CERAMIC PACKAGING FOR MINERAL WATERS: A PRELIMINARY STUDY

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ABSTRACT

The aim of this work is to present a preliminary study for the use of ceramic materials in packaging of natural mineral waters. Handmade ceramic bottles were produced from faience paste and tested for the influence of different glazing areas on the tightness of the ceramic bottles and in physicochemical stability of bottled natural mineral water during storage (8 days, 15º C). Three ceramic bottles (TG) were totally glazed in both the inner and the outer surface, and other nine bottles (PG) were only partially glazed in the outer surface. Glass bottles were used as control (C). Results showed high losses of water through the PG ceramic containers (45.0 - 55.0%) in relation to TG bottles (5.2 % - 6.0 %). Colour of the bottled natural mineral water was below the parametric value while turbidity was above the legal value established in Portuguese national legislation. Cd and Pb were not detected in the water samples. Conductivity increased significantly in water samples conditioned in ceramic packages, compared to initial and control (C) samples, suggesting the existence of two opposites mass transfer phenomena in the ceramic packages.

1. INTRODUCTION

In the twentieth century, the bottling industry undergoes a significant progress in terms of technology and production volume, especially in the 60s, with the appearance of plastic bottles [1]. The consumption of bottled mineral water became popular only in the 80's, due to the increasing concerns with health, caused by a progressive pollution of the water resources. On other hand, bottled mineral water is consumed as a safer alternative in countries where public water treatment systems are not efficient, or simply do not exist. In a general way, sales of mineral water are increasing all over the world [2].
During the last years, the rapid growth in the mineral water consumption in the industrialized societies has contributed to the development of the sector. At the same time, the consumption of mineral water has established itself as a symbol of health and welfare culture. Recently, main bottled water companies are betting on a *gourmet* water market, created for special occasions. In this context of constant innovation, packaging could diversify product in terms of sensorial qualities, package design, and functionality.
The production of new materials to pack mineral water should be first environmentally sustainable, and secondly, enhance the initial sensory value of the water. The package design should link the use of traditional materials with concepts such as authenticity, freshness, innovation, ecological spirit and charm.
Clay can satisfy these requirements, and unlike the conventional packages, the porosity of clay provides a series of physical phenomena that give the water sensorial properties recognized since long time. However, it has not been studied the use of clay as contact material in packaging of natural mineral waters.
Natural mineral water and spring water are subject to a strict European regulation, which defines their denomination, chemical and physical characteristics, and microbiological quality. For the packaging of natural mineral waters, believes, in Article 6 of Directive 2009/54/CE of the European Parliament and the Council of June 18 [3], that "Any containers used for packaging natural mineral waters shall be fitted with closures designed to avoid any possibility of adulteration or contamination".
The aim of this work was to present a preliminary study for the use of ceramic materials for the packaging of natural mineral water. Several aspects were taken into account: (i) production of handmade ceramic bottles from faience paste; (ii) influence of different glazing areas on the tightness of the ceramic bottles (iii) physicochemical stability of bottled water.

2. MATERIALS AND METHODS

2.1 Production of ceramic packages

Twelve ceramic bottles were handmade by local artisans using typical pottery wheel, from limestone faience paste, appropriate for *RAM* pressing and *Roller Head Making* (Mota Pastas Cerâmicas, S.A.) following the steps sequence presented in figure 1.
After cooling, a brilliant transparent lead-free glaze, appropriate for cookery (KGG 71, R2W-Equipamentos e Matérias-Primas para Cerâmica, Lda., Portugal), was applied by immersing each faience piece, in order to obtain

a uniform distribution. After dried, the pieces were placed in an electric oven at 1040º C, during 16h.
Three ceramic bottles (TG) were totally glazed in both the inner and the outer surface, and other nine bottles (PG) were only partially glazed in the outer surface, as outlined in figure 2.

