**PERIODICO di MINERALOGIA**
*established in 1930*

Dipartimento
di Scienze della Terra

Sapienza
Università di Roma

*An International Journal of*
Mineralogy, Crystallography, Geochemistry,
Ore Deposits, Petrology, Volcanology
and applied topics on Environment, Archaeometry and Cultural Heritage

# Optimization of feldspar grinding parameters for unlimited processing: Case of Algerian feldspar

Lwiza Maamar [1,*], Abdellali Bouzenzana [2], Abdeslam Chaib [3], Abderahman Yahi [4,5]

[1] L3M the mining, metallurgy and material laboratory, Higher National School of Technology and Engineering, 23003, Annaba, Algeria
[2] Laboratory of Mines, Institute of Mines; University of Tebessa, 12000, Tebessa, Algeria
[3] Laboratory for Mining and Environment Resource Development, Badji Mokhtar University, 23003, Annaba (LAVAMINE), Algeria
[4] 3G Georesource, Geosystem and Geoenvironment Laboratory, 6072, Gabès, Tunisia
[5] Water resources laboratory and sustainable development, 23003, Annaba, Algeria

## ARTICLE INFO

Submitted: March 2025
Accepted: September 2025
Available on line: October 2025

* Corresponding author:
l.maamar@etu.ensti-annaba.dz

Doi: 10.13133/2239-1002/18869

How to cite this article:
Maamar L. et al. (2025)
Period. Mineral. 94, 255-263

## ABSTRACT

Ore grinding is an essential step in mineral processing, which aims to reduce ore dimension and improve recovery in separation stages. An excessive generation of fines during grinding of feldspar ore frequently limits its treatment. Most of the previous studies have focused on the analysis of ultrafine particles to allow for treatment by flotation or leaching, which costs energy and is not environmentally friendly. the present study aims to increase the yield of potash feldspar in a coarser size range (-0.5 to +0.063 mm), allowing the use of alternative, cleaner, and less energy-consuming processing techniques by optimizing the grinding parameters. Optimal recovery of feldspar using physical separation methods was achieved by modifying ball mill parameters according to particle size and employing Response Surface Methodology (RSM) for particles ranging from 0.5 mm to 0.063 mm. The results present a proportional relationship between weight yield and grinding time; the optimum conditions were 16 minutes of grinding with an 82.5% filling charge. The study demonstrated that feldspar ore needs similar grinding time to attain an equivalent particle size, despite if the process proceeds dry or wet, indicating no difference in grinding performance between the two modes. The ratio of fine particles markedly escalates with extended grinding, underscoring the importance of optimizing and controlling grinding time to avoid overgrinding and ensure effective size reduction.

Keywords: Algerian feldspar; grinding; PSD; RSM; optimization.

## INTRODUCTION

In mineral processing, grinding is a combined operation with the objective of liberating valuable minerals from the gangue. This process constitutes a preliminary stage that optimizes the liberation of minerals or metals by increasing the surface area of mineral particles, promoting selective breakage, and ensuring a more efficient and precise separation during processing (Matsanga et al., 2023; Tian et al., 2024; Lorig and Clarence, 2017; Elbendari et al., 2020; Bouzenzana A., 2015).

Feldspar is among the most abundant minerals on Earth, representing approximately 60% of the rocks (Aliyu et al., 2016). It primarily occurs as anorthite ($CaAl_2Si_2O_8$), albite ($NaAlSi_3O_8$), and orthoclase or microcline ($KAlSi_3O_8$) (Radoslovich, 1975; Liu et al., 2017; Smith, 2012). Owing to its physicochemical properties-such as melting behaviour, transparency, optical properties, thermal expansion, and shock resistance-as well as its chemical composition with quartz, alumina, and alkali oxides (Umucu and Deniz, 2015; Silva et al., 2019), feldspar is extensively used as a fluxing agent in the manufacture of glass and ceramics (Ismail et al., 2018; Dondi, 2019; Bowles and Lee, 1930; Silva et al., 2019; Bozkurt et al., 2006).

In Algeria, the Ain Barbar feldspar deposit is located in the northeastern region. It is a rhyolitic dyke from which feldspar is extracted as an economical material for the ceramic industries (Belaidi et al., 2024; Chaib et al., 2016; Marignac et al., 2016; Gökçen et al., 2015). However, the hardness of feldspar (6 to 6.5 on the Mohs scale) makes it difficult to reduce by conventional crushing techniques, necessitating the use of advanced grinding methods to achieve effective liberation and particle size reduction.

Despite technological advances, grinding feldspar remains a technical challenge, particularly in achieving the desired particle size distribution while minimizing the production of excessive fines. Many studies have investigated micro-grinding, which is increasingly needed in industries because of its effectiveness in applications like glass and chemical fillers (Yassin et al., 2023; Tian et al., 2018). At the same time, many studies have been focused on the fine grinding of feldspar (Gökçen et al., 2015; Ravaszová et al., 2022; Bilir and Ipek, 2021; Marignac et al., 2016). Only a few studies have addressed the enhancement of yield in coarser target size fractions (Yassin et al., 2024); additionally, the clay-rich texture of some feldspar ores often leads to excessive fines during grinding, reducing the usability of the material.

