Post-harvest quality of cassava at CIAT: An overview

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Centro International para la Agricultura Tropical – parte del CGIAR

- 800 researchers + support staff
- Presence in 45 countries
- Beans, Rice, Forages, Cassava
- Decision and Policy Analysis
**Mission:** Create a sustainable cassava production system through *agricultural innovations* that will increase cassava production without increasing environmental pressures.

**Objectives**

1. Ensuring efficient and sustainable *production* of adequate volumes of *cassava* for *new value chains/markets* (i.e. *breeding* for improved, stable varieties: consumers varieties + industrial varieties: waxy, high starch, etc.)

2. Alleviating poverty and increasing wealth through *agricultural innovations* & unlocking new market growth

3. Achieving *better health and nutrition* (i.e., low-GI starch) for consumers and producers and

4. Most effectively *using and conserving the natural resources* upon which all of this depends.
Cassava Program at CIAT
Characterize the quality of fresh roots and cassava-based products to select genotypes that meet consumers preferences
1. Phenotypic and genetic diversity of cassava
Diversity of post-harvest phenotypic traits among the world cassava germplasm held at CIAT

Evaluation in roots

✓ Cyanide
✓ Dry matter
✓ Cooking time
✓ Postharvest Physiological Deterioration

Evaluation in leaves

✓ All trans-β-Carotenes
✓ Protein and Aminoacids
✓ Cyanide

Evaluation of 240 genotypes in 7 geographical groups of genetic diversity
Diversity of cassava shape and color

(CIAT 2016) – Maria Alejandra Ospina
Diversity of plant architecture

1\textsuperscript{st} generation

2\textsuperscript{nd} generation

5 years

18-19\% starch

24-25\% starch
Diversity of plant architecture: “Asparagus”
Stable genotypes during three cycles of harvest for quality traits
Phenotypic variability among the 7 geographical groups

High cyanide: Amazon
Low cyanide: Andean

Long cooking time: Amazon
Short cooking time: Andean
### Selection of postharvest quality cassava genotypes

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Dry Matter (%)</th>
<th>Cyanide (µg/g db)</th>
<th>PPD (%)</th>
<th>Cooking time (min)</th>
</tr>
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<tbody>
<tr>
<td>COL1722</td>
<td>40</td>
<td>150</td>
<td>23</td>
<td>30</td>
</tr>
<tr>
<td>COL2019</td>
<td>35</td>
<td>27</td>
<td>11</td>
<td>25</td>
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<tr>
<td>CR51</td>
<td>36</td>
<td>82</td>
<td>12</td>
<td>18</td>
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<tr>
<td>CR63</td>
<td>37</td>
<td>138</td>
<td>20</td>
<td>20</td>
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<tr>
<td>CUB65</td>
<td>41</td>
<td>84</td>
<td>12</td>
<td>25</td>
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<td>ECU72</td>
<td>36</td>
<td>171</td>
<td>4</td>
<td>25</td>
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<tr>
<td>PAN51</td>
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<td>108</td>
<td>6</td>
<td>20</td>
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<td>PAR105</td>
<td>38</td>
<td>110</td>
<td>12</td>
<td>29</td>
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<tr>
<td>PAR57</td>
<td>40</td>
<td>157</td>
<td>10</td>
<td>25</td>
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<td>PAR68</td>
<td>40</td>
<td>95</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>PAR98</td>
<td>38</td>
<td>151</td>
<td>9</td>
<td>19</td>
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<td>PER183</td>
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<td>117</td>
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<td>PTR19</td>
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<td>18</td>
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<td>VEN117B</td>
<td>37</td>
<td>59</td>
<td>12</td>
<td>27</td>
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<td>VEN270</td>
<td>41</td>
<td>153</td>
<td>12</td>
<td>25</td>
</tr>
</tbody>
</table>
Manhattan graph showing associations between particular SNPs and HCN content (ref. genotype AM560-2).

