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Evaluation of Three Traditional Curing Methods Applied in Mexican Lead-Glazed Ceramics: Detection, Concentration, and Leaching of Lead to Food

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Abstract

In Mexico, the main source of lead (Pb) exposure is the use of lead-glazed ceramic (LGC). Curing is a traditional technique employed to seal the pores of ceramic, enhancing resistance to high temperatures and moisture absorption. One common belief, sometimes promoted by governmental sources, is that this practice can also remove Pb from LGC. In this study, we evaluated the effect of three traditional curing methods (oil/heat, boiling water/lard, and garlic/boiling vinegar) on Pb detection, concentration and leaching in three LGC pieces. Before and after curing, detection (Lumetallix™ and sodium rhodizonate) and concentration (XRF) were measured; meanwhile, leaching after curing was evaluated by ICP-MS in a simulated solution. All pieces were positive for Pb detection. Mean Pb concentration before curing was 164,400 ppm and increased on average to 266,700 ppm after curing, exceeding the limits established for ceramics (100 ppm). The highest level of Pb leaching was in the piece cured with oil/heat (378.18 ppm) followed by garlic/boiling vinegar (2.6 ppm), both exceeding the Mexican Normativity for leaching (0.5 ppm). We find that traditional curing should not be considered as a practice to remove Pb. Even worse, it may increase its availability and leach into food, increasing the health risk to consumers.

Keywords: lead exposure; traditional curing; lead detection; lead concentration; lead leaching; Mexican pottery

Academic Editors: Luis M. Carrillo-López and Rosa Isela Ventura Aguilar

Received: 15 July 2025
Revised: 26 August 2025
Accepted: 27 August 2025
Published: 29 August 2025

Citation: Rodríguez-Hernández, M.F.; Betanzos-Robledo, L.; Mariscal-Moreno, R.M.; Valverde-Arámbula, F.A.; Chuck-Hernández, C.; Peralta-Delgado, N.; Fuller, R.; Cantoral, A. Evaluation of Three Traditional Curing Methods Applied in Mexican Lead-Glazed Ceramics: Detection, Concentration, and Leaching of Lead to Food. *Processes* **2025**, *13*, 2766. https://doi.org/10.3390/pr13092766

1. Introduction

Historically, in Mexico, the use of earthenware pottery is a tradition that dates to pre-Hispanic times. After the conquest, glazing began to be introduced, which consists of melting enamels with mixtures of silica (SiO_2) and lead oxide (PbO) to effectively prevent the filtration of liquids and enhance the appearance of the pieces, giving them a shiny aspect. For these reasons, glazing spread rapidly among artisans and the production of lead-glazed ceramic (LGC) began to have a special importance in Mexican culture [1].

However, the lead (Pb) contained in the enamels used to glaze pieces is considered a toxic metal that can accumulate in tissues, causing damage to renal, cardiovascular, reproductive, hematological, and neurological systems [2,3]. The adverse effects of Pb exposure mainly affect vulnerable populations such as pregnant women, increasing their risk of premature births or miscarriages [4], and infants, inducing, even at low levels, an irreversible and lifelong impact on neurodevelopment, associated with higher rates of school failure, behavioral disorders, decreased economic productivity, and global economic losses [5–9]. Also, the risk is higher for infants because they absorb 40–50% of the Pb present in the digestive tract while adults absorb 3–10% [10]. In Mexico, around 17% of children under 5 years of age have blood Pb levels (BLL) $\geq$ 5mg/dL, representing 1.4 million Mexican preschoolers with Pb intoxication [11]. It has been extensively documented that one of the main sources of Pb exposure is the use of LGC for cooking, serving, or storing food [12–15]. The association with LGC use and frequency is highly significant and varies by region. The resident populations of central and southern Mexico are the most exposed due to the LGC use [16], which is consistent with the higher prevalence of Pb poisoning in children (<5 years) of 20.7% and 25.8% for the central and southern regions, respectively [16] compared with 9.8% in north region. This association may be related to the LGC manufacturing process, such as the use of Pb enamel [12,13] and the inappropriate temperature of the kilns to eliminate or fix the Pb particles in the LGC pieces, which could leave free Pb on the surface of the piece. In addition, this problem may arise during domestic use, due to continuous exposure to heat causing enamel abrasion and contact with acidic foods, such as sauces and citrus fruits, causing the leaching of Pb from the piece to the food [17]. Given this, the Mexican government has implemented actions to control the production of the LGC pieces produced and sold in the country, such as regulations in the Mexican Normativity (NOM-231-SSA1-2016) establishing a permissible Maximum Limits (ML) for Pb that can be leached by any item of pottery intended to contain or process food and/or beverages [18] and through the "The Approved Pottery Program", whose main objective is the promotion of Pb-free pottery production [19]. These actions have shown that potters who used Pb-free glaze in their production had lower BLL (8.1 μg/dL) compared to those who used Pb glaze (17.8 μg/dL) [19]. This is evidence that the use of these Pb-free glaze decreases the Pb exposure of the potters; however, to date, there is no evidence that the use of LGC does not represent a health risk for consumers. Traditionally, Mexican families that use LGC, prior to its use, subject them to a process called "curing", which consists of exposing the pieces to different solutions to seal the pores and make it more resistant to temperature changes and moisture absorption, reduce the permeability to liquids, strengthen its walls, and eliminate the earthy flavor [20]. Additionally, there is a general belief among the population that this practice can remove Pb from LGC [20]. However, there is little evidence evaluating the effect of curing on Pb removal [12,13,20]. Therefore, this study aims to evaluate the effect of three traditional curing methods (oil with heat, boiling water with beef lard, and garlic with boiling vinegar) on Pb detection, concentration, and leaching in LGC pieces. Finally, we compare the Pb concentrations before and after curing, with the ML for ceramics established by the U.S. Consumer Product Safety Commission (CPSC) [21], while Pb leaching concentrations were compared with the ML of Pb established by Official Mexican Normativity (NOM-231-SSA- 2016) [18].

