Banana physicochemical & functional differentiation during ripening. A key study for understanding consumer preferences

O. Gibert, D. Dufour, M. Reynes, A. Giraldo, A. Escobar & A. González

ISHS ProMusa International Symposium
10-14 October 2011
Introduction

Dessert bananas and cooking bananas:

- Highly diverse source of starch
- Staple food for millions of inhabitants

Rationale & objectives

- Standardization of the methods of evaluation
- Evaluation of physicochemical & functional properties
- Identification & hierarchization of quality traits among consumption subgroups to ensure consumer acceptability
Method

- Socio-economic surveys within communities of stakeholders for identification of consumer preferences
  (i) Visit and selection of “fincas” with largest diversity
  (ii) Cooking workshops/demonstrations

- Standardization of the methods & germplasm evaluation
  (i) Selection/isolation of the raw material
  (ii) Physicochemical and functional characterization
  (iii) Chemical characterization during ripening
## Banana genotypes & consumption groups

### Dessert bananas

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>– Sucrier, Samba,..</td>
</tr>
<tr>
<td>AAA</td>
<td>– <strong>Cavendish</strong>, Gros Michel,..</td>
</tr>
<tr>
<td>AB</td>
<td>– Ney Poovan, Kunnan</td>
</tr>
<tr>
<td>AAB</td>
<td>– Silk, Pome, Mysore, ..</td>
</tr>
<tr>
<td>ABB</td>
<td>– Pisang Awack</td>
</tr>
</tbody>
</table>
Dessert bananas

Bocadillo (AA)
Primitivo (AA)
Gros Michel (AAA)
Cavendish (AAA)
Rollizo (AAA)
Tafetán morado (AAA)
Banana genotypes & consumption groups

### Dessert bananas

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>AAAA</td>
<td>– FHIA hybrids, ..</td>
</tr>
<tr>
<td>AAAB</td>
<td>– FHIA hybrids</td>
</tr>
</tbody>
</table>
Dessert hybrids

FHIA 25 (AAAB)

FHIA 18 (AAAB)

FHIA 17 (AAAA)

FHIA 1 (AAAB)
# Banana genotypes & consumption groups

## Dessert bananas

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<th>Type</th>
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<td>AAAB</td>
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</tbody>
</table>

## Cooking bananas

<table>
<thead>
<tr>
<th>Type</th>
<th>Genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA-AAA</td>
<td>Lujugira</td>
</tr>
<tr>
<td>ABB</td>
<td>Bluggoe, Pelipita, Saba,..</td>
</tr>
<tr>
<td>AAT/AT</td>
<td>Féhis</td>
</tr>
<tr>
<td>AAB</td>
<td>Maia maoli,</td>
</tr>
</tbody>
</table>
Cooking bananas

Cachaco (ABB)

Guineo (EA-AAA)

Pelipita (ABB)

Hua moa (AAB)

Guayabo (AAB)
Banana genotypes & consumption groups

Dessert bananas

AA – Sucrrier, Samba,..
AAA – Cavendish, Gros Michel,..
AB – Ney Poovan, Kunnan
AAB – Silk, Pome, Mysore, ..
ABB – Pisang Awack
AAAA – FHIA hybrids, ..
AAAB – FHIA hybrids

Cooking bananas

EA-AAA – Lujugira
ABB – Bluggoe, Pelipita, Saba,..
AAT/AT – Féhis
AAB – Maia maoli, Plantains
Plantains (AAB)

- Cubano blanco
- Dominico
- Hartón
- Maqueño
- África
- Dominico Hartón
Banana genotypes and consumption groups

Dessert bananas

AA    – Sucrier, Samba,..
AAA   – **Cavendish**, Gros Michel,..
AB    – Ney Poovan, Kunnan
AAB   – Silk, Pome, Mysore, ..
ABB   – Pisang Awack
AAAA  – FHIA hybrids, ..
AAAB  – FHIA hybrids

Cooking bananas

AAAea – Lujugira
ABB   – Bluggoe, Pelipita, Saba,..
AAT/AT – Féhis
AAB   – Maia maoli, **Plantains**
AAAB  – FHIA hybrids,..
Cooking hybrids (AAAB)

FHIA 20

FHIA 21
Banana genotypes & consumption groups

**Dessert bananas**
- **AA** – Sucrier, Samba,..
- **AAA** – Cavendish, Gros Michel,..
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- **AAAB** – FHIA hybrids

**Cooking bananas**
- **AAAea** – Lujugira
- **ABB** – Bluggoe, Pelipita, Saba,..
- **AAT/AT** – Féhis
- **AAB** – Maia maoli, **Plantains**
- **AAAB** – FHIA hybrids,..

