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Antacid power and their enhancements in some edible clays consumed by geophagia in Cameroon

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ABSTRACT

The antacid power of five natural clays is reported and compared to two pharmaceutical clay based drugs. The improvement of the antacid properties is attempted through amorphization and calcium carbonate addition. Two mechanisms of pH control are proposed: acido-basic neutralization at amphoteric edge functions and cationic exchange. The later is mostly active for 2:1 clays in the absence of carbonate which induces noticeable acido-basic neutralization. Natural 2:1 clays exhibit high antiacid effect whereas 1:1 clays induce good buffering effect. The antacid effect of the thermally treated 1:1 clays is increased to values ($0.20 \leq \Delta pH \leq 0.41$) close to those of the pharmaceutical clay based drug smecta ($\Delta pH = 0.52$). The addition of calcium carbonate to 1:1 clays material also improves their antacid effect. In calcium carbonate/clay mixture, the presence of clay is favorable to a buffering control and a calcium carbonate dosage of interest is observed at 4.5%.

Keywords: Clay; Amorphization; Antacid; Buffering effect

INTRODUCTION

Clay materials are natural minerals occurring from the decomposition of rocks under influence of climate and water. According to their mineralogical composition, clay materials are usually mixed not only with other clay minerals but also with impurities such as carbonate, feldspars, mica and quartz [1]. Due to their structure, clay minerals exhibit interesting properties such as adsorbent and/or absorbent functions, cationic exchange capacity, and pH regulator or release abilities [2]. These numerous properties are basis for several industrial usages of clay materials, such as additive in rubber, polymers and paper, lubricant drilling, ingredients in pharmaceutical products [3-7].

In the field of pharmacology, clays can be employed as excipients or as an active ingredient due to their high cationic exchange capacity and their specific area, sorptive capacity, rheological properties and chemical inertness; in addition, they are not toxic to patients [8]. Some of the pharmaceutical properties associated to clays can be exploited to cure gastric ulcers. In the human stomach, hydrochloric acid is the molecule responsible for the cause of gastric ulcers [9]. During digestion process, gastric disturbances, characterized by an increase of hydrochloric acid concentration (or hyperacidity) in the stomach medium, can occur. Such gastric disturbances are commonly treated by some pharmaceutical products containing clays. These clays act in the stomach medium as antacid, which tends to neutralize, to some extent, the excess of hydrochloric acid [8, 10]. The acid neutralization capacity (or the antacid power of a drug) is defined as the amount of 0.1 M HCl that can be added to a liquid antacid without reducing the pH of the mixture below pH 3.0 [11]. In Africa and Asia, some clayey materials are marketed and people consume them, either for nutritive elements supplements or for therapeutic purposes [12].

In the present study, antacid effect of some Cameroonian and Nigerian edible clayey materials are evaluated. Attempts to improve this antacid power are subsequently carried out through amorphization and calcium carbonate

incorporation. The measured antacid power was compared to that of two pharmaceutical clays based drugs used for the treatment of gastric ulcers.

EXPERIMENTAL SECTION

2.1. Materials

Five clay samples were used for this study: three from Cameroon (MY41g; B_3 and Ba1'), one from Nigeria (C_2) and one from France (AVP) often used as antacid drug; a sample of calcium carbonate (MERCK) and two pharmaceutical clay based drugs, Smecta and Beidellix, which are used to cure gastric ulcers. The origin and the main minerals of each clay material are given in table 1, the chemical compositions are given in table 2 [13-15]. The mineral compositions of Smecta and Beidellix were determined by powder X-ray diffraction. The X-ray patterns (figure 1) were obtained on a Bruker D8 spectrometer operating on a Cobalt Kα radiation.

