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DEVELOPMENT OF CERAMICS ENAMEL USING BOTTLE GLASS

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ABSTRACT – *The Icoaraci district is an important ceramic pole of Pará state (Brazil). The improvement of certain stages ranging from the treatment of the raw material to the ceramic finish is an important point to the production and marketing of the pieces. One of these improvements is the production of a coverage that can be applied to the ceramic surface, characterized by a thin continuous layer of a material called enamel or glaze, which contributes to its aesthetic, mechanical, electrical and sanitary aspects. This study aimed to develop a suitable glaze for use on Icoaraci ceramics, in which bottle glass was used as the main component, varying the amounts of compounds and their firing temperatures. The characterization of the raw materials was performed by X-ray fluorescence, Thermogravimetric and Differential Thermal Analysis. The best result was firing at 900°C, with 5% borax, during 3 hours.*

1. INTRODUCTION

Among the stages of ceramic production, firing is one of the most important because it may influence the quality of the ceramics obtained. Due to the temperature reached during the process, the products acquire their final properties, such as brightness, color, porosity, flexural strength, resistance to chemical attacks and others (Pinheiro and Holanda, 2010).

The use of enameling techniques has significant effect on the pieces value and provides greater internal protection, since most pieces will be used as tableware, which would justify the enamel use.

Many ceramic products such as sanitary ware, tableware, electrical insulators, and other coating materials, receive a thin continuous layer of a material called enamel or glaze, which, after firing, becomes glassy. The enamel can be defined as a vitreous, water insoluble compound, which is obtained by melting of certain mixtures of raw materials (Casagrande *et al.*, 2008). This glass layer contributes to the improvement of aesthetic, sanitary, mechanical and electrical properties. The glaze compositions and formulations depend on the firing temperature, the ceramic piece and enamel characteristics (Lira and Alarcon, 2004).

In this sense, the objective of this work was to develop a type of ceramic glaze using bottle glass.

2. MATERIALS AND METHODS

The raw materials used were: kaolinitic clay, bottle glass, carboxy methyl cellulose (CMC), water-white glue solution, kaolin and borax (Reis, 2010).

The equipment used was: Ball mill, precision balance, press, muffle, drying oven, glassware and porcelain grail.

The methodology followed was: The raw material was characterized by the chemical analyses: X-ray fluorescence, thermogravimetric analysis (TGA) and differential thermal analysis (DTA).

2.1. Preparation of the Enamel and Its Composition

For the preparation of ceramic glaze, firstly it was necessary to grind the bottle glass. A mill of alumina balls was used in the experiments. The total milling time was 11 hours. The clay was collected on the river Tucunduba (Belém-Pará-Brazil). Then, it was cleaned, dried in forced air circulation oven for 12 hours at 60 °C and grinded in a ball mill for 2 hours.

To prepare the CMC solution, 10g of CMC were diluted in 1 liter of water, heated in a water bath until boiling and complete dissolution. After that, the solution cooled naturally and was stored in a jar.

The water-glue solution was prepared at the proportion 1:10 (glue:water). Borax was added in percentages of 0, 5, 10 and 15.

In all experiments, 50 g of bottle glass, 0.25 mL of water-glue solution, 1 g of clay, 1 mL of CMC and 50 mL of distilled water were mixed in a porcelain grail. The compositions can be seen in Table 1. The enamel was poured in each ceramic piece and applied with a brush. The firing temperatures were tested in a range of 850 to 1000°C (Reis, 2010).

Table 1 – Content of material according to each experiment

Exp	Bottle Glass (g)	Water (mL)	Water-glue solution (mL)	CMC (mL)	Borax (%)	Temperature (°C)
01	50	50	0.25	1	-	900
02	50	50	0.25	1	5	900
03	50	50	0.25	1	10	900
04	50	50	0.25	1	10	850
05	50	50	0.25	1	15	850
06	50	50	0.25	1	-	1000

Exp – experiment; T – temperature; °C – Celsius degrees.

3. RESULTS AND DISCUSSION

The technique of internal pouring was used because there was a little amount of enamel. Then, the brush was used to spread the enamel and prevent the appearing of excess spots (Chavarria, 1998).

3.1. Chemical Analyses

Table 2 shows the results of X-ray fluorescence of the river clay and bottle glass. The presence of SiO_2 in the bottle glass can be highlighted, since it's a glassy material. The fluxing oxides CaO and Na_2O also appear in considerable quantities.

Table 2 – Results of X-ray fluorescence for river clay and bottle glass

Substance	River Clay (%)	Bottle Glass (%)
Al_2O_3	12.929	1.625
SiO_2	68.331	71.992
CaO	0.170	12.332
MgO	0.717	0.057
BaO	0.151	0.050
Na_2O	0.382	11.574
K_2O	1.385	0.520
Fe_2O_3	5.225	0.061
TiO_2	0.954	-
PbO	-	0.025
ZrO_2	0.053	0.018
SrO	-	0.064
P_2O_5	0.033	0.047
SO_3	-	0.190

Figure 1 shows the thermogravimetric and differential thermal analyses in the river clay. The green curve is the weight loss with the increasing temperature; the red curve represents the characteristic points of the materials present in the clay. At 95ºC, there is a downward shift, which conventionally represents an endothermic reaction and the elimination of water. At 335ºC, there is an upward deflection, which conventionally represents an exothermic reaction and the carbonization of organic materials. At the temperature of 581ºC, kaolinite can be seen and at 498 ºC, it possibly can be seen a mix of kaolinite and montmorillonite (Reis, 2012).

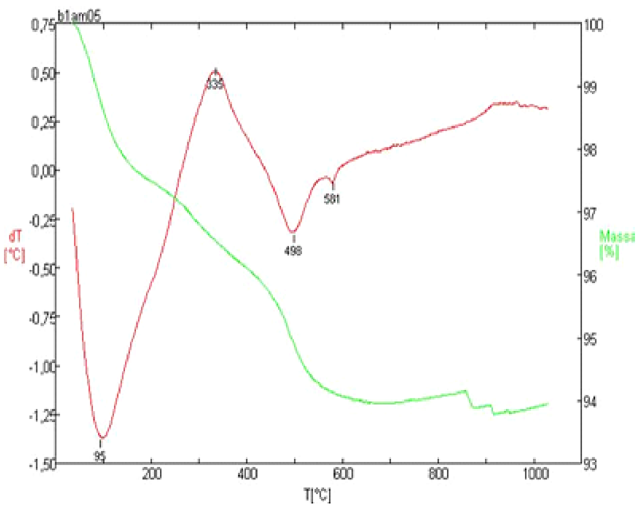

Figure 1 –Thermogravimetric (TG) and differential thermal (DTA) analyses of the river clay

3.3. Enamel Firing Results

Six firing experiments were performed. To choose the best one, it was taken into account the appearance of the glass layer, its thickness and the absence of defects such as bubbles and cracks (Mckingley *et al.*, 2009). Among all, the experiment 02 was chosen (Figure 2) as the best one. The glassification happened, however the glaze application presented flaws such as bubbles from the water vapor arising through the enamel itself (due to pre-existing moisture) and cracks due to the ceramic craft already present these flaws before the glaze application.

Figure 2 -- Exp 02 – Bottle glass, firing at 900°C, with 5% borax

4. CONCLUSION

The best result was firing at 900 °C, with 5% of borax. Glassification ocurred, however it presented flaws such as bubbles from the water vapor arising through the piece. The moisture content at the time of enamel application is the major contributing factor in the final firing result, since it favors the appearance of blisters on the enamel's surface.

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