مجلة النهضة العلمية – الجامعة المفتوحة سبها

Al-Nahda Scientific Journal - The Open University of Sebha

Received 10 /09/2024 Revised 13 / 10/2024 Published online 31 / 12 /2024

Comparative Study of Potash and Soda Feldspar: Evaluating their Suitability for Advanced Ceramic Industry Applications

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Abstract

This study investigates the chemical and physical properties of potash feldspar (orthoclase) and soda feldspar (plagioclase) to determine their suitability in the advanced ceramic industry. Both feldspar types were analyzed using X-rd fluorescence and X-rd diffraction to identify the rate of compounds and reactions at high-temperature differences .10% silica and 10 % kaolin were added to 80% of both feldspars to enhance the cohesion and resistance of the samples and were fired at (1100°C - 1200°C) for that reason , as feldspars exhibited different melting and reaction behaviours at elevated temperatures. The results have shown that potash feldspar contains a higher concentration of alumina (Al_2O_3) and silica (SiO_2), which are desirable for improving ceramic strength and hardness. In contrast, soda feldspar contains fewer beneficial compounds and a higher percentage of impurities, such as iron oxide and titanium, which negatively affect ceramic quality. Furthermore, physical testing revealed that the potash feldspar sample has a greater hardness than the soda feldspar sample. Therefore, potash feldspar proves to be the more effective material for the production of advanced ceramics due to its superior chemical composition and mechanical properties This study is of great importance to academic researchers and industry practitioners by identifying the strengths and weaknesses points of both feldspars while evaluating the suitability of feldspar and the vision of enhancing product performance in the modern ceramic industry ,It aims to identify the most effective feldspar by comparing the melting behavior, hardness and impurity rate that affect their value within these industrial applications.

Keywords: Ceramic industry, Potash feldspar, Soda feldspar , X-rd diffraction , X-rd fluorescenc

دراسة مقارنة فلسبار البوتاس وفلسبار الصودا: تقييم مدى ملاءمتهما لتطبيقات صناعة السيراميك المتقدمة

الملخص

تحقق هذه الدراسة في الخصائص الكيميائية والفيزيائية للفلسبار البوتاسي (الأورثوكلاز) والفلسبار الصودي (البلاجيوكلاز) لتحديد مدى ملاءمتهما للاستخدام في صناعة السيراميك المتقدم, حيث تم تحليل كلا النوعين من الفلسبار باستخدام XRF و XRD لتحديد نسبة المركبات والتفاعلات عند درجات الحرارة العالية المختلفة. ولتعزيز تماسك ومقاومة العينات، تمت إضافة

10٪ من السيليكا والكاولين إلى 80٪ من كلا النوعين من الفلسبار. وبهذا تم حرق العينات عند 1100–1200 C^o، حيث ظهرت سلوكيات انصهار الفلسبار وتفاعلات مختلفة عند درجات الحرارة المرتفعة. وقد أظهرت النتائج أن الفلسبار البوتاسي يحتوي على تركيز عالي من الألومينا ($Al_2\ O_3$) والسيليكا(SiO_2) ، وهي مركبات مرغوبة لتحسين صلابة السيراميك . وعلى النقيض، يحتوي الفلسبار الصودي على نسبة أقل من هذه المركبات المفيدة ونسبة متزايدة من الشوائب، مثل أكسيد الحديد والتيتانيوم، التي تؤثر سلباً على جودة السيراميك. وعلاوةً على ذلك، أظهرت الاختبارات الفيزيائية أن عينة الفلسبار البوتاسي تتمتع بصلابة أكبر مقارنة بعينة الفلسبار الصودي. وبالتالي، ثبت الفلسبار البوتاسي أنه المادة الأكثر فعالية لإنتاج السيراميك المتقدم نظرًا لتكوينه الكيميائي المتفوق وخصائصه الميكانيكية. هذه الدراسة لها أهمية بالنسبة للباحثين الأكاديميين والممارسين في الصناعة من خلال تحديد نقاط القوة والضعف لكلا النوعين من الفلسبار، مع تقييم مدى ملاءمة الفلسبار ورؤية تحسين أداء المنتجات في صناعة السيراميك الحديثة. كما انها تهدف الي تحديد أفضل أنواع الفلسبار الفعالة من خلال مقارنة سلوك الانصهار والصلابه ونسبة الشوائب التي تؤثر على قيمته ضمن هذه التطبيقات الصناعية