Colors indicate different chromosomes (18 x 2 chromosomes in cassava).
Pasting properties of cassava starch (RVA)

Peak Viscosity

Final Viscosity

Pasting temperature

Time (min)

Temperature (°C)

Viscosity (cP)
Variability of Dry matter and Starch Properties

DM, Starch & Amylose, Gel Clarity (%), Pasting temp (°C), Maximum viscosity (cP)
Frequency distribution (3272 landrace accessions from CIAT cassava germplasm)

Dry Matter content (%)
- Maximum: 48.1%
- Minimum: 14.7%
- Average: 36.7%
- St. Dev.: 5.9%

Starch content (%)
- Maximum: 91.0%
- Minimum: 73.0%
- Average: 84.4%
- St. Dev.: 3.0%

Amylose content (%)
- Maximum: 26.5%
- Minimum: 15.1%
- Average: 20.9%
- St. Dev.: 1.60%

Gel Clarity (%)
- Maximum: 86.3%
- Minimum: 12.5%
- Average: 44.5%
- St. Dev.: 10.7%

Pasting Temperature (°C)
- Maximum: 71.1°C
- Minimum: 58.7°C
- Average: 65.2°C
- St. Dev.: 1.8°C

Maximum Viscosity (cP)
- Maximum: 1402 cP
- Minimum: 152 cP
- Average: 776 cP
- St. Dev.: 169 cP
2. Biofortified cassava
HarvestPlus project
(2003-2021)
Breeding for high carotene yellow cassava

<table>
<thead>
<tr>
<th>As of 2016</th>
<th>n° of entries</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (%)</td>
<td>6574</td>
<td>12.3</td>
<td>52.4</td>
<td>33.9</td>
<td>5.8</td>
</tr>
<tr>
<td>HPLC TCC (ppm)</td>
<td>4683</td>
<td>0.1</td>
<td>29.0</td>
<td>12.3</td>
<td>5.4</td>
</tr>
<tr>
<td>HPLC TBC (ppm)</td>
<td>4694</td>
<td>0.0</td>
<td>21.0</td>
<td>7.5</td>
<td>4.0</td>
</tr>
<tr>
<td>NIRS DM (%)</td>
<td>9366</td>
<td>11.5</td>
<td>48.5</td>
<td>34.0</td>
<td>5.3</td>
</tr>
<tr>
<td>NIRS TCC (ppm)</td>
<td>9366</td>
<td>0.0</td>
<td>26.3</td>
<td>13.7</td>
<td>5.0</td>
</tr>
<tr>
<td>NIRS TBC (ppm)</td>
<td>9366</td>
<td>0.0</td>
<td>19.7</td>
<td>8.5</td>
<td>3.7</td>
</tr>
</tbody>
</table>

CIAT database for DM, total carotenoids and β-carotene by HPLC/UV and NIRS

Average increase in TCC and TBC was respectively 120% and 179% between 2009 and 2016
**Objective:** Check that high carotenes in fresh roots are retained after post-harvest processing
- Frying: < 25% retention
- Boiling or steaming: 25-50% retention

✓ **Products made of Fresh cassava roots**

- Cooked Cassava
- Croquettes
- Chips
- Cassava Sweet

✓ **Products made of Cassava Flour**

- Bread
- Cookies
- Pancakes
- Pasta
Recipe book for cassava-based gluten free products

Contents

<table>
<thead>
<tr>
<th>Pages</th>
<th>Cassava Bread</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cassava Chips</td>
</tr>
<tr>
<td>2</td>
<td>Cassava Cookies</td>
</tr>
<tr>
<td>3</td>
<td>Cassava Sweet</td>
</tr>
<tr>
<td>4</td>
<td>Pancakes</td>
</tr>
<tr>
<td>5</td>
<td>Cassava Chips</td>
</tr>
<tr>
<td>6</td>
<td>Cassava Croquettes</td>
</tr>
<tr>
<td>7</td>
<td>Fettuccini</td>
</tr>
<tr>
<td>8</td>
<td>Rigatoni</td>
</tr>
</tbody>
</table>

**Cassava Bread**

**Ingredients**
- 300g Cassava Flour
- 5g Salt
- 60g Sugar
- 50g Margarine
- 12g Yeast
- 60ml Milk
- 1 Egg

**Preparation**
- Mix the sugar, margarine, milk, salt and egg in a mixer.
- Activate the yeast in 100 ml of warm water.
- Incorporate cassava flour, yeast and the first mixture in a mixer.
- Knead for 10 minutes.
- Put the dough in greased molds.
- Cover the molds with the dough with cling film and leave to rest at 40°C for 60 min.
- Bake for 20 min at a temperature of 180 °C.
- Remove from the oven and allow to cool to room temperature.

