An Alternative Flotation Process for Apatite Concentration of the Itataia Carbonaceous Uranium-Phosphate Ore

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_Centro de Tecnologia Mineral (CETEM)_

Ligia Gonzaga  
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Ana Luiza Guedes  
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AN ALTERNATIVE FLOTATION PROCESS FOR APATITE CONCENTRATION OF THE ITATAIA CARBONACEOUS URANIUM-PHOSPHATE ORE

Elves Matiolo, DSc
Lígia Gonzaga, MSc
Ana Luiza Guedes, IC

Melbourne, March 2015
Agribusiness in Brazil

- Grain production (2013) = 188 million ton
- Planted area (2013) = 53 million hectares
- (2013) 23% Gross domestic product = US$ 454 billion

### Projections for international trade (2022)

<table>
<thead>
<tr>
<th>Product</th>
<th>Production (million ton)</th>
<th>Market share (%)</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brazil</td>
<td>World</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>18,6</td>
<td>138,7</td>
<td>13,4</td>
</tr>
<tr>
<td>Soybean (grain)</td>
<td>63,8</td>
<td>144,3</td>
<td>44,2</td>
</tr>
<tr>
<td>Soybean (oil)</td>
<td>2,4</td>
<td>10,8</td>
<td>22,2</td>
</tr>
<tr>
<td>Soybean (bran)</td>
<td>16,9</td>
<td>73,9</td>
<td>22,9</td>
</tr>
<tr>
<td>Cattle</td>
<td>1,9</td>
<td>8,1</td>
<td>23,3</td>
</tr>
<tr>
<td>Pork</td>
<td>0,8</td>
<td>6,3</td>
<td>12,4</td>
</tr>
<tr>
<td>Chicken</td>
<td>4,8</td>
<td>9</td>
<td>52,9</td>
</tr>
</tbody>
</table>

Sources: Ministério da Agricultura, Pecuária e Abastecimento – USDA (United States Department of Agriculture) - CNA
Brazilian fertiliser industry supply

Fertiliser demand in Brazil will grow twice as fast as overall global demand

Brazil = 5.3% y.y 2000-2012

Brazil = 5.3% y.y 2000-2012
Salitre – Vale
Araxá – Vale
Santa Quitéria – INB and Geltani
Tapira – Vale
Catalão – Vale and Copebrás
Cajati – Vale
Typical flowsheet

Crushing

Rod and ball mills $P_{80} = 150 \, \mu m$

Magnetite (discharge)

Low intensity magnetic separator

Slimes (discharge) $90\% < 10 \, \mu m$

Conditioning Fines/ultrafines $D_{50} = 25 \, \mu m$

Conditioning Coarse particles $D_{50} = 105 \, \mu m$

Mechanical cells

Column flotation
Santa Quitéria Project
Phosphate-uranium ore (Itataia - CE)

80's years

Ore
- Apatite – 36%
  (15% P$_2$O$_5$)
- Calcite – 24%
- Silicates – 20%

Reagents
- Tall oil
- Corn starch
- Sodium silicate
  pH – 10 (NaOH)

Air

H$_3$PO$_4$
- 2 kg/t
- pH – 5.6

BULK Concentrate (apatite and calcite)

Calcite

Silicates

32 – 34.5% P$_2$O$_5$
3 - 6% calcite

Apatite concentrate

CDTN
CLDRI Process

Chinese Lianyungang Design and Research Institute
Florida Industrial and Phosphate Research Institute (FIPR)
University of Florida

< 150 µm

Fatty acid soap

$\text{H}_3\text{PO}_4$ and $\text{H}_2\text{SO}_4$

Dolomite

Silicates or apatite flotation

1994 year
Siliceous carbonate phosphate ore from Catalão (Goiás)

**Conditioning**
- 50% solids
- **Collector** (sulphosuccinate) Lupromin FPA 711
- **Corn starch** (depressant)
- **pH** – 9,5 - **NaOH**