Table 1: Origin and main mineral of studied clay materials

Samples	Origin	Main mineral	Type
MY41g	Mayouom (Cameroon)	Kaolinite	1:1
C_2	Calabar (Nigeria)	Kaolinite	1:1
B_3	Balengou (Cameroon)	Antigorite	1:1
Ba1	Baba (Cameroon)	Montmorillonite	2 :1
AVP	Provence (France)	Montmorillonite	2 :1
Smecta	-	Montmorillonite	2 :1
Bedelix	-	Montmorillonite	2 :1

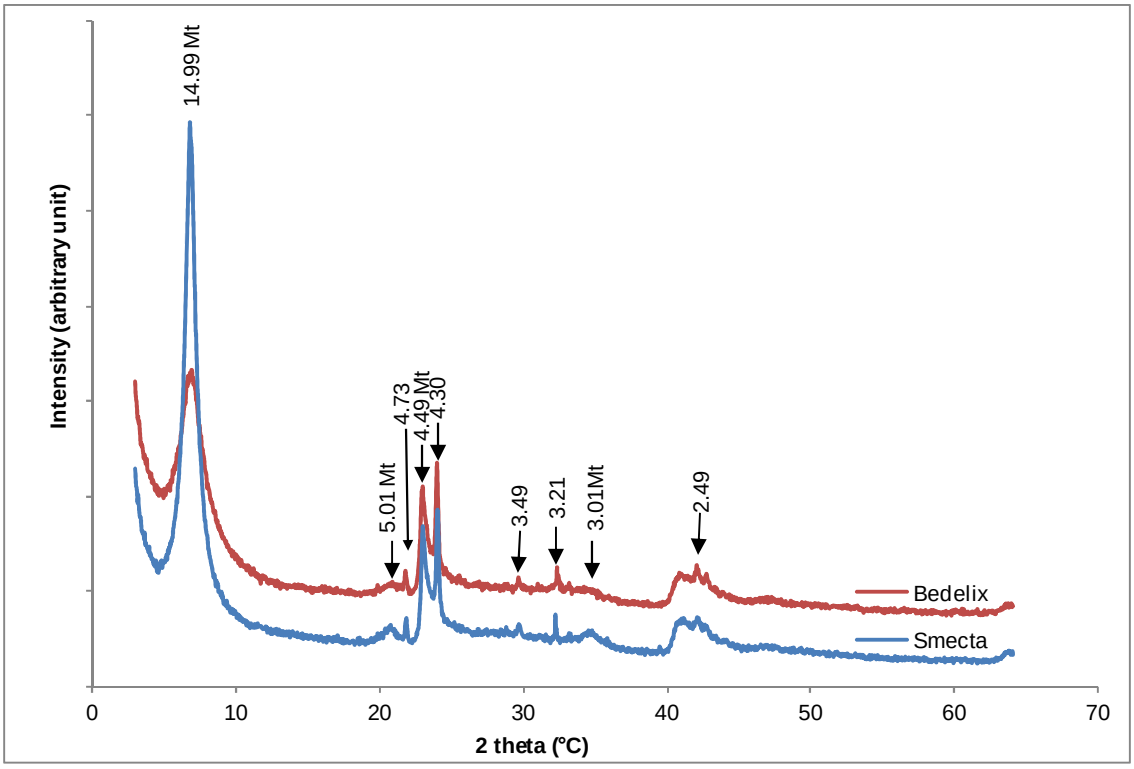

Figure 1: X-ray paterns of Smecta and Bedelix drugs
Mt (Montmorillonite)

Table 2: Chemical compositions (%) of studied clayey materials

Oxide	B_3[13]	C_2[13]	MY41g[15]	Ba1'[14]	AVP	Smecta	Beidelix
SiO_2	51,07	51,40	47,74	53,65	50,17	45,10	42,72
Al_2O_3	27,33	28,65	33,54	23,89	7,74	14,92	14,28
TiO_2	0,31	1,47	3,54	0,48	0,42	0,16	0,33
Fe_2O_3	2,21	2,24	2,57	3,60	2,79	2,38	2,58
K_2O	0,23	0,69	0,4	1,77	0,94	0,13	0,28
Na_2O	0,05	0,01	tr	1,42	0,35	0,24	0,31
MgO	0,04	0,40	tr	0,54	1,26	3,83	4,02
CaO	<0,01	tr	tr	0,35	14,07	1,71	1,48
MnO	tr	tr	0,04	0,03	0,02	0,05	0,04
P_2O_5	0,04	0,06	0,22	0,13	0,03	< LD	< LD
LOI	11,06	14,68	11,80	13,82	15,05	30,13	33,25
Total	99,39	99,54	99,89	99,95	98,46	98,64	99,28

LOI: Loss on ignition; tr: trace; LD: limit of detection

The raw materials were sieved over a 100 µm mesh after drying in air and crushing in a mortar. The sieved powder was homogenized using a RETSCH apparatus.

