Structural and Morphological Characteristics of Hybrid Nanomaterials Type Ascorbic Acid-hydrotalcite Used for Stimulating Salivary Secretion

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A new hybrid nanomaterial type vitamin C/ZnAl-hydrotalcite, acting as drug delivery system for ascorbic acid, was developed in order to use it for stimulating salivary secretion. The synthesis of this nanomaterial was achieved using a simple coprecipitation method for intercalation of ascorbate anions in the ZnAl-hydrotalcite gallery. The stability of vitamin C was significantly increased after its incorporation into the interlayer space. Structural and morphological characterization techniques revealed an alteration of the pristine nanomaterial type ZnAl-hydrotalcite when vitamin C was loaded in its matrix. Structural and morphological analysis showed that ascorbate anions were intercalated in the interlayer of ZnAl-hydrotalcite having no effect on the hydroxide lattice of hydrotalcite, so this new nanomaterial can be used for the intended purpose.

Keywords: ascorbic acid, hydrotalcite, XRD, SEM, salivary secretion, oral health

Saliva has many functions in oral cavity such as protective, digestive and trophic ones (figure 1). There are individuals affected by xerostomia, an uncomfortable disease that involves a dry mouth because of impaired salivary secretion. This consists of a painful process of eating and speaking, diminishing the sense of taste and increasing gingivitis and dental caries. Furthermore, oral mucosa is exposed to damage and vulnerable to infections. Around 95% of total saliva volume is produced by three pairs of major glands: 60-65% provided from parotid glands, 20-30% from submandibular glands and 2-5% from sublingual glands.

To mention is that the minor glands play an important role in ensuring the integrity of mucosa although these glands produce small amount of saliva. Some studies have been done on the control of salivary secretion that established that the autonomic nervous system is fundamental to process controlling. Stimulation of salivary secretion comprises the neural mechanisms that incorporate salivary stimuli response such as taste but is also very important due to its antibacterial properties [1-6].

Among all these functions of saliva presented in figure 1 and knowing the fact that saliva acts not only in the mouth, it should be mentioned that salivary enzymes present in bolus are also active in the stomach. Once swallowed, saliva protects the esophagus from regurgitated gastric acid. Furthermore, saliva protects the upper and the lower respiratory tract from different infectious agents [7-15].

L-Ascorbic acid, also called vitamin C, is a water soluble compound having a wide variety of biological and pharmaceutical functions such as collagen biosynthesis, photoprotection, melanin reduction, antiviral effect and stimulation of salivary secretion. It can also reduce the risk of cancers, cardiovascular diseases decrease LDL-cholesterol and prevents anemia by enhancing iron absorption. However, vitamin C is very unstable to light, air, heat, moisture, base and metal ions decomposing into biologically inactive compounds. For physiological functions human body needs a small amount of vitamin C as insufficient and excessive intake causes harmful effects [16-19]. Taking into account all these aspects, an efficient vitamin C administration method could be a drug delivery system for its controlled release in different purposes.