**Rougher flotation**
- Air
- **H₂SO₄**

**Flotation**

**Bulk concentrate**

- Apatite and carbonates

**Apatite concentrate**

**Calcite/dolomite**

**Froth**
Two stage conditioning process

- High MgO Pebble 65x150 Mesh Feed
  - Basic pH Modifier/Fatty acid
  - Conditioned pH = 10
  - Flotation pH 9-10 → Silica (Sink)
  - Reconditioning
  - H₂SO₄
  - Dolomite Flotation pH 4.5 → Float Dolomite
  - Sink (Apatite & Fine Quartz)
  - Further processing to remove silica
Role of Carbon Dioxide in Flotation of Carbonate Minerals

A. K. BISWAS
Department of Metallurgical Engineering, Indian Institute of Technology, Kanpur

Manuscript received 23 June 1966

The use of carbon dioxide in place of air improves the flotation recovery of calcite and magnesite at low collector (sodium oleate) concentration. With siderite and rhodochrosite, the recovery is almost of the same order with both air and carbon dioxide. The improvement in flotation recovery brought about by carbon dioxide is not related solely to the lowering of pH. Specificity of reaction of carbon dioxide with the surface cation of the carbonate mineral is indicated.

Fundamental Studies on the Role of Carbon Dioxide in a Calcite Flotation System

by V. T. Sampat Kumar, N. Mohan, and A. K. Biswas

Carbonic gas applied in flotation of phosphates ores (Brazil)

Bulk concentrate
Apatite and carbonates

Feed
Air/CO₂

CO₂
Silicates/iron hydroxides
Calcite/dolomite

Apatite concentrate

Catalão’s Mine
Cleaner Flotation columns

CO\textsubscript{2} injection

Cavitation tube
Barreiros’s Mine - Araxá

\[ P_{80} = 150\mu m \]

ROM

Slimes

Carbonates

Coconut soap

Dilution

CO₂

Apatite flotation

\[ \text{Barreiros’s Mine - Araxá} \]
Apatite flotation

Corn starch
NaOH
sulphosuccinate
Fatty acid soap substitution

Apatite concentrate
Tailing Cleaner
Tailing Rougher
Experimental
Ore sample – 1 ton
## Chemical and mineralogical characterization

<table>
<thead>
<tr>
<th>CaO/P₂O₅</th>
<th>Grade (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P₂O₅</td>
</tr>
<tr>
<td>2,8</td>
<td>16,7</td>
</tr>
</tbody>
</table>

Pie chart shows the distribution of materials:
- **Calcite**: 50,7%
- **Apatite**: 5,9%
- **Quartz**: 5,2%
- **Others**: 38,2%
< 3.36 mm

Discharge

Slimes

Fines Fraction

Calcite and Apatite Flotation

Coarse Fraction

Calcite and Apatite Flotation
Particle size distribution

- **Slimes**: $D_{50} = 5\mu m$
- **Fines**: $D_{50} = 28\mu m$
- **Milling Product**: $D_{96} = 150\mu m$
- **Coarse**: $D_{50} = 100\mu m$
## Mass Balance

### Preparation

<table>
<thead>
<tr>
<th>Flux</th>
<th>Recovery (%)</th>
<th>Grade (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mass</td>
<td>$P_2O_5$</td>
</tr>
<tr>
<td>Slimes</td>
<td>18,2</td>
<td>16,4</td>
</tr>
<tr>
<td>Fines</td>
<td>35,4</td>
<td>34,7</td>
</tr>
<tr>
<td>Coarse</td>
<td>46,4</td>
<td>48,9</td>
</tr>
</tbody>
</table>
Calcite flotation
- Coconut soap (calcite collector)
- $CO_2$ – bubble generator
- $pH$ – 5.8

Apatite flotation
- Sulphosuccinate (apatite collector)
- Corn starch (depressant)
- $pH$ – 11 (NaOH)

Conditioning = $50\%_{w/w}$ (coarse) – $40\%_{w/w}$ (fines)
Flotation = $25\%_{w/w}$
Results
Calcite flotation – Coarse fraction

Effect of the collector dosage – Calcite concentrate

Mass recovery; $P_2O_5$ recovery and $P_2O_5$ grade
Calcite flotation – Coarse fraction

