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Research article

Reuse of feldspar ore waste after beneficiation for industrial use (Buzlukdağı/Kırşehir/Türkiye)

Fatih Ozgul[1], Mehmet Ozcelik[2*]

[1]Fides Mühendislik. Cankaya/Ankara/Türkiye
[2*]Süleyman Demirel University, Engineering Faculty, Geological Eng. Isparta/Türkiye

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Corresponding author:
Mehmet Ozcelik
Email address: ozcelikmehmet@sdu.edu.tr

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ABSTRACT

Feldspar is the most widely used raw material in the ceramic and glass industries. This paper investigates the possibility of using flotation process wastes from Buzlukdağı feldspar beneficiation plant as an alternative raw material. The scope of the study includes evaluating the use of wastes from feldspar enrichment and feldspar processes as alternative raw materials in another process and investigating their usability as a final product in various sectors and fields. The priority was to reduce the Fe_2O_3 content of the flotation concentrate to 0.4%. It was made usable in the glass and ceramics industries. The second priority was to analyze the rare earth elements in the waste produced after flotation. The results of the tests on the post-flotation waste show that it can be used for technological purposes. In addition, it has been suggested to investigate whether the wastes resulting from enrichment can be used to provide permeability in urban waste storage areas and hydroelectric dam construction.

INTRODUCTION

Feldspars are anhydrous aluminosilicates of sodium, potassium, calcium, lithium, and occasionally barium and caesium, and isomorphic combinations of these elements make up 60-65% of the Earth's crust. Feldspar is the most commonly used raw material in the ceramics and glass industry. Clays, mica minerals (such as biotite and muscovite), tourmaline, rutile, and sphene are the most common minerals found in feldspar ores (Saklar and Oktay, 2003; Bayat et al., 2006; Orhan and Bayraktar, 2006; El-Rehiem and Abd El-Rahman, 2008; Chatterjee, 2009). The presence of coloring materials such as iron oxides and rutile reduces the quality by forming a black spot in the product body during the firing process (Lewicka, 2016). To use feldspar minerals in various industrial applications, several upgrading processes must be carried out to remove impurities (Hacifazlioğlu et al., 2012; Vrbicky and Prikryl, 2021). Seventy percent of the world's feldspar mineral production is used to manufacture glass products, such as insulating glass fibre (El-Dine et al., 2012). The remainder is used in ceramic products and as fillers and extenders in the plastics, paints, and coatings industries (Vapur et al., 2017). Magnetic separation is the most efficient method for upgrading and removing the coloring materials from feldspars. A high-intensity magnetic separator is used for low-iron content ores. Flotation is the most versatile method for processing feldspar ores with varying iron contents (Kılınç Aksay, 2008; Heyes et al., 2012). Only a few ores can be used without the ore preparation process. Significant amounts of by-products, characterized as waste or residue, emerge due to ore preparation processes, in addition to the ore desired to be enriched, and are challenging to obtain economically with current technological opportunities (Ahmed et al., 2016). Storing and disposing of these wastes can be difficult, amounting to millions of tons per year (Miler et al., 2022). Waste is also significant due to its inactive minerals (Akoto and Anning, 2021). Nowadays, feldspar reserves, used as soon as they are quarried technologically, are rapidly depleting. Türkiye, which has the world's largest feldspar reserves, has also been among the top producers of feldspar in recent years. In 2019, the world's annual feldspar production stood at 26 million metric tons (Mt), with Türkiye (7.5 Mt), Italy (4 Mt), India (4 Mt), and China (2 Mt) being the top feldspar-producing countries (Fuertes et al., 2022). Titanium and iron minerals are the most common impurities in our country's feldspar ores (Terzi and Kurşun, 2013). Because of their coloring properties, feldspars contain iron and titanium minerals in their mineralogical structures and are classified as undesirable impurities (Dino et al., 2020). Titanium minerals such as rutile and sphene, as well as iron oxides such as garnet, hematite, hornblende, tourmaline, biotite, and muscovite, are the most common impurities found in feldspar ores (Özün, 2012; Gaied and Gallala, 2015). If the concentration of these minerals exceeds the reference values, the quality of the glass and ceramics deteriorates, and color changes occur. To be used in the ceramic and glass industries, feldspar's Na_2O content must be at least 7%, 10% of the K_2O content, to produce white ceramics and low-forming oxides, such as Fe_2O_3 and TiO_2. To produce high-quality ceramics and glass, the Fe_2O_3 and TiO_2 concentrations should be less than 0.5% and 0.05%, respectively. In the ceramic industry, high-quality potassium feldspar is used. The region of Kırşehir has a significant potassium feldspar potential (Gülsoy et al., 2005). Chemical analyses reveal that the epidote and apatite in the Buzlukdağı feldspar mine are rich in uncommon Rare Earth Elements (REEs). Lower-quality reserves remained, containing various impurities during the formation of feldspars. As a result, it becomes necessary to apply flotation, magnetic separation, electrostatic separation, and density-based enrichment methods, depending on the ore's grade, quality, and properties. However, new waste is generated during enrichment. This study aims to enrich the feldspar ore and reuse the waste generated after enrichment for industrial use.