METHODS

2.2.2. Amorphization

According to Redferm, reported by Djoufac et al. [16], amorphization of kaolinite is maximal after baking between 700 and 750°C for two hours. Thermal treatment of clays sample was done in a Naberthern furnace. The heating was carried out under a heating rate of 5^oC/min. 10 g of clay material were introduced in an washed and oven dried alumine crucible. The clay material was first heated during one hour at 300°C, then the temperature was increased to 750°C and maintained for 4 hours.

2.2.3. Antacid power of clays

The spontaneous pH of the clay is firsly determine as follow: 2.5 g of clay are introduced into 50 mL of distilled water. The suspension is left for stabilization during 240 minutes and the measured pH was considered as the pH of the natural state. The anticid power is subsequently measured as describe bellow:

2.5 g of a clay material are introduced in a reactor containing 50 mL of hydrochloric acid solution (0.03 N) [17-19]. The pH in the reactor is measured at regular intervals of 15 minutes throughout the experiment. The pH variation gives the value of antacid power of the studied clay. Antacid power, denoted by ΔpH, of a clay material is the difference between pH of the suspension (acid solution + clay) during 180 minutes (pH_2) and pH of the hydrochloric acid solution at the begining of the experiment (pH_1): $\Delta pH = pH_2 - pH_1$

The antacid effect is evaluated on the raw and the amorphizised clays. Calcium carbonate was incorporated to one of the raw clays in order to improve the antacid effect of the clay . For experiments dealing with mixture of clay and calcium carbonate, the mass of the solid phase was 2.5 g. The amount of calcium carbonate added was expressed in percentage weight of calcium carbonate with respect to the total mass of the solid phase. In order to determine the limiting condition for calcium carbonate addition and also to appreciate the influence of clay in the clay-calcium carbonate mixture, the monitoring of the evolution of ΔpH in systems containing only calcium carbonate in the same amount as in the clay-calcium carbonate mixture, is also done. All the experiments were carrried out under simulated conditions of human stomach [9] : Temperature: 37°C; pH condition: $1.4 \leq pH \leq 1.6$ and digestion time: 3 hours.

RESULTS AND DISCUSSION

3.1. Antacid Effect of Natural Clay Materials and Pharmaceutical Drugs

Figures 2 and 3 show the results from antacid effect of clay materials MY41g, C_2, B_3(1:1 clay minerals) and Ba1' and AVP (2:1 clay minerals).