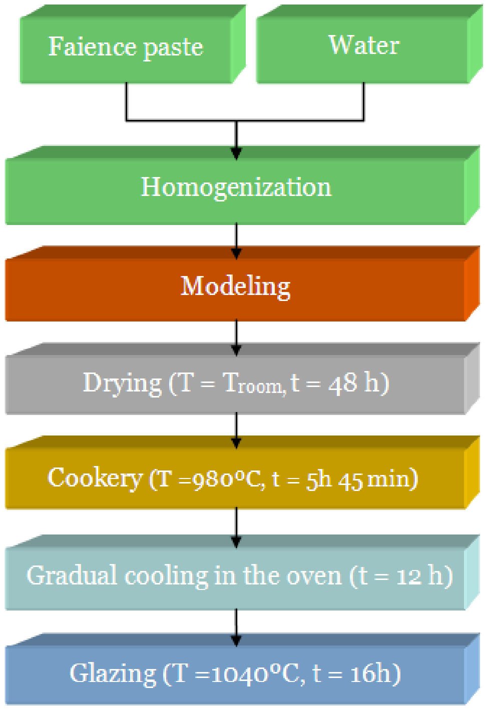

Figure 1: Steps for the production of the ceramic packages

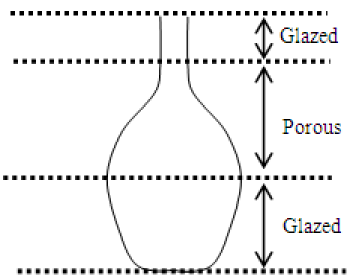

Figure 2: Sketch of the partially glazed ceramic package

Glazing was applied in both the inner and the outer surface of the neck of all bottles, in order to increase the mechanical resistance, and improve the contact between neck surface and sealing system, for a better closure. Bottles sealing system elected – natural cork with plastic cap (T-Cork®) – is usually applied for wines and spirituous drinks bottling, offering an efficient closure, easy manual extraction and posterior reuse [4].

2.2 Preparation, storage and control of the ceramic packages

Simultaneously with the ceramic packages, control assays (C) were performed by using glass bottles with about the same capacity of the first ones and the same sealing system.

After washed, dried, and weighted, all this bottles were sterilized in a dry-heat oven (2h at 180ºC). Afterwards, all the bottles (ceramic and glass) were filled with mineral water in an industrial line, sealed and transported to the laboratory in a cool box. Then, the bottles were weighted and stored in an incubator at 15º C for 8 days.

2.3 Laboratorial procedures

The initial profile and posterior evolution of mineral water stored in ceramic and glass bottles were evaluated through physicochemical analyses for turbidity, colour, conductivity, and measuring the concentration of cadmium (Cd) and lead (Pb). Additionally, the weighing of the entire set of ceramic bottle was carried out during the storage in order to quantify the loss of water through the package.
Photometric measurements allowed for evaluate turbidity (520 nm) and colour (410 nm) of the water samples previously homogenised. Electrical conductivity was performed at 20º C, under continuous stirring, with an instrument (*inoLab-Cond 720, WTW*) with graphite electrodes cell (*TetraCon 325, WTW*).
Cd and Pb contents were quantified by atomic spectrophotometry with graphite chamber (*Perkin Elmer, AAnalyst 600*).

3. RESULTS AND DISCUSSION

3.1 Tightness of ceramic packaging

The preliminary tests showed high losses of water through the partially glazed ceramic containers at a temperature of 15° C, dramatically limiting the duration of the stability tests (Figure 3).

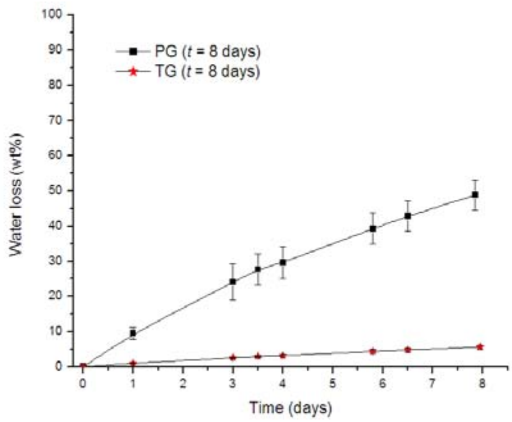

Figure 3: Evolution of the average water loss, expressed as a percentage of mass, in packaging partially glazed (PG) and fully glazed (TG) of the time of storage

The tightness tests carried out on ceramics packaging showed that after eight days, the TG bottles had mass loss of water between 5.2 % and 6.0 %, while in the PG bottles ranged between 45.0 % and 55.0%. Losses detected in packaging TG can be explained by the existence of cracks in the glaze. Such cracks could be due to an excessive

dilution of the glaze powder or because of an improper process of cooking the glaze.
PG ceramic packages have porous inner wall, not coated with the glaze, what favors the permeation of water through that same area, outlining the outer surface of the glaze through the cracks resulting from the "*craquelê*".

