Industrial uses of starch

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Banana production by origin

**Cavendish origin**
- Indonesia: 3%
- Mexico: 4%
- Colombia: 5%
- Costa Rica: 5%
- Philippines: 7%
- Brazil: 7%
- Ecuador: 13%
- China: 13%
- India: 25%
- Others: 18%

**Plantain origin**
- Ecuador: 25%
- Colombia: 17%
- Ghana: 12%
- Nigeria: 10%
- India: 4%
- Congo: 6%
- Peru: 6%
- Cameroun: 6%
- Ivory Coast: 7%
- Others: 25%

**Other cooking bananas**
- Thailand: 4%
- Burundi: 5%
- Indonesia: 8%
- Philippines: 8%
- Rwanda: 9%
- India: 10%
- Uganda: 38%
- Others: 18%

**Others:** 25%
World production of starch = 60 millions of tonnes in 2004
## Composition of various high starch sources

<table>
<thead>
<tr>
<th>Product</th>
<th>Starch (%)*</th>
<th>Proteins (%)*</th>
<th>Lipids (%)*</th>
<th>Fibers (%)*</th>
<th>Ashes (%)*</th>
<th>Water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>84</td>
<td>8</td>
<td>0.5</td>
<td>3</td>
<td>4</td>
<td>78</td>
</tr>
<tr>
<td>Cassava</td>
<td>95</td>
<td>1</td>
<td>0.5</td>
<td>2</td>
<td>1.5</td>
<td>12</td>
</tr>
<tr>
<td>Wheat Rice</td>
<td>75</td>
<td>12</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pea</td>
<td>60-66</td>
<td>25-30</td>
<td>1.5</td>
<td>6-8</td>
<td>1.5-3</td>
<td>75</td>
</tr>
<tr>
<td>Banana</td>
<td>70-85</td>
<td>5</td>
<td>1.5</td>
<td>2</td>
<td>3.5</td>
<td>74</td>
</tr>
</tbody>
</table>

* *Dry weight basis*
Amylose and amylopectin

Amylose: a linear polymer

1-4 linked $\alpha$-D-glucopyranosyl units or seldom branch with $\alpha$-D-1-6 linkages

Amylopectin: highly branched polymer

D-glucopyranosyl units linked by 1-4 bonds with 1-6 linkage branches
Various amylose, amylopectin contents of starch

<table>
<thead>
<tr>
<th>Starch type</th>
<th>Amylose (%)</th>
<th>Amylopectin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>25-28</td>
<td>72-75</td>
</tr>
<tr>
<td>Cassava</td>
<td>17-20</td>
<td>80-83</td>
</tr>
<tr>
<td>Potato</td>
<td>20-23</td>
<td>77-80</td>
</tr>
<tr>
<td>Rice</td>
<td>15-35</td>
<td>65-85</td>
</tr>
<tr>
<td>Wheat</td>
<td>20-26</td>
<td>74-80</td>
</tr>
<tr>
<td>Waxy corn (*)</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Banana</td>
<td>15-23</td>
<td>77-85</td>
</tr>
<tr>
<td>Plantain</td>
<td>9-17</td>
<td>83-91</td>
</tr>
</tbody>
</table>

(*) Genetically modified starch
Banana starch small scale production and derivatives

1/5 of all bananas harvested become culls
Industrial use of culled bananas = a challenge

Potential practical application:

1) Pulp processing for starch production by wet milling

2) Structure and functionalities investigations
   - low cost banana flour ingredient processing
   - formulated banana flour with cassava or yam (fufu,..)
   - by-products valorisation (dietary fibre from peel, pectic polysaccharides and hemicellulose)
Rejected cull bananas alkaline process

Cut and macerated with 0.1 M NaOH

Washed and peeled

Sliced and milled with 0.5 M NaOH

Washed in a shaker and centrifuged

Diced, milled in a 0.05 M NaOH solution and screened

Concentrated counter-current washed with water

Dewatered

Washed, centrifuged and dried

62% yield, purity 94%

70% yield, purity 94%

Purity 95%
Rejected cull bananas non-alkaline process

Washed and peeled

Sliced and mixed in a blender

Centrifugated

Washed and decanted

Purity 99.5%

Steeped in sodium bisulfite solution 4 hours

Slightly heated and screened

Centrifuged

20-60% yield depending on ripeness
Banana starch granule

Irregular in shape and size (5-58μm) ¹
smooth cell walls ²
Excentric hila and birefringence ³
Heat effect on Starch

Native barraganete flour

Native dominico flour

Pre-cooked plantain flour

— 10 μm
Banana pulp tissue

- Starch granule
- Cell wall expansion

Plantain pulp tissue

- Starch granule
- Cell wall expansion

Native

- Heating 2 min

- Heating 3 min

- Heating 8 min
Starch functional properties

Depends on:

- Gelatinisation characteristics;
- Pasting characteristics;
- Swelling power and solubility (influenced by amylose/amylopectin ratio and ripening stage);
- Rheology (shear rate on viscosity).
Gelatinisation

« Order to disorder phase transition with heat and excess of water »

Water diffusion into the granule
Starch granule swelling
Loss of birefringence and cristallinity
Heat uptake
Amylose leaching
Pasting

= the consequence of the gelatinisation

Swollen granules entrapped by amylose-amylopectin network with presence of fragments of starch structures

⇒ Viscosity and gel characteristics

⇒ Amylose and amylopectin retrogradation during cooling

⇒ Gel forming (with more or less hardness depending on cultivar)
Pasting profile using RVA

PV: peak viscosity, SB: Setback, CS: Consistency
BD: breakdown, HPV: hot paste viscosity
Pasting properties

\[ \eta \text{ (RVU)} \]

- Cassava starch 7%
- Potato starch 8%
- Plantain flour 8%
- Fufu USA
- Green banana flour 8%

Time (s)
Example: Native plantain French Clair RVA profile

- High initial pasting temp.
- High peak visc.
- Low BD
- Low SB
- High CS
- Heat resistance (high gelatinisation temperature and initial pasting temp) => high heat process tolerance (ex: industrial sauces)
- High peak viscosity (double to four time of a corn paste at 6%)
- High starch crystallinity => high GT like waxy starch
- Limited breakdown => mechanical shear resistance
- High gel consistency => high gel strength (textural properties for high starch concentrates ie gums, jellies)
- Low setback => low retrogradation (bread staling)

These pasting properties are then conferring to banana starch the potentiality to be substituted to modified starch (cross-linked starches) and replace to some extend some starch industrially produced with similar functional properties.
Other banana starch specificities…

- Restricted swelling power and good stability => low glycaemic index and slow digestion
- Restricted solubility => opacity (ex: formulation of sauces)
- Low starch digestibility => resistance to amylase-catalyzed hydrolysis
- Resistant starch escape digestion => beneficial health effects
Conclusion

uniqueness of banana starch

Promising new base starch (as modified starch)
Superior properties to some existing starches and modified starches for specific niche application
Availability and bio-waste management challenge

Many potentialities to determine and exploit in coming research on Musaceae
Thank you for your attention

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Bibliographic references


Steele, Bath PhD Report, Characterisation of starch in Musa fruits, pp 197 (1997).


Dufour et al., Personal notes on a CIRAD industrial project (2004).