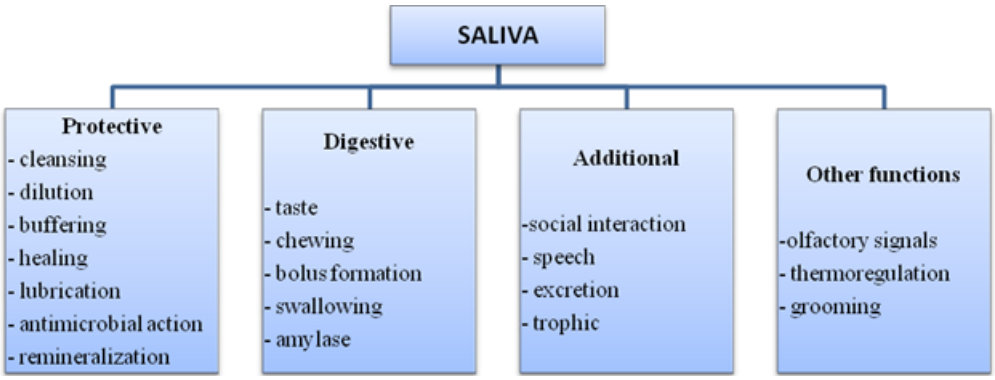

Fig. 1. Various functions of saliva

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In last few years, new inorganic nanomaterials type hydrotalcite (HT) or layered double hydroxides (LDHs) were used as drug delivery and controlled release systems due to their higher biocompatibility and stability compared to other drug vehicles. These nanostructures consist of hydrotalcite-like layer of metal hydroxides and the interlayer space occupied by anions and water molecules counterbalancing positively charged layers [20-25]. Simple coprecipitation, reconstruction and anion exchange method can be used in order to readily introduce and stabilize various inorganic or organic anions into the hydroxide interlayer. New organic-inorganic nanohybrid materials are synthesized and used for different compound intercalation possessing a modified structure and new function. Moreover, incorporation of active molecules into LDHs has been applied for studying storage, transport and controlled release profile of drug [26-31].

Experimental part

Materials and methods

ZnAl-hydrotalcite sample were prepared by coprecipitation method using aluminum nitrate and zinc nitrate precursor salts in a 2:1 molar ratio. Metal salts dissolved in deionized water were added slowly drop wise together to a NaOH/Na_2CO_3 solution under vigorous stirring. The resulting gel was aged for 24h at 80°C, separated by filtration and dried at 60°C for 20h. The sample was then thermally treated at 500°C for 5 h in order to be used for drug intercalation by reconstruction of pristine nanomaterial.

Ascorbic acid intercalation into ZnAl-hydrotalcite interlayer space was carried out by reconstruction method using calcined samples. A base solution containing 0.7g of sodium hydroxide and 2.4g of sodium ascorbate (containing fourfold excess of ascorbate) dissolved in 100 mL of deionized water was prepared. Thereby 1 g of calcined ZnAl-hydrotalcite was added to as prepared solution. The obtained sample type vitamin C/ZnAl-hyrotalcite hybrid nanomaterial was stirred for 120 h at 15°C, separated by filtration and dried at 60°C for 24h resulting in a pale yellow solid.

Structure of final products was analyzed using X-ray powder diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) characterization techniques.

Results and discussions

XRD patterns of ZnAl-hydrotalcite and vitamin C/ZnAl-hydrotalcite are presented in figure 2a. The ZnAl-hydrotalcite sample exhibits obvious Bragg reflections in agreement with the hydrotalcite type nanomaterials.

Instead, XRD pattern of the vitamin C/ZnAl-hydrotalcite conpound reveals that (003) and (006) Bragg reflections become slightly weaker and broader suggesting that the intercalation of ascorbic acid decreases the crystalinity of hydrotalcite.

After releasing of ascorbic acid from vitamin C/ZnAl-hydrotalcite in 0.01M and 0.1 m Na_2CO_3, XRD patterns of samples are shown in figure 2b. Typical hydrotalcite feature diffraction peaks proves that a large amount of ascorbate anions between the interlayer gallery have been exchanged by carbonate anions.

FTIR spectra presented in figure 3 are used to confirm the intercalation of ascorbic acid into the hydrotalcite host. The absorption peak around 1380 cm^{-1} can be attributed to the stretching vibration of nitrate anions as shown in figure 3a.

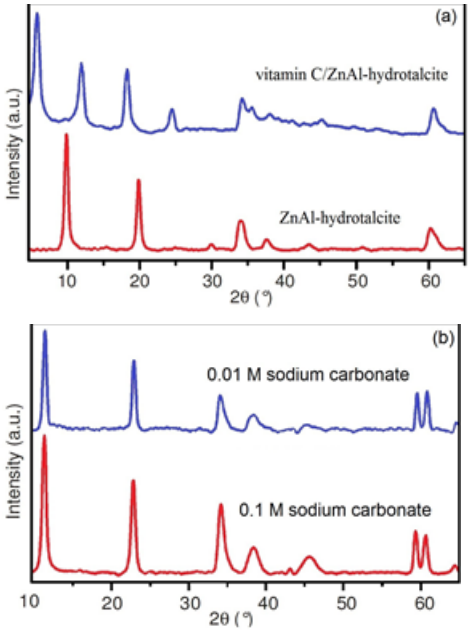

Fig. 2. XRD patterns of (a) ZnAl-hydrotalcite and vitamin C/ZnAl-hydrotalcite and (b) solid samples after vitamin C releasing from vitamin C/ZnAl-hydrotalcite in 0.01 M and 0.1 M Na_2CO_3 respectively

