Alternative Depressor for Apatite Flotation

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André Carlos Silva, Débora Nascimento Sousa, Diego Valentim Crescente Cara, Alex Malue Machado, and Elenice Maria Schons Silva, "Alternative Depressor for Apatite Flotation" in "Beneficiation of Phosphates VIII", Dr. Patrick Zhang, Florida Industrial and Phosphate Research Institute, USA Professor Jan Miller, University of Utah, USA Professor Laurindo Leal Filho, Vale Institute of Technology (ITV), Brazil Marius Porteus, Foskor-Mining Division, South Africa Professor Neil Snyders, Stellenbosch University, South Africa Mr. Ewan Wingate, WorleyParsons Services Pty Ltd., Australia Prof. Guven Akdogan, Stellenbosch University, South Africa Eds, ECI Symposium Series, (2018). [http://dc.engconfintl.org/phosphates_viii/21](http://dc.engconfintl.org/phosphates_viii/21)
ALTERNATIVE DEPRESSOR FOR APATITE FLOTATION

Prof Dr André Carlos Silva
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Introduction

• *Igneous deposits* mostly compose Brazilian phosphate rock mines.

• Currently, the most used technology for processing igneous ores is the froth anionic flotation (fatty acids).

• In Brazil, *cornstarch* is widely used as depressant for several ores.
Objectives

- Analyze the potential of three botanical sources (cassava, potato, and sorghum) to be used as depressant on apatite flotation and compare the results with corn.
Apatite sample preparation

Blue crystals of igneous apatite from Ipirá-BA, Brazil

Crushing
Jaw crusher (lab scale)

Grinding
Ball mill (lab scale, closed circuit)

Wet sieving
Tyler series for 15 min

Vacuum filt. and drying
60 °C for 24 h

Magnetic sep.
Ferrite magnet with 2 kG

+106-150 μm (+150-100 #)
Apatite sample characterization

- **XRD**
  - PANalytical XRD Empyrean

- **XRF**
  - PANalytical XRF AXIOX MAX DY 5001

- **SEM**
  - Jeol SEM JSM-6610

- **EDS**
  - Scientific NSS Spectral Imaging

- **Particle size analyze**
  - Sympatec HELOS laser diffraction

- **Zeta potential**
  - Malvern ZS90 Nano zetasizer
XRF results in percentage for apatite sample

<table>
<thead>
<tr>
<th></th>
<th>CaO</th>
<th>P_{2}O_{5}</th>
<th>K_{2}O</th>
<th>SiO_{2}</th>
<th>SO_{3}</th>
<th>I</th>
<th>Cl</th>
<th>Na_{2}O</th>
<th>ThO_{2}</th>
<th>Fe_{2}O_{3}</th>
<th>MnO</th>
<th>BaO</th>
<th>SrO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54.02</td>
<td>38.49</td>
<td>4.20</td>
<td>1.10</td>
<td>0.63</td>
<td>0.39</td>
<td>0.34</td>
<td>0.27</td>
<td>0.18</td>
<td>0.11</td>
<td>0.11</td>
<td>0.10</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Apatite samples had 95.5% of purity, regarding its chemical composition
**X-ray diffraction**

100% fluorapatite

**Zeta potential**

IEP not detected

**Particle size distribution**

\[ P_{80} \approx 108 \, \mu m \]

\[ P_{20} \approx 22 \, \mu m \]

**Optical microscope image**
Materials and methods

• The Brazilian company **Agroceres** donated samples of graniferous **sorghum** [*Sorghum bicolor* (L.) Moench] grains, cultivated on a farm situated on Ipameri, Goiás, Brazil.