**Notes**
- 90 min

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**Recipe Book**

**Yellow Cassava Roots**
3. Boiling quality
RTBfoods project
(2017-2023)
Boiled cassava cooking quality

More than 60 min of cooking

Less than 30 min of cooking
Cooking time is an important acceptability criteria for boiled cassava, linked to softness.

- Diversity of cooking times and water absorptions among cassava genotypes.

- Short-cooking genotypes tend to have high water absorption, and vice-versa.
**Water Absorption correlates with Cooking Time**

Water absorption at 30 mins shows significant correlation with cooking time \( r^2 = 0.63 \).

Water absorption takes 30 mins per sample instead of up to 60 mins with the conventional fork method.

36 genotypes
Two-year data confirm the correlation

- Dataset from Jan.-March 2021 confirms the stability of the correlation over 2 years
- Correlation stable for different ages of the plants at harvest (9 to 11 months)
- Able to screen out long-cooking genotypes, for which the correlation can be considered linear.

2020: Cooking time (min) = \(-1.79 \times \text{WAB30} \% \) + 56.51

Combined 2020+2021 dataset: Cooking time (min) = \(-1.46 \times \text{WAB30} \% \) + 53.98
Water Absorption adopted as new criteria for breeding selection

- Selection of short-cooking clones among F1C1 biofortified cassava at CIAT (May-July 2020).
  - Population: F1C1 with 3196 clones.
  - Selected: 389 clones advanced to CET.
  - 4 selection criteria: WAB, DM, BCC, TCC.

- Evaluation of the RTBfoods progeny to study inheritance of cooking quality traits.
Pollination to develop new breeding populations for cooking quality

**Variety Dvt**
Good Cooking Quality

**Population Imp. +VD**
Dry Matter to Cooking Quality

**Trait Introgression**
CMD / CBSD Resistance to Cooking Quality

### Elite Population
- 5 CQ progenitors
- 10 crosses x 50 <= 500 seeds <100 seeds/family
- For variety development

### Variety Development
- 5 best CQ progenitors
- Two recombination events
- 5 crosses x 50 <= 250 seeds

### Population Improvement
- 8 best DM progenitors + 15 good cooking quality
- 40 crosses x 50 <= 2000 seeds
- * DM progenitors with low HCN

### Trait Improvement
- Improve germination, dry matter, plant type, yield
Three distinct behaviors:

• Soft, not break
• Hard, not break
• Hard, break
Cooking time by Mattson cooker (developed by IAPAR)
4. High throughput phenotyping: NIRS
Prediction of DM and b-carotens: > 100 samples/day instead of 20-40

Portable NIRS?

Prediction of cooking quality: WAB, texture?
5. Specialty starches
In March 2006, the first natural waxy cassava (after self pollination) was discovered (AM206-5) at CIAT, Cali, Colombia after in-breeding to reveal recessive traits

## Physico-chemical properties of waxy cassava starch

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TMS60444</th>
<th>AM206-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average granule diameter ($\mu$m)</td>
<td>12.1</td>
<td>16.9</td>
</tr>
<tr>
<td>Crystallinity (%)</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>A type (%)</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>Onset temperature $T_0$ ($^\circ$C)</td>
<td>54.0</td>
<td>61.2</td>
</tr>
<tr>
<td>Gelatinization Enthalpy $\Delta H$ (J.g$^{-1}$)</td>
<td>12.9</td>
<td>16.9</td>
</tr>
<tr>
<td>temperature range $\Delta T$ ($^\circ$C)</td>
<td>18.7</td>
<td>14.5</td>
</tr>
<tr>
<td>Amylose DSC (%)</td>
<td>14.4</td>
<td>0.0</td>
</tr>
<tr>
<td>$\lambda_{max}$ (nm)</td>
<td>583</td>
<td>528</td>
</tr>
</tbody>
</table>

AM206-5 = waxy starch  
TMS60444 = control  
(normal cassava starch)
Freeze-thaw stability comparison

**Fresh gels**

- Wx Corn
- Wx Cassava
- Wx Potato
- Wx Rice

After 2 Freeze-Thaw cycles

- Wx Corn
- Wx Cassava
- Wx Potato
- Wx Rice

5% dry solids in distilled water
Expansion properties of waxy cassava starch: Pan de queso

Normal cassava

Waxy cassava
6. Post-harvest processing: Flash dryer for cassava starch and flour at small scale

https://flashdryer.cirad.fr/
Cassava processing at small and large scale

Nigeria 0.3t gari/day

Colombia 2-3t starch/day

Paraguay 25-100t starch/day

Tanzania 2t HQCF/day

Vietnam 3-11t starch/day

Thailand 250t starch/day
Large scale factory 200t starch/24 hours, 9-12 months/year
Washing

Rasping and extraction

Roots 8-9 t/day

Small scale factory 2t starch/24 hours, 2-3 months/year
Drying represents 70-80% of energy use for cassava starch or flour.

