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Technical Note

Recycling of ash from mezcal industry: A renewable source of lime

L. Chávez-Guerrero [a,c,*], J. Flores [b], B.I Kharissov [a,d]

[a] Department of Nanotechnology, PIIT Monterrey, C.P. 66600, Apodaca, Centre of Innovation Research and Development on Engineering and Technology, Universidad Autónoma de Nuevo León (UANL), Nuevo León, Mexico
[b] División de Ciencias Ambientales, Camino a la presa San José 2055, C.P. 78216, Instituto Potosino de Investigación Científica y Tecnológica, San Luis Potosí, Mexico
[c] Facultad de Ingeniería Mecánica y Eléctrica, Cd. Universitaria s/n, C.P. 66450, Universidad Autónoma de Nuevo León, Nuevo León, Mexico
[d] Facultad de Ciencias Químicas, Cd. Universitaria s/n, C.P. 66450, Universidad Autónoma de Nuevo León, Nuevo León, Mexico

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ABSTRACT

Agave bagasse is a byproduct generated in the mezcal industry. Normally it is burned to reduce its volume, then a byproduct is generated in the form of residual ash, which can contaminate the water in rivers and lakes near the production places called "mezcaleras". This report details measurements of the *Agave Salmiana* fiber transformation after the burning process. The wasted ash was heated at 950 °C, and then hydrolyzed. The compounds were indentified using the X-ray diffraction. The images obtained by scanning electron microscope showed all the morphological transformations of the lime through the whole process. Thermal, elemental and morphological characterization of the agave bagasse were done. Experiments showed that 16% of ash was produced in the burning process of agave bagasse (450 °C), and 66% of the ash remains after heating (950 °C) in the form of calcium oxide. The results show an important renewable source of calcium compounds, due to the high production of agave based beverages in México.

1. Introduction

Agave has been used by man for 10 000 years, it was used as a source of food and the fibers were used as footwear (Kuttruff et al., 1998). These days Agave is used to produce primarily the alcoholic beverages mezcal and tequila, as well as aguardiente, aguamiel and other products such as food and candies (Harshberger, 1897; Iñiguez-Covarrubias et al., 2001; Dalton, 2005; De León-Rodríguez et al., 2006). By mezcal we mean an alcoholic beverage obtained using *Agave angustifolia Haw, Agave esperrima Jacobi, Agave weberi Cela, Agave potatorum Zucc,* or *Agave Salmiana* (Norma Oficial Mexicana, 1994; De León-Rodríguez et al., 2006; Michel-Cuello et al., 2008; Martínez-Aguilar and Peña-Álvarez, 2009). The production of mezcal is of high importance in México, especially for communities where it is the only source of income. It is known that 15–33 kg of agave are needed to produce 1 L of mezcal. The making of mezcal produces a byproduct or waste (bagasse) representing about 40% of the total weight of agave used to produce the alcoholic beverage on a wet weight basis (Iñiguez-Covarrubias et al., 2001). The wasted fibers are used for informal applications, such as animal feeding or papermaking (Idarraga et al., 1999). The byproduct or bagasse is normally burned to reduce its volume, producing large quantities of ash, which is a hazardous pollutant for humans, animals, and the environment around the factory, especially for rivers and water corps that can be easily contaminated. Tequila production in the first 6 months of the 2008 was 8254 L per month, this information is given in order to have an idea of the mezcal production and consequently the huge amount of bagasse and ash produced (INEGI, 2008).

Calcium is required for structural roles in the cell wall and membranes, this divalent cation is taken up by roots from the soil solution (White and Broadley, 2003). It is known that needle-like calcium oxalate crystals are found in all tissues of agave plants (Salinas et al., 2001). Crystals are sharpened at both ends (raphides) with length of 30–500 μm. Calcium oxalate is a common biomineral in plants, it appears in monohydrate (whewellite) or di-hydrated (weddelite) form. Among the biological function of the crystals, they play an important role in physical protection (defense mechanism) against herbivores animals (Demiray, 2007).