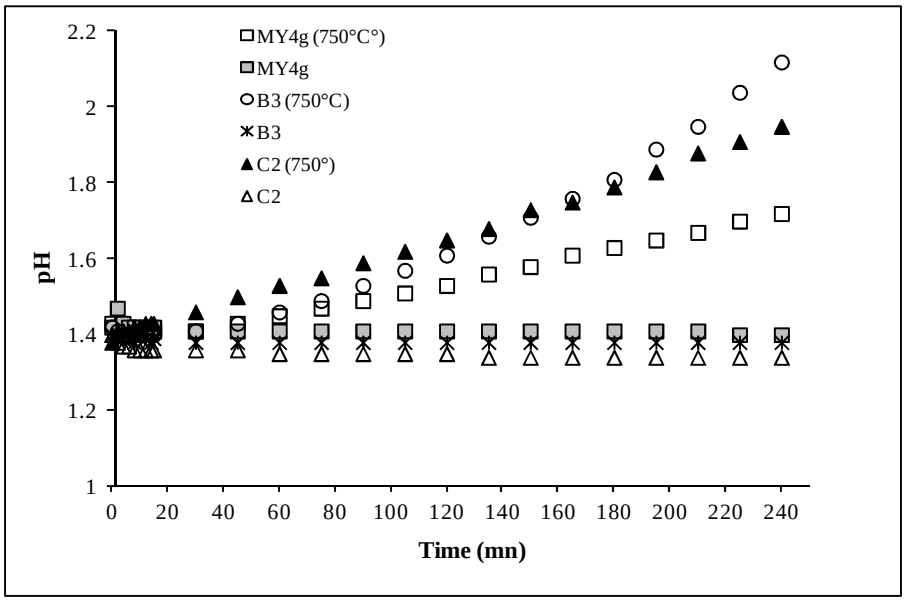

Figure 2: pH evolution for natural and thermally treated 1 :1 based clayey materials: MY41g ; C_2 and B_3

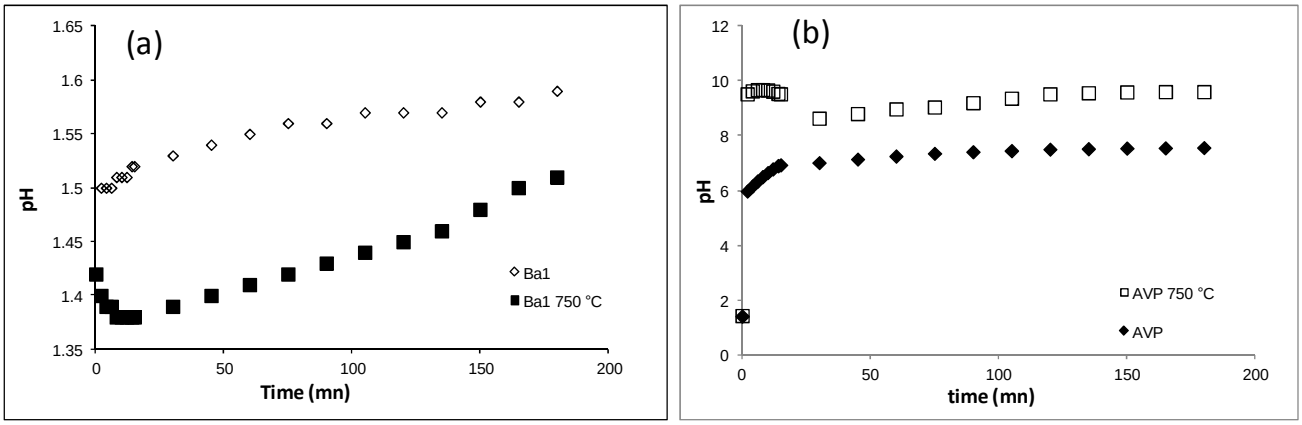

Figure 3: pH evolution of natural and thermally treated 2:1 based clay material: (a) Ba1' (b) AVP