MATERIAL AND METHODS

Locality and Basic Characteristics of Experimental Material

The experimental material was sampled from the currently operated Buzlukdağı deposit (south of Alişar and Tatarilyas villages of Kırşehir province) in the Central Anatolian Crystalline Complex region (Turkey). Buzlukdağı syenites generally contain foide and can be divided into three main groups of grain size: fine, medium, and coarse-grained. Coarse crystalline, medium crystalline, and fine crystalline foide syenites are pinkish, pinkish gray, and gray, respectively. Buzlukdağı foide syenite has a petrographically similar mineralogical composition but is divided into rock groups with different colors and different mineral ratios (Deniz and Kadıoğlu, 2017). It consists mainly of nepheline, orthoclase, oligoclase, pyroxene, biotite, amphibole, and small amounts of garnet, cancrinite, sphene, and opaque minerals (Kangal et al., 2019). The Buzlukdağı feldspar mine's apparent reserve area is 1800 m long, 500 m wide, and 15 m thick (Fig. 1). The total reserve for this deposit is 21,937,500 tons. Feldspar has properties suitable for the tile, vitreous ware, frit, porcelain, glass, insulator, cement, insulation, and electrode industries (BS Investment, 2021). The feldspar ore produced is found in veins in the gneisses of the field. Sodium and potassium feldspars were found in the field. In other words, they are alkaline and alkaline earth anhydrous aluminum silicates. Because these minerals are found in various forms and proportions in each magma mass, feldspar zones or beds form in places due to cooling and crystallization. The parent rocks are schists and gneisses. In the studies, feldspar ore fed to the flotation facility of a private company operating as a Buzlukdağı (Kırşehir, Turkey) feldspar mine was used. First, representative sampling, determination of grain size details, and chemical and mineralogical change studies were carried out with the sample as foam generators MIBC (Methyl Isobutyl Carbinol) and DF-250 (Dow-Froth 250) were utilized.

Fig. 1 3D view of the site based on digital terrain model (DTM) with 1 m resolution and draped orthophoto.

Methods

The chemical analysis of a representative sample with a grain size of -500 µm was ground and evaluated for chemical analysis. The chemical contents of the sample were determined by the Inductively Coupled Plasma (ICP) method, and the results are presented in Table 1.

Table 1. Chemical composition of representative ore sample

Sample No	Na_2O (%)	K_2O (%)	Fe_2O_3 (%)	SiO_2 (%)	CaO (%)	MgO (%)	P_2O_5 (%)	Al_2O_3 (%)	TiO_2 (%)	MnO (%)	LOI: loss on ignition (%)
SG-K	9.2	5.8	1.4	56.6	1.4	0.2	<0.1	22.7	<0.1	0.1	1.15

When the chemical analysis results were examined, the sample It was determined that the total alkali content (Na_2O+K_2O) was 15%, while the sample contained 1.4% Fe_2O_3, <0.1% TiO_2, 22.7% Al_2O_3, and 56.6% SiO_2.

Enrichment Methods

The enrichment processes are carried out using various methods based on the physical and chemical properties of the feldspar and other minerals that comprise the ore (Burat, 2017). These techniques include manual sorting, size sorting, magnetic separation, electrostatic separation, and flotation (Heyes et al., 2012; Bentli et al., 2018). These methods can be used individually to enrich feldspar minerals and in various applications where they can be used together (Çınar and Durgut, 2019).

Enrichment by Magnetic Processing Method

Experiments in magnetic processing were carried out using two different methods: dry and wet. Because the goal of the experiments was to reduce the iron content of the feldspar sample and obtain a clean feldspar concentrate, the non-magnetic products of the experiments were referred to as concentrate. In contrast, the magnetic products were referred to as waste. The sample preparation flow chart is given in Figure 2.