Due to their optimum adaptation, the agave plants (and their byproducts) can be used to generate fuel, food, and chemicals, using arid lands with unfavorable conditions for the production of other crops (Hinman, 1984; Jordan et al., 2007). There have been lots of works being done in the area of ash usage, mainly in the cement, glass and steel industries which can be an incentive to propose new ash sources from industrial byproducts. (Stout et al., 1997; Renedo and Fernandez, 2002; Rostami and Brendley, 2003; Katayama, 2004; Oner et al., 2005; Sakai et al., 2005; Mahmoudkhani et al., 2007; Mymrin and Correa, 2007). Commonly, the $CaCO_3$ is

* Corresponding author at: Facultad de Ingeniería Mecánica y Eléctrica, Cd. Universitaria s/n, C.P. 66450, Universidad Autónoma de Nuevo León, Nuevo León, Mexico. Tel./fax: +52 81 13404000.
E-mail address: leonardo.chavezgr@uanl.edu.mx (L. Chávez-Guerrero).

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extracted from rocks, which are heated to expulse the CO_2 in order to obtain the CaO. These rocks are not a renewable source of calcium carbonate, so it is desirable to find alternative sources and methods to provide the industry with this important product (Hinman, 1984; Stout et al., 1997; Katayama, 2004; Sakai et al., 2005; Jordan et al., 2007; Mymrin and Correa, 2007). An important point to consider is that for every 1000 kg of $CaCO_3$, 560 kg of CaO are produced along with 440 kg of CO_2, which is a pollutant related to global warming (Ragauskas et al., 2006).

In this paper, ash from the mezcal industry as a new source of lime is investigated. The objectives are to minimize pollution (ash), and to propose an alternative way to obtain chemical compounds using renewable feedstocks produced in arid lands (agave).

2. Materials and methods

2.1. Thermal analysis of the bagasse

The bagasse was collected direct from the mezcal factory IPIÑA S.A de C.V. in San Luis Potosí, México. A Thermolyne 48000 furnace was used to heat the bagasse (450 °C) to obtain ash (ASH-450). The ash was sieved to obtain a powder less than 1.5 mm in size, using a USA Standard test sieve No. 12 (1.7×1.7 cm^2). The sample consisting of 10 g of ASH-450 was placed in the alumina (Al_2O_3) crucible and then into the furnace, 30 samples were used to ensure reproducibility. Then, the ash was heated from 25 to 950 °C and the temperature was kept for 2 h to expulse the water, CO_2 and volatile compounds in the material. This sample was termed ASH-950. After that, the sample ASH-950 was loaded in de-ionized water. The mixture was stirred for 2 h at 25 °C. The sample was dried at 100 °C for 5 h in order to eliminate the moisture. De-ionized water was used in all the reactions. This hydrated sample was termed ASH-950–H_2O. Baggase (4 mg) were tested in a Thermo gravimetric analyzer (TGA) Thermo Cahn modelo Versatherm, with temperature range of 25–1000 °C and heating rate of 10 °C min^{-1} in N_2 atmosphere.

2.2. Imaging of the samples

The samples were glued to aluminium holders, sputter-coated with gold (Cressington Sputter Coater 108 auto) using 40 A for 20 s under argon atmosphere for scanning electron microscope (SEM) studies. The morphology and composition (qualitatively) of the samples were determined by SEM (FEI XL 30 SFEG with an energy dispersive X-ray microanalysis system, standard-less analysis) with acceleration energy of 15 kV. X-ray powder diffractions patterns were obtained with Cu Kα radiation ($\lambda = 1.5406$ Å) in a D8 Advance Bruker powder diffractometer. The diffractogram patterns were ranged from $2\theta = 10°$ to 90°. Atomic Force Microscope (AFM) images were taken with a Jeol JSPM-5200 Scanning Probe Microscope in order to investigate the morphological changes at the nanoscale.