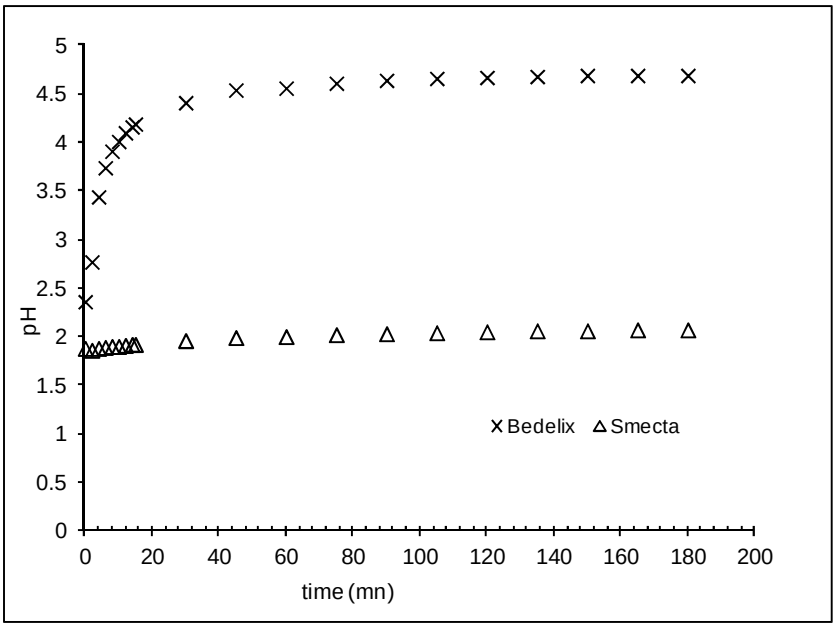

Figure 4: pH evolution in Bedelix and Smecta two commercial clay based antiacid drugs

As it can be observed, clays MY41g, C_2 and B_3 present no antacid effect ($\Delta pH = 0$), while Ba1' and AVP materials have an antacid effect: $\Delta pH = 0.09$ for Ba1' and $\Delta pH = 6.15$ for AVP. For the pharmaceutical clay drugs, Smecta and Bedelix, the antacid effect is high: $\Delta pH = 0.52$ for Smecta and $\Delta pH = 3.11$ for Bedelix (figure 4).

Suspensions (distilled water + clay (natural or thermally treated)) have acidic pH, for all clay samples except for AVP which has a basic pH probably due to its high content of CaO (table 3).

Table 3: pH of clay aqueous suspensions (natural and thermally treated materials)

Samples	MY41g	MY41g (750°C)	C_2	C_2 (750°C)	B_3	B_3 (750°C)	Ba1'	Ba1' (750°C)	AVP	AVP (750°C)
pH	4.63	5.13	4.62	4.71	5.11	4.86	4.44	4.79	8.23	8.37

Addition of clay in a solution of hydrochloric acid (0.04 N) induced a weak decrease of pH of the suspension for clays MY41g, C_2 and B_3 whose main mineral is a 1:1 clays mineral, while 2:1 clays mineral (Ba1' and AVP) induced for the suspension an increase of pH (or a decrease of the acidity). The difference of behaviour could be attributed to their main mineral (kaolinite and montmorillonite). However chemical analysis shows that the behavior observed with AVP and Ba1' is mainly due to the content of CaO of these clay materials. The same behavior was observed with pharmaceutical samples Smecta and Bedelix. But in the presence of a solution of hydrochloric acid (2 M), samples Smecta or Bedelix did not show effervescence phenomenon. We concluded that, pH increased of the suspension (acid solution + samples Smecta or Bedelix) was not due to carbonate content of these samples. This was confirmed by X-ray analysis of these samples (figure 1) in which no peak could be attributed to calcium carbonate. Montmorillonite as foud to be the main mineral of these pharmaceutical drugs. It was concluded that, the main minerals of sample Smecta and Bedelix was the source of their antacid power. In particular the Mg content of this mineral, because common antacid products are Mg, Ca and Al based salt products [20]. In addition, the high CEC of montmorillonite also help to increase the pH through the intercalation of H^+ within the interlayer of this clay.

3.2. Atempts for Amelioration of The Antacid Power

3.2.1. Thermal Treatment of Clays

Three 1:1 clay materials, MY41g, C_2 and B_3 were thermaly treated. The thermal treatment contributed to the increase of the pH of the system (acid + clay) after 20 minutes (figure 2). Between 0 and 20 minutes, amorphizised and non amorphizised clays almost have the same effect on pH (weak decrease of the pH of the suspension of about 0.01 unit). After the first 25 minutes, an increase of pH is observed for suspensions containing amorphizised clays ($0.20 \leq \Delta pH \leq 0.41$) while the pH, of the systems containing non amorphizised clays were almost constant.

The decrease of pH observed in systems containing non amorphizised clays was attributed to acido-basic reactions with hydroxyle groups at the edges of the clays (aluminol or silanol), which have amphoteric behavior [21, 22]. However, the presence of 1:1 clays contribute to stabilize the pH value to an average of 1.4 which was closed to the pH of stomachal medium (1.5 to 1.8) [9].