2. Materials and Methods

2.1. Sample Collection

Three new LGC pieces were purchased between the months of November and December 2024 through different pottery suppliers in the municipality of Cohuecan, Puebla, Mexico. The three pieces traditionally manufactured with PbO enamel consisted of a dish, a pot, and a jar, identified as piece 1, piece 2, and piece 3, respectively; the characteristics of each piece are shown in Table 1.

Table 1. Characteristics of the LGC pieces analyzed.

Piece	Shape	Model	Volume (L)	Picture
Piece 1	Flat	Dish	—	
Piece 2	Flat	Pot	2	
Piece 3	Round	Jar	1.85	

2.2. Sample Analysis

The three pieces were transported and analyzed at the Laboratory of Food Physicochemical Analysis of the Iberoamericana University, Mexico City. The three traditional curing methods for LGC were simulated following the instructions published in June 2021 by the PROFECO institution, through the "Consumer Magazine", which are explained as follows [22].

2.2.1. Method 1: Curing with Heat and Vegetable Oil

Piece 1 was immersed in tap water for 24 h; after drying it with a clean and dry cloth, it was placed on the stove until the piece was heated. Vegetable oil (sunflower and canola oil) was then spread all over the internal surface with the help of a kitchen shovel. It is emphasized that for this method, it was not indicated that the piece should be washed at the end of the procedure.

2.2.2. Method 2: Curing with Boiling Water and Beef Lard

Piece 2 was filled with tap water and heated until it reached its boiling point, allowing it to evaporate completely. Then, using cloth, beef lard from a new package was spread on the entire internal surface. As with the previous method, washing the piece at the end of the procedure was not instructed.

2.2.3. Method 3: Curing with Garlic and Boiling White Vinegar

Piece 3 was submerged in tap water for 24 h; it was then dried with a clean cloth, and the entire internal and external surface was rubbed with a head of garlic cut in half. Then, a cup (250 mL) of commercial white vinegar (cane alcohol vinegar at 5% acidity, and sodium metabisulfite) was added. The piece was heated on the fire until it boiled. The remaining vinegar was removed, the piece was left at room temperature until it cooled completely, and, finally, it was washed with commercial soap and water.

Figure 1 shows the procedure of the three traditional curing methods performed for the three pieces of LGC.

