Preparation, Microstructure Studies and Mechanical Properties of Glazes Ceramic Sanitary Ware Based on Kaolin

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Abstract: In this paper, the use of local kaolin coming from Djebel Debbagh (denoted DD1) in the composition of ceramic glazes for sanitary ware was examined. Because of its natural abundance, low price and good characteristics, this kaolin represents an interesting economic alternative to other mineral clays. The chemical composition showed that this kaolin contains 38.49 wt.% Al2O3 and 44.85 wt.% SiO2. Two glazes based on kaolin DD1 denoted as GaDD1 and GbDD1 were prepared with conventional ceramic processing techniques at temperature 1250 °C. As a reference, another glaze (Gref) based on kaolin Remblend was also prepared in the same conditions. The samples were characterized with X-ray diffraction and Scanning Electron Microscope. The results revealed that zircon and quartz are the crystalline phases present in these glazes. In the sample GaDD1, it was found that the degree of whiteness is very high and reaches 93.30 %. However, the water absorption coefficient is low which is about 0.19 ± 0.04 %. In addition, the flexural strength and the Vickers microhardness are respectively, about 56.07 ± 5.61 MPa and 7952.80 ± 101.76 MPa. These properties are compatible with those of the glaze reference Gref and commercial sanitary ware glazes, indicating the potential use of kaolin DD1 in the production of glazed ceramic for sanitary ware applications.

Keywords: Kaolin DD1; Ceramic sanitary ware; Whiteness; Flexural strength; Microhardness.

1. Introduction

Many local raw materials, like kaolin, feldspar, quartz, calcite and dolomite, are very abundant and they are used in industrial ceramics because of availability and low cost. Several research studies have already been published about the valorization of raw materials for the production of ceramic membranes [1], dental porcelains [2], bioceramics [3], technical
porcelain [4], glass [5] and glass-ceramic [6]. Therefore, the exploitation of new raw material resources satisfying the criteria of ceramic industries is important.

Algeria has large deposits of kaolin raw materials, particularly in the east of the country. Several work projects were carried out in recent years to assess the Algerian kaolin properties such as formation of anorthite containing cordierite materials through reaction sintering kaolin, MgO and CaO precursors [7], preparation and microfiltration membranes and their supports using kaolin (DD$_2$) and CaCO$_3$ [8], elaboration of tubular supports for membranes filtration based on kaolin DD$_2$ and lime extracted from limestone [9]. Chargui et al. [10] showed that kaolin, whose main constituent is kaolinite (Al$_2$Si$_2$O$_5$(OH)$_4$), undergoes successive structural and microstructural transformations during its firing. The last transformation step is the vitrification of cristobalite, which occurs at a temperature generally above 1400 °C. The presence of some impurities, such as CaO, Na$_2$O and K$_2$O, in the initial kaolin favors cristobalite vitrification at lower temperatures. But to date, there have been no studies on the possibility of using this kaolin in glazes production in the literature.

It is well known that glazes are stable glassy coatings applied to ceramic to attain stunning surfaces and formerly obtained by cooling oxides applied on the surfaces of ceramic objects. Originally, glazes were considered as an innovation for sanitary ware when associated with a porous ceramic substrate because it is making a clean and hygienic surface [11]. Most of the glazes are applied to ceramic bodies in order to ensure their liquid and gas impermeability while remaining mechanically stronger, resistant to scratching, readily cleanable, chemically more inert. The aesthetic qualities of the product are also enhanced [12].

Generally, glaze, as used for sanitary ware, contains many raw materials such as zircon, feldspar, limestone, quartz, talc, ZnO, calcite, sodium carbonate, wollastonite, pegmatite and kaolin. Each of those materials gives special properties to the glazes. Among them, kaolin was used to introduce alumina and, to a lesser extent silica in glazes. The addition of kaolin has a stabilizing effect on the aqueous suspension of glaze; its application to the body allows obtaining a consolidated glaze layer that gives rise to the final glaze coating on firing [13]. However, its use was limited due to the possibilities of high iron content that could tint the glaze to give brown color.