Thermal treatment at 750°C of kaolinite clays lead to metakaolinite containing SiO_2; Al_2O_3 and also MgO for antigorite, the main mineral in B_3 clay material. Al_2O_3 has an amphoteric behavior and MgO is a basic oxide. Hence they can react in acidic medium as a base. This property justified the increasement of the pH of the system [1, 22].

Clay material B_3 in which the main mineral is antigorite gave a pH value intermediate to those of kaolinitic samples. This behavior was attributed to the cristallinity of these clay materials. The cristallinity of clay materials determines the availability of edge reactive sites. However, after amorphization, increase in the pH was determined by the availability of basic oxide. This justified the higher increase of the pH for the system (acid + B_3 [750°C]) in which basic magnesium oxide (MgO) is formed. Except B_3, the similarities of the curves obtained can be justified by the formation of the same amorphous phase which is metakaolinite.

The buffering effect was more sensitive with systems containing natural clays than those with modified clays. For systems containing modified clays, pH values still increased after 180 minutes. Buffering effect was better controlled with natural clays belonging to 1:1 clay minerals group, but the limitation and/or availability of edge functions, that may react to lead to a constant value of the pH, could be the key factor.

For clay materials MY41g; C_2; B_3 and Ba1', thermal treatment induced a decrease of pH. In fact SiO_2 is an acidic oxide and at the begining of each experiment, it can react with water molecules, thus releasing H^+ ions in the medium. So we observed a little decrease of the pH of the medium (or an increase of the acidity). After this reaction, Al_2O_3 which is an amphoteric oxide and MgO a basic oxide react with H^+. Then the pH of the medium started increasing again. It must be noted that the pH shift obseved for amorphizised AVP was due to a partial

transformation of calcite to calcium oxide which was more basic [23]. We also observed for amorphizised AVP and Ba1' system, a pH decrease before it increased slowly and became constant to a pH value close to that of the system containing non amorphizised AVP or Ba1' (Figure 3). This observation was attributed to the nature of the main mineral in the clay material. By comparison to 1:1 clays, previous observations with 2:1 clays suggest a second mechanism of pH regulation which could be cationic exchange [24]. In fact, for these two 2:1 clays (Ba1' and AVP), we observed an acidification of the medium between 0 and 20 minutes which suggest that thermal treatment induced an increase of acidic cationic species. These cations fastly react with water in the solution and caused an increase of the acidity in comparison to that of natural material. But after 20 minutes, the acidity of the medium began to decrease again. So the acidic species formed after thermal treatment were all transformed after 20 minutes. The hypothesis of cationic species formation was in accordance with a mechanism based on cationic exchange within the 2:1 minerals because, the amount of cationic species that could appear after thermal treatment depend on the interfoliated cations in the mineral. That is why, after 120 minutes, the pH of the two systems (system containing natural 2:1 clays and system containing thermally treated 2:1 clays) reached approximatively the same value (pH = 1.6 for Ba1' and pH = 8 for AVP). This observation indicates that thermal treatment did not bring great change to antacid effect of 2:1 clays and confirms that, whithin this type of mineral, the main mechanism for antacid effect is more probably based on cationic exchange.

3.2.2. Addition of Calcium Carbonate

MY41g was choosen for an improvement of antacid effect through mixing with calcium carbonate. In order to find out at which limit the antiacid power was dependent on both clay and $CaCO_3$ for a total solid mass content of 2.5 g, the ΔpH is measured for various fractions of $CaCO_3$ in the mixture. Simultaneously, the effect of the corresponding amount of $CaCO_3$ in the same volume of acid solution is measured. In figure 5, it appeared that for an upper limit of 4.5%, the ΔpH was dependent on both constituents of the mixture. Beyond 5 %, the antacid effect is almost only due to the $CaCO_3$.

