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IDENTIFICATION AND PHYSICOCHEMICAL CHARACTERIZATION OF CLAY QUARRIES USED FOR THE PRODUCTION OF BIOCHARBON IN FARANAH, REPUBLIC OF GUINEA

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Abstract:

This research work on the identification and physicochemical characterization of clay quarries used for the production of biochar in Faranah, Republic of Guinea, constitutes a basis for the exploitation of the national reserves of clay used in the ceramic industry. The aim of this research is to develop these sources of exploitation in the Faranah Region. The characterization of these clay quarries was made on the basis of thermal analysis and chemical mineralogical method. These analyzes, carried out on samples from the four (4) clay quarries, reveal that these samples consist essentially of silica (38%), aluminum (14%) and calcium oxide (14%) on average., an average content of about (66%). Furthermore, the content of alkali and alkaline earth oxides is low. Thermogravimetric studies allowed us to follow the evolution of the sample mass as a function of temperature and to establish an idea on the appropriate cooking program. Technological tests have enabled us to highlight certain characteristics, for which the maximum plasticity index of the clay tested is 35%. This study could provide a basis for using the material (clay) for the ceramic industry in Guinea. Also, to serve as a binder for the production of biochar used as another efficient energy source by households.

KEYWORDS: Identification, Characterization, Physicochemical, Clay, Biochar, Guinea.

1. Introduction

Clay is one of the oldest materials used by humans [1, 2]. It occupies a predominant place in all sedimentary rocks [1]. Argillaceous rocks are formed from a mixture of clay minerals, to which are combined allogenic (quartz, feldspars, micas, heavy minerals) or authigenic (anatase, sulphates, etc.) [2]. Clay minerals are only beginning to be well known, these are the results of technical progress, in particular methods: differential thermal analyzes and especially x-rays, allowing the structure of minerals to be determined [3, 4]. The arrangement of atoms in the elementary sheets of clay minerals is the only possible basis for a classification. In the reference works, different challenges of clays are proposed. For example, enslingers & peaver define clays as a mineral which dominates in the fine <2 micron fraction of rocks and soils [4].

Harvested, the clayey earth in quarries, clays meet many indications, especially in waste management, as a binder for the production of bio charcoal. Because, clay is deformable, transformable, adherent, flowing, slippery, stringy and above all plastic [3,4].

Clay soils are widely used by the local populations of the prefecture of Faranah in the republic of guinea, for various needs (making pottery, stabilized and fired clay bricks.

In this study, we present the physicochemical characteristics of four clay quarries exploited in this prefecture.

2. Material and Methods

2.1. Material

2.1.1. Presentation of the study area

The Faranah Administrative Region is the central part of the country which stretches between Fouta Djallon, Forest Guinea and Upper Guinea. It is located at 8°50 and 12° North Latitude and 9°15 and 11°29 West Longitude. It covers an area of 35,581 Km^2 [5].

It is bounded to the east by the administrative Region of Kankan, to the north by the Republic of Mali, to the west by the administrative region of Mamou and Labé, to the southwest by the Republic of Sierra Leone and to the west. South by the administrative Region of N'Zérékoré.

The climate is Sudano-guinean with the alternation of two seasons: rainy which extends from (may to october) and dry which extends from (november to april). The region, due to its intermediate geographical position between Fouta Djallon, Upper Guinea and Forest Guinea, is subject to the influence of three types of micro climates which are: the tropical mountain type or "Foutanian" type. Sub-sudanese tropical and subequatorial type. The relief is not very rugged and consists of the mountain ranges of daro in the south-east and fitaba in the north-east. The Sankaran and Oulada plateaus are generally lateritic with an altitude varying between 200 and

400 meters cut by the rivers of Niger, Tinkisso and Banié, leading to the formation of numerous flood plains. The soils are of the ferralitic, clayey-silty and hydro-morphic type [5].

Demographically, the Faranah Region has a total population of 1,006,314 inhabitants in 2016, it is one of the least populated regions of Guinea (7TH out of 8). Women make up a little more than half of the population with 523,941 inhabitants. It is predominantly rural (80%). The average density is 24 inhabitants per km^2 [5].