In case of C/ZnAl-hydrotalcite spectrum, ν(C=O) for sodium ascorbate appears at 1720 cm^{-1} as presented in figure 3b showing very weak absorption. The absorption band occurring at 1615 cm^{-1} comprises overlapping water binding and the 1390 cm^{-1} band corresponds to lactone linkage vibration. Figure 3b also reveals the absorption in 1180-1000 cm^{-1} area attributed to the C-O stretching vibration. FTIR data evidence the presence of vitamin C into the hydrotalcite interlayer space.

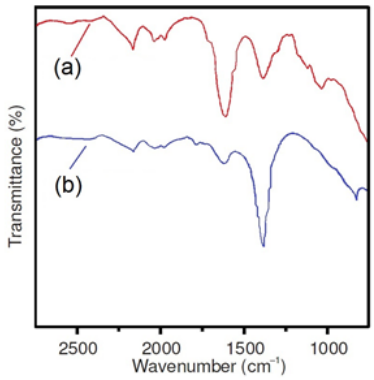

Fig. 3. FTIR spectra of (a) ZnAl-hydrotalcite and (b) vitamin C/ZnAl-hydrotalcite

SEM image (fig. 4a) highlights a good crystalinity typical for hydrotalcites-like compounds. ZnAl-hydrotalcite nanocrystals have variable dimensions presenting irregular and agglomerated sheets being on top of one another. These textural aspects are specific for hydrotalcites prepared by coprecipitation method.

SEM micrograph (fig. 4b) for vitamin C/ZnAl-hydrotalcite sample reveals a stronger cohesion between the particles

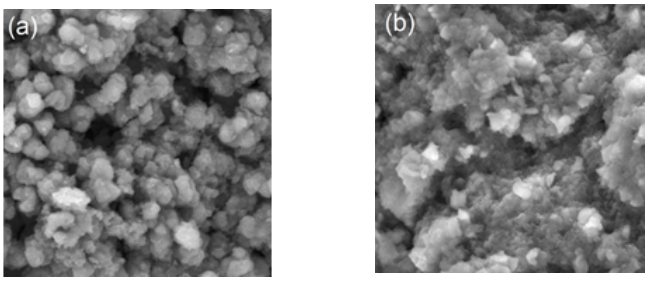

Fig. 4. SEM images of a) ZnAl-hydrotalcite and b) vitamin C/ZnAl-hydrotalcit

being the result of changing the initial hydrotalcite type structure.

Conclusions

Vitamin C is an important compound for human body being able to promote collagen biosynthesis, increase the immunity system and stimulate salivary secretion although it decomposes easily into natural light and high temperature conditions. The new hybrid nanoastructure involving ascorbic acid and ZnAl hydrotalcite was prepared by coprecipitation route and analyzed using XDR, FTIR and SEM characterization methods proving that vitamin C has been successfully embedded in the hydrotalcite interlayer gallery due to strong hydrogen bond and electrostatic attractions.

Our study revealed that the ascorbic acid is stabilized in the hydrotalcite interlayer space without any changes in its structure and that once stabilized can be released from the hybrid nanomaterial type vitamin C - ZnAl-hydrotalcite in a controlled manner. Therefore, ZnAl-hydrotalcite proved to be an excellent host for vitamin C storage and an efficient delivery vehicle for this active molecule that is unstable under normal environmental conditions. The structure and morphology of ZnAl-hydrotalcite revealed that this nanomaterial can be used as an important drug carrier for vitamin C in order to stimulate salivary secretion. All these knowledge make possible maintaining a good oral health.

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