Effect of the collector dosage – Float

Mineralogical composition

<table>
<thead>
<tr>
<th>Mineral</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>93,1</td>
<td>90,8</td>
<td>89,9</td>
<td>86,3</td>
</tr>
<tr>
<td>Apatite</td>
<td>2,0</td>
<td>3,2</td>
<td>4,4</td>
<td>9,6</td>
</tr>
<tr>
<td>Calcite</td>
<td>1,4</td>
<td>1,1</td>
<td>1,2</td>
<td>1,1</td>
</tr>
</tbody>
</table>

Coconut soap (g/t)
Calcite flotation – Coarse fraction

Effect of the collector dosage – Sink

Mineralogical composition

<table>
<thead>
<tr>
<th>Mineral (%)</th>
<th>Coconut soap (g/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>6.9</td>
</tr>
<tr>
<td>Calcite</td>
<td>7.3</td>
</tr>
<tr>
<td>Apatite</td>
<td>16.8</td>
</tr>
<tr>
<td>Quartz</td>
<td>7.5</td>
</tr>
<tr>
<td>Calcite</td>
<td>7.2</td>
</tr>
<tr>
<td>Apatite</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Graph showing the mineral composition as a function of coconut soap dosage.
Apatite flotation – Coarse fraction

Effect of the collector dosage (sulphosuccinate)

<table>
<thead>
<tr>
<th>Collector g/t</th>
<th>P₂O₅ (%)</th>
<th>CaO (%)</th>
<th>Fe₂O₃ (%)</th>
<th>SiO₂ (%)</th>
<th>Al₂O₃ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>26,6</td>
<td>38,9</td>
<td>3,3</td>
<td>18,3</td>
<td>3,6</td>
</tr>
<tr>
<td>700</td>
<td>26,4</td>
<td>36,4</td>
<td>3,4</td>
<td>20,9</td>
<td>4,1</td>
</tr>
</tbody>
</table>
Apatite flotation – Coarse fraction

Scavenger

Corn Starch = 300 g/t
Sulphossucinate = 500 g/t
pH = 11,0

<table>
<thead>
<tr>
<th>Grade (%)</th>
<th>P$_2$O$_5$</th>
<th>CaO</th>
<th>Fe$_2$O$_3$</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>26,6</td>
<td>37,0</td>
<td>3,4</td>
<td>19,4</td>
<td>4,3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade (%)</th>
<th>P$_2$O$_5$</th>
<th>CaO</th>
<th>Fe$_2$O$_3$</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrate</td>
<td>65,5</td>
<td>32,9</td>
<td>42,8</td>
<td>2,3</td>
<td>11,3</td>
</tr>
</tbody>
</table>

Balance coarse fraction

Mass recovery = 28,6%
P$_2$O$_5$ recovery = 42% - 85% flotation
P$_2$O$_5$ grade = 32%
SiO$_2$ grade = 7,1%
Calcite flotation (fines fraction)

500 g/t collector
2 L/min CO₂
Apatite flotation (fines fraction)

Corn starch = 700 g/t  
Sulphosuccinate = 700 g/t  
pH = 11

<table>
<thead>
<tr>
<th>Flux</th>
<th>Recovery (%)</th>
<th>Grade (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mass</td>
<td>P₂O₅</td>
</tr>
<tr>
<td>Feed</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Concentrate</td>
<td>66,2</td>
<td>76,9</td>
</tr>
<tr>
<td>Tailings</td>
<td>33,8</td>
<td>23,1</td>
</tr>
</tbody>
</table>

Balance fines fraction

Mass recovery = 15%

P₂O₅ recovery = 26,31% - 75,7% flotation
Global balance

Mass recovery = 43.6%

$P_2O_5$ recovery = 68%

$P_2O_5$ (%) = 32.4%

$SiO_2$ (%) = 6.0%
The use of carbon dioxide in combination with coconut soap showed high selectivity on separation between apatite and calcite in the Itataia’s phosphate ore;

This carbonate flotation process concept based on use carbon dioxide and coconut soap as carbonates collector was applied in others two differents carbonaceous phosphate ores from Brazil (Araxá and Catalão) with very good results;

Quartz flotation must be evaluated in replacement of apatite flotation in the sink fraction of calcite flotation.
This work is dedicated to the Mining Engineer Lauro Akira Takata
Acknowledgments

Dr. Reiner Neumann - CETEM

To all institutions that support research in Brazil