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Using Two Alternative Vegetable Oil’s as Collector in Apatite Froth Flotation

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USING TWO ALTERNATIVE VEGETABLE OILS AS APATITE COLLECTOR

Prof Dr André Carlos Silva
E.M.S. Silva; A.M. Machado; D.V.C. Cara; D.N. Sousa
About UFG and the LaMPPMin Modelling and Mineral Processing Research Lab

• Founded at December 14th 1960

• Federal public institution for higher education

• Eight campuses all over Goiás:
  • Aparecida de Goiânia (1)
  • Catalão (2)
  • Goiânia (2)
  • Goiás (1)
  • Jataí (2)
About UFG and the LaMPPMin Modelling and Mineral Processing Research Lab

• UFG IN NUMBERS

➢ Staff
  ✓ 2,500 teaching
  ✓ 1,880 PhD’s;
  ✓ 472 research groups;
  ✓ 2,400 administrative staff;

➢ Undergraduate
  ✓ 145 courses;
  ✓ 28,000 students;

➢ Postgraduate
  ✓ 38 Doctorate courses
  ✓ 69 Master courses;
  ✓ 4,000 graduate students.
About UFG and the LaMPPMin Modelling and Mineral Processing Research Lab

- Dedicated to Mineral Processing

- Founded in 2013

- Researches on
  - Flotation
  - Agglomeration
  - Concentration
  - Computer simulation
  - Comminution
• Teaching and Research

➢ Undergraduate
  ✓ 55 Scientific initiation
  ✓ 32 monographies

➢ Postgraduate
  ✓ 34 Lato Sensu monographies
  ✓ 11 Master thesis
  ✓ 2 Doctorate thesis (on going)

➢ Papers
  ✓ 40 in journals
  ✓ Over 150 in conferences

➢ Patents
  ✓ 5 applications for flotation new reagents
  ✓ 2 more to be deposit in 2018!
LaMPPMin as a consultant
Mine companies
LaMPPMin as a consultant
Mine companies
Introduction

• **New collectors**
  • Fatty acids based
  • Natural
  • Sustainable
  • Biodegradable
  • Cheaper
Macauba (*Acrocomia aculeata*) is a typical fruit from Brazilian Cerrado, and a perennial palm that naturally occurs throughout the tropical zone of Latin America.
Its economic exploitation occurs both in extractive systems as for rational cultivation with diverse products and applications as pharmacological, nutraceutical, timber, craft, forage, food, and fuel.
It is possible to extract oil from macauba pulp and nut.
Jatropha curcas (Jatropha curcas L.) has high oil productivity, resistance to hydric stress, soil and weather variations, and low production cost.
The seeds present good conservation after harvest and can be stored for long periods without degradation of the oil on them.
It was brought to Brazil to be used as hedge and for small-scale oil production and nowadays is cultivated in many areas of the country.
# Fatty acids profile

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>Macauba pulp*</th>
<th>Jatropha curcas**</th>
<th>Oils blend (50/50 in weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oleic – ω9 (C18:1)</td>
<td>58.7</td>
<td>25.7</td>
<td>42.2</td>
</tr>
<tr>
<td>Palmitic (C16)</td>
<td>19.7</td>
<td>19.6</td>
<td>19.7</td>
</tr>
<tr>
<td>Stearic (C18)</td>
<td>2.0</td>
<td>9.6</td>
<td>5.8</td>
</tr>
<tr>
<td>Cis-vaccenic – ω7 (C18:1)</td>
<td>1.9</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Linoleic – ω6,9 (C18:2)</td>
<td>7.3</td>
<td>40.0</td>
<td>23.7</td>
</tr>
<tr>
<td>Palmitoleic – ω7 (C16:1)</td>
<td>2.8</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Linolenic - ω3,6,9 (C18:3)</td>
<td>1.1</td>
<td>-</td>
<td>0.6</td>
</tr>
<tr>
<td>Gadoleic (C20:1)</td>
<td>0.1</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>Arachidic (C20)</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Myristic (C14)</td>
<td>1.1</td>
<td>-</td>
<td>0.6</td>
</tr>
<tr>
<td>Caprylic (C8)</td>
<td>1.1</td>
<td>-</td>
<td>0.6</td>
</tr>
<tr>
<td>Capric (C10)</td>
<td>0.5</td>
<td>-</td>
<td>0.3</td>
</tr>
<tr>
<td>Lauric (C12)</td>
<td>3.8</td>
<td>-</td>
<td>1.9</td>
</tr>
<tr>
<td>Elaidic (C18:1t)</td>
<td>-</td>
<td>2.5</td>
<td>1.3</td>
</tr>
</tbody>
</table>