To address these limitations, the present study aims to optimize the grinding performance of feldspar by maximizing the yield of desirable particle size fractions and minimizing fine production. A full factorial design was applied to focus on the impact of variables such as the time and filling charge using the surface response methodology (RSM). This statistical approach allows for an in-depth analysis of factor interactions while reducing the number of required experimental runs, ultimately leading to more efficient and cost-effective process optimization (Bilir and İpek, 2021).

## MATERIALS

The sample used in this study was a potash feldspar ore from the Felsite deposit at Ain Barbar, Annaba, in Algeria (Figure 1). This deposit is divided into seven blocks; the samples collected are 5 points from the sixth block, which is currently the only one in operation.

The milling method for this study was conducted using a semi-autogenous ball mill (the laboratory of the

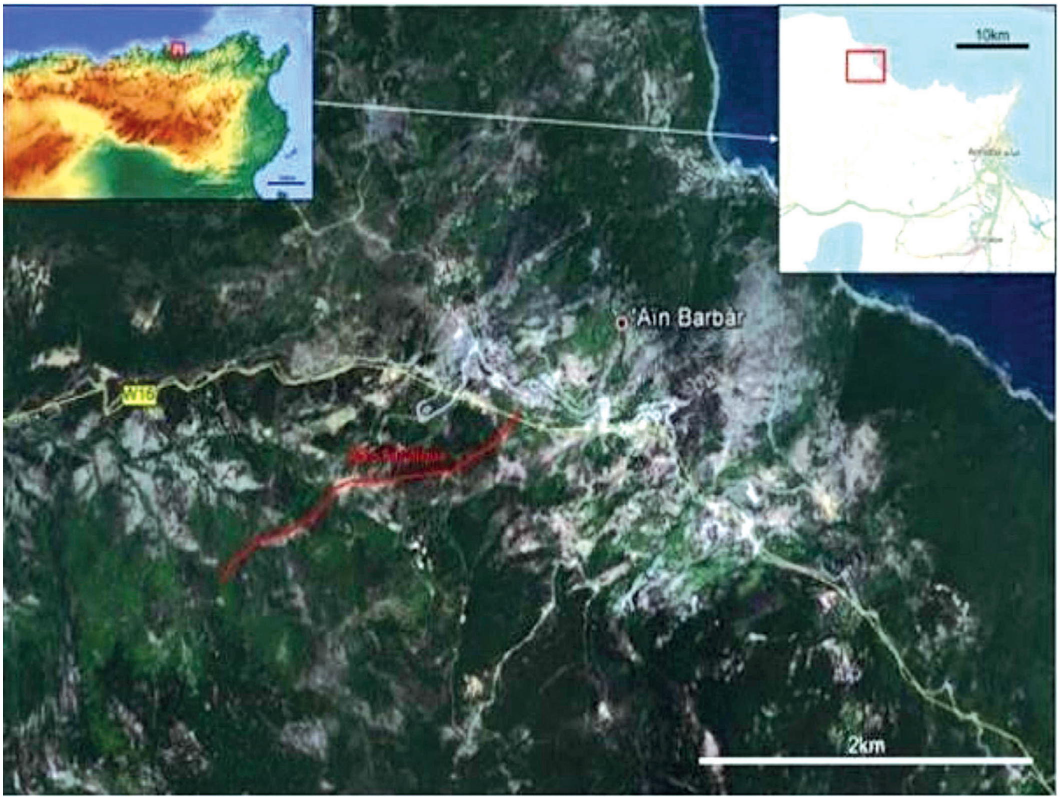

Figure 1. Representation of the deposit's geographic positioning.

Mining Department at Badji Mokhtar University-Annaba, Algeria), in which both feldspar ore and balls served as grinding media (Figure 2a). The sieve analysis was conducted using a RETSCH vibratory sieving apparatus (Figure 2b), in compliance with European Standard EN12620, the comminuted feldspar feed was classified and regrouped into three size classes: +0.5 mm, -0.5 +0.063 mm, and -0.063 mm. The choice of cut sizes was based on the feldspar liberation size (≈0.25 mm), ensuring proper representation of coarse, intermediate, and fine fractions.