3.2 Physicochemical stability of bottled water

The measured values for the colour of the bottled natural mineral water were below the parametric value of the Portuguese national legislation (< 20 mg/L Pt) [5]. On the other hand, after eight days all the packages tested shown values of turbidity above the legal value established in the same legislation (4 UFT). This result could be attributed to microbial growth (these results are not shown).
Concerning the conductivity, it can be seen that the results obtained are below the legal limit. A significant increase of the conductivity is observed in the water samples conditioned in ceramic packages, compared to initial and control (C) samples. Despite the lower loss of water in the PG samples, the values of the conductivity are similar to the ones found in the TG samples. This fact can be explained by the variation of the mass of minerals (Figure 4).

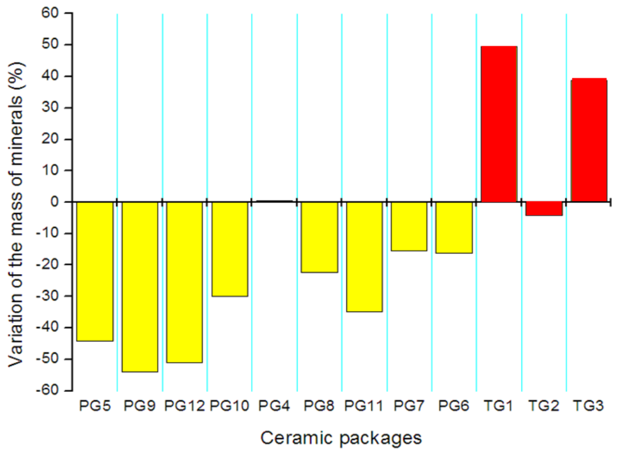

Figure 4: Variation of the mass of minerals in the water after 8 days of storage. Represented in yellow are the packages PG; in red are the packages TG

Regarding water-ceramic package interaction, these results suggest the existence of two opposite mass transfer phenomena in the ceramic packages: (i) the retention of minerals, coming from the water, in the non-glazed ceramic (PG) wall, which results from the humidity gradient across the package; (ii) the migration of components from the ceramic package (TG) to the water, as suggested from the conductivity results. In PG bottles, the movement of water molecules towards exterior drag minerals, retained in ceramic wall. In TG bottles, water molecules gradient is much smaller due to internal and external glaze, but cracks in internal glaze may allow entry of water into the wall, enabling the migration of minerals.
The principle underlying European Regulation is that "(…) any material or article intended to come into contact directly or indirectly with food must be sufficiently inert to preclude substances from being transferred to food in quantities large enough to endanger human health or to bring about an unacceptable change in the composition of the food or a deterioration in its organoleptic properties" [7]. Lead and cadmium assays, performed at the end of the storage period, did not detect the presence of these elements in the water samples. Accordingly, the concentrations are below the detection limit of the apparatus, which are 0.46 µg/L and 1.48 µg/L for cadmium and lead, respectively, fulfilling legal criteria for performance of analytical methodology [6]. Thus, it can be concluded that the concentrations are also below the maximum parametric value (< 5 µg/L Cd, and < 25 µg/L Pb) [6].

4. CONCLUSIONS AND FUTURE WORK

From this study emerges the importance of selecting a method of manufacture of ceramic bottles that ensure the achievement of uniformity of packaging and its tightness.
As future work, it would be interesting to test an alternative to glaze for the manufacture of ceramic packages. The vitrification of the ceramic material, could contribute for a significant reduction of the total porosity of the packages, reducing in that manner the loss of water evidenced in this work.
Another possibility is the use of a ceramic paste which does not acquire porosity after firing. The surface of these containers would not be wrinkle, will be almost smooth, resulting in an easy cleaning and disinfection.
These studies need to be carried out first with "model-packages systems" that could set variables related with packaging and the posterior use of mathematic models to predict migration phenomena at different conditions, specially storage temperature.

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BIOGRAPHY

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