• The other starches samples were acquired on the **local market**.
Sorghum starch extraction

**Sieving**
Remove straw residues and other impurities

**Remove residual moisture**
Dried in the drying oven at 35 °C for 30 hours

**Comminution**
Using two cereal mills

**Extraction**
Rupollo (2011)

Sorghum starch
Starches characterization

Morphology
- SEM

Amylose content
- Method 61-03.01 (AACC, 1995)

Ash content
- Method 08-21.01 (AACC, 1997)

Protein amount
- Bradford (1976)

Lipids amount
- Bligh-Dyer (1959)

Swelling power and solubility index
- Leach et al. (1959)
Materials and Methodology

- Flotigam 5806 from Clariant, a synthetic mix of fatty acids, at a dosage of 300 g/t were used as collector and its preparation (saponification) followed the manufacturer recommendations.

\[
\begin{align*}
\text{5 g of Flotigam 5806} & + 20 \text{ mL of distilled water} \\
\text{Magnetic stirring} & \quad 5 \text{ min} \\
+ 7.5 \text{ mL of NaOH @ 10 \%} & \\
\text{Magnetic stirring} & \quad 5 \text{ min} \\
+ \text{ distilled water until 100 g of solution} & \\
\text{Magnetic stirring} & \quad 10 \text{ min}
\end{align*}
\]
• Starches alkaline gelatinization:

1 g of starch + 20 mL of distilled water + 2.7 mL of NaOH @ 10% Magnetic stirring Until complete gelatinization

• Collector and depressant solutions were used **fresh daily** in order avoid any degradation of the collector or retrogradation of the depressant.
Starch retrogradation

When a starch gel is left to stand for some time, the amylose molecules will lose water and bind together. This process of recrystallization of starch is called **retrogradation**.

Gelatinisation and retrogradation of starch. (a) native starch, (b) gelatinized starch, and (c) retrogradated starch
Gelatinization, pasting and retrogradation of starch influenced by heat and time, where AM is amylose and AP amylopectin. Adapted from Schirmer et al. (2015).
## Starch retrogradation

### Characteristics of starch solutions

<table>
<thead>
<tr>
<th>Starch</th>
<th>Viscosity</th>
<th>Retrogradation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>Very high</td>
<td>Medium</td>
</tr>
<tr>
<td>Corn</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Wheat</td>
<td>Low-medium</td>
<td>High</td>
</tr>
<tr>
<td>Waxy corn</td>
<td>Medium-high</td>
<td>Very low</td>
</tr>
</tbody>
</table>

[http://www.food-info.net/uk/carbs/starch.htm](http://www.food-info.net/uk/carbs/starch.htm)
High grade ore
High tec.
On line system
Outstanding equip.
Cutting edge collectors
Perfect conditions pH, rpm, air, etc
Bad depressant

Garbage in – Garbage out
Materials and Methodology

- **Air flow:** 40 cm$^3$/min @ 10 psi
- **Apatite samples:**
  - 1.0 g @ +106-150 μm (+150-100 #)
- **Collector:** Clariant Flotigam 5806, 300 g/t
- **Depressants:**
  - Cassava starch, cornstarch, potato starch, and sorghum (flour and starch)
  - Dosages: 0, 400, 800, and 1200 g/t
- **Conditioning time:**
  - Collector: 7 minutes
  - Depressant: 5 minutes
- **Flotation time:** 1 minute
- **pH:** 10
- **pH regulators:** HCl and NaOH (1%)
- **Distilled water**
Cassava starch
Cornstarch
Potato starch
Sorghum starch
Sorghum flour
Pinto et al. (1992) showed that **amylopectin** is more efficient depressant for hematite than **amylose** in microflotation tests.

For **apatite**, the same authors showed that pure amylose has lower depressant action, followed by pure **amylopectin** and starch.
According to Guimarães et al. (2004), in the flotation of phosphate ore, the froth is not affected when oil content is lower than 4%, possibly due to the fact that the collector used in this flotation system, normally ionized fatty acids soap species, is also a frothing agent. Therefore, no restriction were found for the tested starches regarding the lipid content.
Additional test work is still required to investigate the influence of proteins in the mineral flotation.

It appears that different flotation systems react differently to the protein presence.