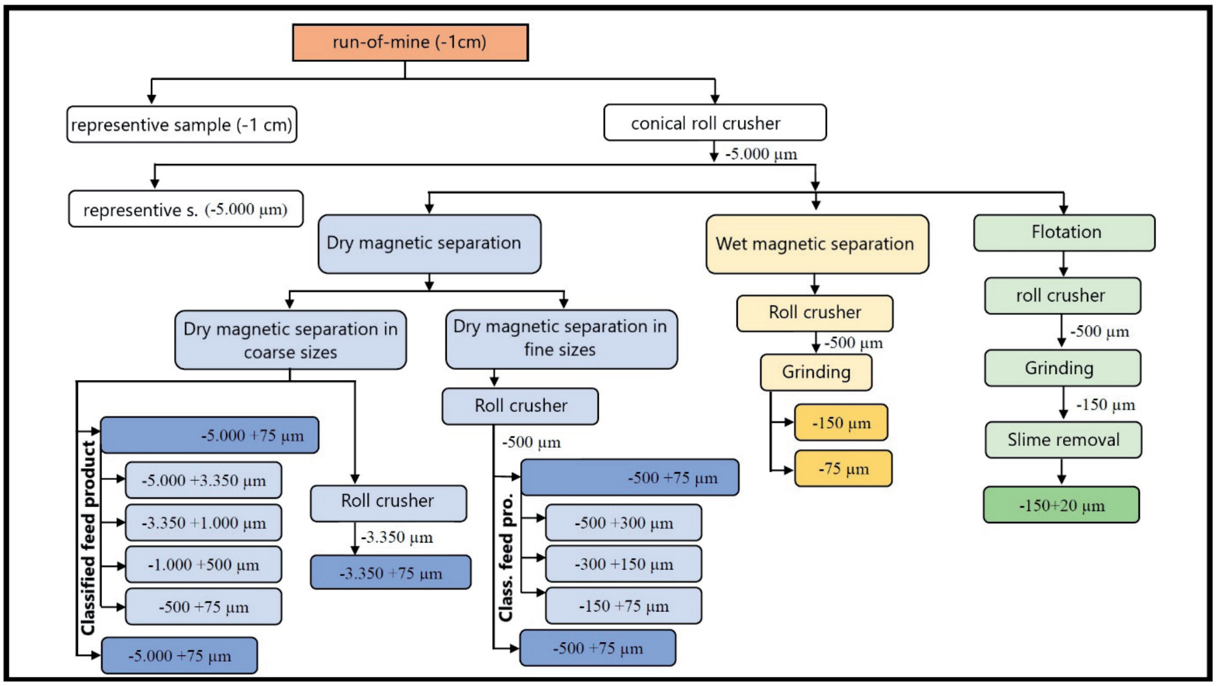

Fig. 2 Sample preparation flow chart

RESULTS AND DISCUSSION

Dry Magnetic Processing Test

A high field intensity, high gradient, permanent neodymium magnet roll type (Permroll brand) dry magnetic separator was used in dry magnetic processing experiments. Permroll-type dry magnetic separators have been used successfully in recent years to enrich many industrial raw materials, including glass and ceramic raw materials, and remove colorant components (Ilyina and Bubnova, 2021). The most critical issue in dry magnetic processing is excellent particle size processing. Otherwise, static electricity causes the fine particles to adhere to the coarse particles and the band, reducing the success of clustering and processing. Another disadvantage is that as grain size decreases, separator capacity decreases significantly (Bayraktar, 2010). As a result, in dry magnetic processing experiments, a particle size of -75 µm was separated as slurry.

Large Size Dry Magnetic Processing Tests

A sample with a grain size of -1 cm was passed through a cone and roller crusher and sieved through a 5.000 µm sieve in a closed circuit, and the total grain size was reduced to -5.000 µm. The sample with a particle size of -5.000 µm was then sieved dry through a 75 µm sieve, and the slime was discarded. To determine the grain size of the feldspar concentrate with the lowest Fe_2O_3 grade, a sample with a grain size of -5.000+75 µm was first classified and subjected to dry magnetic processing in a narrow grain size range. In the large-scale magnetic processing experiments, coarse processing was performed at 50 rpm belt speed after adjusting the feed rate and blade positions (0^o - 30^o); three different products were purchased as concentrate, waste, and intermediate products. The coarse concentrate, taken in the two most significant fractions, -5.000+3.350 µm and -3.350 +1.000 µm grain sizes, was cleaned at 30 rpm belt speed, and the final concentrate was collected, while other products were combined as waste. The intermediate product was swept at a belt speed of 120 rpm in the other two fractions, -1.000+500 m and -500+75 µm; the resulting concentrate was combined with the coarse concentrate obtained in the previous step and was taken as the final concentrate, and the other products were separated as waste. The weight distribution (%) of the products obtained due to fractional magnetic processing is given in Table 2, and the chemical analysis results are shown in Table 3.

