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# FROTH FLOTATION OF PHOSPHATE ROCK WITH HIGH CARBONATE CONTENTS, USING FATTY ACID SOAP IN THE PRESENCE OF DIFFERENT DEPRESSANTS: BENCH TESTS

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## ABSTRACT

The main Brazilian phosphate deposits (of igneous origin) have a complex mineralogy that is constituted by a carbonate gangue associated with the apatite. Due to this peculiarity, the mining industry has to look for new reagents and process conditions, that are able to decrease the production costs without compromising the process selectivity portrayed by high metallurgical recovery and useful substance ($P_2O_5$) and impurity (CaO and others) contents inside fertilizer industry specifications. This work aimed to study different depressant types in order to obtain concentrates with smaller $CaO/P_2O_5$ ratios. An ore with a high carbonate content that feeds the industrial plant of Tapira/MG was used. The studied variables were the collector hydrogenated soy bean oil soap dosages and the dosages of depressants (corn starch, sodium and potassium tartarate, sodium phosphate and sodium silicate) at 10.5 pH value. The $P_2O_5$ contents and $CaO/P_2O_5$ ratios in the concentrates and $P_2O_5$ metallurgical recoveries were analyzed, using factorial design of experiment. The depressant efficiency order in the studied ore froth flotation was: corn starch, sodium and potassium tartarate, sodium silicate and sodium phosphate.

KEY-WORDS: Phosphate rock froth flotation, apatite and calcite selectivity.

# 1 – INTRODUCTION

In general, the Brazilian phosphate rocks are very poor and these present quite complex mineralogy as in the case of alkaline pipe deposits that have high carbonate content. These ores are concentrated by froth flotation. It is known that one of the great challenges in phosphate froth flotation with high carbonate contents is to produce concentrates with smaller $CaO/P_2O_5$ ratios, since the apatite and the calcite have similar superficial properties, which result in low selectivity between these species in the froth flotation process. So, more detailed studies are required, such as, detailed technological characterization studies for each deposit ore typology, and the development of reagents and process conditions that are able to produce concentrates with $P_2O_5$ and impurity contents inside fertilizer industry specifications ( 33% of $P_2O_5$ content and maximum $CaO/P_2O_5$ ratio of 1,44).

Chula et al. (2004) have performed the mineralogical characterization of ten different phosphate ore samples that have a large amount of carbonates and silicates from the Fosfertil Mine in Tapira, Minas Gerais State, which were collected at a depth of about 120m. The X-ray diffraction, chemical analyses, optic microscopy, scanning microwave electronic techniques were applied to determine the mineralogical species, their chemical composition, their mineral association, and the carbonate form occurrence and apatite characteristics. The studied ores were subdivided into three groups: clinopyroxenites with low-grade weathering, mica clinopyroxenites and finally, clinopyroxenites with high magnetite and pirvskite contents. The carbonate minerals identified were calcite and dolomite that usually appear as a small vein across the other minerals or as inclusions in the apatite. These can make the flotation process difficult because an intense size reduction is needed in order to make the apatite particles free from the gangue minerals, which could be unfeasible.

Guimarães (2004) studied the behavior of the froth flotation process for four different typologies of phosphate ores from Tapira-MG: semi-compact silicified pyroxenite, compact silicified pyroxenite, silexite and serpentine pyroxenite, whose $CaO/P_2O_5$ ratios were 2.1; 3.5; 2.5 and 1.33, respectively, using the hydrogenated soy bean oil soap, a sulfossuccinate (Ke883) and the mixture of soy bean oil soap / Ke883 in the 7 : 3 proportion in the presence of a corn starch depressant. Through these studies, it was verified that the $CaO/P_2O_5$ ratios of the concentrates for all collectors studied were larger for the ores that had larger $CaO/P_2O_5$ ratios, and that the $CaO/P_2O_5$ ratios increased with the increase of the collector dosage at 11 pH value, except for the silexite ore, whose pH value was 8. In general, the concentrates that were obtained with the collector Ke883 possessed smaller $CaO/P_2O_5$ ratios; however the recovery of $P_2O_5$ was smaller than the values reached with the other tested collectors.

Wellenkamp et al. (2001) performed studies of phosphate ore froth flotation from Barreiro-Araxá/MG supplied by the Serrana Fertilizantes S.A. company that had the following chemical characteristics: 22.96% of $P_2O_5$; 29.22% of CaO; 16.22% of $Fe_2O_3$; 11.84% of $SiO_2$; 0.98% of MgO and 1.42% of $BaSO_4$. In these studies a rice oil soap collector (80 g/ton) was used in the presence of an impure corn starch gelatinized depressant (300 g/ton). The value of the froth flotation pH was 11.5. Under these conditions, a concentrate with 34.7% of $P_2O_5$ content and a 51.2% metallurgical recovery of $P_2O_5$ was produced.