This work aims to study and characterize the Algerian kaolin DD$_1$ for potential use in industrial glazes. This kaolin was chosen because of its natural abundance, low price and good characteristics. Kaolinite has a hydrothermal geological formation [14], its valorization for the manufacture of low-cost glazes ceramic products in multicomponent oxides system as well as the improvement of whiteness, mechanical properties and chemical durability of glazes are the main objectives of this work.

2. Materials and Experimental Procedures

2.1 Selection and characterization of the raw materials

The starting raw materials used for the preparation of the glazes; in industrial grade, were natural white kaolin DD$_1$ obtained from the Algerian site of Guelma. Kaolin RMB was supplied by Imerys Minerals Ltd, Austell, Cornwall, UK. Sodium feldspar was derived from Çine, Aydin of Turkey. Quartz, calcite, dolomite and ZnO were derived from deposits in Algeria, zircon was provided by Chilches Materials, Castellón, Spain. The raw DD$_1$ kaolin materials, which their absolute density, measured with a helium pycnometer apparatus is 2.63 g/cm$^3$, was milled dry using a Retsch PM100 ball mill for 15 minutes. The chemical compositions of raw materials were determined by an X-ray fluorescence spectrometer Rigaku ZSX Primus IV (see Table I).

Besides, kaolin DD$_1$ was characterized by Fourier transform infrared spectroscopy (FTIR) using an IR Affinity Shimadzu Japan spectrophotometer in the 400-4000 cm$^{-1}$ range.
A numerical approach based on calculated crystalline indices CI\textsubscript{1} and CI\textsubscript{2} from the intensities of selected vibration modes and structural OH bands [15] of the FTIR spectrum of kaolin DD\textsubscript{1} was applied using the equations (1) and (2):

\[
CI_1 = \frac{I(\gamma_1)}{I(\gamma_2)} \quad (1)
\]

\[
CI_2 = \frac{I(\gamma_3)}{I(\gamma_1)} \quad (2)
\]

where \(I(\gamma_1)\) and \(I(\gamma_3)\) are intensities of the OH stretching bands at 3693 and 3620 cm\(^{-1}\) and \(I(\gamma_2)\) is the intensity of the OH bending band at 910 cm\(^{-1}\). According to the obtained values of crystallinity indices, kaolinites are classified as poorly ordered structures when \((CI_1 < 0.7, CI_2 > 1.2)\); partially ordered structures if \((0.7 < CI_1 < 0.8, 0.9 < CI_2 < 1.2)\) and ordered structures if \((CI_1 > 0.8, CI_2 < 0.9)\).

The mineralogical composition of DD\textsubscript{1} was determined using an X-ray Panalytical diffractometer with Cu Kα X-ray radiation \(\lambda=1.5406\) Å, in the \(2\theta\) range of 0-80°.

The DD\textsubscript{1} morphology was observed by Scanning Electron Microscopy (SEM) (WD S, JEOL JSM 6360LV).

### Tab. I Chemical compositions of raw materials (wt.%).

| Oxides | Kaolin DD\textsubscript{1} | Kaolin Remblend | Sodium feldspar | Quartz | Calcite | Dolomite | ZnO | Zircon |
|--------|----------------|----------------|----------------|--------|---------|----------|-----|--------|
| Al\textsubscript{2}O\textsubscript{3} | 38.49 | 36.50 | 18 | 0.45 | 0.09 | 0.03 | 0 | 0 |
| CaO | 0.01 | 0.07 | 0.70 | 0.80 | 55.63 | 31.45 | 0 | 0 |
| Fe\textsubscript{2}O\textsubscript{3} | 0.06 | 1.01 | 0.06 | 0.40 | 0.02 | 0.03 | 0 | 0.08 |
| MgO | 0.01 | 0.30 | 0.20 | 0.13 | 0.01 | 20.38 | 0 | 0 |
| K\textsubscript{2}O | 0 | 2 | 0.30 | 0.20 | 0 | 0 | 0 | 0 |
| Na\textsubscript{2}O | 0 | 0.10 | 0.10 | 0.09 | 0 | 0 | 0 | 0 |
| SiO\textsubscript{2} | 44.85 | 48 | 70 | 98.50 | 0.06 | 0.20 | 0 | 35 |
| TiO\textsubscript{2} | 0 | 0.05 | 0.09 | 0.04 | 0 | 0.02 | 0 | 0.15 |
| ZnO | 0 | 0 | 0 | 0 | 0 | 98 | 0 | 0 |
| ZrO\textsubscript{2} | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 65 |
| L.O.I* | 16.46 | 12 | 0.40 | 0 | 43.80 | 47 | 1.90 | 1 |

