PERFORMANCE COMPARISON BETWEEN COMMERCIAL PORCELAIN STONEWARE TILE BATCHES

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INTRODUCTION

Porcelain stoneware tile is used for covering floors and walls in commercial and residential buildings. It has water absorption below 0.5 % w/w and a low level of closed porosity, < 6%. Since its introduction into the market in Italy at the end of the 1970s, porcelain tile has spread worldwide. Currently, porcelain tile combines high added value and production scale, making it a very successful product in terms of sales and profit for all supply chain stakeholders. The main industrial route for producing it involves wet milling, spray-drying, pressing, glazing, firing and post-fired finishing stages.

Despite the added value, the process is energy intensive. Porcelain stoneware tile also requires higher performance raw materials. In some cases, they are not near the industrial plants, requiring truck transportation at a higher cost than the raw materials price itself.

Local raw materials selection and usage is one of the key aspects associated with sustainability for a porcelain tile plant. The main performance aspects associated with bathroom tile compositions are related to achieving standard water absorption at conventional peak firing temperatures <1200 °C, a low level of high-temperature deformation to meet flatness requirements, and a low level of Fe_2O_3 to obtain the desired whiteness.

The objective of this study is to compare the composition and performance of different batches used in porcelain stoneware tile manufacturing. The sampling consisted of 31 spray-dried powders used for glazed tile products. The Brazilian samples accounted for 74%, followed by 13% from Italy, 10% from Spain, and 3% from Argentina. All samples were characterized in terms of their chemical and mineralogical composition. Test specimens measuring 80x20x5 mm were obtained by pressing the powders with 7% w/w moisture content at a pressure of 35 MPa. After drying, bulk density and bending strength were measured. The specimens were fast fired in a laboratory roller kiln for 40 min cold-to-cold. The firing temperatures ranged from 1155 to 1245 °C to obtain the vitrification curves. The same firing conditions were applied to measure the pyroplastic deformation index. After firing, the samples were characterized in terms of water absorption, bulk density, bending strength, and color.

RESULTS AND DISCUSSION

Figure 1a shows a wide range in the Na_2O content, from 1 to 5%, in contrast to the $K_2O+CaO+MgO+Fe_2O_3$ content, from 2% to 10%, with correlation R = -0.92. Basically, albite is replaced by K_2O-rich rocks and clays and strong fluxing agents, such as talc and carbonates. In general, this replacement is also associated with an increase in Fe_2O_3 content (R = -0.67 between Na_2O and Fe_2O_3) and loss of whiteness (R = -0.94 between Fe_2O_3 and Lh), as can be observed in Figure 1b. The European batches exhibited higher Na_2O than the Brazilian ones.

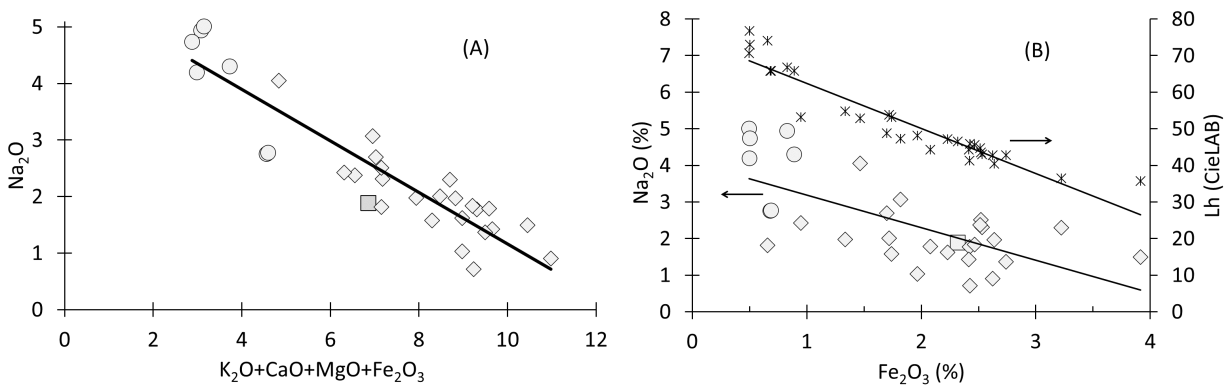

***Figure 1**. Correlation between selected batch components (A, B), and correlation between luminosity (Lh) and Fe_2O_3 content (B); European (○), Brazilian (◆), and Argentinian (□) batches.*

Table 1 shows some results statistics according to the origin of the samples. In general, bulk density ranged from 1800 to 1960 kg/m^3, and dry bending strength ranged from 3.0 to 7.0 MPa. Maximum firing temperature ranged from 1159 to 1220 °C, fired bending strength from 46 to 101 MPa, pyroplastic index from 2.3 to 14.9 x 10^{-5} cm^{-1} and whiteness (Lh) from 36 to 76.

Despite the above performance differences and ranges in the compositions and performance, most of the batches met the final requirements for marketing as porcelain stoneware tile. Some batches did not meet the water absorption requirements at the maximum densification point. In those cases, firing is conducted in the expansion region, which is an unstable condition in terms of dimensional and flatness control.

On average, the European batches exhibited greater whiteness and were fired 22 °C above peak firing temperature of the Brazilian batches, though they presented a lower pyroplastic deformation index than the Brazilian batches. The use of strong fluxing agents, lower dry bulk density and unbalanced batch compositions explain this behavior. On other hand, the lower peak firing temperature represents 1-3% less thermal energy consumption.

Region	Statistic	DBS (MPa)	BD (kg/m^3)	WA (%)	PI (x10^{-5} cm^{-1})	Tmax (°C)
Brazil	Max	7.0	1922	0.62	14.9	1215
	Average	4.7	1865	0.36	6.7	1177
	Min	3.2	1803	0.15	3.7	1159
Italy and Spain	Max	4.4	1960	0.93	6.2	1217
	Average	3.8	1909	0.43	3.9	1199
	Min	3.0	1861	0.25	2.0	1184
Argentina	One	5.9	1855	0.80	2.8	1181

Table 1. *Average, minimum and maximum values for Dry Bending Strength (DBS), Bulk Density (BD), Water Absorption (WA), Pyroplastic Index (PI), Maximum Firing Temperature (Tmax) according to the region.*

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