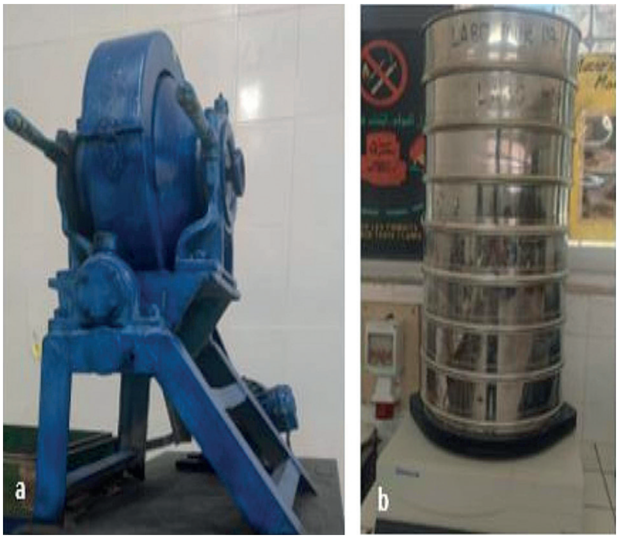

Figure 2. Laboratory equipment used in the grinding experiments. a) laboratory-scale ball mill used for grinding tests; b) RETSCH vibratory sieve shaker used for particle size analysis.

The chemical composition of the feldspar ore was analyzed through X-ray fluorescence (XRF) spectroscopy (ZSX Primus II). The results are presented in Table 4.

For the mineralogical analysis, an X-ray diffraction analysis was performed to determine the various mineral phases present in the sample, with the results summarized in Table 5.

An SEM analysis was done on the rock cube of the feed (Figure 3).

## METHODS

The feldspar samples were crushed using a jaw crusher, which reduced the particle size to less than 10 mm After the crushing operation, the material was divided into thirteen (13) samples.

The experiments were carried out with three different grinding times; the grinding times studied were 10 minutes, 15 minutes, and 20 minutes.

The grinding media ratio to the total filling charge (40% of the total volume) in the mill was another variable considered. Three different ratios of grinding media to the full charge were utilized to determine their effect on the grinding process. The ratios were 75%, 82.5%, and 90% of the filling charge. The detailed specifications of the laboratory ball mill used in this study are presented in Table 1, and the factorial design matrix including the experimental variables and their respective levels is provided in Table 2.

To evaluate milling performance, the ground samples

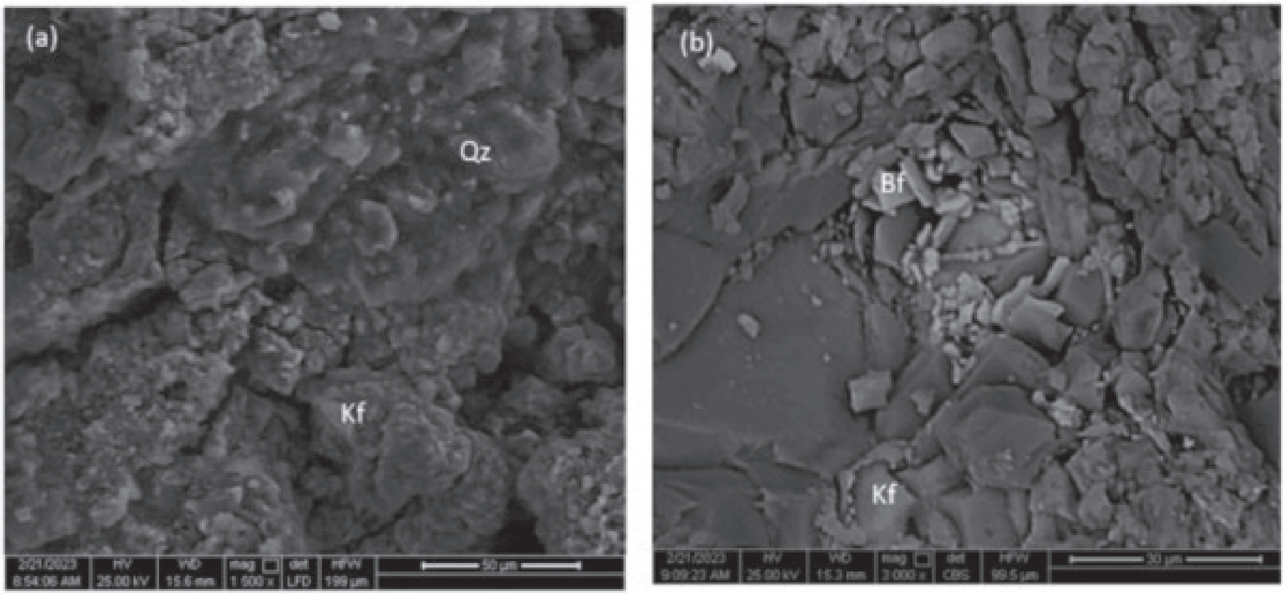

Figure 3. SEM images for the feed rock of feldspar.