2.1.2. Clay

The term clay originates from the greek word argilo, the root of which is argos meaning white.

Clay has been a raw material since ancient times in all civilizations; the oldest ceramics in the world were discovered on the banks of the amur river in eastern russia. Three sites are to be noted: gasya, gromatukha and chemigovka. In the far east, figurines dated 10,000 years ago have been found [6,7, 8].

Clays are made up of extremely small minerals [1,9]. Their nature, structure and classification are determined by the refined techniques offered by mineralogists in the twentieth century. These clay minerals are in the form of micron sheets or slats, hence their name phylliths [9,10].

There are two kinds of layers, depending on whether the oxides or hydroxides are associated in tetrahedra or octahedron. In the tetrahedral layer, the cavity of the tetrahedra is occupied by the silicon cation, which can be substituted by aluminum. In the octahedral layer, the octahedral cavity is occupied by small cations of. This lies in the exchange capacities of clays and their absorbency [7,8].

The minerals of the kaolinite family: kaolinite, halloysite, dickite and nacrite are two-layered minerals. A tetrahedral layer with a silicon core and an octahedral layer with an aluminum core. The structural chemical formula is. The inter-leaf equidistance of 7 [10,11].

Illites are three-layered clays, an octahedral layer associated with two tetrahedral layers in which part of the silicon is replaced by aluminum. Aluminum ions in the octahedral layer can be replaced by mg and fe ions, and potassium ions ensure the neutrality of the whole, in the interfoliar position. The interfoliar equidistance is 10 [11,12].

The smectites or the montmorillonite family are built on the same model as the illites. Smectites contain divalent mg and ca cations contain two layers of water in the inter-leaf area. The inter-leaf equidistance is 14-15. In contrast, smectites with monovalent cations such as na only contain a single layer of water (12) [12].

2.2.Methods

the methods relate to two analytical approaches, which constituted to be done:

- An in situ observation for the preliminary reconnaissance of the clay quarries;

- A laboratory analysis to determine the physicochemical properties of the clay samples from these four quarries.

2.2.1. Study techniques - sampling

The samples are used after extraction in the quarries, this simple process is similar to that used by local potters and craftsmen for the manufacture of tiles, briquettes, bricks and tiles.

2.2.2. Chemical analysis

The clay samples are attacked by a mixture of three acids HCl, H_2SO_4, HNO_3; all the elements going into solution, namely the major elements $(Al, Fe, Si, Mg, Na, Ca, K, Ca; P)$, and the heavy metals, are measured by a good resolution inductively coupled plasma atomic emission spectrometer (ICP-AES). It allows elementary analysis of the elements.

X-ray diffraction (xrd)

The xrd study was carried out on a "philips-xpert-pro diffractometer" pw 3064, with copper radiation $K\alpha_{1,2}$, two types of diffractograms are studied: diffractograms of disoriented powders where all lines appear (h, k, l).

2.2.3. Differential thermal analysis

These analyzes were carried out using an atg-type apparatus were carried out on all the samples with a temperature varying from 25 to 950°C with a heating rate of 10 degmin-1 using a device of staram scientific & industrial equipment brand, setsys 24 series. The material of difference was alumina previously calcined at 1500°C.

2.2.3.1. Technological test

The particle size analysis was carried out by wet sieving on a series of decreasing mesh sieves (afnor). The sieving is carried out on particles whose diameter is less than 0.125 mm then a sedimentometry carried out on particles with a maximum diameter of 0.2 mm.

a) The limits of atterberg

His determination is made using the casagrande apparatus. This limit is defined by the water content expressed in (%) for which the two halves of a mortar prepared from the sample placed in a cup and divided into two parts by a groove, manage to join over a length of 1cm after 25 shocks printed on the cup.