Luvizzoto (2003) performed several microflotation tests with the apatite, calcite and dolomite minerals. In these studies, a hydrogenated soy bean oil soap collector was used in the presence of several depressants (corn starch, sodium silicate, sodium and potassium tartarate and sodium phosphate) in order to obtain selectivity conditions among apatite mineral separation from the other two carbonates (calcite and dolomite) by froth flotation Through these studies, it was verified that the efficiency order in the depression of the mineral calcite was the following: corn starch, sodium silicate, sodium and potassium tartarate and sodium phosphate at the same pH value of 10.5. However, only the corn starch was efficient in the dolomite depression. The depression of the mineral apatite was larger or of the same level as the depression of the dolomite. It was observed that the sodium silicate was not efficient for dolomite depression.

This work objected to verify the behavior of a phosphate ore with a high $CaO/P_2O_5$ ratio sample by using fatty acid (commercial soap of soy bean oil) in the presence of the depressants: gelatinized corn starch, sodium silicate, sodium phosphate, and sodium and potassium tartarate in the froth flotation bench scale tests.

# 2 – MATERIALS AND METHODS

The ore sample used in this work, that feeds the Fosfertil/Tapira-MG industrial processing plant, had 8.4% of $P_2O_5$ and 21.75% of CaO content, respectively. So the $CaO/P_2O_5$ ratio in the feed was 2.60.

The rougher bench scale froth flotation tests were done by using a Denver Cell at the UFOP Mineral Processing Laboratory. The reagents used were:

- Collector - soy bean oil soap (manufactured by Hidroveg) at 5% w/v concentration
- Depressant - commercial corn starch (manufactured by Cargill), gelatinized with sodium hydroxide, at 2% w/v; sodium silicate, sodium phosphate and sodium and potassium tartarate of analytical degree at 5% w/v.
- pH modifiers - solutions of NaOH or HCl at 1% w/v.

The operational conditions were the following:
- Percentage of the solids in the conditioning and in the froth flotation - 60 and 30%, respectively;
- Cell rotation in the conditioning and in the froth flotation - 800 and 1000 RPM, respectively;
- Froth flotation pH – 10.5 value.

The investigated variables were the collector dosages, type and depressor dosages using factorial design of experiment $2^2$. In Table I the variable levels of the first factorial design of experiment are presented with their respective codes. The results analyzed were $P_2O_5$ content in the concentrate - X; $CaO / P_2O_5$ ratio in the concentrate - Y and $P_2O_5$ metallurgical recovery - Z.

Table I – Level variables of the first factorial design of experiment.

| Variables | Levels | | Code |
|---|---|---|---|
| | - | + | |
| Collector dosage (g / ton) (hydrogenated soy bean oil soap) | 300 | 1200 | A |
| Depressant dosage (g / ton) | 300 | 1200 | B |

After analyzing the results of the first factorial design of experiment by using the Yates's algorithm, it was observed that there was a need for a second factorial design of experiment with the systems: soy bean oil soap/sodium phosphate, soy bean oil soap/sodium and potassium tartarate. In the case of the system soy bean oil soap/sodium and potassium tartarate, the soy bean oil soap dosage was fixed at 300 g/ton, which resulted in lower $CaO/P_2O_5$ ratios of the concentrates. In this case the sodium and potassium tartarate dosage were carried out at 150 and 600 g/ton. In the case of the system soy bean oil soap/sodium phosphate, the sodium phosphate dosage was fixed at 1200 g/ton, for the same reason mentioned previously (lower $CaO/P_2O_5$ ratios of the concentrates), the tests were done at 750 and 1500 g/ton of soy bean oil soap dosages.

## 3 – RESULTS

After analyzing the results of the factorial design of experiment for the experiments with the hydrogenated soy bean oil soap collector and the corn starch and the sodium silicate depressants, it was verified that at 300 and 1200 g/ton levels for all reagents studied, no significant effects were produced in the analyzed response variables: the $P_2O_5$ metallurgical recovery, the $P_2O_5$ concentrate contents and the $CaO/P_2O_5$ ratio in the concentrates. Both collector (soy bean oil soap) dosages and sodium phosphate dosages had influence on the $P_2O_5$ content and $CaO/P_2O_5$ ratios of the concentrates and only the depressant dosage had significant effect on $P_2O_5$ metallurgical recovery. For the system soy bean oil soap/sodium and potassium tartarate, it was verified that only the depressant dosage had influence on the content of $P_2O_5$ in the concentrate and the metallurgical recovery of $P_2O_5$; see the equations in Table II.