Table 1. Specifications of the laboratory ball mill.

| Parameter | Description | Value |
|---|---|---|
| Mill | Type<br>material<br>Volume, $cm^3$<br>Speed mill, rpm<br>Time, minute<br>Filling charge | Ball mill<br>Stainless steel<br>3532<br>109<br>Variable<br>Variable |
| Balls | Material<br>Mass of balls, % Ball size, mm | Steel variable<br>25-40 |
| Material | Specific<br>Feed size, mm | Feldspar<br>10 |

Table 2. DOE parameters.

| Factors | Levels | | |
|---|---|---|---|
| | -1 | 0 | +1 |
| Grinding time, minute | 10 | 15.0 | 20 |
| Filling charge, % | 75 | 82.5 | 90 |

were subjected to a standardized dry sieving procedure to determine the particle size distribution (PSD), as summarized in Figure 4. The sieve stack comprised the following mesh sizes, arranged in descending order: 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, and 0.063 mm. Each sieving session was performed for 30 minutes to ensure complete separation. To verify repeatability and reliability, all sieving analyses were conducted in duplicate (r=2), and mean values were used for further interpretation.

The primary response variable was defined as the cumulative yield of particles passing the 0.5 mm sieve and retained on the 0.063 mm sieve (500-63 μm). Particular attention was given to the -0.5 +0.063 mm fraction, as it contains most of the liberated feldspar and represents the optimal range for physical beneficiation. Targeting this size fraction minimizes excessive fine generation, improves energy efficiency, and broadens feldspar upgrading pathways beyond conventional leaching or flotation. In addition, the percentage of fines (<63 μm) was recorded to assess the extent of overgrinding.

Optimization experiments were conducted using a $3^2$ full factorial design to investigate the effect of residence time and filling charge on the grinding of K-feldspar ore. Thirteen experimental runs, including replications of

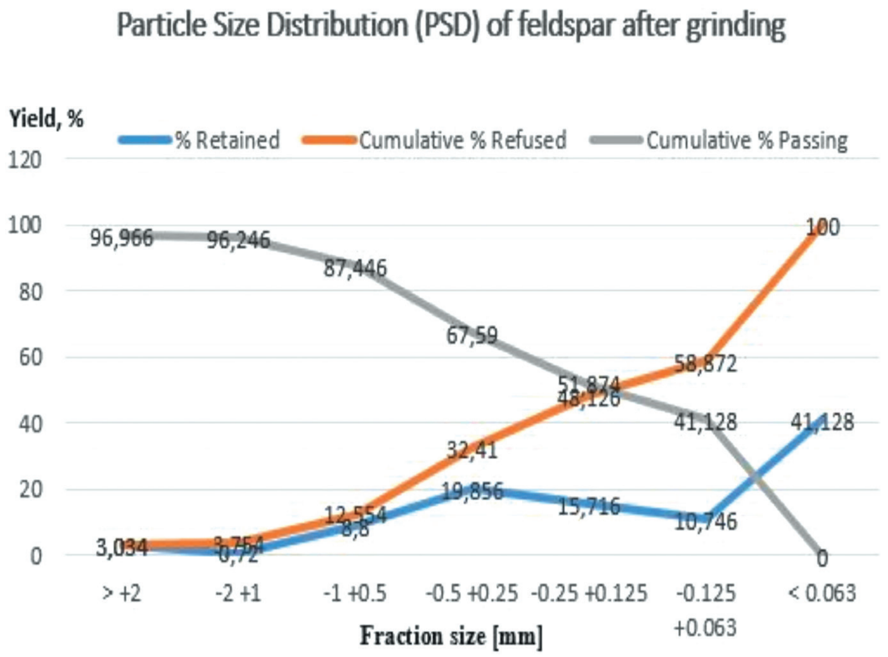

Figure 4. Particle size distribution (PSD) of the ground feldspar sample.

center points, were conducted. Table 3 presents the DOE matrix along with the measured yields in two particle size fractions: [-05+0.063] mm and [-0.063] mm.

## RESULTS

The chemical composition of the feldspar sample, as determined by X-ray fluorescence (XRF), is presented in Table 4. The analysis reveals that the ore contains 72.15% $SiO_2$ and 14.15% $Al_2O_3$, which are consistent with typical feldspathic materials. Minor components include $K_2O$ at 10.43% and $Fe_2O_3$ at 1.28%, indicating the presence of potassium feldspar and a moderate level of iron impurities.

X-ray diffraction (XRD) analysis reveals that the Ain Barbar feldspar ore is predominantly composed of quartz, orthoclase, and muscovite as clay mineral (Table 5). A minor presence of kaolinite was also detected.

The SEM image provides key insights into the texture and liberation potential of the sample. The micrographs reveal a compact interlocking of feldspar with associated gangue minerals such as quartz, highlighting the necessity for intensive grinding to achieve adequate liberation (Figure 3b). Moreover, the micro-fractures indicate previous alteration (Figure 3a), which makes it very easy for associated minerals to be released during late processing steps.

The results of the particle size analysis indicate that the significant range of the yield is between 0.5 mm and 0.25 mm and below 0.063 mm in all tests (Figure 4). This suggests that the liberation of feldspar occurs mainly within the particle size range of [-0.5, +0.25] mm.

