

## Study of as-synthesized and calcined hydrocalumites as possible antacid agents

CARLOS F LINARES\*, FREDDY OCANTO, PABLO BRETTO and MARICELA MONSALVE

Unidad de Síntesis de Materiales y Metales de Transición, Facultad de Ciencias y Tecnología,  
Departamento de Química, Universidad de Carabobo, Valencia, Edo. Carabobo, Apartado Postal 3336, Venezuela

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**Abstract.** A hydrocalumite-type solid was synthesized by the homogeneous co-precipitation method by using Ca and Al nitrate solutions in a basic medium (NaOH). This solid was calcined at 700 and 900 °C, respectively. Then, solids were characterized by X-ray diffraction, FT-IR spectroscopy and BET surface area measurements. Finally, these solids were tested as antacids by using a synthetic gastric juice. Results showed that calcined samples were able to neutralize the synthetic gastric juice in more extension as an as-synthesized hydrocalumite; however, the last solid showed better conditions as a potential antacid.

**Keywords.** Hydrocalumite; calcination; antacid; basicity; characterization.

### 1. Introduction

Hydrocalumites and hydrotalcites are a close family of layered double hydroxides. While, hydrotalcites-like materials can be often synthesized by using different cations of (II) and (III) compositions, hydrocalumites show  $\text{Ca}^{2+}$  and  $\text{Al}^{3+}$  having a typically very narrow composition in the hydroxide layers. Both structures are based on positive brucite-like layers alternating with anions and water molecules (Rousselot *et al* 2002).

Synthetic hydrocalumite-type  $[\text{Ca}_2\text{Al}(\text{OH})_6]\text{NO}_3 \cdot m\text{H}_2\text{O}$  is made up of octahedral Ca and Al hydroxides which share edges to form bidimensional layers. Ca and Al octahedra are accommodated in the layers in an orderly manner, while in the hydrotalcite-type structures, the sheets contain randomly arranged metal hydroxides components (López-Salinas *et al* 1996).

Hydrocalumite shows a marked effect in the basic properties, when it is calcined at different temperatures. Thus, for example, hydrocalumite calcined at 1073 K shows 90% of strong basic sites, while these basic sites are absent in hydrocalumites calcined at 573–673 K (López-Salinas *et al* 1996). These differences in the basic properties of hydrocalumite have permitted to be used as basic catalysts in the isomerization of 1-butene reaction (Rousselot *et al* 2002), biodiesel production (Campos *et al* 2009) or aldol condensation reactions (Cota *et al* 2010).

On the other hand, hyperacidity is defined as an abnormal increment of HCl in the stomach. Hyperacidity should be controlled to avoid several diseases such as

peptic ulcers, gastroesophageal reflux or stomach cancer (Beers and Berkow 1999). Usually, antacids are used for controlling the pH in the stomach. They could act as neutralizing of stomach acidity and maintaining an adequate pH in the stomach. Normally, such antacids can be formulated as soluble or no-soluble basic salts ( $\text{NaHCO}_3$  or  $\text{CaCO}_3$ ), basic hydroxides such as  $\text{Mg}(\text{OH})_2$  or  $\text{Al}(\text{OH})_3$  or mixed basic oxides, such as calcined Al–Mg hydrotalcites (Beers and Berkow 1999). All of them have advantages and disadvantages which allow their use according to the patient's pathology.

Hydrotalcites are very popular as antacids because they can maintain the stomach's pH between 3 and 5 avoiding an abrupt increase in the stomach's pH 'rebound effect'. The rebound effect is characterized by an abrupt increase in pH.

Therefore, taking into the account the excellent hydrotalcites properties as antacids, it is plausible that hydrocalumite could present a similar behaviour due to its structure and basic properties are also comparable.

The aim of this work is to synthesize, characterize and calcine at different temperatures Ca/Al hydrocalumite-type solids for evaluating their basic properties *in vitro* as antacid. Results are compared to those obtained with a commercial antacid based on hydrotalcite as active agent.

### 2. Experimental

#### 2.1 Synthesis of hydrocalumite (HC)

Hydrocalumite was synthesized by the co-precipitation method previously reported by López-Salinas *et al* (1996). A Ca–Al solution was prepared dissolving  $\text{Al}(\text{NO}_3)_3 \cdot$

\*Author for correspondence (clinares@uc.edu.ve)

9H<sub>2</sub>O (11.90 g) and Ca(NO<sub>3</sub>)<sub>2</sub>·4H<sub>2</sub>O (14 g) in distilled water (100 mL). This solution was added dropwise to 25 mL of a NaOH solution (6.90 g) and kept under stirring in an inert atmosphere.