Through table III, it is possible to conclude that both concentrate content and metallurgical recovery of $P_2O_5$ obtained with the 300 g/ton of soy bean oil soap and 1200 g/ton of corn starch dosages were greater than those values obtained with the same collector dosage and at 300 g/t of sodium silicate dosage.

For the system soy bean oil soap/sodium phosphate, it was observed that the largest metallurgical recovery of $P_2O_5$ was obtained with the 300 g/ton soy bean oil soap dosage. However, the concentrate $P_2O_5$ contents were around 15%. In all the tested dosages, except for 750 g/ton of soy bean oil soap, the $P_2O_5$ content in the concentrates varied from 15 to 18.5%. In other words, the enrichment ratio reached was around 2 (Figure 1). The $CaO/P_2O_5$ ratio in the concentrates varied from 1.5 to 2 with the increase of the collector dosage. It was expected, see Figure 2. The $P_2O_5$ contents and $CaO/P_2O_5$ ratios in the concentrates were smaller than the values reached with the same corn starch dosage. A much smaller dosage of sodium silicate (300 g/ton) was enough to obtain concentrates with superior quality to that which was obtained at 1200g/ton sodium phosphate, in spite of the smaller $P_2O_5$ recovery level obtained for the dosage of soy bean oil soap that was of 300 g/ton. So, it can be affirmed that this reagent had a smaller performance to depress the carbonates minerals than the corn starch and the sodium silicate depressants, which confirms the microflotation tests results obtained by Luvizzoto (2003).

Table II – Effect equations of the A (soy bean oil soap dosage) and B (depressant dosage) variables of the first factorial design of experiment on the $P_2O_5$ content, $CaO/P_2O_5$ ratio in the concentrate and $P_2O_5$ metallurgical recovery of the phosphate rock studied.

| Depressant | Results | | |
|---|---|---|---|
| | $P_2O_5$ content (X) % | CaO / $P_2O_5$ ratio(Y) | $P_2O_5$ recovery (Z) % |
| Corn starch | 22.40 | 1.64 | 52.71 |
| Sodium silicate | 20.16 | 1.42 | 67.16 |
| Sodium phosphate | 16.98 + 5.39 A – 3.72 B – 5.83 AB | 1.98 – 0.65 A – 0.65 B + 0.75 AB | 53.99 + 60.65 B |
| Sodium and potassium tartarate | 22.70 – 9.76 B | 1.48 | 68.60 + 39.76B |

Table III – Optimized results values: $P_2O_5$ (X) and $CaO/P_2O_5$ ratio (Y) in the concentrates and $P_2O_5$ metallurgical recovery (Z) with the system soy bean oil soap/corn starch and the system soy bean oil soap/sodium silicate.

| Collector/depressant (g/ton) | Optimized response |
|---|---|
| Soy bean oil soap/corn starch (300/1200) | X = 33.18%<br>Y = 1.50<br>Z = 73.74% |
| Soy bean oil soap/sodium silicate (300/300) | X = 27.83%<br>Y = 1.4<br>Z = 52.28% |