b) Making briquettes and measuring shrinkage, weight and porosity principle

For the manufacture of the briquettes, 500 g of ground material were mixed with the quantity of water, then this paste was left to stay for 24 hours in a desiccator, then 10 briquettes were made with this paste using a metal mold provided. To this manipulation; two diagonal segments, each 50 mm long, were marked on their upper face, together with the sample references.

c) Shrinkage measurement and weight loss

After demoulding, the briquettes are weighed and then allowed to air dry, weighing them periodically and measuring the length of the diagonals every 24 hours using the caliper until the weight stabilizes and shrinkage. The briquettes in the study were dried at 105 ± 5oc repeatedly the same weighing and shrinkage measurement were performed. At different temperatures, namely 800°C, 900°C, 1000°C, 1100°C and 1200°C, in a programmable oven with a level of 30 minutes and a cooking temperature rise rate of 10°C/min [10, 11].

2.2.4. Porosity

This characteristic makes it possible to evaluate the percentage of voids in each briquette. To do this, the briquettes are immersed in a beaker filled with distilled water and heated to a boil, which is maintained for two hours [3,4].

And, then we took the beaker off the heat and let stand for 24 hours, then we remove the excess water from their surface and weigh them. Porosity is expressed by:

$$P(\%) = \frac{(MI - Mo)}{Mo} X100$$

(1)

With, Mo = initial mass of the fired briquette (g);

M1 = final mass of the briquette after the test (g)

3. Results and discussion

At the end of the analyzes, we obtained the following results:

3.1. Chemical analysis

The results of the chemical analyzes are given in the table below.

Table 1: Percentage of major elements

N^0	**Sample**	Al_2O_3	CaO	FeO	K_2O	MgO	Na_2O	P_2O_5	SiO_2
1	Career1	15,06	13,95	3,2	1,09	2,56	1 ,37	1 ,28	36,51
2	Career2	10,61	14,51	0,77	0,97	2,53	1,33	1,55	39,09
3	Career3	14,78	14,47	3,85	1,95	2,78	1,12	0,76	37,46
4	Career4	13,78	14,45	4,85	1 ,96	2,98	1,22	1,66	37,86

The results (figure 1) obtained by the chemical analysis of the various clay samples from the four quarries of the Faranah zone (1, 2, 3 and 4), show a certain homogeneity of the contents of the major elements despite slight variations, thus translating a rapprochement between their concentration, which will be confirmed by the mineralogical analysis [7,8]. Because the presence of CaO is linked to the presence of calcite with the high rate of CaCO3 found in the screen (CaCO3 assay), this element increases the mechanical resistance of the material [8].

The Fe2O3 contents correspond to sulphides in the form of free iron oxide, such as pyrite, or integrated into the crystal lattice of silicates. It is however likely that the presence of iron responsible for coloring the briquettes, ranging from blue to yellow [8,9].