*L.O.I = Loss. On. Ignition.

### 2.2 Glazes preparation and characterization

Initially, the glazes formulations in suitable proportions are presented in Table II. The experimental glazes GaDD\textsubscript{1} and GbDD\textsubscript{1} were prepared using kaolin DD\textsubscript{1}. As for the sample, Gref (as a reference) was prepared in the same conditions as our glazes using kaolin Remblend.

The glazes slurries were prepared by directly milling the weighed starting raw materials with water in a porcelain jar during 3 h, with added milling balls (10 mm). The raw materials: balls: water ratio was 1:1:0.5. During the homogenization process, 0.5 % sodium silicate (99.90 %, grade ACS reagent) was added to the slurry to obtain a better dispersion. The slurries were sieved through a sieve of 63 \(\mu\)m to remove coarse particles [16]. The fluidity behavior of the slurries was determined at 20 °C in a Ford cup time, these values vary between 20 and 30 s. The required density of the glaze suspension onto a ceramic substrate ranges between 1.70 and 1.72 g/cm\(^3\) [17].
Tab. II Glazes sanitary ware composition formulations (wt.%).

| Glazes | Kaolin DD | Kaolin Remblend | Sodium feldspar | Quartz | Calcite | Dolomite | ZnO | Zircon |
|--------|-----------|----------------|-----------------|--------|---------|----------|-----|--------|
| GaDD₁  | 6         | 0              | 34              | 26     | 10      | 7        | 1.25| 15.75  |
| GbDD₁  | 5         | 0              | 35              | 26     | 10      | 7        | 1.25| 15.75  |
| Gref   | 0         | 6-9            | 34-35           | 24-26  | 8-10    | 7-8      | 1.3 | 9-16   |

The glaze slurries were sprayed on dried sanitary ware bodies with a compressed-air sprayer. The glazed bodies were then dried for 1 h at 100 °C.

Later the glazed bodies were fired at temperature of 1250 °C in a tunnel kiln for 21 h. At firing zone, all the raw materials are fused and glazes were fused evenly. At cooling zone, sudden cooling is done to create a glossy surface.

To identify the crystalline phases formed after the thermal treatment, the glazes were analyzed by X-ray diffraction (XRD). The powdered samples were inspected using a PANalytical diffractometer, Cu Kα X-ray radiation, λ = 1.5406 Å, in the 2θ range of 10-70°.

The microstructure of the glazes was examined using a Scanning Electron Microscope WD S, JEOL JSM 6360LV.

The grain size distributions of glaze powders were measured with a laser granulometer (HORIBA, model analyzer LA-960).

The unfired glaze powder was subjected to differential thermal analysis (DTA) and thermo-gravimetric analysis (TGA) using DSC-DTA-TGA analyzer (SDT Q 600 - TA instrument) with α-alumina as the reference material. About 40 mg of raw powder mixture was placed in an alumina crucible and heated at a rate of 10 °C/min from room temperature to 1050 °C.

The whiteness parameters L, a* and b* of the fired samples were measured using a Minolta CR-400 series Chroma Meter. L (whiteness) from absolute white L = 100 to absolute black L = 0, a* and b* whiteness indices; a* (a*> 0 red; a*< 0 green), b* (b* > 0 yellow; b*< 0 blue). Further, a* represents the variation between green and red colors; and b* indicates the variation between blue and yellow colors [18].