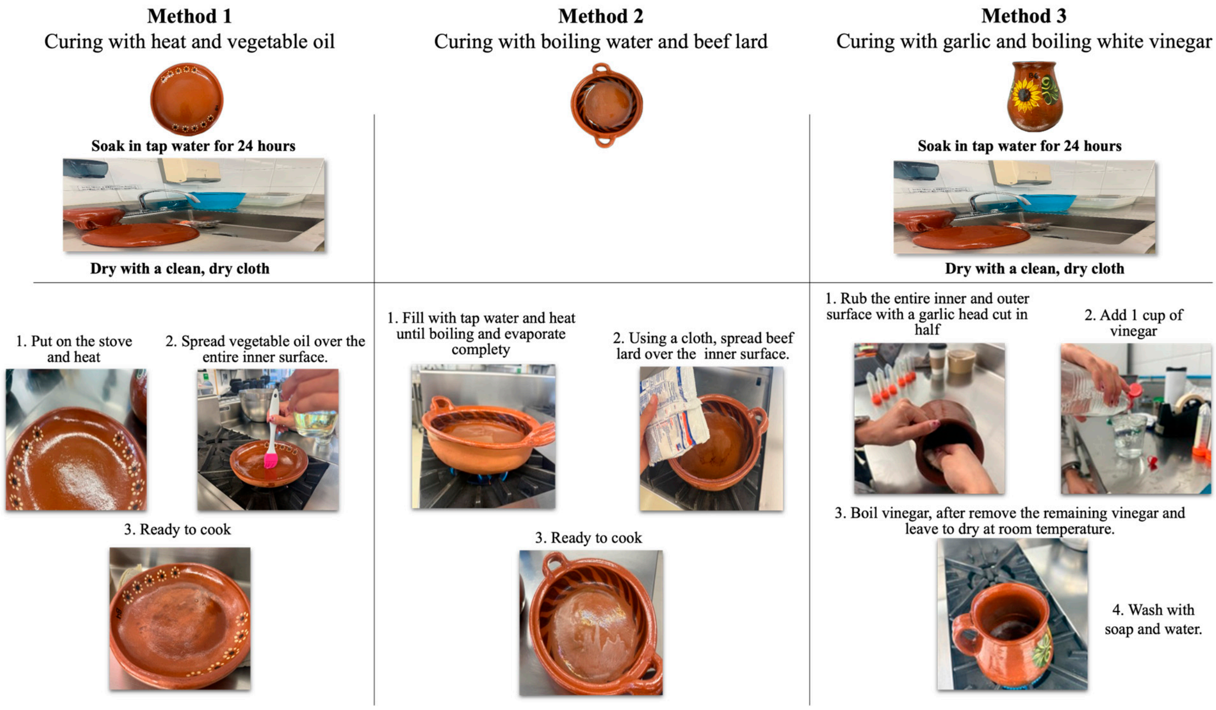

Figure 1. Description of the three traditional curing methods evaluated.

2.3. Detection and Quantification of Pb by Validated Qualitative and Quantitative Methods

Validated qualitative and quantitative methods were employed to determinate the presence of Pb in the LGC pieces before and after curing [23–25]. Using qualitative methods, the presence of Pb was detected by colorimetry with Lumetallix^{TM} and sodium rhodizonate, and as a quantitative method, Pb concentrations were quantified by X-ray fluorescence (XRF). The procedure used for each of these methods is described below.

2.3.1. Sodium Rhodizonate—Qualitative Method for Colorimetric Pb Detection

We used sodium rhodizonate, a qualitative method used for Pb detection by colorimetry. Following a standardized protocol for the application of this method [26], a saturated solution was prepared, where rhodizonic acid and disodium salt ($C_6O_6Na_2$) (Sigma-Aldrich Quimica, Burlington, MA, USA) were dissolved in commercial white vinegar (with 5% cane alcohol vinegar and sodium metasulfite). Subsequently, a swab was immersed into the solution and rubbed on the internal base of piece. A positive result for the detection of Pb is indicated by the yellow swab developing a scarlet red color; all measurements were recorded by an observer. The limit of detection (LOD) for Pb in this method in ceramic pieces is 400 ppm [27].

2.3.2. Lumetallix^{TM}—Qualitative Method for Colorimetric Pb Detection

We also used the qualitative method of colorimetric Pb detection using Lumetallix^{TM} AMS, NETH. We followed the manufacturer's instructions. The Lumetallix^{TM} kit consists of an ultraviolet (UV) lamp and a solution of methylammonium bromide (CH_3NH_3Br) dissolved in isopropanol (C_3H_8O), which, when exposed under the UV lamp and in the presence of Pb, reflects a fluorescent green color. The Lumetallix^{TM} solution was sprayed on the internal base of the 3 pieces. The UV lamp was passed back and forth over the entire sprayed surface to detect the presence of green fluorescence, which was recorded by a single observer; to improve the measurements, they were performed in a darkroom. According to the manufacturer, the LOD for Pb for this method in ceramic pieces was 500 ppm [28].