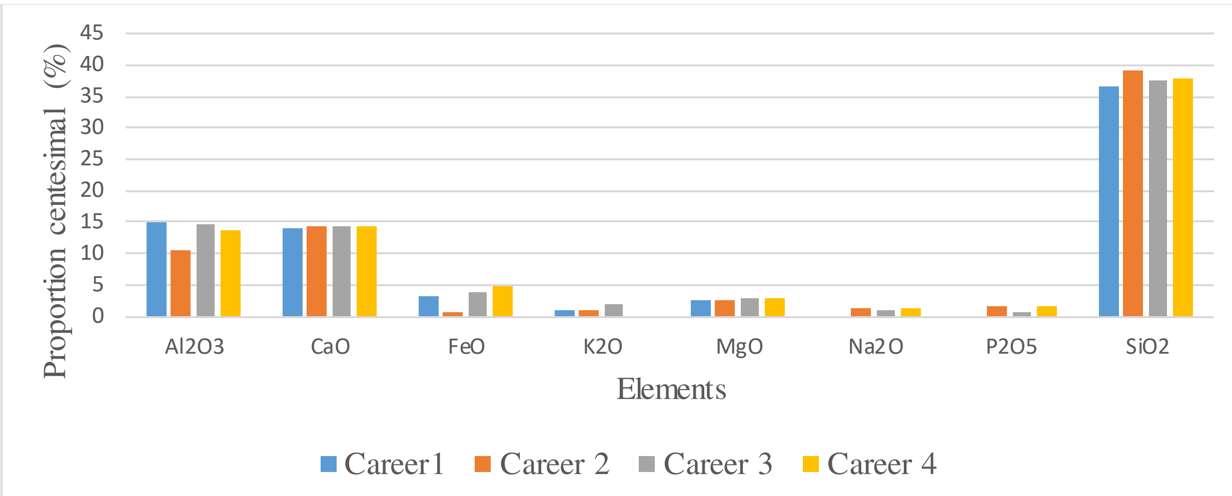

Figure 1: Variation of major chemical elements of samples from the Faranah Region

This study confirms the hypothesis, the sample from quarry 2 has a very high SiO_2 content compared to the samples from quarries (1 and 3), so there is a virtual absence of FaO and a low percentage of K_2O [9, 10].

This variation of this element can lead to variations in technological testing.

3.2. Identification test

The soil samples tested reveal a fine grain size, characterized by a percentage of elements less than 20 µm between 95 to 99%, silt clay.

This shows that the whole series consists of a reworked soil, the latter which is considered fine, then that more than 50% of these grains have a diameter of less than 20 µm [12].

Knowing the water content of a soil is therefore very important, because it allows, along with other characteristics, to assess the state in which this soil is found. The natural water content varies from 2.47 to 5.49% for the samples from the quarry (1, 2.3 and 4).

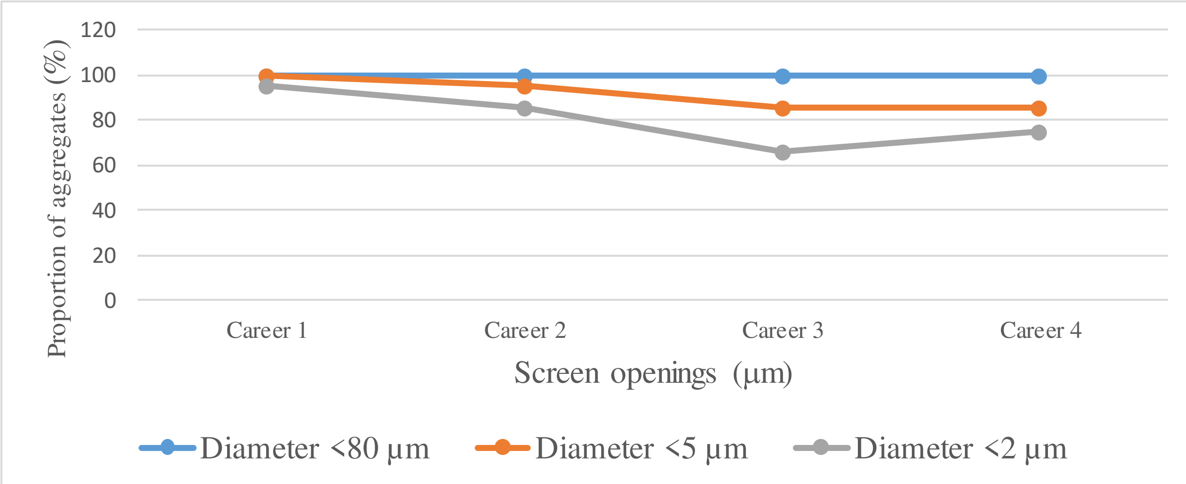

Figure 2: Particle size characterization of samples from the Faranah region (Guinea)

Based on the casagrande diagram, marls show high plasticity and gray marl is classified in very high plasticity and yellow marl has high plasticity.