The regression analysis used to optimize the yield weight of feldspar in the particle size range [-0.5, +0.063] mm provides important insights into the impacts of grinding time and filling charge. The findings are shown in Table 6.

The regression equation for the ball mill was:

$$\text{Yield weight} = 49.8775+1.78875X_1-0.3645X_2-0.1279(X_1-15)^2-0.0941(X_2-82.5)^2-0.0113(X_1-15)(X_2-82.5)$$

Table 3. Applied DOE matrix for grinding process of K-feldspar. α=1

| Run | $X_1$ | $X_2$ | Experimental value % | |
|---|---|---|---|---|
| | | | In [-0.5+0.063] mm | In [-0.063] mm |
| 1 | -1 | 1 | 29.370 | 33.200 |
| 2 | 1 | 1 | 45.600 | 36.400 |
| 3 | 0 | 1 | 46.318 | 41.128 |
| 4 | -1 | 1 | 45.352 | 46.292 |
| 5 | 0 | 1 | 46.000 | 40.000 |
| 6 | 0 | 1 | 46.008 | 41.100 |
| 7 | 0 | 1 | 45.000 | 41.500 |
| 8 | 1 | 1 | 43.122 | 49.068 |
| 9 | -1 | 1 | 41.286 | 39.520 |
| 10 | 1 | 1 | 31.200 | 26.000 |
| 11 | 0 | 1 | 47.000 | 42.000 |
| 12 | 1 | 1 | 30.422 | 33.600 |
| 13 | -1 | 1 | 39.200 | 32.800 |

Table 4. Chemical analysis by XRF.

| Elements | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | $K_2O$ | $Na_2O$ | $P_2O_5$ | $TiO_2$ | PF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Content (%) | 72.15 | 14.15 | 1.28 | 0.37 | 0.05 | 0.1 | 10.43 | O.24 | 0.17 | 0.11 | 1.08 |

Table 5. Mineralogical analysis by X-ray diffraction.

| Minerals | Quartz | Dolomite | Orthoclase | Muscovite | Kaolinite | Chlorite | Anatase |
|---|---|---|---|---|---|---|---|
| Content % | 32 | - | 55 | 9 | 2 | - | - |

Table 6. Result of the Response Surface Methodology.

| Term | Effect | Coef | SE Coef | T-Value | P-Value | VIF |
|---|---|---|---|---|---|---|
| Constant |  | 45.231 | 0.913 | 49.52 | 0.000 |  |
| Grinding time | 14.361 | 7.180 | 0.898 | 8.00 | 0.000 | 1.00 |
| Filling charge | -0.390 | -0.195 | 0.898 | -0.22 | 0.834 | 1.00 |
| Grinding time*Grinding time | -11.570 | -5.780 | 1.320 | -4.37 | 0.003 | 1.17 |
| Ball filling charge* Filling charge | -5.810 | -2.900 | 1.320 | -2.19 | 0.064 | 1.17 |
| Grinding time* Filling charge | -0.850 | -0.430 | 1.100 | -0.39 | 0.711 | 1.00 |

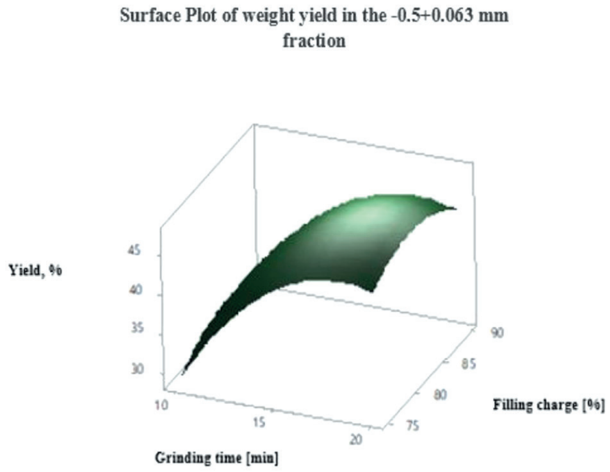

Figure 5. Response surface plots showing the effect of the filling charge and grinding time on the yield weight in [-0.5+0.063] mm.

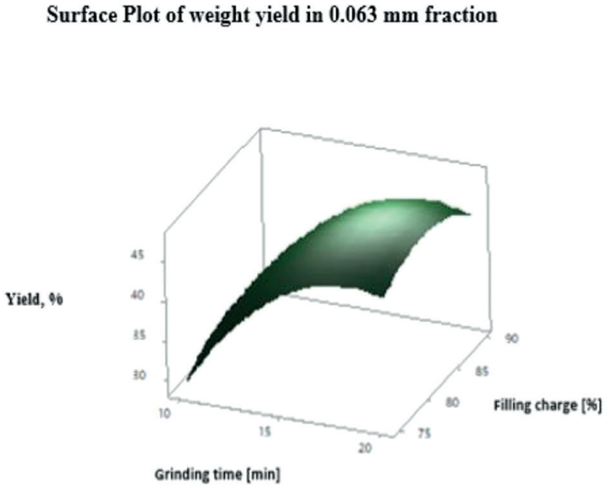

Figure 6. The interaction between the grinding time and filling charge under 0.063 mm.