2.3.3. X-Ray Fluorescence (XRF)—Quantitative Method for Pb Concentrations

According to a standardized protocol [29], we quantified the Pb concentration in each LGC piece using XRF portable equipment (Thermo Fisher Scientific model NITON XL3T, Waltham, MA, USA); the readings were taken after the three pieces were rinsed with distilled water (Wöhler de Mexico S.A de C.V, Iztapalapa, MEX) and dried with a dry and clean cloth. Measurements were taken at the internal surface of the pieces, and the equipment was previously configured in the "metals and ceramics" mode, according to the manufacturer; the readings were taken in an interval of less than 20 s. The LOD for this method is 5–10 ppm [30].

2.4. Pb Leaching from Cured LGC to Food Simulation by ICP-MS

To assess Pb leaching from cured LGC pieces to food, we simulated the use of these three pieces by serving an acidic food simulated solution. In each of the three cured LGC pieces, we added commercial white vinegar and let it sit for one hour. Subsequently, we collected 10 mL samples of vinegar from each piece. Additionally, a sample of the commercial vinegar used was analyzed to estimate the basal Pb content. Samples were ultra-frozen (−70 °C) and transported to the Biotechnology Center of the Technological University of Monterrey in Nuevo Leon, Mexico, for their analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Samples were digested as follows: 1 mL of sample with 10 mL of concentrated nitric acid (plasma pure, 67–70%, SCP Science, ON, Canada) was digested for 20 min at 180 °C, or until the solution became colorless in a microwave system (MARS 5, CEM, Matthews, NC, USA). After digestion, the samples were cooled down to room temperature and the volume was adjusted to 25 mL with Milli-Q water. The solution was filtered using Whatman No. 41 ashless filter paper (pore size 2.5 µm) to remove any solid particles before analysis. For the quantification of Pb, ICP-MS (7800 Agilent Technology, Delaware, CA, USA) was used under the following conditions: purge time and stabilization time 50 s, peak pattern to three points, 100 cycles and 3 replicates. An element standard product containing Pb (20 µg/mL) (Accustandard Co., New Haven, CT, USA) was used for calibration. The analyses were performed in triplicate with a limit of quantification (LOQ) for Pb of 0.0005 ppm [31].

As acidic foods could increase the leaching of Pb when in contact with the LGC [20,32], we determined the pH of water and white vinegar (10 mL per solution) using a calibrated Conductronic potentiometer (Model pH 140, Puebla, PUE, MEX), rinsing the electrode with distilled water before and after each measurement. For oil and lard, we determined the acid value following the methodology of Paucar-Menacho et al. [33] in triplicate analyses. A sample of 5 g of vegetable oil and beef lard were collected; subsequently, 50 mL of denatured ethyl alcohol (C_2H_6O) (Reactivos Química Meyer, Tláhuac, MEX) and 2 drops of a phenolphthalein indicator ($C_{20}H_{14}O_4$) (Hycel Zapopan, JAL, MEX) were added, then titrated with 0.1 N sodium hydroxide (NaOH) (J.T. BAKER, Radnor, PA, USA) solution until the mixture turned a pink color. The equation used to calculate the acid value is as follows:

$$AV = \frac{V \times N \times 40}{W}$$

where AV = milligrams of NaOH required to neutralize the free fatty acids in the sample (mg NaOH/g oil or fat); V = volume in mL of the NaOH titration solution used; N = normal concentration of NaOH; and W = weight in g of the sample analyzed.

2.5. Statistical Analysis

The results of Pb colorimetric detection by Lumetallix™ and sodium rhodizonate, obtained before and after the three curing methods, are presented as dichotomous variables in the analyzed pieces (yes/no). The results of the Pb concentrations obtained through the XRF method are presented in graphical form as median values (ppm). We calculate the ratio increase by subtracting the initial Pb concentration from the final concentration and dividing it by the initial concentration. Furthermore, a paired *t*-test was performed to determine the statistical difference between average Pb concentrations before and after the curing; this analysis was carried out using the statistical software StataNow/BE 18.5 (StataCorp LLC, College Station, TX, USA).

For the evaluation of the Pb leaching simulation, the basal Pb concentration quantified in the vinegar sample (0.03 ppm) was subtracted from the Pb concentration in the leaching of each piece.

Finally, Pb concentrations obtained using the XRF method before and after curing were compared with the ML of Pb (100 ppm) for ceramics established by CPSC [21], and the Pb concentration obtained in the leaching simulation by ICP-MS was compared with the ML for Pb (0.5 ppm) established by the Mexican Normativity [18], which is the limit of Pb that can be leached by any item of pottery intended to contain or process food and/or beverages.