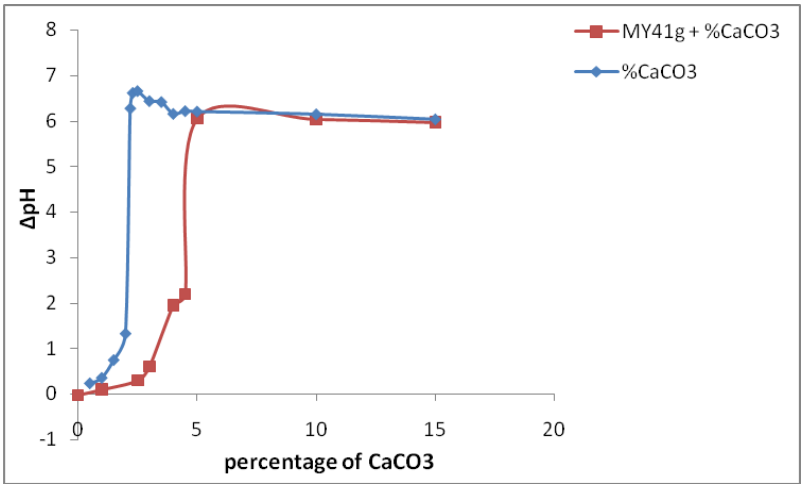

Figure 5: Variation of ΔpH in acidic solution + $CaCO_3$ or + (MY41g + $CaCO_3$) mixture at various $CaCO_3$ proportions

On the basis of these measurements, a formulation made up of 2% of $CaCO_3$ was studied. The comparison of pH variation of natural MY41g and two systems containing 1% and 3% $CaCO_3$ (percentage relative to the proportion of $CaCO_3$ for a total solid mass of 2.5 g) made it evident that clay and $CaCO_3$ interact so as to give a material that has an antiacid effect that was constant and greater than that of natural MY41g (figure 6).

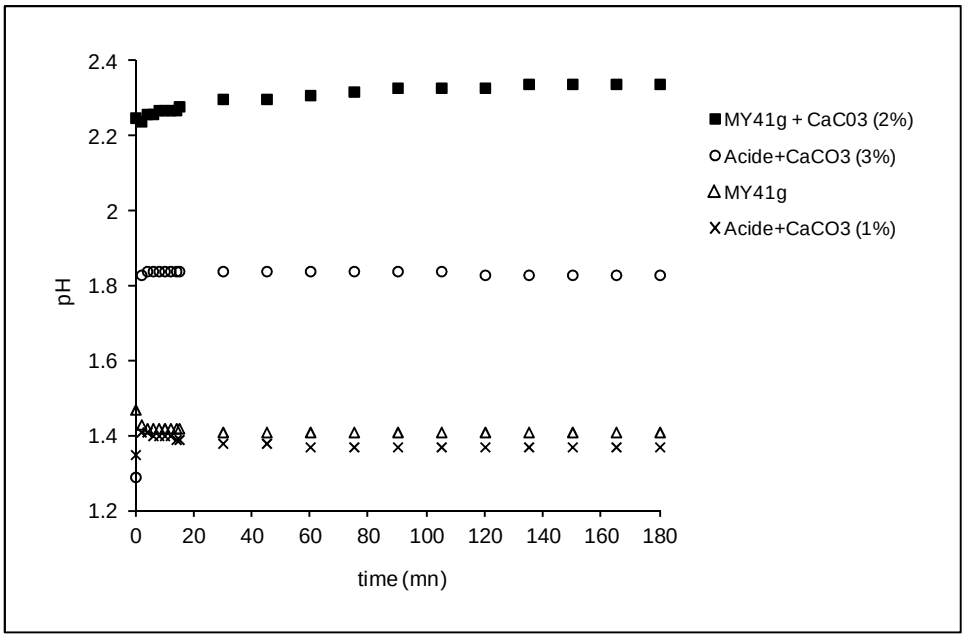

Figure 6: Evidence of the influence of the presence of clay in the mixture of $CaCO_3$ with MY41g

It is also obvious that mixing $CaCO_3$ to clay eliminates the rapid (an even brutal) jump of pH when $CaCO_3$ was used solely. In figure 7 a comparison of the antacid power and the buffering effect of the mixture MY41g + 2 % CaCO3, to that of pharmaceutical drugs Smecta and Bedelix is done.