الكلمات المفتا حية: صناعة السيراميك ، فلسبار البوتاس ، فلسبار الصودا ، حيود الأشعة السينية ، فلورسنت الأشعة السينية

INTRODUCTION

Feldspar is one of the raw materials spread in nature. It consists of a series of minerals and is one of the most substantial materials used in the manufacture of advanced ceramics at different high temperatures due to containing many compounds that enable him to improve the quality of ceramics, such as Silica that melts at high temperatures which gives rigidity to the product. Therefore, there are many types of feldspars, such as soda and potash feldspar is the second element that is important after silica [1]. Feldspar minerals are essential components of igneous, metamorphic, and sedimentary rocks thus; most classification of several crags depends on the Feldspar content. The mineral composition of most feldspar can be expressed in terms of the ternary system Orthoclase ($KAlSi_3O_8$), Albite ($NaAlSi_3O_8$), and Anorthite ($CaAl_2Si_2O_8$). Chemically, feldspar is an Aluminium silicate, Sodium, Potassium, Iron, Calcium, and Barium, or a combination of these elements [1],[2]. The mineral composition between Albite and Anorthite is known as Plagioclase feldspar, which contains sodium much more potassium [2], while feldspar potassium is called orthoclase. There is a chemical reaction difference between orthoclase and albite. Moreover, there are compounds with a similar function in the orthoclase compounds that appear at high temperatures, such as Silimenite and Microcline where potassium feldspar melts asymmetrically and forms as a mixture of glass starting at 1100 C^o therefore, all feldspars do not have a strict melting point because gradually melts at different temperatures [1]. However, the components of soda feldspar and potassium feldspar differ in their components from one type to another. When reacting at high temperatures, some components dissolve with other compounds and improve the components of the product, while others contain many impurities. Therefore, the best components must be selected and monitored when adding them to materials to produce modern ceramic applications. Some researchers have investigated the effect of feldspars not this exclusively, Williaime (1979) has pointed out the effects at different temperatures on feldspar, as well as the pressure and uses of recent thermal data for soda feldspar, which is related to the deformation of feldspar in the earth [3]. Summarized Ban - Ban-Bin (2010) the processing of weathering, the mechanisms of feldspar weathering, simulated chemical weathering, and biological weathering [4]. Examined Liu (2019) Study of Feldspar and Lime Hydrothermal, the phases formed using different techniques, how to form crystallized compounds, and the effect of their reaction at several temperatures, thermal reaction, and reaction time [5]. A Roy (2010) has focused on Bio-beneficiation of Kaolin and Feldspar and its effect on fired characteristics of triaxial porcelain [6]. Illustrated Kimambo(2014) Suitability of Tanzanian kaolin, quartz and feldspar as raw materials for the production of porcelain tiles[7].This study has significance for academic researchers and industry practitioners by Identifying the strengths and weaknesses points of both feldspars, while evaluating the suitability of feldspar for advanced ceramics, and the vision of enhancing product performance in the modern ceramic industry ,while aiming to identify the best types of effective feldspar for advanced ceramics by comparing the melting behavior, hardness and impurity rate that affect their value within these industrial applications.

MATERIALS AND METHODS

Materials

The essential raw materials prepared in this paper were two types of feldspars, potash and soda feldspar, obtained from commercial materials. This stage of work was started as a mixture consisting of 80% feldspars, 10% kaolin, and 10% silica that gave results under x-ray fluorescence (XRF) to know the ratio of chemical compounds in those materials, which is considered most substantial in this work as shown in table (1).