3. Results

According to Pb detection by Lumetallix™ and sodium rhodizonate, all pieces showed the presence of Pb on the analyzed surface before and after the three types of curing (Supplementary Table S1). Regarding the Pb quantification, in Figure 2, we show the Pb concentrations obtained by XRF. All LGC pieces had concentrations ranging from 40,300 ppm to 262,900 ppm and 123,800 ppm to 358,300 ppm before and after curing, respectively. Before curing, the average Pb concentration was 164,400 ppm and after curing, the pieces increased to an average of 266,700 ppm, with all these differences being statistically significant ($p < 0.05$). The highest increase in Pb concentration was observed in piece 3, cured with garlic and boiling vinegar, with a Pb increase ratio of 2.07 (twice its basal Pb concentration); followed by piece 1, cured with heat and vegetable oil, with a Pb increase of 0.88 times; and, lastly, piece 2, cured with boiling water and beef lard, with an increase of 0.2 times in its Pb concentration. The same figure shows the comparison between Pb concentrations obtained by XRF before and after curing and the ML of Pb (100 ppm) for ceramics established by the CPSC; we observed that all Pb concentrations exceeded the ML of 100 ppm established by the CPSC.

The results of the Pb leaching simulation are presented in Figure 3; we observe that all vinegar samples, used as a simulated food solution, contain detectable levels of Pb. The highest level of Pb leaching was found in the vinegar sample from piece 1, cured with heat and vegetable oil (378.18 ppm); followed by piece 3, cured with garlic and boiling vinegar (2.56 ppm); and the lowest Pb concentration was found in piece 2, cured with boiling water and beef lard (0.23 ppm). The Pb leaching concentration from piece 1 and piece 3 exceed the ML for Pb (0.5 ppm) for leaching to food or beverages established by the Mexican Normativity.

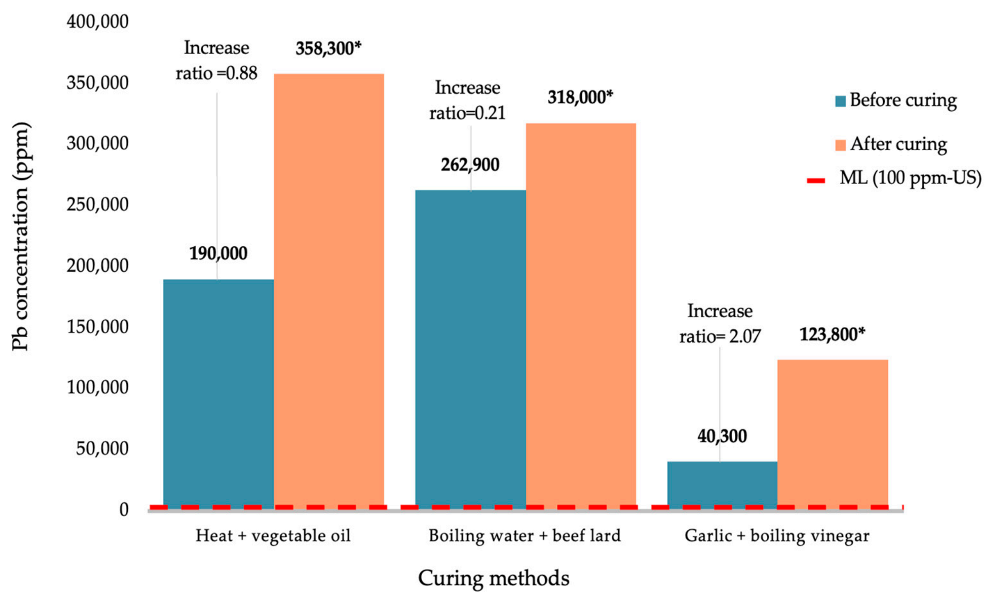

Figure 2. Results of Pb concentrations obtained by X-ray fluorescence (XRF), before and after submitting LGC to traditional curing and comparison with the maximum limits of Pb established by the U.S. Consumer Product Safety Commission. * $p < 0.05$ (statistical differences of Pb concentrations before and after curing methods were determined using paired t-test). **Values in bold exceed ML**.