The water absorption percentage (Wabc) was determined using the following method [19]: the samples with dimensions 8 cm × 2 cm × 1 cm were dried for 12 h at 110 °C and its weight (M₁) measured using an analytical balance; these samples were then immersed in distilled water and boiled for 2 h, cooled in situ for 12 h and re-weighed (M₂). After this, Wabc was calculated using the formula (3):

\[ W_{abc} = 100\left(\frac{M_2-M_1}{M_1}\right) \]  (3)

The flexural strength of the glazes ceramic was measured by a three-point bending test (sample dimensions 9 cm × 2 cm × 2 cm) carried out with a machine NETSZH, using the formula (4):

\[ S_f = \frac{3PL}{2bh^2} \]  (4)

where P is the force at the fracture load (N), L is the distance between supports (mm), b is the width (mm) and h is the height (mm). Each value illustrates the average of measurements made on eight individual specimens.

The Vickers microhardness measurements were done for glazed samples (2 cm × 8 cm × 1 cm) by using a Vickers Hardness Tester (AFFRI DM2D Digital) at the load of 1000 gf for 25 s. The Vickers microhardness HV was measured using the formula (5) [20]:
where $F$ is the indentation load (N), $d$ is the diagonal of the imprints (µm), and 1.8544 is a geometrical constant of the diamond pyramid which was calculated from the specific geometry of the indenter. Chemical resistance was tested according to the NF D14-506 and NF D14-508 standard method. Then, the studied glaze test pieces (dimensions 2 cm × 2 cm × 1 cm) were immersed in an aqueous solution of HCl (pH 1.8, grade ACS reagent) and NaOH (pH 13.5, grade ACS reagent) for 7 days at 20 °C [21]. The glazes were weighed before and after the tests using an analytical balance. The samples were visually examined to verify possible changes in color and gloss.

3. Results and Discussion

3.1 Characteristics of the raw material DD₁

The chemical composition of kaolin DD₁ is given in Table I, the predominant oxides were SiO₂ and Al₂O₃. The SiO₂/Al₂O₃ molar ratio was 1.16. However, Fe₂O₃ amount was 0.06 % and the total absence of TiO₂ in this kaolin suggests the obtention of a very white glaze.

![FTIR spectrum of kaolin DD₁](image)

**Fig. 1.** FTIR spectrum of kaolin DD₁.

The FTIR spectrum corresponding to kaolin DD₁ (see Fig. 1) reveals the presence of four bands at 3693, 3668, 3647 and 3620 cm⁻¹ related to the stretching vibrations of O-H bond [22, 23]. The bands located at 3693 cm⁻¹ and 3668 cm⁻¹ are assigned to the hydroxyl which belongs to sheet edges. The bands situated at 3647 and 3620 cm⁻¹ reveal the interaction between surface hydroxyls of octahedral and basic oxygen of tetrahedral layer. The H–O–H bending band vibration of adsorbed water molecules is observed at 1633 cm⁻¹. The bands observed at 1113 and 1088 cm⁻¹ were attributed to Si–O–Si stretching vibration. The Al–O–H absorption peak was revealed at 891-911 cm⁻¹ for the studied samples [24], where the band at 910 cm⁻¹ is assigned to stretching vibration of Al–O–H with Al in coordination VI [25]. The bands located at 789 and 755 cm⁻¹, can be attributed to the vibrations of Al–Mg–OH and Si–O–Al groups of the network. Noteworthy, bands at 690, 538 and 467 cm⁻¹ can be assigned to the Si–O and Si–O–Al vibrations of the kaolin sheet [26]. In addition, the values of
crystallinity indices CI\textsubscript{1} and CI\textsubscript{2} of 0.41 and 3.73 lead to classify kaolinites as poorly ordered structures.

![X-ray diffractogram of kaolin DD\textsubscript{1}.](image)

Fig. 2. X-ray diffractogram of kaolin DD\textsubscript{1}.