Bakry et al., 2009; Lescot, Fruitrop 2010
Socio-economic survey

- Identification of the varieties cultivated locally
- Cooking workshops to describe the consumption patterns & for hierarchization of preferences
<table>
<thead>
<tr>
<th>Process/use</th>
<th>D Harton</th>
<th>Guayabo</th>
<th>Guineo</th>
<th>Gros Michel</th>
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<tbody>
<tr>
<td>Fried products</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>
Moneditas

Tostadas

Patacón pisado

Tostones
# Few consumption preferences

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<th>Process/use</th>
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<td></td>
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<tr>
<td>Product texturization</td>
<td></td>
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Empanadas

Masa precocida

Marranitas
### Few consumption preferences

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<tbody>
<tr>
<td><strong>Fried products</strong></td>
<td>![Image]</td>
<td>![Image]</td>
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<tr>
<td><strong>Product texturization</strong></td>
<td>![Image]</td>
<td>![Image]</td>
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<tr>
<td><strong>Boiled products</strong></td>
<td>![Image]</td>
<td>![Image]</td>
<td></td>
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</table>
Sancocho

Cooking with peel

Colada
# Few consumption preferences

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<tr>
<td><strong>Intermediate products</strong></td>
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</table>
Raw and pre-cooked flour

Cake

Tortas

Juices

Fructose syrup
Few consumption preferences

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<tbody>
<tr>
<td><strong>Fried products</strong></td>
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<td><img src="image2.png" alt="Image" /></td>
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<tr>
<td><strong>Product texturization</strong></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boiled products</strong></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intermediate products</strong></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

Adapted from Quintero et al. 2009 in Gibert et al. 2009
Consumption modes/preferences

- great diversity of cultivated varieties identified (> 30) ¹
- various consumption patterns (6 modes) ¹
- preferences based on the selection of varieties at a specific stage of ripeness for a use (4 stages)

Is it possible to identify some objective quality traits to:

- differentiate genotypes & banana subgroups?
- to justify the consumption patterns/acceptability at various stages of ripeness?

¹ Quintero et al. 2009, in Gibert et al. JAFC 2009
Starch & flour Isolation: an accurate method

1. Crushed pulp
2. Slurry filtration
3. Washed 3X & decantation
4. Centrifuged (10000rpm -4°C)
5. Starch oven-dried (50°C – 48h) & stored (4°C)

6. Cut in thin slices
7. Freeze-drying
8. Flour ground
9. Flour stored (4°C)

Stage I

Stage II & III

N₂ Crushing

Paint mixer grinding
Germplasm evaluation

Morphological characterization
Bunch/finger dimension & weight distribution, edible fraction,...
Germplasm evaluation

➢ Morphological characterization
Bunch/finger dimension & weight distribution, edible fraction,...

➢ Physicochemical characterization
pH, TA, DM, specific gravity, ash, TSS, soluble sugars, organic acids, proteins, starch content, crude fiber, minerals, texture

➢ Functional characterization
Pasting & thermal properties

Gibert et al., JAFC 57, 2009, err. 58, 2010
Dufour et al., JAFC 57, 2009
Gibert et al., JFE, 2010
Pasting properties by RVA

Viscosity (cP)

Time (s)

Temperature (°C)

CA

BD

SB
Germplasm evaluation

- **Morphological characterization**
  Bunch/finger dimension & weight distribution, edible fraction, ...

- **Physicochemical characterization**
  pH, TA, DM, specific gravity, ash, TSS, soluble sugars, organic acids, proteins, starch content, crude fiber, minerals, texture

- **Functional characterization**
  Thermal & pasting properties

*Gibert et al., JAFC 57, 2009, err. 58, 2010*
*Dufour et al., JAFC 57, 2009*
*Gibert et al., JFE, 2010*
Functional properties by DSC

Onset
PCA illustration of the germplasm evaluation

Dessert hydrids

Cooking bananas

Dessert

DM

Starch

K+

Amylose

Fructose

Glucose

Plantains

Bunch W

Hand W

Finger d

PC1 : 29%

PC2 : 16%

Gibert et al., JAFC 57, 2009, err. 58, 2010

Dufour et al., JAFC 57, 2009
PCA illustration of the germplasm evaluation

Onset

Cooking bananas

Dessert hydrids

Plantains

DM

Starch

Dufour et al., JAFC 57, 2009

Gibert et al., JAFC 57, 2009, err. 58, 2010

Cooking hydrids

Dessert

PC1 : 29%

PC3 : 13%

Ca$^{2+}

Sucrose

Gibert et al., JAFC 57, 2009, err. 58, 2010

Dufour et al., JAFC 57, 2009
How to guaranty consumer acceptability?