Peres and Correa (1996) showed that zein act as an efficient hematite depressant, corroborating industrial observations. On the other hand, phosphate ore plants reported opposite results.
Since the starch’s quality is greatly influenced by its ash content and protein amount, a low ash and protein content lead to a high quality starch.

The results indicated that the extract sorghum starch present a high purity degree and the extraction process in laboratory scale was efficient (Rocha et al., 2008).
The solubility results could be related with the amount of protein present in the starch.

No difficult or differences were found during the sorghum (starch or flour) homogenization in water.
<table>
<thead>
<tr>
<th>Ash (g/kg)</th>
<th>Solubility (%)</th>
<th>Swelling power (g/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava starch</td>
<td>14.63</td>
<td>27.94</td>
</tr>
<tr>
<td>Cornstarch</td>
<td>12.57</td>
<td>25.20</td>
</tr>
<tr>
<td>Potato starch</td>
<td>3.49</td>
<td>6.68</td>
</tr>
<tr>
<td>Sorghum flour</td>
<td>1.43</td>
<td>5.25</td>
</tr>
<tr>
<td>Sorghum starch</td>
<td>9.88</td>
<td>22.85</td>
</tr>
</tbody>
</table>

High values of swelling power can be correlated with high amount of amylose and amyllopectin present on the starch.
<table>
<thead>
<tr>
<th>Starch</th>
<th>Avg. flotability</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava starch</td>
<td>1.11</td>
<td>0.21</td>
</tr>
<tr>
<td>Sorghum flour</td>
<td>2.25</td>
<td>1.15</td>
</tr>
<tr>
<td>Cornstarch</td>
<td>8.10</td>
<td>1.51</td>
</tr>
<tr>
<td>Sorghum starch</td>
<td>12.03</td>
<td>1.39</td>
</tr>
<tr>
<td>Potato starch</td>
<td>57.10</td>
<td>1.23</td>
</tr>
</tbody>
</table>

**Graph**:

- **Y-axis**: Apatite flotability (%)
- **X-axis**: Depression dosage (g/t)

Lines represent different types of starch:
- **Cornstarch** (yellow line)
- **Cassava starch** (red dashed line)
- **Potato starch** (blue dashed line)
- **Sorghum starch** (black dashed line)
- **Sorghum flour** (green dashed line)

The graph shows the decrease in flotability (%) of apatite with increasing depressant dosage (g/t). The data points for each starch type are marked with error bars indicating standard deviation.
The characterization of botanical sources showed that the tested samples showed similar results compared with literature data.

Potato starch showed the highest amylose content and sorghum flour the lowest, followed by sorghum starch.

The protein content of sorghum flour was 219% higher than sorghum starch. Additional test work is still required to investigate the influence of proteins in the mineral flotation.
Conclusions

• **Lipids** content was higher in sorghum flour than suggested in literature for use in the flotation process (oil could affect the froth inhibiting the flotation itself).

• However, the microflotation tests performed with Hallimond tube *no* such interference was observed.

• Even more, the visual aspect of the froth **was no different** between the froth formed when using the three depressants.
Conclusions

• The lowest apatite recoveries were found for **high dosages of depressant** (1,200 g/t).

• The **best results** were found for **cassava starch** and **sorghum flour**, indicating that these two botanical sources are better depressants then cornstarch, the standard depressant in Brazil nowadays.
Conclusions

• Besides the fact that *cassava starch* shows higher viscosity than cornstarch, the main issue is its *high price* when compared with cornstarch.

• The found results indicate that *sorghum*, no matter if milled as a flour or purified as a starch, can be used in apatite flotation as a depressant and its *depressant action is similar, or higher*, than cornstarch.
Conclusions

• Since sorghum price is 70 to 80% lower than corn, the flotation results can be seen not only technically but also economically important.
Acknowledgements

• The authors thank financial support from the Brazilian agencies CNPq, CAPES, FAPEG and FUNAPE.

• In addition, we like to thank LaMPPMin, Agroceres, Copebras, Labmic, UNIFESSPA, UFOP, UFG, UFMG, and TUC.
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