

# Energy saving in sintering of porcelain stoneware tile manufacturing by using recycled glass and pottery stone as substitute materials

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## ABSTRACT

Commercial porcelain stoneware tiles are vitrified tiles (noted as C) that are composed of clay, feldspar, and quartz. They require high temperature sintering at 1230 °C that result in high energy costs. This study aimed to compare the energy consumption during sintering process of the porcelain stoneware tiles, which recycled glass and pottery stone were used in substitution of clay, feldspar, and quartz (noted as N). The sintering temperatures of the commercial (C) and the substituted (N) tiles were, respectively, at 1230 °C and 1050 °C. The physical, mechanical, and chemical properties of the N tiles were compared with those of the C tiles. As a result, the N tiles showed good properties according to several standards, such as water absorption of less than 0.1% (ISO 10545-3), linear shrinkage of less than 10% (ASTM C326), modulus of rupture of more than 40 N/mm<sup>2</sup> (ISO 10545-4), and good resistance of chemicals (ISO 10545-13). The N tiles were in compliance with the ISO 13006:2012 (group BI<sub>0</sub>) Standard. In the sintering process, the energy consumption and CO<sub>2</sub> emission of the N tiles were, respectively, 9191.24 kJ/kgProduct and 0.0782 kg CO<sub>2</sub>eq/kgProduct, while those of the C tiles were, respectively, 13304.84 kJ/kgProduct and 0.1132 kg CO<sub>2</sub>eq/kgProduct.

## 1. Introduction

Modern ceramic tiles are expected to be continuously developed to meet an increasing challenge of vitrified tiles or porcelain stoneware tiles [1]. To advance new product research and development, the ceramic manufacturers need to explore and modify their products in several aspects, including cost reduction, energy saving, and management of technology. One of research studying in two parallel lines is to develop raw material composition quality, and the other is to improve manufacturing process with environmental and social considerations [2–4].

Porcelain stoneware is one of the popular materials for floor tiles, and the most common manufacturing process of the single fire ceramic tile [4–7] is showed in Fig. 1. Usually, the raw materials of the commercial porcelain stoneware tile or known as the vitrified tile is composed of clay, feldspar, and quartz [8–11]. The tile is formed by dry pressing method and fast single fired at high

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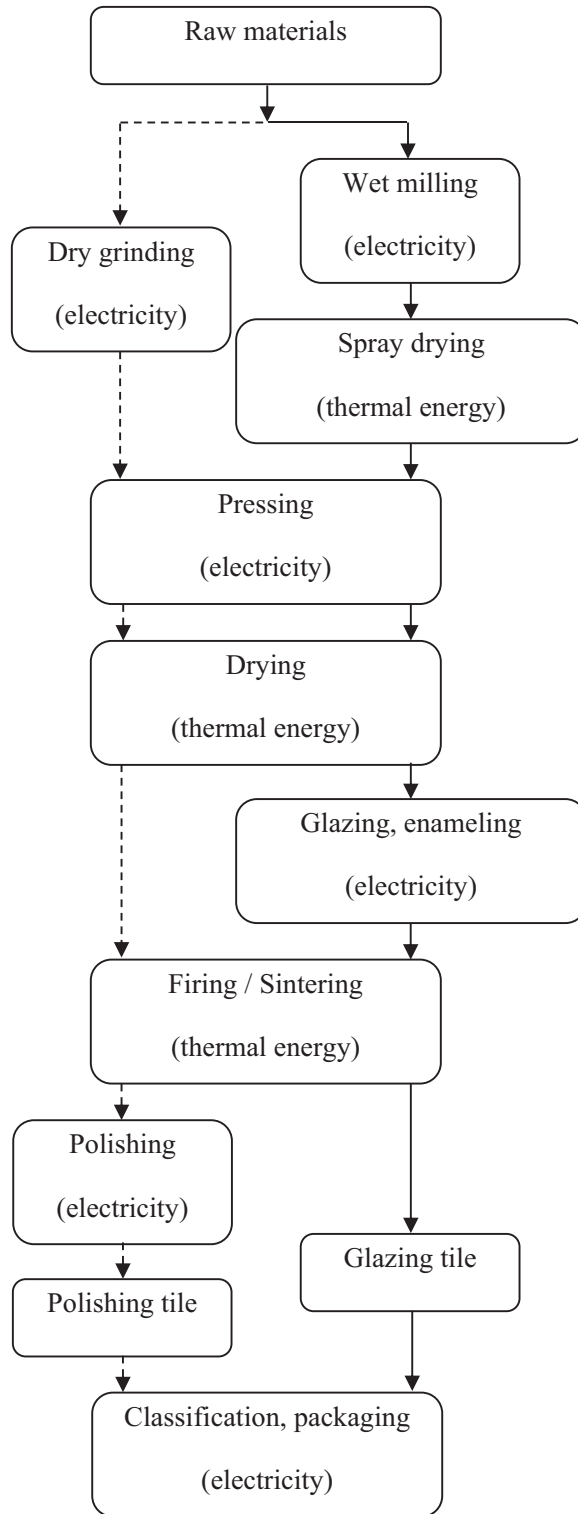


Fig. 1. Diagram in the productive process of the ceramic tiles industry.

temperatures around 1190–1230 °C [12]. Water absorption of the tile is less than or equal to 0.5%, which is classified as class BI<sub>a</sub> according to the ISO 13006 for ceramic floor tiles. The porcelain stoneware tile is heterogeneous materials with a very compact structure made up of crystalline phases surrounded in a glassy matrix [13]. However, the tile requires very high sintering temperatures, which lead to high energy production cost and effect on environment. Therefore, researchers and ceramists are of interests

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