Fig. 2 shows the X-ray diffractogram of kaolin DD\textsubscript{1}. It is evident that the main mineral constituents of the clay are kaolinite (Al\textsubscript{2}Si\textsubscript{2}O\textsubscript{5}(OH)\textsubscript{4}) and halloysite (Al\textsubscript{2}Si\textsubscript{2}O\textsubscript{5}(OH)\textsubscript{4}·2H\textsubscript{2}O) identified respectively by using the JCPDS database files 14-0164 and 29-1489. Halloysite is a naturally occurring hydrated polymorph of kaolinite and has a similar structure and chemical composition; however, the unit layers are separated by an additional monolayer of water molecules [27].

The observation of the SEM microstructure of kaolin powders (Fig. 3) revealed randomly shaped, elongated and oriented in all directions. In kaolin, randomly shaped and intermixed agglomerates favor a good porosity.

![Microstructure of kaolin DD\textsubscript{1} powder.](image)

Fig. 3. Microstructure of kaolin DD\textsubscript{1} powder.

### 3.2 Properties of the prepared glazes

#### 3.2.1. X-ray diffraction

Fig. 4 shows the X-ray patterns corresponding to the examined glazes GaDD\textsubscript{1}, GbDD\textsubscript{1} and Gref. The sharp diffraction peaks could be indexed as zircon and quartz peaks identified by using the JCPDS database files 06-0266 and 46-1045.
Fig. 4. X-ray diffractogram of all glazes after firing at temperature 1250 °C.

3.2.2. Scanning Electron Microscopy (SEM)

Fig. 5. SEM micrograph of the a) GaDD1 sample; b) GbDD1 sample and c) Gref sample, zircon (indicated by rectangles), quartz (indicated by ellipses) and glassy phase (indicated by arrows).
Fig. 5 shows the microstructure of glazes GaDD₁, GbDD₁, where two distinct crystalline phases are observed. The first represents zircon whose grain size is submicron (indicated by rectangles in Fig. 5), the second crystalline phase is quartz (many pieces of dark areas indicated by ellipses in Fig. 5). The dispersion of the zircon grains in the glassy matrix (indicated by arrows in Fig. 5) seems homogeneous and random. This uniform distribution is very important to improve the surface densification of glazed ceramic.

3.2.3. Particle size Distribution of glazes powder

Fig. 6 shows the particle size distributions of the samples GaDD₁, GbDD₁ and Gref. Glazes prepared with local kaolin GaDD₁ and GbDD₁ exhibited a bimodal particle size distribution with the same particle populations but with different rates. GaDD₁ and GbDD₁ glazes show a mean particle size $D_{50}$ of 42.21 and 19.76 µm respectively. In contrast, the initial Gref glaze powder distribution is composed of three particle populations, with a mean particle size $D_{50}$ of 58.92 µm, the first two populations of Gref glaze powder particles are similar to those of the kaolin DD₁ glazes. The third family of particles consists of large particles of a few hundred µm, such results are consistent with SEM observations.

Gorodylova et al. studied the impact of particle size reduction on glaze-melting, they noted an increase of milling time, resulting in an improved homogeneity and a decrease of the mean size values [28], which agrees with the low values of mean size obtained for the samples GaDD₁ and GbDD₁.

![Particle size distributions of the glazes mixture raw powders.](image)