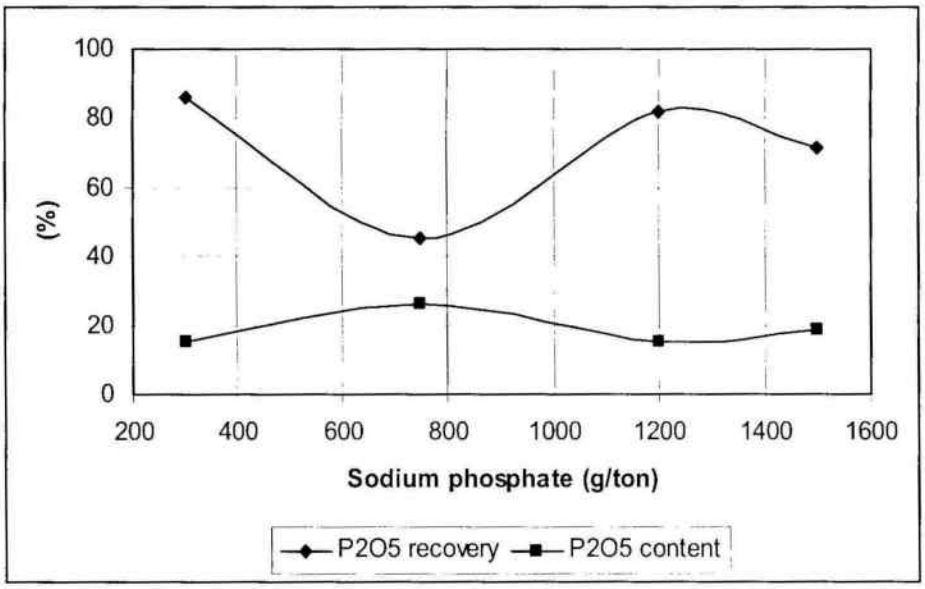


Figure 1 –Metallurgical recovery of $P_2O_5$ and $P_2O_5$ concentrate contents at 1200 g/ton of sodium phosphate dosage related to soy bean oil soap dosages at 10.5 pH value.

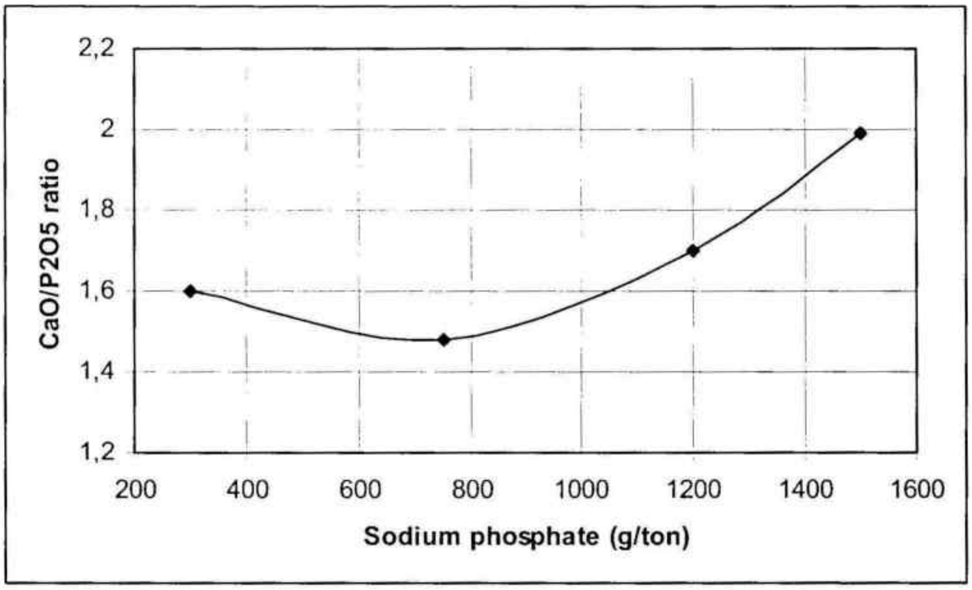


Figure 2 – $CaO/P_2O_5$ ratio in the concentrates at 1200 g/ton of sodium phosphate dosage related to the soy bean oil soap dosages at 10.5 pH value.

Metallurgical recoveries of $P_2O_5$ from 30 to 58% were obtained when the soy bean oil soap dosage was fixed at 300 g/ton and the sodium and potassium tartarate dosages were varied. However, in a general way, it can be affirmed that the concentrate $P_2O_5$ contents obtained were much greater than that obtained with the 1200 g/ton sodium phosphate dosage, compare the Figures 1 and 3. The concentrate $CaO/P_2O_5$ ratios changed from 1.5 to 1.6. The $P_2O_5$ metallurgical recoveries, the $P_2O_5$ contents and the $CaO/P_2O_5$ ratios in the concentrates were compatible with those values obtained with the sodium silicate. However, both $P_2O_5$ contents and the $CaO/P_2O_5$ ratios in the concentrates were quite smaller than those values reached with the system soy bean oil soap and corn starch (300/1200 g/ton), but with much smaller $P_2O_5$ metallurgical recovery levels, see Table III.