Table 2. Dry magnetic separation fractional (-5.000+75 µm) weight distribution (%)

Size fraction (µm)	Products	Wt. (%)	
		General	Fractional
(-5.000 + 3.350)	Concentrate	23.31	82.31
	Reject (impurities)	5.01	17.69
-3.350 + 1.000	Concentrate	32.63	75.99
	Reject (impurities)	10.31	24.01
(-1.000 + 500)	Concentrate	9.32	78.21
	Reject (impurities)	2.59	21.79
(-500 + 75)	Concentrate	10.06	75.29
	Reject (impurities)	3.3	24.71
-75	-	3.47	-
Total	Feed (raw material)	100.00	-

Table 3. Dry magnetic separation fractional (-5.000+75 µm) chemical analysis results

Component	-5.000 + 3.350 µm		-3.350 + 1.000 µm		-1.000 + 500 µm		-500 + 75 µm		Initial ore (%)
	Cons. (%)	Reject (impurities) (%)	Cons. (%)	Reject (impurities) (%)	Cons. (%)	Reject (impurities) (%)	Cons. (%)	Reject (impurities) (%)	
Na_2O	9.3	8.6	9.4	8.7	9.4	8.1	9.1	7.6	9.2
K_2O	6.1	5.9	5.7	6.1	5.9	6.8	5.5	7.4	5.8
Fe_2O_3	0.8	3.0	0.5	2.5	0.4	4.2	0.4	5.2	1.4
TiO_2	0.1	0.2	<0.1	0.2	<0.1	0.3	<0.1	0.4	<0.1
SiO_2	57.8	56.1	58.4	56.6	58.2	55.8	55.8	55.2	56.6
Al_2O_3	21.9	21.1	22.0	21.6	22.3	21.6	21.4	21.6	22.7
CaO	1.7	1.7	1.3	1.3	1.3	0.8	3.1	0.6	1.4
MgO	0.5	0.4	0.1	0.3	0.2	0.4	0.3	0.6	0.2
MnO	<0.1	0.2	<0.1	0.2	<0.1	0.3	<0.1	0.3	0.1
P_2O_5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
LOI	0.55	1.05	1.00	1.15	1.00	0.65	1.35	0.30	1.15

Table 3 shows that the Fe_2O_3 grade in the concentrates did not vary in any other fractions except the -5.000+3.350 µm fraction, which was 0.5 % or less. The Fe_2O_3 grade of the concentrate obtained in the experiments with a grain size of -5.000+75 µm, in which the slime was eliminated, was 0.6 % for both products (Coarse Combined Product and Coarse Single Dimension). This value remained higher than the TSE's allowed Fe_2O_3 grade (0.5 %) (TSE-11325). As a result, studies with a grain size of -3,350 +75 µm were continued. A sub-dimension sample with a grain size of -3.350+75 µm was exposed to a dry magnetic processing test in one dimension. Table 4 shows the weight distribution of the generated products, whereas Table 5 shows the chemical analysis results.

Table 4. Dry magnetic processing (-3.350 +75 µm) % weight distribution

Products	Dry magnetic enrichment	
	Distribution by total entries (%) (-3,350 µm)	Distribution by magnetic separator feed (%) (-3,350 + 75 µm)
Concentrate	65.52	69.08
Reject (impurities)	29.34	30.92
Slime	5.14	-
Feed	100.00	100.00

Table 5. Dry magnetic processing (-3.350 +75 µm) chemical analysis results

Component	Size fraction -3.350 + 75 µm		Initial ore (%)
	Concentrate (%)	Reject (impurities) (%)	
Na_2O	9.5	8.4	9.2
K_2O	5.8	7.0	5.8
Fe_2O_3	0.4	2.6	1.4
TiO_2	<0.1	0.2	<0.1
SiO_2	58.6	56.6	56.6
Al_2O_3	21.5	21.3	22.7
CaO	2.0	1.1	1.4
MgO	0.3	0.6	0.2
MnO	<0.1	0.2	0.1
P_2O_5	<0.1	<0.1	<0.1
LOI	0.20	0.90	1.15

The chemical analysis results of the concentrate obtained by dry magnetic processing with a grain size of -3.350 +75 µm, which are the TSE-11325 (1994) criteria, are shown in Table 6.

Table 6. Chemical contents of dry magnetic processing concentrate (-3.350 +75 µm), which are criteria for TSE-11325 standard

Component	(-3.350 + 75 µm) Concentrate (%)
K_2O+Na_2O	15.3
K_2O	5.8
Na_2O	9.5
Fe_2O_3	0.4
Ti_2O	<0.1
CaO+MgO	1.4
TiO_2+CaO+MgO	1.4

Table 6 shows that the chemical analysis results of the dry magnetic processing concentrate with a particle size of -3.350 +75 µm meet the TSE-11325 standard.