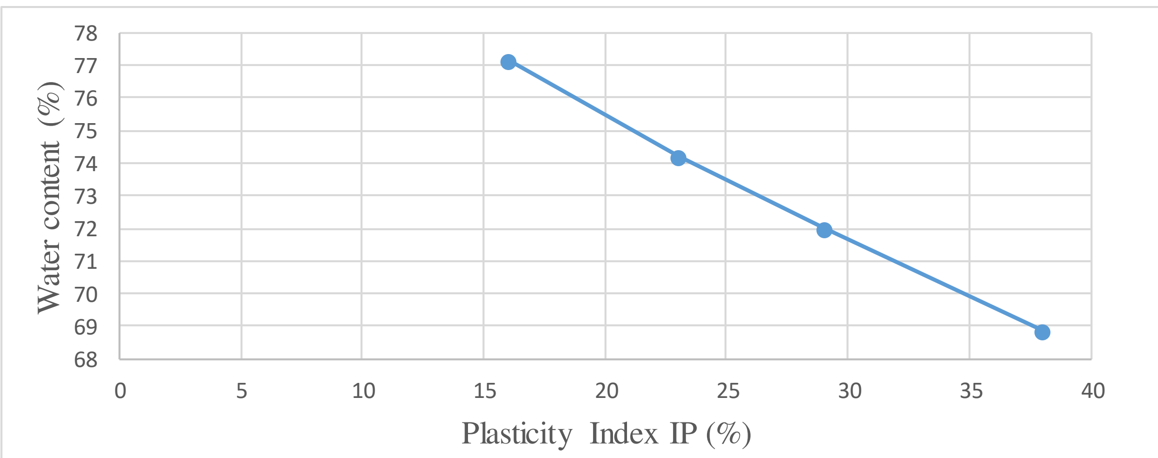

Figure 3: Determination of the plasticity index of a quarry sample from the Faranah region (Guinea)

According to these results, the material from these four quarries can be used in pottery and serve as a binder for the production of biochar.

Table 2: Summary of the results of the clay sample identification tests

PARAMETERS		Unit	1	2	3	4
Designation of the career sample		-	E1	E2	E3	E4
Natural water content		%	19,85	21,01	18,49	22,47
Consistency limits	Liquidity limit	%	60,85	76,40	73,50	57,50

	Plasticity limit	%	25,15	45,25	44,78	27,65
	Plasticity index	%	35,7	31,15	28,72	29,85
	Consistency index	-	4,32	3,73	3,63	3,56
Granulometry	Diameter					
	< 80µm	%	100	100	100	100
	< 5 µm	%	99,75	95,35	85,25	85,75
	< 2 µm	%	95,25	85,65	65,85	75,25

From Table 2, on average 80% of the elements tested by sedimentometry have a particle size of less than 2 µm. Thus, even if the quarries have been altered in places following exploitation not controlled by traditional operators, these results show a predominance of clay in general. These quarries can be selected for the manufacture of biochar. The results on the plasticity index, the ignition loss and the porosity, are presented in figures (4,5 and 6), below.

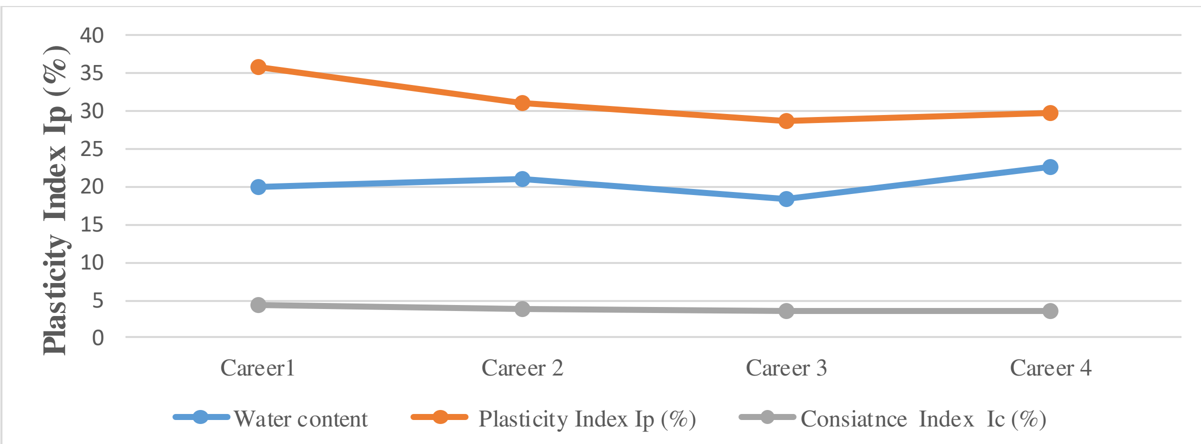

Figure 4: variation of the plasticity and consistency index according to the natural water content