- A specific firmness
- A specific appearance
- A « flavor profile »:
  - volatile compounds
  - taste
    - Sweetness: glu, fru, suc
    - Sourness: malic, citric & TA
    - Astringency: oxalic

Ripening influence on OA & soluble sugars? Any differences among genotypes?

5 Soares et al. 2011;  6 Kyamuhangire et al. 2002;  7 Bugaud et al. 2011;  8 Shimokawa 1972
Ripening stage definition

13 varieties harvested at optimal green stage

13 varieties let to ripen until being fully-ripe

13 varieties let to ripen until being over-ripe
Soluble sugars & organic acids: stage I

- Raffinose
- Oxalic
- \( \alpha \)-ketoglutaric
- Trans-aconitic
- Malic
- Total sugars
- Glucose
- Fructose

DM

PC1: 42%

PC2: 20%
Soluble sugars & organic acids: stage II

PC1 : 39%
PC2 : 26%

Sucrose
Cis-aconitic
Trans-aconitic
R fum/mal
Total sugars
Glucose
Malic
Citric
Fructose

DM
R cit/mal
AAB
AAA
AAAea
AAAB
Soluble sugars & organic acids: stage III

- Soluble sugars & organic acids
- Stage III

PC1: 28%
PC2: 25%

- AAA
- AAAB
- AAB
- AAAea
- AA
- R fum/mal
- fumaric
- R fum/mal
- DM
- citric
- R cit/fum
- glucose
- TTA
- R cit/mal
## Quality traits: a hierarchization trial & limits

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Issue</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphological</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Hand w-finger w Finger d</td>
<td>• Differentiation pl-cook. des. hyb.</td>
<td>• Cooking behavior? Sensorial acceptability?</td>
</tr>
<tr>
<td>• Edible food fraction</td>
<td>• Yield &amp; productivity</td>
<td></td>
</tr>
<tr>
<td>• Spatial dimensions</td>
<td>• Intra bunch variability (sampling strategy) Potential for industrial application</td>
<td>• Edaphoclimatic conditions</td>
</tr>
<tr>
<td>Functional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Onset temp. Breakdown (BD)</td>
<td>• Sensorial acceptability Prediction of cooking behavior Industrial formulation &amp; neglected var. valorization</td>
<td>• Environmental contribution &amp; interaction with genetic origin</td>
</tr>
<tr>
<td>• Setback (SB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cooking ability (CA)</td>
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### Quality traits: a hierarchization trial & limits

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<tr>
<td>DM- Starch, Amylose</td>
<td>• Differentiation between subgroups at stages I, II, III Potential for processing</td>
<td>• Environmental contribut. &amp; interaction with genetic origin</td>
</tr>
<tr>
<td>Ca(^{2+}), K(^{+})</td>
<td>• Subgroup differentiation</td>
<td>• Farming practices</td>
</tr>
<tr>
<td>Pulp firmness</td>
<td>• Sensorial acceptability Differentiation on consumption mode</td>
<td>• Dependence on stage of ripeness</td>
</tr>
<tr>
<td>Soluble sugars</td>
<td>• Genotype differentiation Fermentation ability</td>
<td>• Dependence on stage of ripeness</td>
</tr>
<tr>
<td>Organic acids</td>
<td>• pH or TA prediction</td>
<td>• Relationship with sensorial acceptability to established</td>
</tr>
</tbody>
</table>
Prospects..

- Validation of prioritized traits
- Environmental contribution to hierarchized traits
- Taste prediction (sweetness, taste & aroma dynamics) based on chemical attributes, with genotype/ripening stage
- “Full use of genetic diversity through consumer-oriented evaluation”:
  - adding value to neglected varieties
  - contributing to breeding strategy improvement
  - ensuring consumer acceptability
Thank you for your attention

Obrigado pela sua atenção

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