The resultant gel was refluxed by using a glycerin bath at 80 °C for 12 h, constant agitation and controlled pH (pH ≅ 11) under an inert atmosphere.

A white solid was filtered from the mixture, washed up with abundant distilled water and dried at 100 °C for 18 h.

Then, portions of as-synthesized hydrocalumite (HC) were calcined to 700 (HC 700) and 900 °C (HC 900), respectively in an air atmosphere for 4 h.

To ascertain the effectiveness of the synthesized and calcined hydrocalumites as antacid, their behaviour was compared to that of a commercial antacid based on hydrocalumites as active agent.

## 2.2 Characterization

Solids were characterized by XRD, BET surface area and FT-IR. XRD studies were conducted using a Phillips PW 3442 diffractometer with a CuK $\alpha$  radiation (154,060 Å) for crystalline phase detection between 4 and 80° (2 $\theta$ ), and the patterns obtained were compared with JCPDS data files. Physisorption measurements were performed with a Beckman Coulter SA 3100 instrument; BET surface areas were determined by nitrogen adsorption at -196 °C with an Ar/N<sub>2</sub> ratio of 70/30. The presence of functional groups and evaluation of purity of solids were achieved by FT-IR; spectra were recorded in a Perkin-Elmer 283 spectrometer in the 4000–500 cm<sup>-1</sup> range. Samples were prepared mixing the solids with KBr to form a thin pastille.

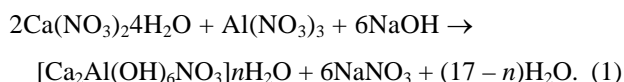
## 2.3 Antacid capacity

Antacid capacities of as-synthesized and calcined hydrocalumites were evaluated using the methodology previously reported by Rivera *et al* (1998) and Linares *et al* (2005). Solids were tested in a synthetic gastric juice (HCl + pepsin, pH ≈ 1.5), contacting 50–500 mg of the solids with an aliquot of 10 mL of the synthetic gastric juice. This dispersed solution was shaken for 1 h at 37 °C to simulate rhythmical movements of the stomach. The solution was then filtered and an aliquot of 10 mL was evaluated using a calibrated pH meter.

## 3. Results and discussion

### 3.1 Characterization of HC and calcined HC

The reaction can be followed as:

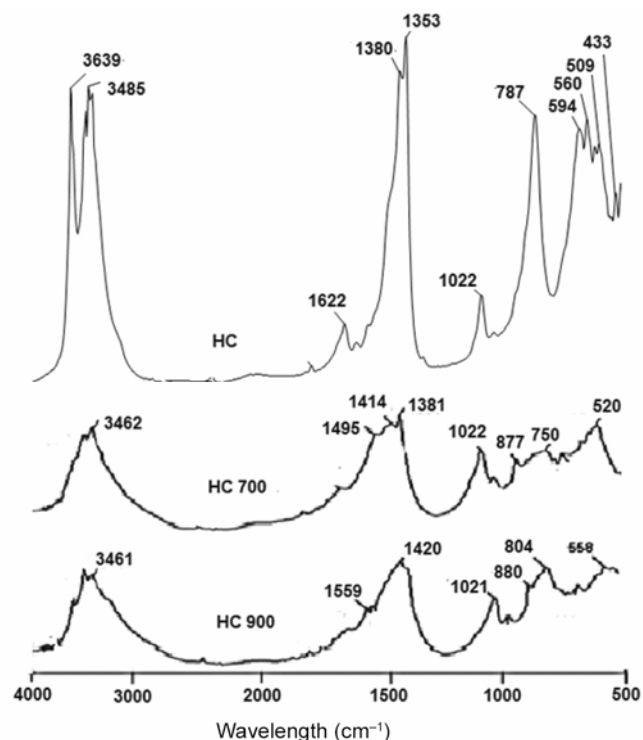


As synthesized (HC) and calcined hydrocalumites (HC 700 and HC 900) were characterized by FT-IR (figure 1).