Based on the Casagrande diagram, marls show high plasticity and gray marls are classified in very high plasticity and yellow marls have high plasticity. According to these results, the material from these four quarries can be used in pottery and serve as a binder for the production of biochar.

3.3. The effects of cooking

As the firing temperature rises, a number of phenomena, such as physicochemical transformations, will affect the clay phase of the material under consideration [11].

Indeed, each mineral behaves in a mixture as if it were alone, but its decomposition products, or the new structural varieties which have arisen under the effect of heat, react with each other to give new compounds [10, 11.12].

3.4. Weightloss

At 110°C, the weight loss of the samples (figure 5) displays average values of 25.61%, it is very important at this temperature which corresponds to the last phase of the briquettes drying, which corresponds to the elimination of residual fractions of absorbed and zoolitic water [9,10].

At 900°C, the loss in weight of the samples is identified by an average value of 29.33%. In general, this loss is generally attributed to the dehydration, under the action of temperature, of the mineral species present, and therefore the nature of these species, their respective proportions, their states of deterioration, makes the quantification of the proportion of the weight loss of each mineral species very easy in a mixture with several mineralogical components [10,11].

1000 and 1100°C, the reactions of water loss by constitution of the different mineralogical phases continue, at these temperatures, the dehydration of water of constitution of the clayey species are almost total, thus translating an absolute disorganization of the crystalline network and a formation new compounds [3].

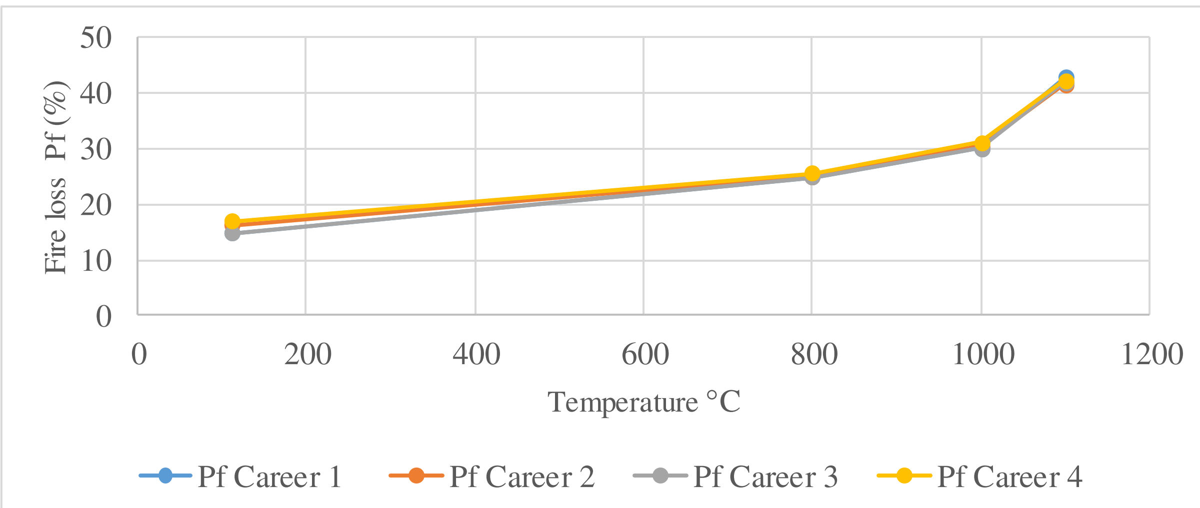

Figure 5: variation in loss on ignition of samples from quarries in the study area

3.5. Porosity

After firing, the material obtained, which is only constituted by the metaphase including the degreaser, is porous, and the brittleness of the terracotta also increases.