Tran et al., 2015. A comparison of energy use, water use and carbon footprint of cassava starch production in Thailand, Vietnam and Colombia.
Energy represents 7-20% of production costs

**Thailand**

- 81.24%
- 1.95%
- 4.13%
- 1.41%
- 3.34%
- 0.45%

**Vietnam**

- 92.5%
- 1.5%
- 1.2%
- 4.8%

**Colombia**

- 66%
- 15%
- 15%
- 1%
- 3%
- 1%

**Nigeria**

- 63%
- 7%
- 10%
- 9%
- 11%
- 2%

2nd highest cost after cassava roots
Key components of a flash dryer
No consensus on the design of flash dryers

- Pipe length: 10 – 60 m
- Temperature: 130 – 180°C
- Air velocity: 10 – 25 m/s
- A/S ratio: 8 – 40 kg/kg
- Energy use: 1200 – 10000 MJ/t starch
- Diversity of shapes of the drying tube
Small-scale flash dryers use more energy

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity t/day</th>
<th>Energy use MJ/t starch</th>
<th>Energy type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thailand</td>
<td>200</td>
<td>1500 - 2000</td>
<td>Biogas</td>
</tr>
<tr>
<td>Vietnam</td>
<td>2</td>
<td>5000</td>
<td>Coal</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1 - 2</td>
<td>3000 - 10000</td>
<td>Oil / Biomass</td>
</tr>
<tr>
<td>Paraguay</td>
<td>25 - 100</td>
<td>2000 - 3400</td>
<td>Wood</td>
</tr>
<tr>
<td>Colombia (AdS)</td>
<td>50</td>
<td>2600</td>
<td>Natural gas</td>
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<tr>
<td>Colombia (Cauca)</td>
<td>2</td>
<td>-</td>
<td>Sun drying</td>
</tr>
</tbody>
</table>

Can we make dryers at small scale with same energy efficiency as large scale?

25 - 30 USD/t
42 - 100 USD/t
Energy efficiency is possible at small-scale

Model predicts that longer tube reduces energy use. Min 20 m.

Use long pipes even for small dryers
Adjust capacity with pipe diameter

Small scale dryers length: 10-12m
→ NOT EFFICIENT

Large scale dryers length: 30-40m
→ EFFICIENT
Pilot: Energy-efficient small-scale flash dryer

- Equipment layout: Adjustable drying duct length

  - Capacity: 100 kg/hr
  - Adjustable length: 15 – 35m
  - Adjustable air velocity
  - Adjustable temperature
The pilot flash dryer developed at CIAT

- Equipment layout: Adjustable drying duct length
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  - Adjustable air velocity
  - Adjustable temperature
The pilot flash dryer developed at CIAT

- Equipment layout: Adjustable drying duct length

- Capacity: 100 kg/hr
- Adjustable length: 15 – 35m
- Adjustable air velocity
- Adjustable temperature
Pilot at CIAT: Energy efficient, small-scale flash dryer

Adjustable temperature: 120 - 210°C
LPG gas consumption: 3-4 kg/h at 180°C
Cost: 4 USD/h or 0.04 USD/kg starch

Energy: 1500-2000 MJ/t starch similar to large scale dryers
Scaling out flash dryer innovations

**Drying pipe:** Recommended 25 to 30 m

**Air velocity:** Recommended 10-12 m/s

- Blower ~ 7-8 kW *with negative pressure*
- ~ 11-13 kW *with positive pressure*

For production capacity 200-300 kg flour/h
Post-harvest quality and functional properties of:
- Cassava
- Rice
- Beans

Health aspects:
- Nutrition
- Resistant starch
- In-vitro and in-vivo tests of glycemic index (with CIRAD)

Share experimental protocols: Amylose, resistant starch; texture (beans)

Diversity of cassava, rice, bean varieties and consumer expectations

Any other topics
Obrigado !
Gracias !
Thanks !

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