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ORIGINAL ARTICLE

# Beneficiation of feldspar ore for application in the ceramic industry: Influence of composition on the physical characteristics

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**Abstract** In this study, physical and physicochemical experiments were carried out to improve the quality of feldspar ore in Sidi Aïch massive, located in the Gafsa region of south-western Tunisia. After determination of the mineralogical and the chemical composition, flotation methods were applied. In this study, non-hydrofluoric acid flotation methods used in feldspar-quartz separation were compared with each other and with the conventional HF/amine method. The results showed that conventional HF/amine method is the most effective and selective method.

Experimental studies indicate that an acceptable concentrate for industrial application can be obtained from these rocks. The feldspar yield was used to evaluate the process efficiency. Besides, the cone shrinkage, water absorption, degree of vitrification, mechanical properties (flexural strength) and dielectric behaviour were used to monitor the quality of the recovered feldspars.


## 1. Introduction

The demand for feldspar as a raw material for the ceramic and glass industries is continuously increasing. In Tunisia, the traditional sources of feldspar, pegmatite and nepheline syenite ores do not exist. This implies a great importation of this raw material (26 millions dinars, at 2007). It became, therefore, imperative to look at other types of deposits, such as arkosic sandstone. In south and central Tunisia, extensive deposits of arkosic sandstone (Sidi Aïch Formation) are present. In this formation, there are two major industrial minerals potash feldspar (microcline) and quartz.

Many papers on the application of collectors in the flotation of feldspar have been published. Feldspar has been traditionally separated from quartz using amine type cationic collectors and hydrofluoric acid as activator for feldspar (Rabone, 1957; Shimoiizaka et al.,1976; Manser, 1975; Thom, 1962; Crozier, 1990; Demir et al., 2003).

The use of HF is no longer acceptable due to environmental restrictions and health hazards. Several research investigations

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**Table 1** Chemical analysis of the different size fractions of Sidi Aich sand.

| Size fraction (μm) | Mass (%) | CaO | MgO | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | $Na_2O$ | $K_2O$ |
|---|---|---|---|---|---|---|---|---|
| Feed (raw material) | 100 | 0.12 | 0.06 | 89.85 | 0.28 | 4.07 | 0.15 | 2.94 |
| −500 + 315μ | 2.85 | 0.62 | 0.19 | 82.22 | 0.57 | 7.95 | 0.18 | 4.77 |
| −315 + 200μ | 9.63 | 0.21 | 0.07 | 86.64 | 0.28 | 6.57 | 0.16 | 4.86 |
| −200 + 125μ | 75.7 | 0.46 | 0.05 | 83.56 | 0.31 | 8.16 | 1.83 | 2.21 |
| −125 + 80μ | 8.57 | 0.16 | 0.09 | 92 | 0.39 | 3.4 | 0.23 | 1.97 |
| −80 + 63μ | 1.1 | 0.45 | 0.19 | 87.71 | 0.85 | 4.91 | 0.54 | 2.12 |
| −63μ | 1 | 1.23 | 0.38 | 79.08 | 1.37 | 8.81 | 0.59 | 2.74 |

and experimental studies have been successful in developing a non-HF flotation process for the separation of quartz and feldspar (Katayanagi, 1974; Malghan, 1976; Malghan, 1981). El Salmawy et al. (1993a) floated quartz from feldspar using an anionic surfactant in the presence of metal hydroxy complexes or by using nonionic surfactants (El-Salmavy et al., 1993b). A combined cationic–anionic collector, N-tallow-1,3-propylene diamine/dioleate, was also applied on feldspar ores (Vidyadhar et al., 2002).

This paper describes the application of non-hydrofluoric acid flotation methods used in feldspar-quartz separation and the comparison with conventional HF/amine method. In order to enhance the feldspar beneficiation, this study seeks to determine the mechanical and dielectric behaviour of ceramic based on floated feldspar.