3.2.4. Thermal analysis of glazes powder

Thermogravimetric (TGA) and differential thermal analysis (DTA) were employed to study weight change and all the transformations taking place during the heating cycle. TGA/DTA curves of the three investigated glazes from ambient temperature to 1050 °C are reported in Fig. 7. An initial weight loss of about 3 % is observed in the TGA curve, which is attributable to the evaporation of adsorbed water [29, 30]. The departure of the structural water or the dehydroxylation of kaolin DD₁ occurs between 500 and 550 °C [31], accompanied by a loss of mass of the order of 3 %. The DTA curve does not show the endothermic and exothermic peaks of its transformations given its low content in the mixture relative to feldspar and quartz. At temperature around 570 °C, the α-quartz is transformed into
\(\beta\)-quartz without weight loss [32]. A mass decrease of about 5 % was observed during the decomposition of calcium carbonate [33] to \(\text{CO}_2\) and \(\text{CaO}\) between 600 and 750 °C. The decomposition of dolomite (\(\text{CaMg}\left(\text{CO}_3\right)_2\)) [34] into \(\text{CaO}\) and \(\text{MgO}\) with a new mass loss of 2 % and the recrystallization of kaolinite into mullite and cristoballite occur at temperatures comprising between 750 and 1050 °C. Overall, the mixture of the starting powders undergoes a total mass loss estimated to be around 9 to 11 % after heating at 1050 °C. With increasing of temperature, the sodium feldspar begins to melt congruently and decompose at about 1100 °C [35], favored by the presence of sodium oxide. At temperatures above 1200 °C, the mixture melts to form the glaze, the zircon remains stable in this temperature range and dispersed in the glassy matrix (see Fig. 5), it dissociates in zirconia and silica only above 1500 °C [36]. According to the thermal analysis results, samples GaDD\(_1\) and GbDD\(_1\) showed some differences compared with sample Gref.

![Graph showing TGA/DTA curves of the investigated glazes.](attachment:fig7.png)

**Fig. 7.** The TGA/DTA curves of the investigated glazes.

### 3.2.5. Whiteness

| Glazes   | Whiteness(%) | \(a^*\) | \(b^*\)  |
|----------|--------------|---------|---------|
| GaDD\(_1\) | 93.30        | -0.38   | +2.23   |
| GbDD\(_1\) | 92.04        | -0.11   | +2.17   |
| Gref     | 89.15        | -0.67   | +3.22   |

As can be seen from Table III, the L value for GaDD\(_1\) sample is 93.30 % which is higher than that of GbDD\(_1\) (92.04 %) and Gref (89.15 %). In general, opaque glazes exhibit high whiteness values [37]. The values of L in GaDD\(_1\) and GbDD\(_1\) are superior to 92 %, indicating, therefore, a high degree of whiteness of glazes, there is also a tendency to shift slightly in the left quadrant (green and yellow), which is probably due to the presence of zircon crystals in the glaze. It may also be noted that the kaolin DD\(_1\) containing compositions GaDD\(_1\) and GbDD\(_1\) showed higher L values due to the presence of lower amounts of \(\text{Fe}_2\text{O}_3\) and \(\text{TiO}_2\) compared to the kaolin Remblend containing composition Eref [38]. Benkacem et al. found the optimum value of whiteness for opaque glazes used in ceramic sanitary ware is 87.00 % due to the presence of zircon crystals and thus effectively scatters light to ensure opacity [39]. Also, the Mie scattering calculations identify that maximum light scattering and
whiteness with zircon occur with a particle size range of 0.60-0.75 µm and a mass fraction
0.16 [40].

3.2.6. Water absorption percentage of elaborated glazes

The water absorption percentages of the glazes studies are summarized in Table IV, the low values of water absorption percentages suggest a high degree of vitrification. Moreover, low water absorption percentage (< 0.5 %) is essential to ensure hygiene during the product life cycle of glazes ceramic sanitary ware [41]. On the other hand, during the firing process, liquid phase viscosity decreases and contributes to reduce the pore size [42, 43].

| Glazes | Water absorption percentage (%) | Flexural strength (MPa) | Microhardness of Vickers (MPa) |
|--------|-------------------------------|------------------------|-------------------------------|
| GaDD₁  | 0.19 ± 0.04                   | 56.07 ± 5.61           | 7952.80 ± 101.76              |
| GbDD₁  | 0.23 ± 0.06                   | 50.20 ± 3.22           | 7133.11 ± 120.80              |
| Gref   | 0.36 ± 0.03                   | 38.77 ± 5.32           | 6438.13 ± 131.54              |

3.2.7. Flexural strength and microhardness of Vickers

According to the results of Table IV, it is noticed that GaDD₁ exhibits higher flexural strength (56.07 ± 5.61 MPa) than the reference sample Gref. At higher firing temperatures, the mechanical strength of a glaze increases with decreasing water absorption, which is inversely proportional to the flexural strength of samples. It is easy to understand that the highest mechanical strength corresponds to the maximum development of the crystalline phase and the development of the glassy phase insofar as it must not be in excess, but in a sufficient quantity to allow good cementation of the crystalline grains [44].