Table (1) Chemical composition of raw materials wt%

Elements	feldspar/p	Feldspar/s	Silica	Kaolin
SiO_2	67.00	69.00	98.88	46.97
Al_2O_3	18.00	20.00	0.12	38.04
Fe_2O_3	0.14	0.16	0.08	0.45
K_2O	11.00	2.59	0.06	1.14
CaO	0.26	1.7	0.01	0.02
Na_2O	2.1	5.56	0.03	0.04
TiO_2	-	0.21	0.07	0.04
ZrO_2	-	0.02	-	-
P_2O_5	-	0.36	0.02	0.11
SO_3	-	0.01	0.001	-
L.O.I	1.5	0.19	0.729	13.19

These analyses confirm that the compound ratio of SiO_2 and Al_2O_3 are high and substantial for all raw materials and suitable for the industry before making samples, whilst the K_2O is the highest of potash feldspar, and Na_2O is the highest of soda feldspars moreover, by analyzing the X-ray phase, the raw materials has appeared such as silica (quartz) with the symbol(Q)and kaolin with the symbol (K), as well as potash feldspar (P) and soda feldspar appeared as Albite (A) as shown in figure (1).

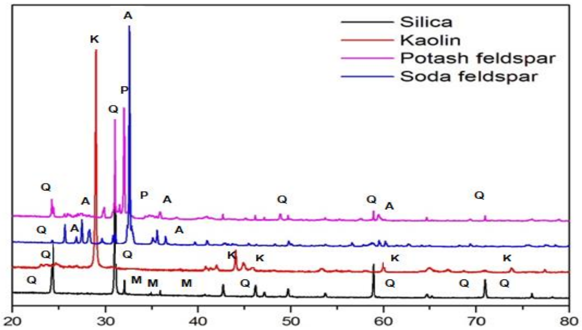

Figure: (1) X-RD amylases of raw materials

Preparation of samples

In this stage was prepared four types of samples and fired at different temperatures after the milling processing, by grinding device and mixing them well and estimated around (30-40) minutes were required manner as follows: 80% of potash feldspar, 10% silica, and 10% kaolin moreover,80%soda feldspar,10% silica, and 10% kaolin too. The specimens were created as small samples without adding water to the mixtures, which were dimensioned around (4x 4 x 60 mm) with diameter thickness ranging from (3-4mm) then the specimens were pressed by a press device estimated under (1.2-1.5) ton hydraulic press) therefore, different mixtures were created for four different specimens (A-A1-B-B1), and then the specimens were placed in the thermal dryer at (110 C°) before firing to rid excess water, as the picture below shows the samples before firing as Figure (2).

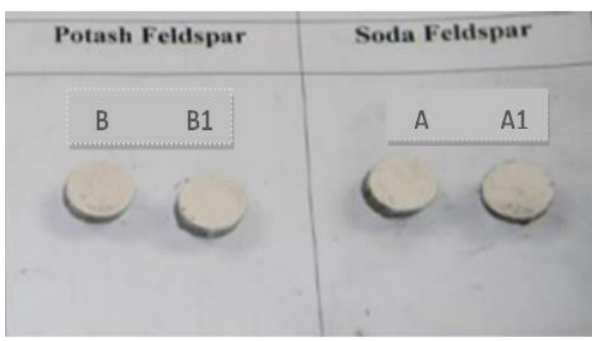

Figure: (2) Samples before firing

Subsequently, for 1 hour 5 °C per minute was distributed into two parts for each part under different temperatures, as the first samples consisted of 80% soda feldspar, 10% kaolin, and 10% silica placed as (A, A1) heated up to 1100 - 1200°C then second samples nearly also up to1100- 1200°C which is consisting of 80% of potash feldspar, 10% of kaolin and 10% of silica placed as (B, B1) that picture (3) below show the samples after firing. After being naturally cooled, we noted the colour of the samples changed, which means there were different interactions between them. The microstructure of the samples was studied with X-ray diffraction for knowledge of chemical interactions and device fracture of specimens for physical properties such as fracture toughness and also to study the ratio of shrinkage and absorption of water.

Figure: (3) Samples after firing

RESULTS AND DISCUSSION

The chemical composition of both feldspars is tabulated after firing specimens during different temperatures, which were (1100,1200C°), where through these temperatures appeared some interactions on both samples by x-rd diffraction explained the importance of the resulting materials as well as testing of Volumetric shrinkage and hardening test.