Dry magnetic processing tests of thin-size material

Fine-size dry magnetic processing studies were carried out to study the potential of further reducing the Fe_2O_3 grade of the concentrate obtained in the magnetic processing experiments, which is regarded as the coarse size. The samples are dry magnetic in one dimension (-500+75 µm) and fractionally in three dimensions (-500+300 µm, -300+150 µm, and -150+75 µm) for this purpose, having been entirely prepared with a grain size of -500+75 µm. Processed is a word that has a lot of different meanings. The narrow grain range was projected to be more effective in dry magnetic processing studies. In magnetic processing studies, coarse processing was carried out at 50 rpm belt speed after the feeding speed and blade positions (0^o - 30^o) were changed, and the products obtained were cleaned and swept at various belt speeds. As a result of the studies, three different products were selected for chemical analysis: concentrate, waste, and intermediate. Intermediate products were classified as concentrate or waste based on how they affected the Fe_2O_3 grade according to the chemical analysis results and then combined with the appropriate product in proportion to their weight, resulting in the final concentrate and the chemical analysis of the waste. After the intermediate products are distributed, the fractionally obtained concentrate and % weight distributions of the reject (impurities) are given in Table 7, and the chemical analysis results calculated by calculation are shown in Table 8. In Table 8, the chemical contents of the concentrate were obtained with a particle size of -500 +75 µm, which are criteria for the TSE-11325. Table 9 shows that the CaO + MgO value of the concentrate obtained with a particle size of -500 +75 m stayed above the acceptable amount (1.60 %) according to the TSE-11325 standard (1.80 %). As a result, dry magnetic processing experiments were carried out in various sizes, with the largest size (-3.350 + 75 µm) yielding a concentrate that met the TSE-11325 requirement.

Table 7. Fractional (-500 +75 µm) % weight distribution as a result of dry magnetic processing

Size fraction (µm)	Products	Wt. (%)	
		General	fractional
-500 + 300	Concentrate	29.27	81.84
	Reject (impurities)	6.50	18.16
-300 + 150	Concentrate	23.23	77.45
	Reject (impurities)	6.76	22.55
-150 + 75	Concentrate	10.98	66.28
	Reject (impurities)	5.59	33.72
-75	-	17.67	100
Total	Feed	100	-

Table 8. Dry magnetic processing fractional (-500 +75 µm) chemical analysis results

Component	-500+300 µm		-300+150 µm		-150 + 75 µm		Initial ore (%)
	Conc. (%)	Reject (impurities) (%)	Conc. (%)	Reject (impurities) (%)	Conc. (%)	Reject (impurities) (%)	
Na_2O	9.2	7.3	9.3	7.3	9.3	7.8	9.2
K_2O	5.7	7.2	5.5	7.4	5.1	7.2	5.8
Fe_2O_3	0.4	4.8	0.4	4.6	0.4	5.2	1.4
TiO_2	0.1	0.4	0.1	0.3	0.1	0.2	0.1
SiO_2	59.2	55.6	58.8	54.9	58.0	53.7	56.6
Al_2O_3	21.9	20.8	21.6	20.8	20.8	20.7	22.7
CaO	1.1	0.6	1.6	0.4	2.7	0.5	1.4
MgO	0.4	0.8	0.2	0.4	0.2	0.4	0.2
MnO	0.1	0.3	0.1	0.3	0.1	0.1	0.1
P_2O_5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
LOI	0.8	0.8	0.8	1.4	1.0	1.8	1.15

Table 9. Chemical contents of dry magnetic processing concentrate (-500 +75 μm), which are criteria for TSE-11325 standard

Oxide components	(-500 + 75 μm)
K_2O+Na_2O	15.0
K_2O	5.6
Na_2O	9.4
Fe_2O_3	0.4
TiO_2	0.1
CaO+MgO	1.8
TiO_2+CaO+MgO	1.8

Wet magnetic processing test

Master Magnets Limited's high-field intensity wet magnetic separator was used in wet magnetic processing studies. For wet magnetic processing tests, a representative sample with a grain size of -500 μm was generated by closed-circuit grinding in two different grain sizes, -150 μm and -75 μm. Wet magnetic processing was performed on the samples at a solids density of 30% and a current intensity of 5 amperes (10.500 gauss), respectively. As a result of the experiment (Table 10), it was discovered that the sample's reject (impurities) component collected most of the sample's weight. As a result, cleaning was not required at higher field intensities. A wet magnetic test with a field intensity of 20 amperes (19.600 gauss) was performed once as a second parameter. As a result, it was discovered that studies with 5 ampere and 20 ampere field strengths produced similar results. Table 10 shows the percent weight distribution of the goods, whereas Table 11 shows the chemical analysis results. The Fe_2O_3 grade was higher for both field strengths in the chemical analysis results than in the dry magnetic processing trials, as shown in Table 11. This sample did not respond well to the wet magnetic processing procedure.