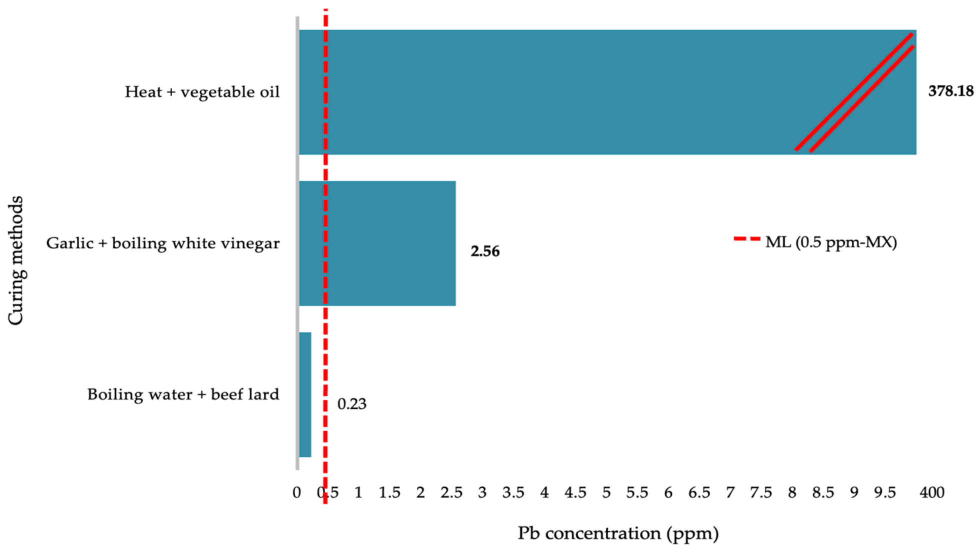

Figure 3. Results of Pb leaching from cured LGC to an acidic food simulant solution and comparation with the maximum limits of Pb established by the Official Mexican Normativity (NOM-231-SSA-2016). Pb concentrations in the Pb leaching simulation were obtained by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). **Values in bold exceed ML**.

4. Discussion

In this study, we highlight that this is the first study that analyzes, using different validated methods, the colorimetric detection and concentration of Pb before and after three different traditional curing methods for LGC, and we furthermore prove that Pb could leach from the cured pieces into the food (simulated with white vinegar) served on it. Our results are consistent with those reported by Paniagua et al. [32], who evaluated 17 pieces of LGC from Guatemala using atomic absorption spectrophotometry (AAS) for a Pb leaching 24 h test with 4% acetic acid; acidic beverages such as lemonade, orange soda, cola, and tomato juice; and homemade vinegar [32]. The authors found that most pieces leached Pb above the ML of 7 ppm, with the Pb concentration ranging from 0 to 2050 ppm in acetic acid and 2 to 3100 ppm in the homemade vinegar. On the other hand, Torres-Sánchez et al. [20] analyzed 27 ceramic pieces from the states of Oaxaca, Puebla, Mexico, and Tlaxcala, which were subsequently subjected to a curing with 3% glacial acetic acid for four consecutive days and the concentrations of Pb released were determined using AAS [20]. Although they found a decrease in Pb concentrations proportional to the number of washes with acetic acid, the average concentrations of Pb per day were 788.75 ppm (day 1), 471.59 ppm (day 2), 1151.36 ppm (day 3), and 733.74 ppm (day 4), indicating that despite curing the pieces for consecutive days, they continued leaching Pb, never at a rate less than the ML established by the Mexican normativity of 2.5 to 7.0 ppm (NOM-010-SSA1-1993) [20]. Similarly, in 1966, Viniegra and Escobar [13] evaluated the Pb concentrations released in different LGC pieces from five states of Mexico, using commercial chili vinegar. They concluded that most of the samples analyzed released Pb in high quantities through the effect of vinegar, with some of them exceeding the ML for Pb of 5 ppm [13]. Therefore, as can be seen in the available studies, after subjecting LGC pieces to an acid medium, in all cases, Pb leaching was observed in concentrations that exceed the MLs established at the time and in the countries studied. A possible explanation for this is that a route of contamination is the formation of Pb citrates and acetates during storage, where the release of Pb continues and reacts with the food [12].