Figures 5 and 6 illustrate the response surfaces for the yield in the [-0.5+0.063] mm fraction and fines (<0.063 mm), respectively.

## DISCUSSION

The chemical composition results of the Ain Barbar feldspar align closely with previous Algerian feldspar studies by Chaib et al. (2016), Jouamaa et al. (2005), Akal and Khoja (2020), and Kecir (2014). The high $SiO_2$ (72.15%) and $Al_2O_3$ (14.15%) contents confirm its suitability for ceramic and glass industries, whereas the $Fe_2O_3$ (1.28%) content suggests that additional processing may be necessary for high-whiteness applications (Chaib et al., 2016; Akal and Khoja, 2020). The minor presence of kaolinite (2%), likely from weathering, is consistent with the mineralogical trends reported by Akal and Khoja (2020).

The particle size distribution (PSD) findings show that feldspar liberation occurs mainly in the [-0.5, +0.25] mm fraction (19.8 %), which agrees with results found by Yassin et al. (2024) and Cayirli (2018). This confirms that comminution should target this size range to maximize mineral liberation efficiency (Yassin et al., 2024; Cayirli, 2018).

The regression results clearly demonstrate that grinding time plays a decisive role in determining feldspar grinding efficiency. The positive regression coefficient, combined with a T-value of 8.00 and a P-value confirming significance at the 95 % confidence level, indicates that yield in the [-0.5+0.063] mm fraction increases with grinding time. In contrast, the filling charge showed no significant effect within the tested range of 75-90% (P=0.83). This suggests that, under the studied conditions, ball load density variations exert only a minor influence on yield compared to grinding time.

The quadratic coefficient related to filling load approached significance (P=0.064), while the interaction between grinding time and filling charge was not statistically significant (P=0.711). Importantly, the presence of a significant negative quadratic term for grinding time highlights the risk of overgrinding, where excessive milling duration reduces yield in the [-0.5+0.063] mm fraction while generating an increased proportion of fines. Thus, careful optimization of grinding duration is essential to avoid energy losses and excessive fine production.

The model achieved an $R^2$ value of 92.95%, indicating strong explanatory power and confirming that the selected variables account for most of the variability in grinding performance. The surface plots (Figure 5) further illustrate this relationship, showing a curved plane that reflects modest interaction between grinding time and filling charge.

Experimental evidence also confirms that increasing both grinding time and filling charge enhances grinding efficiency. This improvement arises from more intense mechanical interactions between feldspar particles and grinding media, leading to greater comminution efficiency and finer products. Higher filling charges amplify the number and energy of particle-media collisions, thereby improving fragmentation. These observations are consistent with previous findings by Cayirli (2018), who underscored the critical role of operational parameters in optimizing mineral comminution.

The influence of grinding variables on fine particle generation (<0.063 mm) was further quantified using Response Surface Methodology (RSM). The interaction plots (Figure 6) reveal that both prolonged grinding times and higher filling charges lead to an increased yield of fines, a phenomenon attributed to intensified breakage mechanisms and higher attrition rates.

While this effect improves overall size reduction, it also highlights the trade-off between fine generation and target product recovery.

Consequently, the application of RSM proved effective not only in modeling the effects of grinding parameters but also in identifying optimal operating conditions. The results indicate that a balance must be achieved between maximizing yield in the [-0.5+0.063] mm fraction and minimizing the overproduction of fines (<0.063 mm). This balance defines the most energy-efficient and industrially relevant milling conditions for feldspar processing.

Table 7 presents a comparative analysis between the present work and previous studies on feldspar grinding. In the current study, a grinding time of 15 minutes was identified as optimal; beyond this duration, a decline in performance was observed, likely due to overgrinding and energy inefficiency. Similarly, Acarcavak and Aras (2017) reported that 16 minutes of dry grinding was effective in achieving a $d_{80}$ of 150 µm, reinforcing the notion that an intermediate grinding duration yields optimal results.

Studies by Vedat Deniz and Yakup Umucu (2015); (2023) further emphasized that grinding performance is highly dependent on maintaining an optimal filling charge, with diminishing returns observed at excessive loads or durations. Regarding the grinding method, this study employed a dry ball milling process, contrasting with wet milling approaches used by Yakup et al. (2015) and Gökcen et al. (2015). While wet grinding generally

Table 7. Comparison of study of grinding parameters and their impact on feldspar grinding.