For HC, band at 1353 correspond to NO<sub>3</sub>-ion in the interlayer region (Kok *et al* 2008). While, two bands between 3500 and 3700 cm<sup>-1</sup> could be attributed to OH<sup>-</sup> groups. The band at 3639 cm<sup>-1</sup> corresponds to O–H stretching vibrations in structural Al–OH groups; while bands at 3485 and 1022 cm<sup>-1</sup> can be assigned to OH groups of Ca(OH)<sub>2</sub> present in the hydrocalumite-type material (Palmer *et al* 2009; Mora *et al* 2011). Also, OH<sup>-</sup> groups corresponding to water molecules placed in the hydrocalumite interlaminar region could be overlapping the other two bands (Campos *et al* 2009). A band at 1622 cm<sup>-1</sup> confirms the physisorbed water presence.

Between 787 and 509 cm<sup>-1</sup>, Al–O vibrations of the hydrocalumite structure were observed (Domínguez *et al* 2011). A band at 1380 cm<sup>-1</sup> is characteristic of C=O stretching of CO<sub>3</sub><sup>2-</sup> anions adsorbed on the hydrocalumite surface (Domínguez *et al* 2011).

When the hydrocalumite is calcined (HC 700 and HC 900), FT-IR spectrum of HC changed. According to López-Salinas *et al* (1996), Vielle *et al* (2003) and Campos *et al* (2009), the transformation of hydrocalumite during calcination occurs in three steps: in the first step (100–200 °C), the physisorbed water is lost from the hydrocalumite structure. The second (200–300 °C) and third steps (300–800 °C) correspond to hydroxylation and expulsion of anions. An exact sequence has not been established.



**Figure 1.** FT-IR spectra of as-synthesized (HC) and calcined hydrocalumite (HC 700 and HC 900).

For FT-IR spectra of HC 700 and HC 900 samples, the main bands corresponding to nitrate and carbonate anions or physisorbed water diminished or not observed. Then, other wide bands emerged. This could suggest that hydrocalumite structure collapsed, as was mentioned above and other phases could be formed.

A clear identification of hydrocalumite phases could be done by using XRD. Figure 2 shows XRD patterns of HC, HC 700 and HC 900.

Characteristic intense peaks at 10, 20 and 29 degrees ( $2\theta$ ), and also other less intense bands belonging to HC (López-Salinas *et al* 1996) were found in the corresponding sample; moreover, a minor phase of  $\text{CaCO}_3$  (JCPDS: 85-1108) could also be identified. The basic conditions of synthesis of hydrocalumite, permitted the formation  $\text{CaCO}_3$  due to absorption of atmospheric  $\text{CO}_2$ .

When hydrocalumite is calcined (700 and 900 °C), the structure collapsed and other phases, such as CaO

(JCPDS: 17-0912) or  $\text{Ca}_{12}\text{Al}_{14}\text{O}_{33}$ , mayenite (JCPDS: 48-1882) are identified. According to López-Salinas *et al* (1996), the calcination of HC at 500 °C produces CaO, while calcination at higher temperatures (upon 600 °C) produces CaO and  $\text{Ca}_{12}\text{Al}_{14}\text{O}_{33}$ .

For samples calcined to 700 and 900 °C, hydrocalumite peaks were also identified. Rehydration of the calcined product, the HC, where water and  $\text{CO}_2$  are absorbed from an air atmosphere could restore HC (Palmer *et al* 2009).

BET surface area measurements of selected samples were also carried out (table 1). Results showed low BET surface area values. Similar results were reported by López-Salinas *et al* (1996).

### 3.2 Antacid characterization

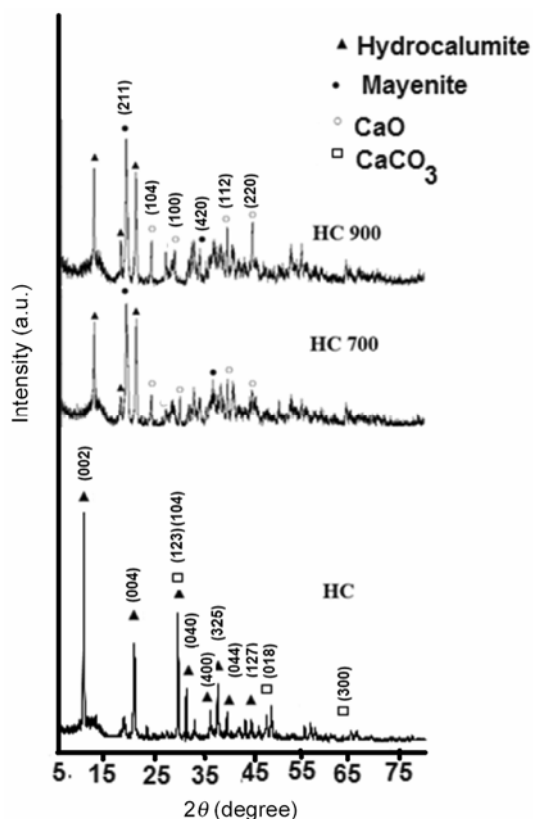
Figure 3 shows neutralization capacity as a function of as-synthesized and calcined hydrocalumite masses.