In our study, after applying the recommended curing methods, published by the Mexican Institution PROFECO [22], all Pb concentrations increased after curing, with an average increase of 266,700 ppm. The pot cured with garlic and boiling vinegar, was the one with the highest Pb concentration with an increase in ratio of two times, followed by the piece cured with heat and vegetable oil (0.88 times over basal concentration). One possible explanation for the increase is that the acid pH (2.5) of white vinegar can increase the leaching of Pb through enamel abrasion, reaching deeper layers, releasing PbO that was not detected before curing [34]. Additionally, the highest rate of Pb leaching was observed in the piece cured with heat and vegetable oil (378.18 ppm), followed by that cured with garlic and boiling vinegar (2.56 ppm). With regard to the piece cured with heat and vegetable oil (sunflower and canola oil mixture), which presented the highest concentration of leached Pb, this could be explained by the fact that heat harmed the enamel, cracking it and allowing the release of PbO, especially if the enamel of the LGC piece was not properly melted during the processing of the piece [12]. In the results obtained by Seth et al. [35], who evaluated Pb leaching in a heated solution of 4% acetic acid, the average Pb concentration found was 4.2 mg/mL, with the highest Pb concentration (28 mg/L) being when the acid was between 70 °C and 90 °C [35]. For this curing method, vegetable oil (results not shown), we estimate an average acid value of 15.20 mg NaOH/g. According to the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/OMS) CODEX ALIMENTARIUS, the maximum level for the acid value of refined oils is 0.6 mg KOH/g Oil [36]. The acid value is an indication of the quality of the fatty acids in the oil; a higher acid value means that the fatty acids in the oil are hydrolyzed due to the effects of heat, exposure to oxygen, light, and humidity, causing the product to become rancid [37]. This suggested to us that the oil we used for the curing was of low quality, and its free fatty acids may influence the Pb leaching from the LGC piece. A previous report indicates that presence of certain types of fatty acids such as oleic and palmitic increase the removal of Pb content [38]. A last factor to be considered, which could contribute to the increase in Pb concentration observed after curing with vegetable oil, is the Pb contamination of seeds destined for vegetable oil manufacturing; according to previous publications, the presence of Pb in vegetable oils were above the limit established by the World Health Organization (WHO) of 0.1 mg/L [39,40].

Finally, in the case of the curing with boiled water and beef lard, this method shows the lowest Pb increase and leaching, this effect could be due to the fact that this solution (solidified beef lard with water) can act as temporary protection, where the protective layer prevents Pb leaching from the piece to the food; however, once the piece is washed, this protection could disappear. Although there are no specific studies evaluating how lard may facilitate or hinder the leaching of heavy metals from one medium to another in food systems, there is evidence from previous evaluations on the use of coated materials and barrier substances. For example, paraffin and wax-based coatings applied to paper and cardboard intended for food contact did not exceed release limits for Pb and cadmium (Cd), indicating that such coatings can serve as effective barriers to metal leaching [41].

Therefore, our results suggest that the ingredients used in each curing method can act as Pb-precipitating agents depending on the acidity or exposure to heat, as well as in the case of the curing method with beef lard, which can act as a potential temporary protective layer that prevents Pb release. However, it is important to note that fatty acids can promote or inhibit the release of heavy metals, as reported in the context of oil paintings and other oil-based systems [42], but they are not studies that address the role of free fatty acids in inhibiting Pb release in LGC materials.

It is important to note that in this study, the Pb concentrations obtained before and after curing, quantified by XRF, exceeded the ML established by the CPSC for ceramics. At the international level, due to the importation of LGC into the United States, the CPSC established the ML for ceramic pieces used for human consumption at 100 ppm to reduce the impact on consumer health [21]. Additionally, our Pb leaching results determined by ICP-MS exceed the ML established for the Mexican Normativity. In Mexico, NOM-231-SSA1-2016 established a permissible ML for Pb of 0.5 ppm that can be leached by any item of pottery intended to contain or process food and/or beverages [18]. We quantified the leaching of Pb by a solution (simulated with white vinegar) after curing. We further proved that Pb could leach at significant amounts into the solutions after the traditional curing methods were applied. The highest rate of Pb leaching was observed in the piece cured with heat and vegetable oil (378.18 ppm), followed by the piece cured with garlic and boiling vinegar (2.56 ppm), both exceeding the ML (0.5 ppm). The Mexican Normativity also indicates that the pieces that do not comply with the ML must contain the legend: "do not use with food or beverages, contains Pb" or must be relegated from this use; for example, by making a perforation on the side of the base [18]. It should be noted that this legend or perforation was not found in any of the pieces analyzed in this study, despite being produced with PbO, as normative indications, reflecting a lack of compliance.

Among the strengths of our study is that we applied different methods for Pb detection and quantification [23–25,31]. Furthermore, by evaluating Pb leaching from the cured pieces to an acid medium, we had an overview of the real effect of curing on the served or stored food, analyzing in triplicated the leached concentration using ICP-MS, the method considered as a gold standard for its quantification according to the Mexican Normativity. Another important aspect is that we evaluated popular curing methods in the Mexican population, because "Consumer Magazine" is a media with a nationwide reach [22]. Regarding the limitations of our study, we identify, firstly, the small number of pieces analyzed. In addition, all LGC pieces were purchased in the state of Puebla; a larger number of pieces and from different regions of the country could give us an overview comparing the different manufacturing and glazing methods. The choice of purchasing from Puebla was due to the fact that it is one of the main pottery states in the country; in addition, according to the National Health and Nutrition survey, Puebla has the highest prevalence of Pb poisoning in children under 5 years of age (>40%) [11].