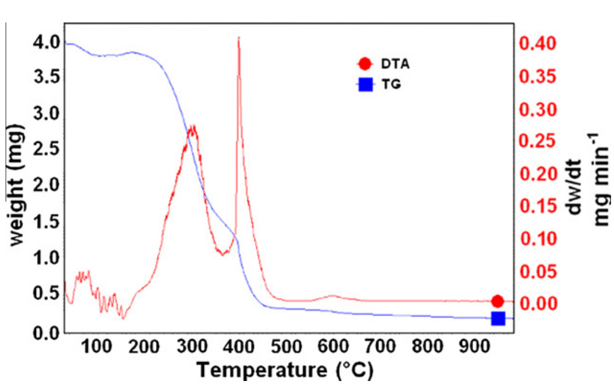

Fig. 1. TGA/DTA data showing the loss weight versus the temperature of the bagasse.

3. Results and discussion

3.1. Thermogravimetric analysis

The weight loss shown by the bagasse (450 °C) in the burning process was 84 ± 2% which means that 16% of ash was produced.

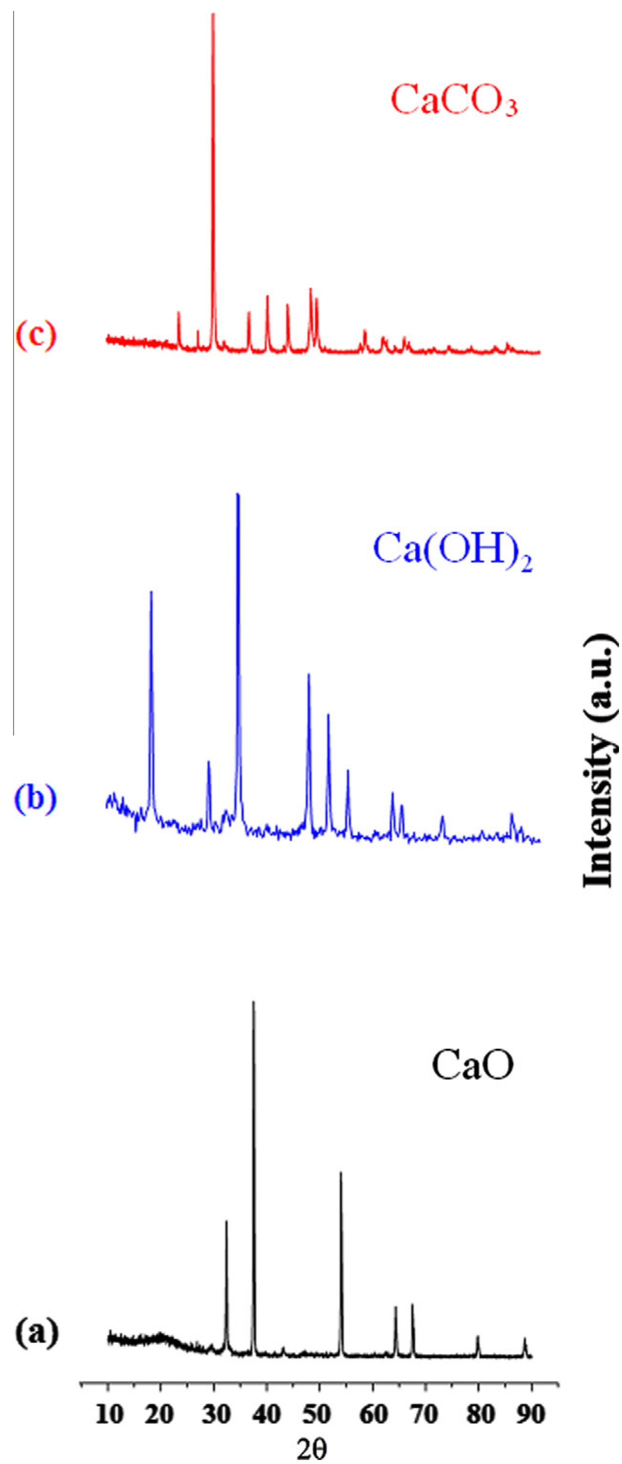

Fig. 2. X-ray diffractogram patterns that correspond with: (a) CaO, (b) $Ca(OH)_2$ and (c) $CaCO_3$.