## 2. Materials and methods

The representative ore sample is obtained from Gafsa Province (Kanguet El Ouara), Tunisia (Table 1). For the size analysis, standard sieves from the "AFNOR" series were used. Minus 63 μm particles were separated by wet sieving after attrition in Wemco, Unitec machine, equipped with a 9 l cell. Attrition was carried out at 1400 rpm impeller speed for 5 min and 70 percent solids by weight. The oversized particles were reground to −250 μm in a ceramic ball mill in order to minimize the iron contamination of the sample. Flotation experiments were conducted with −250 + 63 μm test sample in a self-aerated Denver D12 flotation machine, equipped with a 3-l cell. Both conditioning and flotation were carried out at the same impeller speed (1200 rpm) and percent solids by weight (20–30%). A conditioning period of 5 min. for the first-stage conditioning and 3 min. for the subsequent stages of collector addition was utilized.

In order to reduce the $TiO_2$ and $Fe_2O_3$ content of the ore, an anionic collector, namely E 526 supplied by ArrMaz Florida, United States, which is based on sodium petroleum sulfonates and known to have selectivity for these minerals, was used.

The feldspar minerals and quartz were separated from each other by flotation of feldspar minerals and depression of quartz minerals. Both feldspar and quartz in amine flotation and in the absence of HF need not be floated at pH less than 4. However, in the presence of HF feldspar is floated at pH 2–3 while quartz does not float. Feldspar was floated using tallow amine acetate at a pH of 2–3 (Abdel-Khalek et al., 1994; Sekulic et al., 2004), with a pulp density of 25%. Hydrofluoric acid (HF) was used as quartz depressant and feldspar activator. This is accomplished by adding about 2000 g/t of 40% concentrated HF. No frother was added and the collector dosage was optimized at 600 g/t of Aero 3030C, collector supplied by CYTEC United states and composed of Amines, tallow alkyl acetates and Ethyl hexanole. Non-hdrofluoric acid flotation method was applied using anionic–cationic collector combination (Cutusamine 9002 + E 526 supplied by ArrMaz Florida, United States).

The floated fraction (the feldspar concentrate) and unfloated fraction (the quartz concentrate) were analysed for total balance by an Atomic Absorption Spectrophotometer (AAS) "Perkin Elmer" for the following oxides: $SiO_2$, $Al_2O_3$, $Fe_2O_3$, MgO, CaO, $Na_2O$, $K_2O$, $TiO_2$.

This feldspar was dry milled in a ball mill for 30 min to homogenize the mixture. The samples were dried for 48 h in air and then at 110 °C for 24 h in an electric furnace. After drying, they were formed into a cylinder with 16 mm in diameter and 5 mm in thickness using uniaxial moulding and then pressed at 100 MPa. The formed sample was sintered at 1230 °C for 24 h (condition used by the industrial).

The densification behaviour was described in terms of firing shrinkage, water absorption, and diametral compressive strength. Firing shrinkage values upon drying and sintering were evaluated from the variation of the length of the bodies. Water absorption values were determined from the weight differences between the as-sintered and the water saturated samples (immersed for 2 h in boiling water), according to the French standard (AFNOR EN 99, 1982).

The bending strength values were determined by using an universal testing machine (model NETSZH). We calculated average values of bending strength using the equation: $R$ (N/mm$^2$) = $3FL/bh^2$, where $F$ is the breaking load in kilograms, $L$ = 29.67 mm the distance between supports, $b$ the sample width in millimetres and $h$ the sample thickness in millimetres. This test is carried out according to the French standard (AFNOR EN 100, 1982).

## 3. Sample characterization

Sidi Aïch sand is composed of weekly cemented grains. Grain size distribution of sample is shown in Table 1, about 90% of the sample is more than 125 μm. Examination of thin and polished sections was supplemented by SEM-EDX and X-ray diffraction analysis showed that the ore contains mainly quartz and microcline that display cross-hatch twinning and fresh cleavage (Fig. 1) with minor amounts of albite, kaolinite and illite (Fig. 2). Microscopic examination of heavy minerals, after separation in dense liquid (bromoforme), reveals accessorily the presence of zircon, rutile tourmaline and staurolite. The amount of this fraction does not exceed 1% (Gallala et al., 2009a,b).