Finally, another limitation is that the different sizes and volumes of the pieces could influence Pb dilution or concentration, resulting in a more saturated Pb concentration in small pieces [43]. Therefore, it is important to conduct analyses of LGC pieces of the same size and volume.

We recognize the used of LGC as one of the main sources of Pb exposure in the Mexican population; however, the manufacture of these pieces represents an economic income for 154 thousand people throughout the country [44], which contributes 0.6% of the gross domestic product in 2021 [45]. In addition, pottery is a national and international heritage, where the pieces manufactured are creations that help us understand the customs, esthetics, and vision of our culture. Therefore, it is necessary to improve manufacturing conditions to positively impact the health of potters and their families, as well as the consumers [11,46]. It is necessary to establish monitoring systems that control the quality of materials (such as enamels) and promote the use of Pb-free materials and kilns that reach the appropriate melting temperature, as well as monitoring compliance with the Mexican regulations established for these types of pieces. Additionally, it is important to reduce misinformation on the use of curing as a method to remove Pb in LGC in the population. According to our results and reports from public and private institutions in Mexico and the United States, such as the California Department of Public Health [47], the FDA [48], the National Institute of Public Health of Mexico [20], and the non-profit organization Pure Earth [49], curing methods can improve resistance and avoid an earthy flavor in food; however, is not safe for Pb removal and should not be taken as a strategy to reduce poisoning by this metal.

5. Conclusions

Curing is a traditional technique that has been carried out since the beginning of pottery in Mexico and represents a cultural legacy that should be disseminated as such; however, it is necessary to alert the population that although curing can strengthen their LGC pieces, it is not a method that can remove the presence of Pb and could even increase its leaching to the food. Our results represent an effort to reduce misinformation about the use of curing methods for the elimination of Pb in LGC pieces and the need for artisans to migrate to the use of Pb-free materials and methods for the manufacture of LGC pieces, thus ensuring the health of both artisans and consumers.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/pr13092766/s1, Table S1. Results of Pb detection and concentrations by qualitative and quantitative methods before and after submitting LGC to traditional curing.

Author Contributions: Conceptualization, A.C.; methodology, R.M.M.-M. and N.P.-D.; validation, C.C.-H.; formal analysis, M.F.R.-H., F.A.V.-A., C.C.-H. and N.P.-D.; investigation, M.F.R.-H. and L.B.-R.; resources, R.M.M.-M. and A.C.; data curation, M.F.R.-H. and F.A.V.-A.; writing—original draft preparation, M.F.R.-H., L.B.-R. and A.C.; writing—review and editing, M.F.R.-H., L.B.-R., R.M.M.-M., F.A.V.-A., C.C.-H., N.P.-D., R.F. and A.C.; visualization, M.F.R.-H. and L.B.-R.; supervision, F.A.V.-A.; project administration, L.B.-R.; funding acquisition, R.F. All authors have read and agreed to the published version of the manuscript.

Funding: This study received funding from the Pure Earth Mexico/Blacksmith Institute (Proyec: 2407 Pure Earth Bio) and Betanzos-Robledo is supported by the Consejo Nacional de Humanidades, Ciencia Tecnología (CONAHCyT) as a doctoral student (#18593).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors acknowledge Carrillo Zúñiga Andrea for the support in the laboratory analysis and Pure Earth Mexico for the support with the equipment for lead determination and facilitating the field work team: Lázaro Rosas Karina, Violante Moreno Max Armando, Aguilar Bazaldúa Joshelin A, and Águila Sandoval Julia. We acknowledge the support of the Health Research Consortium, CISIDAT, in Mexico.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

AAS	Atomic Absorption Spectrometry
FAO	Food and Agriculture Organization of the United Nations
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
JECFA	Joint FAO/WHO Expert Committee on Food Additive
LGC	Lead-Glazed Ceramic
LOD	Limit of Detection
LOQ	Limit of Quantification
ML	Maximum Limits
Pb	Lead
PbO	Lead Oxide
PROFECO	Procuraduría Federal del Consumidor
CPSC	The U.S. Consumer Product Safety Commission
WHO	World Health Organization
XRF	X-Ray Fluorescence

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