*Pachêco et al., 2014; **Lemões et al., 2011.
Apatite sample preparation

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

Blue crystals of igneous apatite from Ipirá-BA, Brazil

+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>P2O5</th>
</tr>
</thead>
<tbody>
<tr>
<td>K2O</td>
<td>4.20</td>
<td>0.63</td>
</tr>
<tr>
<td>SiO2</td>
<td>1.10</td>
<td>0.39</td>
</tr>
<tr>
<td>SO3</td>
<td>0.34</td>
<td>0.34</td>
</tr>
<tr>
<td>I</td>
<td>0.27</td>
<td>0.18</td>
</tr>
<tr>
<td>Cl</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Na2O</td>
<td>0.10</td>
<td>0.06</td>
</tr>
<tr>
<td>ThO2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe2O3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MnO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BaO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SrO</td>
<td></td>
<td></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**

- $P_{20} \approx 22 \, \mu m$
- $P_{80} \approx 108 \, \mu m$

**Optical microscope image**
Materials and Methodology

- **Flotigam 5806** from Clariant, a synthetic mix of fatty acids, were used as collector benchmark.

- The oils preparation (saponification) followed the *manufacturer recommendations*.

\[
\begin{align*}
&5 \text{ g of Flotigam 5806 } + \\
&20 \text{ mL of distilled water } \\
&\text{Magnetic stirring } 5 \text{ min } \\
&+ 7.5 \text{ mL of NaOH } @ 10\% \\
&\text{Magnetic stirring } 5 \text{ min } \\
&\text{Magnetic stirring } 10 \text{ min } \\
&\text{+ distilled water until 100 g of solution}
\end{align*}
\]
Materials and Methodology

- **Air flow**: 40 cm³/min @ 10 psi
- **Apatite samples**: 1.0 g @ +106-150 μm (+150-100 #)
- **Conditioning time**: 7 minutes
- **Flotation time**: 1 minute
- **pH regulators**: HCl and NaOH (1%)
- **pH**: 8, 9, and 10
- **Collectors**: Macauba pulp oil, Jatropha curcas oil & Flotigam 5806
- **Collector dosage**: 0.5, 1, 2.5, 5, 7.5, and 10 mg/L
- **Distilled water**
APATITE RECOVERY (%) vs COLLECTOR DOSAGE (MG/L)

- Flotigam 5806 - pH 8
- Jatropha curcas - pH 8
- Macauba pulp - pH 8
APATITE RECOVERY (%)

COLLECTOR DOSAGE (MG/L)

- Flotigam 5806 - pH 9
- Jatropha Curcas - pH 9
- Macauba pulp - pH 9
Flotigam 5806: 91.66%
Pequi: 78.68%
Macauba nut: 34.91%
Macauba pulp: 95.40%
Jatropha curcas: 95.35%
Blend (50/50): 84.30%
Conclusions

- Macauba pulp and Jatropha curcas have potential as fatty acids source to be used as apatite collectors.

- In one hand, macauba pulp oil showed excellent results for all dosages and pH tested, with more than 90% of apatite recovery.

- In the other hand, Jatropha curcas oil, the second best collector tested, produced apatite recovery results almost as high as macauba pulp oil at high dosages (≥ 7.5 mg/L), and even higher at pH 10.
Conclusions

• Regarding the blended oil (50/50) no real advantages were found that could justify its industrial adoption.

• Flotation tests on bench scale (cell or column) using phosphate rock ore samples are required to validate the results from Hallimond tube, especially nowadays where carbonatites have risen as the predominant typologies within Brazil.
Acknowledgements

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Using two alternative vegetable oils as apatite collector

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