| Study | Grinding type | Grinding time (min/h) | Filling charge (%) | Yield (%) | Desired particle size (µm) |
|---|---|---|---|---|---|
| Present study | Dry grinding with ball mill | 10, 15, 20 | 75, 82.5, 90 | 46 | [-500+63] µm |
| Ipek et al. (2005) | Bond mill | 0.5-9 | 22% (ball volume) |  | Below 200 µm |
| Gökçen et al. (2014) | Stirred ball mill | 30, 60, 90, 120, 150 | Ball filling 52% |  | d80=10 µm (with grinding aids) |
| Yassin et al. (2024) | Wet ball mill | 15, 30, 60 | 25% (optimal) |  | <250 µm<br>(optimal -250+45 µm fraction) |
| Agacayak and Aras (2017) | Steel ball mill (dry) | 16 min (max) | 20% ball filling |  | d80=150 µm |
| Yakup Umucu (2015) | Wet grinding (Wedag Rod Mill) | Up to 10 min | 40% |  | Feldspathic sand: <1600 µm; Albite feldspar: <1000 µm |
| Vedat Deniz (2015) | Dry batch grinding | 0.5, 1, 4, and 8 min | 22% (of mill volume) |  | -3350+2360, -850+600, -300+212 µm |
| Vedat Deniz and Yakup Umucu (2023) | Dry grinding |  | 30% |  |  |

offers enhanced particle size reduction, as noted by Ipek et al. (2005) it incurs higher operational and energy costs, making it less favorable for cost-sensitive applications.

Vedat Deniz and Yakup Umucu (2023) highlight the importance of optimizing this parameter for enhancing the profitability of feldspar milling. The final grain size achieved ranges from 500 to 63 µm, while Yakup Umucu (2015) notes sizes below 1600 µm through wet grinding. This study reinforces the significance of grinding time and filling charge as critical factors in maximizing both energy efficiency and product fineness, all while minimizing the risk of over-milling. In comparison with other research, it effectively balances energy consumption with performance, thereby confirming the advantages of dry grinding in optimizing feldspar production.

The findings related to optimal grinding time align closely with those reported by Yassin et al. (2024), which remains one of the few studies specifically focused on the minimization of fine particles in feldspar grinding. Yassin's work investigates the influence of various operational parameters in the wet grinding of K-feldspar ore using a ball mill and demonstrates that the determined optimal grinding time is transferable to both wet and dry milling processes. Employing Response Surface Methodology (RSM) for optimization, the study identifies 16 minutes as the optimal grinding duration-closely corroborating the 15-minute optimum established in the present work. This convergence in results across different milling environments further validates the relevance and robustness of time optimization in feldspar comminution processes**.**

## CONCLUSION

This study aims to optimize the grinding parameters in order to minimize the production of fines and improve the yield in the [-0.5+0.063] mm size range for multiple separation methods. The results indicated that increasing grinding time generally leads to a higher yield within the specified particle size range but also results in greater fines production. A grinding time of approximately 16.3 minutes and a ball filling charge of 82.5% were identified as the optimal conditions to achieve these objectives.

These findings lay the foundation for future developments and advancements in the grinding of feldspar ore for diverse applications and various separation methods. The research emphasizes the importance of optimizing grinding time to enhance energy efficiency and achieve desired particle fineness while avoiding over-grinding. In comparison with previous studies, it demonstrates a balanced approach between performance and energy consumption, thereby confirming the effectiveness of dry grinding in optimizing feldspar production.

## REFERENCES

Agacayak T. and Aras A., 2017. Dry Grinding Kinetics of Gölbaşı (Ankara) Andesite in Ball Mill. International Journal of Economic and Environmental Geology 8, 53-55.

Akkal R. and Khodja M., 2020. Purification of feldspar from iron oxide impurities using nitric acid in presence of ammonium biuoride. Journal of Fundamental and Applied Sciences 12, 118-140. doi: 10.4314/jfas.v12i1S.10

Aliyu Z.S., Garkida A.D., Ali E.A., Dauda M., 2016. Characterization of Feldspar by instrumental analytical techniques. Characterization of minerals, metals, and materials 2015, 291-297.

Belaidi H., Kitouni S., Chellat S., 2024. Evaluation of some granitic rocks of the Algerian coast as a source of feldspar raw material. Periodico di Mineralogia 93.

Bilir K. and İpek H., 2021. Analysis of factors affecting the grindability of k-feldspar in stirred ball mill by full factorial design. doi: 10.31796/ogummf.1009481

Bouzenzana A., 2015. Effect of calcination on the grindability of concentrated phosphate of Djebel Onk, Algeria. In IMCET 2015 Proceedings (Vol. 1, pp. 1144-1152) Mehtap Gülsün Kılıç, Öznur Önül, Hakan Başarır, Mehmet Karadeniz, Elif Torun Bilgiç (Eds.). ISBN: 978-605-01-0705-0.

Bowles O. and Lee C.V., 1930. Feldspar (Vol. 6381). US Department of Commerce, Bureau of Mines.

Bozkurt E., Winchester J.A., Mittwede S.K., Ottley C.J., 2006. Geochemistry and tectonic implications of leucogranites and tourmalines of the southern Menderes Massif, southwest Turkey. Geodinamica Acta 19, 363-390.