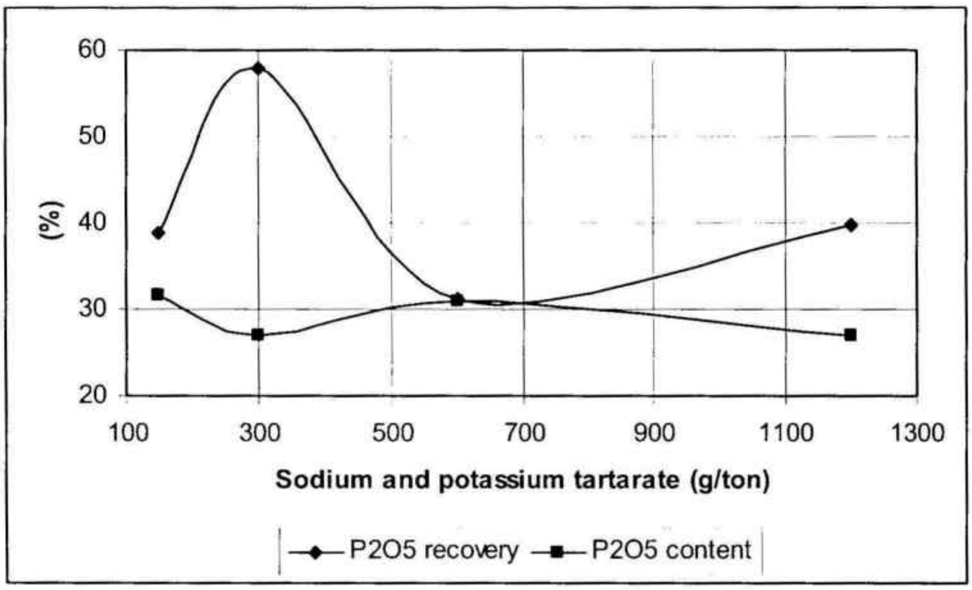


Figure 3 – Metallurgical recovery of $P_2O_5$ and $P_2O_5$ concentrate contents at 300g/ton of soy bean oil soap related to sodium and potassium tartarate dosages at 10.5 pH value.

It can be affirmed that the depressant performances, investigated for the phosphate rock froth flotation that feeds the industrial processing plant of Tapira-MG, were the following: corn starch, sodium and potassium tartarate, sodium silicate and sodium phosphate were compatible with the data of the microflotation investigated by Luvizzoto (2003), except that the sodium silicate and sodium phosphate.

## 4 – CONCLUSIONS

- The efficiency order in the depression of the carbonates minerals in the phosphate rock froth flotation from Tapira/Mg was: corn starch, sodium and potassium tartarate, sodium silicate and sodium phosphate.

- The best result obtained in the froth flotation tests was at 300 and 1200 g/ton of soy bean oil soap and corn starch dosages, respectively: 33.18% of $P_2O_5$ content, 1.5 $CaO/P_2O_5$ ratio in the concentrate and $P_2O_5$ metallurgical recovery of 73.74%. This signifies that the analyzed items are practically inside market fertilizer industry specifications (minimum 33% of $P_2O_5$ content and maximum of 1.44 of $CaO/P_2O_5$ ratio in the concentrate).

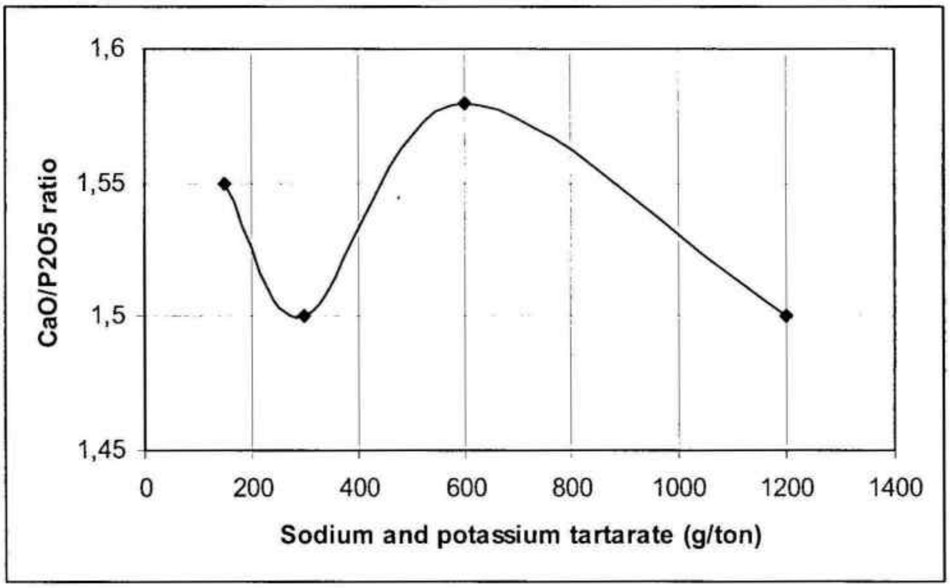


Figure 4 – $CaO/P_2O_5$ ratio of the concentrate at 300 g/ton of soy bean oil soap dosage related to sodium and potassium tartarate dosage at 10.5 pH value.

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