Results of Soda feldspar

Analyses of XRD illustrated the interactions of samples (A, A1) at a high temperature of (1100 C° compared with 1200 C°, there is a high ratio of impurities at 1200 C° more than at1100 C° as Iron Oxide (Fe_2O_3) 37% while Iron Oxide at1100 C° was 1.2% and increased titanium Oxide (TiO_2) 31% at 1200 C° compared at 1100 C° was 24% then Zirconium oxide (ZrO_2) is 28% with Sodium Aluminum was12%. Therefore, the compound of Albite appeared as Na ($AlSi_3O_8$) at 1100 C° silicate Aluminum Sodium is much higher with the Quartz (SiO_2) turned out to be 20% at 1200 C° with Aluminum Oxide (Al_2O_3)13%, was much low not desirable and suitable for industry, thus, the samples were as brittle due to frequent appearance of impurities for soda feldspar as shown over in figures (4, 5)

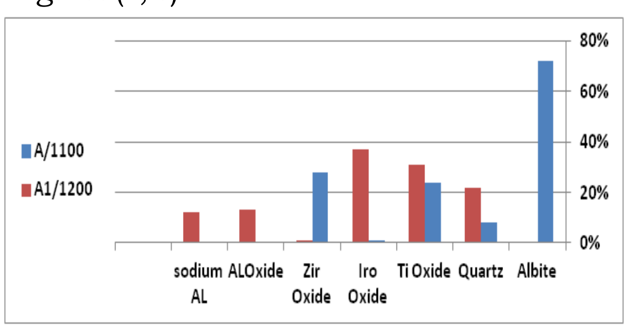

Figure:(4) Chemical interactions of Soda feldspar

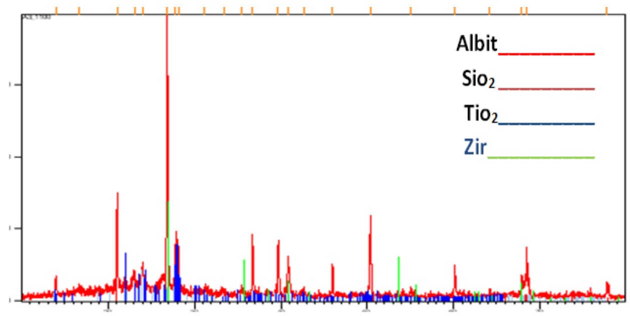

Figure:(5) X-RD results of Soda feldspar at 1100C°

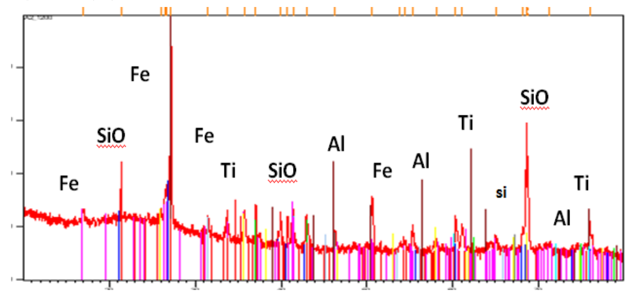

Figure: (6) X-RD results of Soda feldspar at 1200C°

Results of potash feldspar

In this stage of interactions at different temperatures between samples (B, B1) that consist of potash feldspar, whilst illustrated the results that a high proportion of Quartz (SiO_2) on two types of samples (B, B1) at different temperatures 1100 -1200C° that means a perfect ratio through the react. However, there is a slight increase in the impurities at 1100 C° however, they almost disappear at 1200 C°, which is evidence of the melting of the impurities and replaced by silicon oxide called (Quartz)and an aluminum oxide called (Alumina), which led to the emergence of a new compound called (Mullite) with a high percentage at a temperature of 1200 C°, that consist of silicon and aluminum hence, it is an excellent thermal compound, which has the properties of hardness as well, with the appearance of another compound in a small proportion called Sillimanite with the same properties as Mullite,which also consists slights of silicon oxide and aluminum oxide, as shown in figures (7,8,9).