Table 10. The weight distribution of wet magnetic processing test products

Size Fraction (μm)	Field Intensity	Products	Wt. (%)
-150 μm	5 Ampere	Concentrate	36.30
		Reject (impurities)	63.70
	20 Ampere	Concentrate	39.10
		Reject (impurities)	60.90
-75 μm	5 Ampere	Concentrate	24.12
		Reject (impurities)	75.88
	20 Ampere	Concentrate	27.59
		Reject (impurities)	72.41

Table 11. Chemical analysis results of wet magnetic test products

Component	-150 μm /5A Concentrate (%)	-150 μm / 20A Concentrate (%)	-75 μm / 5A Concentrate (%)	-75 μm / 20A Concentrate (%)
Na_2O	8.9	8.5	8.3	8.2
K_2O	4.3	4.3	4.8	5.0
Fe_2O_3	0.5	0.7	0.6	0.6
TiO_2	<0.1	<0.1	<0.1	<0.1
SiO_2	59.3	59.5	59.0	59.4
Al_2O_3	20.5	19.8	19.9	19.9
CaO	2.5	2.9	3.1	2.9
MgO	0.2	0.4	0.3	0.3
MnO	<0.1	<0.1	<0.1	<0.1
P_2O_5	<0.1	<0.1	<0.1	<0.1
LOI: loss of ignition	1.35	1.60	1.90	1.80

Flotation Experiments

Flotation is a method that uses air/gas bubbles to selectively separate materials based on their degree of hydrophobicity (water-repelling property) (Heyes et al., 2012). The first effort to use a froth flotation apparatus was recorded in 1905 (Broken Hill, Australia), with solid pulp stirring and air bubble injection (Zhang et al., 2020). Between 1900 and 1910, Australia was home to most of the early developments in flotation processing (Sajjad and Otsuki, 2022). No metallurgical process invented in the twentieth century compares to froth flotation, which has significantly impacted the mineral industry (Sekulic et al., 2004; Mondal et al., 2021). Enrichment studies with flotation were carried out to see if it was possible to reduce the Fe_2O3 and TiO_2 content of the ore to lower values than those obtained by magnetic processing. The representative sample chosen from the -500 μm grain size sample from the roller crusher output was ground in a closed circuit to -150 μm grain size for this operation. More slime is produced when the grind is finer. The slime coating complicates the selective processing procedure during flotation. As a result, sludge removal is done before flotation. -20 μm sludge material was sieved out for adequate flotation. Flotation studies were conducted with a 1-liter cellule and 500 g sample in a Denver brand flotation machine at a mixing speed of 1,300 rpm during conditioning and 1,200 rpm during flotation. Mica and oxide flotation tests were carried out in two stages. Mica flotation was performed in the first phase using H_2SO_4 in the pH range of 2.5-3.0. This method tested armac-T, an amine-type collector, as a cationic collector. Heavy minerals were created in the second stage, oxide flotation, employing H_2SO_4 at a pH of 6.5-7.0. Na-oleate was employed as a collector in oxide flotation, while R-825 was used as a sulfonate-type collector. In the case of feldspar and quartz, H_2SO_4 has inhibitory characteristics. As a result, no suppressing reagent was used. Dosing was determined in mica and oxide flotations based on the foam condition, which was gradually provided to the collectors. Due to the carbonate component, it was tough to lower the sample to the acceptable pH range of 2.5-3.0 and maintain it there. Even though about 100 kg/ton of acid was consumed, the pH could not be kept in this range. As a result, the sample was handled with tap water instead of mica flotation, and the removal of coloring components was attempted with just oxide flotation at natural pH. (8.5-9.0). The types and amounts of reagents used in the flotation experiments are given in Table 12, the percent weight distribution of the products obtained in Table 13, and the results of chemical analysis are shown in Table 14.

Table 12. Reagent types and amounts used in flotation experiments

Test no	Armac-T (%1) (g/t)	Na-Oleat (%10) (g/t)	R-825 (%1) (g/t)	DF-250 (%1) (g/t)	MIBC (%1) (g/t)
1	250 + 250	2.000	-	30	30
3	-	-	200	30	30

Table 13. Weight distribution of flotation test products

Products	Mass (%)	
	Test-1	Test-3
Mica Concentrate	3.65	-
Oxide Concentrate	4.65	6.63
Feldspar Concentrate	71.10	73.6
Slime	20.60	100.00
Feed	100.00	100.00

Table 14. Chemical analysis results of flotation test products

Component	Feldspar concentrate	
	Test-1	Test-3
Na_2O	8.5	9.3
K_2O	6.9	5.6
Fe_2O_3	0.5	0.4
TiO_2	<0.1	<0.1
SiO_2	61.5	60.9
Al_2O_3	21.5	22.0
CaO	0.1	0.1
MgO	0.1	0.1
MnO	<0.1	<0.1
P_2O_5	<0.1	<0.1
LOI	0.5	1.20