In general, the behaviour of hydrocalumites (as-synthesized and calcined samples) is similar, inclusive for the commercial antacid used as reference, pH increases as the weight of the studied solid is increased.

HC 700 and HC 900 showed the major antacid capacity and their behaviour is quite similar. According to López-Salinas *et al* (1996), calcined hydrocalumites show a marked effect in the formation of medium and strong basic sites. Medium basic sites derive from  $\text{O}^{2-}$  ions adjacent to the surface OH group which transform into isolated  $\text{O}^{2-}$  ions upon increasing the calcination temperature. The later sites are responsible for the basicity.

In spite of the high neutralization capacity shown for both solids, they cannot be considered as good candidate antacids because the pH value is violently increased when few amounts of these solids are used. When the pH is abruptly increased, the 'rebound effect' is emerged (Beer and Berkow 1999).

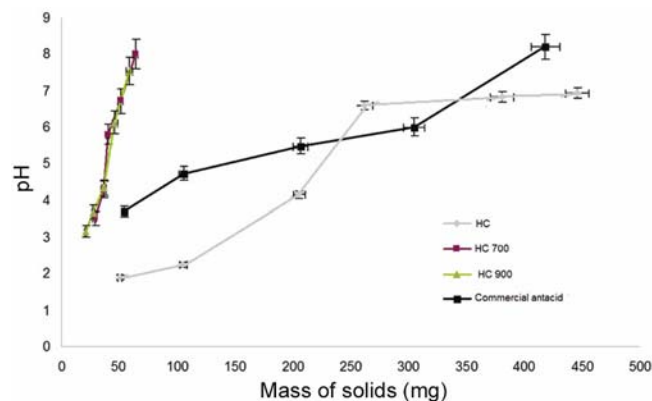
HC and commercial antacid showed similar activities as antacid. The neutralization capacity of HC is derived



**Figure 2.** XRD patterns of as-synthesized hydrocalumite (HC) and calcined hydrocalumite (HC 700 and HC 900).

**Table 1.** BET surface area of as-synthesized and calcined hydrocalumite.

Solid	BET surface area ( $\text{m}^2/\text{g}$ )
HC	$40.3 \pm 0.5$
HC 700	$13.9 \pm 1.7$
HC 900	$10.0 \pm 2.5$



**Figure 3.** Antacid capacity of as-synthesized, calcined hydrocalumite and a commercial compound as a function of solid masses.

from surface OH group and they can be considered as weak basic sites (Malinowski *et al* 1964). These OH groups can neutralize the free protons in the synthetic gastric juice.

In spite of that HC showed the highest surface area and it is plausible that the behaviour of antacid capacity of as-synthesized and calcined hydrocalumite is due to different basic sites showed by the solids as was mentioned above.

The observed similarity between antacid capacity of HC and the commercial antacid looks very promising since it is known that the active component of this solid is hydrotalcite. This compound is of ample use as antacid due to the ease of Al and Mg to form buffer type equilibrium with protons of gastric juice, inhibiting sudden increases of pH of the gastric juice, avoiding the so-called 'rebound effect' (Fordtran *et al* 1973), usually observed with sodium carbonate based antacids.

HC and the commercial compound showed a buffer capacity between 4 and 6 pH units which is considered as an ideal pH for alleviating symptoms of heartburn.

#### 4. Conclusions

It is possible to use as-synthesized hydrocalumites as effective antacid drugs. It was observed that the effectiveness of the hydrocalumite depends on calcination temperature. BET surface area does not seem to be a fundamental parameter for neutralizing a synthetic gastric juice. Neutralization tests indicate that doses as small as 150–200 mg of as-synthesized hydrocalumite increase the pH to normal acidity conditions of the stomach juice.

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