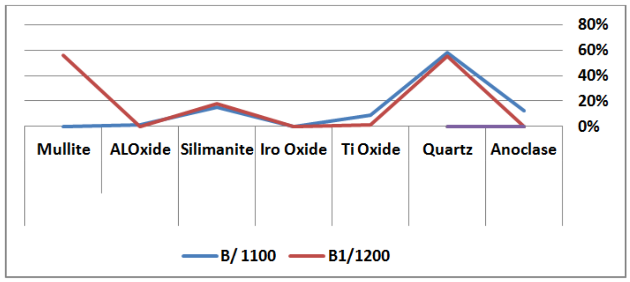

Figure: (7) Chemical interactions of potash feldspar

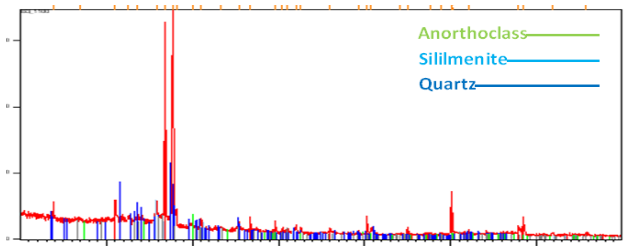

Figure: (8) X-RD Results of potash feldspar at 1100 C°

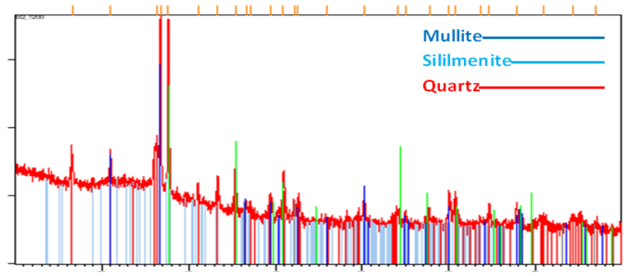

Figure: (9) X-RD Results of potash feldspar at 1200 C°

Volumetric shrinkage test

This processing of the test, which determines the shrinkage rate according to determining the porosity and its weight after the firing process, is due to the quality of the samples and their ability to absorb. The table below illustrates the ratio of shrinkage at different temperatures, where the samples (B, B1) consisting of potash feldspar had more shrinkage than (A, A1) consisting of soda feldspar thus, the sample (B1) at 1200C° more shrinkage, according to the rule of shrinkage Whilst , $V.Sh\% = \frac{V1-V}{V1} \times 100$ Thus, V1= Volume of the specimen before firing, V= volume of the specimen after firing, figure (10) below shows the evaluates.

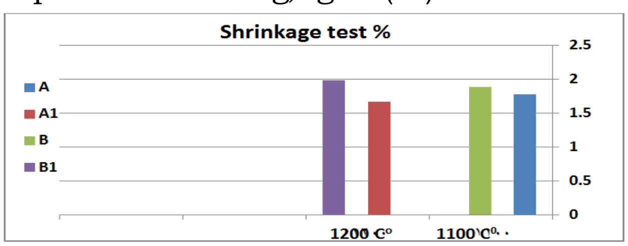

Figure: (10) Evaluations of Shrinkage %

Fracture toughness test

All industrial materials are subject to fracture and cracking because of the pressure force, mechanical properties, or other factors that affect the manufactured materials. Therefore, it is necessary that the strength be tested and measured, and the aim is to ensure the resistance of the material concerning the load and the force .In this test pressing the sample under the fracture device and the extent of its tolerance at a certain point by concentrating load or pressure on all specimens (A, A1, B, B1) as shown in figure (11)Through the hardness results, we have noticed that the endurance of samples (B-B1) at a temperature of 1200 C° is approximately 150 /N more than at a temperature of 1100 C°, including samples (A-A1), which are less stiff at both temperatures under fracture device test, where the load was (N). Likewise was shown at the shrinkage test, the sample (B1) had more shrinkage compared with other samples .