Mica concentration contains illite, fluorite, plagioclase, alkali feldspar, nepheline, pyrite, analcime, dolomite, magnetite, and oxide concentrate contains plagioclase, alkali feldspar, nepheline, analcime, illite, dolomite, quartz, pyrite, and magnetite, according to XRD analysis results. When the flotation results were compared, it was discovered that the results achieved with one-stage oxide flotation without using acid were superior in concentrate Fe_2O_3 grade. The Turkish Standard Institute is met by the resulting concentrate (TSE-11325). The obtained feldspar concentrate was subjected to feldspar-quartz processing, but the amount of HF necessary to decrease the pH to 2.5-3.0 was too high. The pH could not be kept in the acceptable range once reduced. Despite these circumstances, defoaming has been attempted but failed. Chemical analyses reveal that the epidote and apatite in the Buzlukdağı feldspar mine are particularly rich in uncommon REEs. REEs manufacture high-tech products resistant to heat, abrasion, and corrosion. They are called critical raw materials because of their high economic value and scarcity risk. REEs are used in various fields where advanced technological products, particularly high-tech consumer products such as cellular phones, computer hard drives, electric and hybrid vehicles, and flat-screen monitors and televisions, are used. Electronic displays, guidance systems, lasers, and radar and sonar systems are all critical defense applications. Although the amount of REE used in a product may not constitute a significant portion of that product in terms of weight, value, or volume, the REE may be required for the device to function. The total REEs in epidotes range from 2% to 8%. Between 3% and 7% of apatite (Britolite-Silicate apatite) contains REEs. Apatite also has high Pr ratios and Nd (Table 15).

Table 15. Microprobe analyzes of albite–epidote hornfels epidotes

Rare Earth Oxides	Sample 1	Sample 2
Lanthanum Oxide (La_2O_3)	16.352	13.780
Cerium Oxide (Ce_2O_3)	26.580	23.742
Praseodymium Oxide (Pr_2O_3)	1.809	2.156
Neodymium Oxide (Nd_2O_3)	4.272	3.977

Feldspar-quartz separation was attempted on the resulting feldspar concentrate, but the HF consumption required to reduce the pH to 2.5-3.0 was too high. After lowering the pH, it could not be kept constant within the desired range. Despite these conditions, de-foaming was attempted but was not successful. According to the results obtained, the flow chart of the flotation experiment (Test-3) that gave the best results in terms of Fe_2O_3 grade is shown in Figure 3.

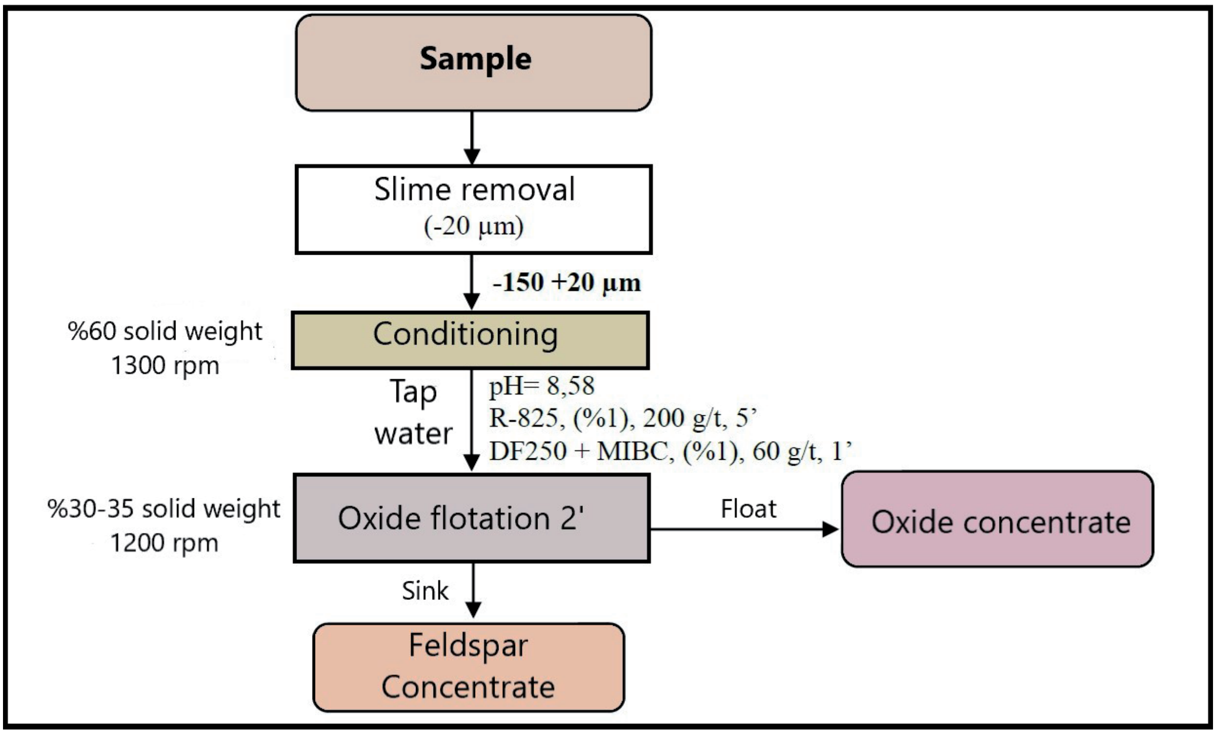

Fig. 3 Flow diagram of the flotation experiment that gives the best results (Test-3)

