jacobson et *al*. (1997) showed that the storage of gels to the cold temperature would accelerate the retrogradation of the amylose and reduce clarity of the gel.

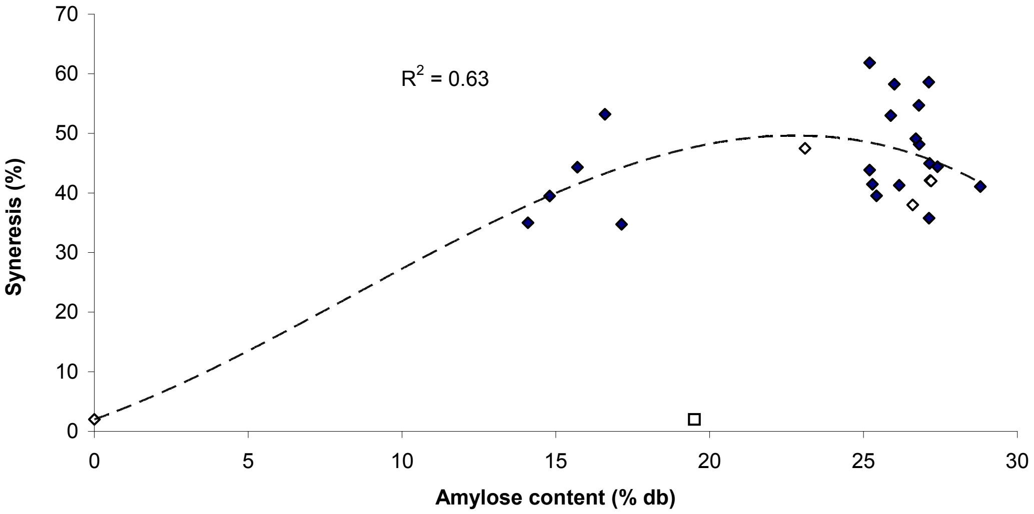

**Figure 4: Relation between syneresis and amylose content**

The gels of starches with a low amylose content are predisposed to resist in acid area . in fact the stability to the acid treatment and the content in amylose are negatively correlated (r = - 0.70 ). Just us the negative correlation between the acid resistance and the viscosity RVA shows that the gels of starch with a high viscosity are the most sensitive to the acidity (figure 5). In the case of the waxy maize which goes against the rule can be explained by the fact that the effect of the acidity has been majored under constraint of shearing. Furthermore yam starches gels are also instable to high shearing, compared to chemically modified ones (Purity HPC and Cofflo 67). That is probably due to a weak rate of macromolecular reticulation of yam starches. In fact << Purity HPC >> and << cofflo 67 ) have been obtained by the combination of a reticulation by adipate and a stabilisation by acetate, with high degree of crossbonding. This reticulation create some decking between the macromolecules leading to a amylose network resisting to the shearing and also to the acid treatment (Langley, 1995 ; De-Cock, 1996 ; Rôper, 1997).