At 900°C, the graph shows a set of samples with a certain homogeneity of values which nevertheless remain significant 15% [9, 10,11].

At 1000°C, in general, the evolution of the porosity layers as a function of the temperature (fig…) shows a slight increase in the values of this for all the samples showing an average of 17.15% for a quarry. [3,4].

At 1100°C, it should therefore be noted that this change in the porosity of the samples, with a few exceptions, follows the rule of the change in texture, in mineralogical composition as a function of the firing temperature, and which says that: pore diameter begins by increasing while the fine pores gradually disappear, then when approaching the degreasing temperature, open pores decreases as well as their diameter while appearing closed pores, the open porosity is practically zero and the alveolus continues with an increase in the diameter of the closed pores [11].

So the porosity at this temperature after having reached its maximum around 1000°C, decreases to reach relatively low values.

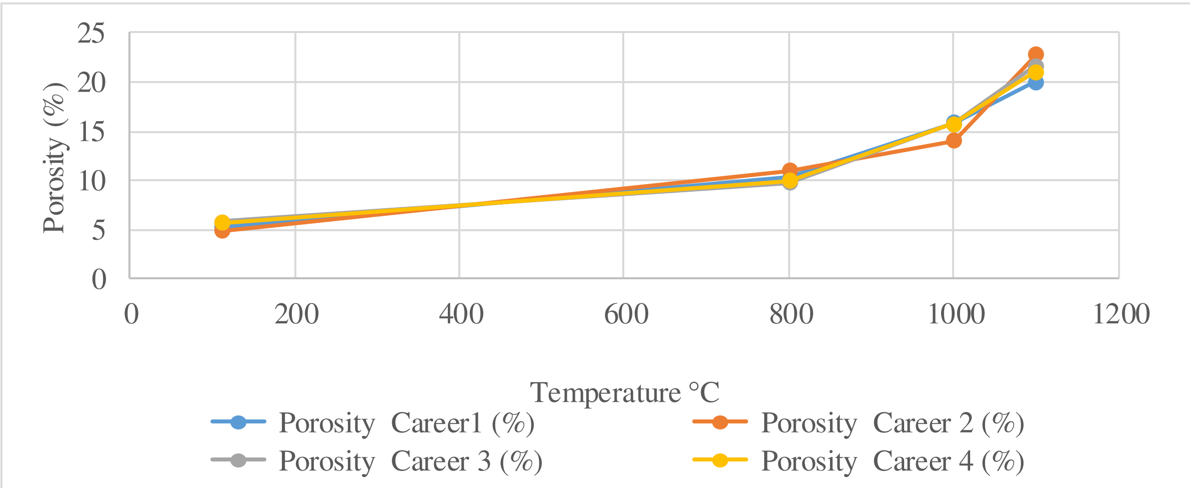

Figure 6: variation in the porosity of samples from the quarries in the study area in anointing of the firing temperature

3.6. Color

The samples result after each firing almost at the same color range; with the exception of sample 2 which is yellow before cooking and which cooks red for all cooking temperatures. It is characterized (figure 6):

a) By changing to light and dark brown color 900°C;

b) By changing to light red at 100°C;

c) Varies between yellow and red at 1100°C

4. Conclusion

From this study, it emerges that Faranah clay contains mainly minerals in the form of kaolinite and muscovite and non-clay minerals namely: quartz, and calcite, which varies are the proportions of these elements, something that was tested for technological results.

Indeed, the formations present a slight heterogeneity, which was observed at the level of the firing of the briquettes. The porosity of the briquettes reveals a material of good thermal insulation. Sample 3 exhibits briquette fracturing at different firing temperatures which reduces its use in brickyards. The samples show significant plasticity, which allows them a good eventual use in pottery, and can be used as a binder in the production of biochar, a source of energy for cooking.

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