The comparison of the Vickers microhardness shows that GaDD₁ exhibits higher microhardness than other glazes which is about 7952.80 ± 101.76 MPa. Generally, the microhardness of glaze ceramic is related to both crystalline and residual glassy phases [45]. It is evident that there is an increase in the amount of zircon crystals in both GaDD₁ and GbDD₁ samples, which leads to the increase in microhardness values. According to Levistskii et al. [46], the microhardness values of the opacified glazes produced by high temperature firing for sanitary ware range approximately from 6500 to 7500 MPa, in good agreement with our results.

3.2.8. Chemical resistance

According to the NF D14-506 and NF D14-508 standard methods, glazes GaDD₁, GbDD₁ and Gref were classified class AA and showed very good chemical resistance to aqueous solutions of HCl and NaOH with no visual changes on the surfaces of the samples after the tests. This good resistance can be attributed to the very well balanced composition of raw materials. The mass loss after 7 days attack using HCl and NaOH solutions was very low, detected only in the last decimal digit, showing that it is possible to synthesize glazes with excellent chemical resistance to strong solution attack starting from kaolin DD₁ combined with commercial raw materials.

The physico-chemical properties of the samples based on kaolin DD₁ are the result of a proper combination of crystalline phases and their distribution in the glassy matrix, forming a uniform glass-crystal structure.
4. Conclusion

In this paper, an Algerian kaolin (DD₁) was tested as raw glaze ceramic for sanitary ware production. From the obtained results, the following conclusions can be drawn:

- XRD and SEM analysis revealed the presence of zircon and quartz crystals in glazes.
- Zircon crystals contribute to the opacity and enhancing the properties of the final glazes.
- Glazes prepared with local kaolin exhibited a bimodal particle size distribution.
- Glazes ceramic sanitary ware based on kaolin DD₁ developed interesting characteristics in terms of higher whiteness (93.30 %) and smaller coefficient of water absorption (0.19 ± 0.04 %).
- The values of flexural strength and microhardness of the glazes prepared with kaolin DD₁ were higher than those of glaze reference and commercial sanitary ware glazes.
- Studied glaze samples show good chemical resistance.

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Саметак: У овом раду, испитивана је употреба локалног каолина из Djebel Debbagh (ознаке DD1) у саставу керамичких превлака за санитарије. Услед заступљености у природи, ниске цене и добрих својстава, каолин преставља интересантну економску альтернативу другим минералним глинама. Хемијски састав је показао да каолин садржи 38.49 wt.% Al₂O₃ и 44.85 wt.% SiO₂. Две глазуре на бази каолина DD1 ознacenе као GaDD1 и GbDD1 су припремљене конвенционалном техником процесирања керамике на 1250 °C. Као референтни, под истим условима је припремљен и узорак (Gref) базиран на Remblend каолину. Узорци су карактерисани рендгенском дифракцијом и скенирајућом електронском микроскопијом. Резултати су показали да су цирконијум и кварц кристалне фазе у саставу глазуре. У узорку GaDD1, нађено је да је степен белила веома висок и износи 93.30 %. Ипак, коефицијент абсорпције воде је низак и износи око 0.19 ± 0.04 %. Отпорност на савијање и тврдоћа по Vickers-u су 56.07 ± 5.61 MPa и 7952.80 ± 101.76 MPa, истим редом. Ова својства су компатибилна са референтним Gref узорком и превлакама које су у комерцијалној употреби, указујући на потенциjalну употребу каолина DD1 у производњи керамичких превлака за апликацију у керамичким санитаријама.

Кључне речи: каолин DD1; керамичка санитарија; отпорност на савијање; микротврдоћа.

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