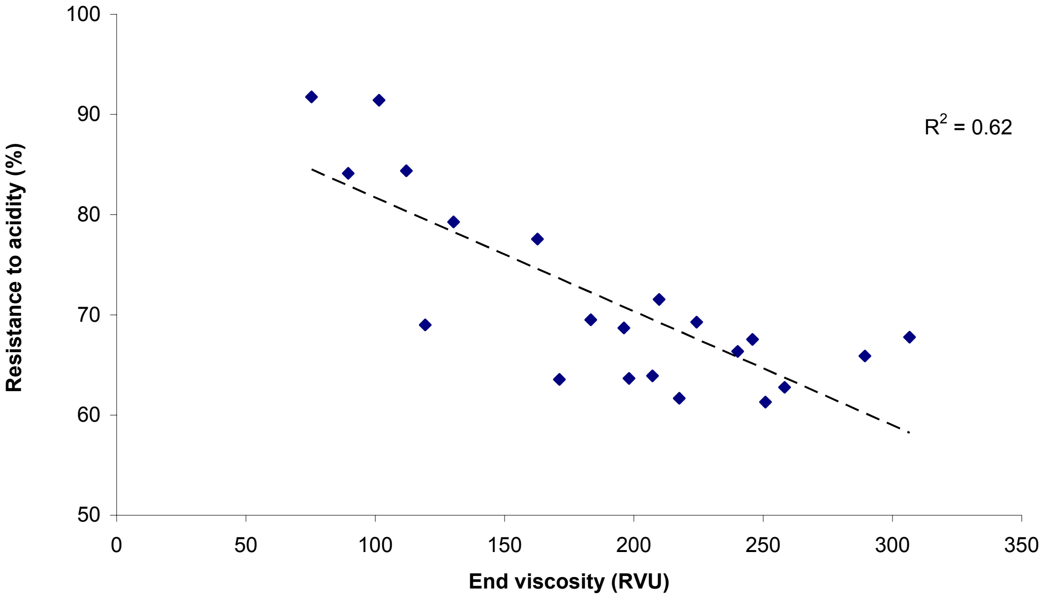

**Figure 5: Relation between RVA viscosity and acid resistance of starch gels**

The heat stability of starch gels is negatively correlated (r = - 0.70) with the swelling (Figure 6). That correlation is revealing of another property most likely molecular because the swelling power previously characterised by Amani and *al.* (2002) indicates a stage of complete solubilization, and then gelation. On the other hand the resistance to the sterilisation is independent of amylose content (r = 0.23) . Nevertheless the amylose is strongly correlated to the viscosity after sterilisation (r = 0.88). In fact some yam cultivars with high amylose content (sopéré, lokpa et kponan) belonging to the *D. cayenensis-rotundata* complex develop the best parts of viscosities after sterilisation (table 2) compared to the acetyled di-starch adipate ( colflo 67 and purity HPC ) modified to be stable to the sterilisation.

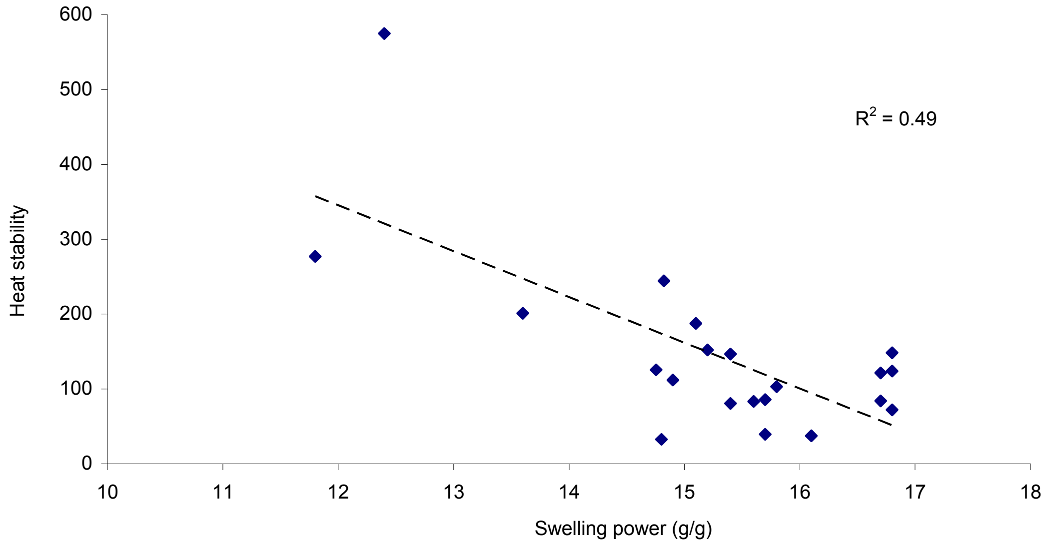

**Figure 6: Relation between swelling power and Heat stability of starch gels.**

## Conclusion

It emerges from this study that all species of the yam starches present in general the same behaviours at the technological stress dissociating oneself from modified starches and some commercial natives starches. Only the << kangba >> starch (*D. cayenensis-rotundata*) shows properties close to the modified starches. They can be used like natural component in the emulsified sauce, because of their tolerance to shearing and to the acidity. Moreover its stability to high temperature treatment promote a good texture agent of manufactured products at high temperature or as a highly sterilised products stabilising, like baby foods and the UHT products. The << kangba >> starch gel with those of *D. dumetorum* and of *D. esculenta* species, stable in acid area and which develop low viscosity can be substitute to modified starches as functional ingredient for low pH processed food, like sauce and salad dressing, and also ideal for the retorted food.

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