PROCESS WASTES

Mineral resource processing can have a significant detrimental impact on the environment. Mining activities, for example, can modify landscapes, deposit vast amounts of hazardous tailings, and discharge contaminated liquid and air effluents, all of which can harm natural habitats. As a result, it causes substantial environmental damage, including poor air, water, and soil quality and biodiversity loss. Many academics have assessed the degree of the ecological harm caused by mining operations, notably mining waste, due to growing worries about the repercussions of mining activities, particularly mining waste (Benidire et al. 2020). End-of-enrichment wastes are sent to the 6-meter dewatering drill, then to the dewatering sieve, filled with the dewatered waste belt. Waste products from the beneficiation plant contain iron-containing minerals. The daily waste amount varies depending on the tonnage and iron concentration of the supplied material (52-104 tons/month (21-42 m^3/month), 572-1144 tons/year (229-458 m^3/year). These wastes are kept near the border of the crushed stockpile for subsequent use. Pumps move water from the waste dewatering sieve to the settling tank, where it is reused. The quality of the products obtained from the enrichment plant is classified and stocked. These items are sent in response to customer demand. The needed components are held in the drying facility, and the water will be purified at the conclusion. The stocks are fed into a drying bunker with a capacity of 10 m^3 and dried with a 12-meter-long, 2.2-meter-diameter rotary drier after being drained of their water and having a moisture level of roughly 10 %. The dryer filter collects the dust formed during drying and transports it beneath the filter via big-bag bags. This product can be used to construct hydroelectric dams and provide permeability in municipal waste storage areas. The dried product is conveyed in a closed elevator to a 50 m^3 silo and then returned to the first sieve with dimensions of 1700 mm x 2000 mm. The first sieve is a 700-micron sieve fed to the magnetic separators by an elevator above the sieve. It is here that dry ferrous minerals are sorted. A total of 10 tons of waste is generated per day here. These wastes are mixed and recycled in a wet plant. The feldspar circuit's plant waste contains iron minerals and will first be transferred to the waste pool. The flocculants will then be injected into the cylindroconical settling tank. The solid material that has settled in the tank will be transported to the filter press and pressed into a cake with a solids content of 93%. The solid garbage generated here is transported to a waste disposal facility. Chemical analyses reveal that epidote and apatite in the Buzlukdağı feldspar mine are particularly rich in REEs.

CONCLUSIONS

The coloring minerals contained in feldspar ore can be removed using various techniques. It has been discovered that the flotation and magnetic processing techniques can remove 90% of Fe_2O_3. However, only the TiO_2 content can be removed by flotation. The technological testing of feldspar ore was carried out in this study. In technological research, dry magnetic processing, wet magnetic processing, and flotation procedures have all been used. Dry magnetic processing tests in coarse and fine dimensions were carried out. In studies carried out in coarse size (-3.350 +75 µm grain size), the Fe_2O_3 grade was lowered to 0.4 %. The Fe_2O_3 grade was reduced to 0.5 % in wet magnetic processing studies. Experiments using dry magnetic processing outperformed those with wet magnetic processing. The particle size used in the flotation trials was -150 +20 µm. The collector was 200 g/t R-825, and the foamier was a mixture of MIBC and DF-250 (60 g/t) in the experiment that yielded the best results. The experiment was conducted in a natural pH environment. The Fe_2O_3 grade of the concentrate was lowered to 0.4% as a result of the experiment. Air pollution, soil destruction, change in relief, a local fall in groundwater level, sewage pollution, and trash are all possible adverse environmental effects of feldspar mining. The creation and condition of tailing dumps and the possibility of processing waste are crucial for all facilities with processing plants. Approximately 10 tons of waste are created per day here. The depreciation of disturbed mining sites and their early reclamation, backfilling during underground mining, maximum extraction, and processing of all valuable mineral components, which decrease production waste, are all essential and practical steps for improving facilities. The Fe_2O_3 content of the concentrate obtained from the flotation tests was lowered to 0.4%. Due to the physical size of clay, it has been shown that flotation wastes can be utilized in hydroelectric dam construction to create permeability in urban waste landfills. Furthermore, it has been suggested that REEs recovered from feldspar flotation wastes can be used for technological applications due to the investigation.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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