Cayirli S., 2018. Influences of operating parameters on dry ball mill performance. Physicochemical Problems of Mineral Processing 54, 751-62.

Chaib A., Bounouala M., Bouabdallah S., Benselhoub A., 2016. New condition for separation of orthoclase from quartz by flotation; case of Ain Barbar quarry (Algeria). Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu 6, 67-74.

Djouama M.C., Bounouala M., Ain-Souya A., Ghers M., 2005. Caractérisation et préconcentration granulométrique de la matière feldspathique d'Ain-Barbar, Algérie. In Journal de Physique IV (Proceedings) (Vol. 124, pp. 103-109). EDP sciences. doi: 10.1051/jp4:2005124016

Dondi M., Guarini G., Conte S., Molinari C., Soldati R., Zanelli C., 2019. Deposits, composition and technological behavior of fluxes for ceramic tiles. Periodico di Mineralogia 88(3). doi: 10.2451/2019PM861

Elbendari A.A., Aleksandr N., Nadezhda A. Anastasiya, 2020. Selective flotation of phosphorus-bearing ores. E3S Web of Conferences 192, 02021. doi: 10.1051/e3sconf/202019202021

Gökcen H.S., Cayirli S., Ucbas Y.A.Ş.A.R., Kayaci K., 2015. The effect of grinding aids on dry micro fine grinding of feldspar. International Journal of Mineral Processing 136, 42-44.

Ipek H., Ucbas Y., Yekeler M., Hosten Ç., 2005. Grinding of ceramic raw materials by a standard Bond mill: quartz, kaolin and K-feldspar. Mineral Processing and Extractive Metallurgy 114, 213-218.

Ismail A.I., Ghabrial D.S., Wahab W.A., Eissa M., Cazzaniga A., Zanelli C., Dondi M., 2018. Exploring syenites from ring complexes in the Eastern Desert (Egypt) as ceramic raw materials. Periodico di Mineralogia 87. doi: 10.2451/2018PM749

Kecir M., Zibouche M.H., Kecir A., 2014. Ain Barbar feldspar magnetic beneficiation. Inżynieria Mineralna 15, 131-136.

Liu S., Li J., Liu J., 2017. An updated model of Rietveld structure refinement of Na/K- feldspar. Periodico di Mineralogia 86. doi: 10.2451/2017PM684

Lorig H.G. and Clarence H., 2017. Mineral processing. Encyclopedia Britannica, November 17, 2006. Accessed September 9, 2023. https://www.britannica.com/technology/mineral- processing.

Ma Z., Tian J., Xu L., Li C., Wang D., Xue K., 2024. Comparison of surface physicochemical properties of spodumene and feldspar using different grinding media: Implications for flotation separation. Minerals Engineering 216, 108878.

Marignac C., Aissa D.E., Deloule E., Cheilletz A., Gasquet D., 2016. Edough-Cap de Fer Polymetallic District, Northeast Algeria: I. The Late Miocene Paleogeothermal System of Aïn Barbar and Its Cu-Zn-Pb Vein Mineralization. Mineral Deposits of North Africa, 249-276.

Matsanga N., Nheta W., Chimwani N., 2023. A Review of the Grinding Media in Ball Mills for Mineral Processing. Minerals 13, 1373.

Radoslovich E.W., 1975. Feldspar minerals. In Soil Components: Vol. 2: Inorganic Components (pp. 433-448). Berlin, Heidelberg: Springer Berlin Heidelberg.

Ravaszová S., Dvořák K., Vaičiukynienė D., Sisol M., 2022. Application of a Method for Measuring the Grindability of Fine-Grained Materials by High-Speed Milling. Materials 15, 8085.

Silva A.C., Carolina S.D., Sousa D.N., Silva E.M.S., 2019. Feldspar production from dimension stone tailings for application in the ceramic industry. Journal of Materials Research and Technology 8, 1-7. doi: 10.1016/j.jmrt.2018.02.011

Smith J.V., 2012. Feldspar minerals: 2 chemical and textural properties. Springer Science & Business Media.

Umucu Y. and Deniz V., 2015. The effect of ball type in fine particles grinding on kinetic breakage parameters. Inżynieria Mineralna 16, 197-203.

Umucu Y., Deniz V., Gursoy H.Y., Tokcan I., Arsoy Z., 2023. The relationships between the kinetic grinding parameters with interstitial fillings and the liberation degree of a chromite ore. Physicochemical Problems of Mineral Processing 59.

Umucu Y., Haner S., Tunay T., 2015. The investigation of effect of wet-dry grinding condition and ball types on kinetic model parameters for kaolin. Inżynieria Mineralna 16, 205-211.

Yassin K.E., Hassan E.S.R., Abdel Khalek N.A., Elbendari A.M., 2024. Some aspects on grindability of feldspar ore using ball mill. Particulate Science and Technology, 1-12.