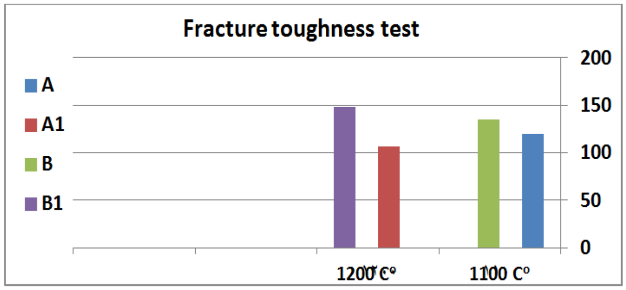

Figure: (11) valuations of fracture toughness (N)

CONCOLUSION

This study succeeded in comparing and determining the best type of feldspar, as laboratory experiments proved that potassium feldspar has an excellent property in the manufacture of advanced ceramics at the beginning of the temperature of 1200C°, despite the presence of a small percentage of impurities therefore, at this point predicts its disappearance at a temperature that is higher than 1200 C° and increases in the reacting of new compounds which have appeared, such as the Mullite and Similite compound, which increases the hardness of the product, which consists of aluminum oxide, silicon oxide as structure is ($3Al_2O_3,2SiO_2$) where this was much convenient when the color of the samples changed therefore, there was a clear difference, as the sample (B) containing potassium feldspar was white in color, which indicates that it is a component of porcelain that appeared and melted at 1200C° Unlike the samples (A) that contain sodium feldspar, the study of the samples succeeded under shrinkage testing in porosity and hardness, which indicates the sustainability of the product under pressure and fracture conditions, where that potassium feldspar is the best of soda feldspar through of ceramic industry . Therefore, potassium feldspar is considered one of the sources of wealth in Libya and is suitable for manufacturing advanced ceramics.

REFRANCES

[1] Mishra, M. & Samant, B., 2021. Feldspars: Life-Sustaining Minerals on the Earth. In: S. j. Dhoble, et al. eds. MINERALS AND THEIR PROPERTIES NOVEL. New York: Nova Science Publishers, pp. 250-257

[2] Brown, W. L., 2013. *Feldspars and Feldspathoids: Structures, Properties and Occurrences.* s.l.:Springer Science

[3] Williaime, C., Christie, j. M. & Kovacs, M. P., 1979. Experimental deformation of K-feldspar single crystals. *Bulletin de Minéralogie,* 102(2-3), pp. 168-177.

[4] Ban-Ban & Bin, A., 2010. Study on feldspar weathering and analysis of relevant impact factors. *Earth Science Frontiers,* 17(3), p. 512.

[5] Liu, S., Han, C. & Liu, J., 2019. Study of K-Feldspar and Lime Hydrothermal. *minerals,* 14 January, p. 17.

[6] A Roy, S. S. P. B. K. D. S. D. K., 2010. Bio-beneficiation of kaolin and feldspar and its effect on fired characteristics of triaxial porcelain. Indian Academy of Sciences, 33(3), pp. 333-338.
[7] V Kimambo, J. P. E. L., 2014. Suitability of Tanzanian kaolin, quartz and feldspar as raw materials for the production of porcelain tiles. Technology and Society, 2(6), pp. 201-209.
[8] Wang, H. et al., 2020. Synthesis of silicon nanosheets from kaolinite as a high-performance anode material for lithium-ion batteries. *Journal of Physics and Chemistry of Solids,* 137(109), p. 277.
[9] Du, H. & Dai Pang, S., 2020. High-performance concrete incorporating calcined kaolin clay and limestone as cement substitute. *Construction and Building Materials,* 264(120), p. 152.
[10] Yalley, P. P. and Kankam, C. K. (2021) *Experimental and Computational Analysis of Compressive Strength of Bricks with Granite Powder and Fibres as Binder to Soil.* Journal of Materials Science Research and Reviews, 7 (2). pp. 25-40.
[11] Rafael Guelfi Frizzo, A. Z. V. d. S. N. V. d. S. N., 2020. Pyroplasticity on porcelain tiles of the albite-potassium feldspar-kaolin system: A mixture design analysis. *Journal of Building Engineering,* 31(101432).

[12] Bansal, N. P. & Boccaccini, A. R., 2012. *Ceramics and Composites Processing Methods.* s.l.:Wiley.

[13] Barry, C. C. & Norton, G. M., 2013. *Ceramic Materials.* New york: Springer..

[14] Pampuch, R., 2014. *An Introduction to Ceramics.* s.l.:Springer.