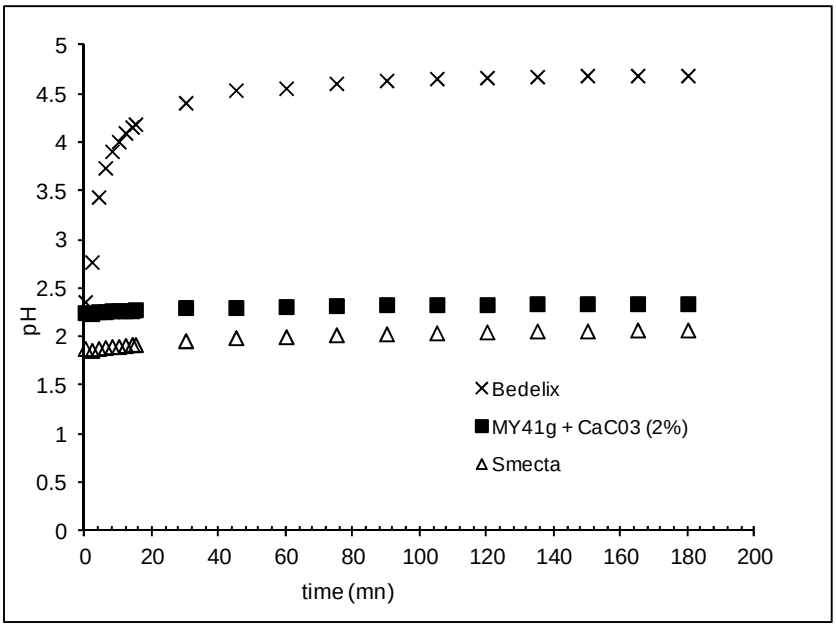

Figure 7: Comparison of antacid effect of the mixture [MY41g + $CaCO_3$ (2%)], samples X and Y.

It appears that the new material has an antacid power that was greater than that of sample Smecta but has almost the same buffering behavior. Sample Smecta and the mixture experimented here has a rapid and constant buffering action in contrast to sample Bedelix where there was a 5 minutes delay during which the pH increases before buffering starts. So, the mixture studied here could potentialy be used as an antacid drug.

CONCLUSION

Natural clayey materials MY41g, C_2 and B_3 did not have any antacid effect, they rather had a good buffering behaviour. Ba1' ($\Delta pH = 0.09$), a 2:1 clay, has an antacid effect, contrary to the first three materials that are 1:1 clays.

This difference was attributed to the nature of the main mineral in the clayey materials because the mechanism involved was dependent on the nature of this mineral.

Amorphization of 1:1 clays induces, for system containing the modified clays, an antacid effect ($0.20 \leq \Delta pH \leq 0.41$) close to that of sample Smecta. For clay materials with main mineral belonging to 2:1 group, cationic exchange was the main regulator of the pH, this justified the great acidity impairement compared to samples belonging to 1:1 clays minerals. For the later clays, the main mechanism for pH regulation remaind acido-basic transformation of edges functions in natural clay materials and oxides of amorphous systems from thermal treatment at 750°C.

Amorphization induced in 2:1 clays minerals formation of acidic cationic species that rapidly reacted with water and decreased the pH during the first 20 minutes of the experiment.

Chemical composition of initial clay material has an effect on its antacid property. The use of clay material AVP as pharmaceutic antacid was more justified by its content in calcium carbonate. The later was mixed in variable proportions with MY41g in an attempt to have an antacid effect that is closed to that of a pharmaceutical anti-ulcer formulation. The search for the better mixing proportion have permited to establish that for a total solid phase of 2.5 g, the weight proportion of calcium carbonate is limited at arround 4.5%. From this limit, antacid power and buffering effect of a formulation containing 2% of calcium carbonate was compared to that of samples Smecta and Bedelix and it was concluded that this mixture could be used as an antacid. This formulation has an antacid power higher than that of pharmaceutical clay based drugs (Smecta) and a buffering behavior similar to that of the same pharmaceutical clay based drugs (Smecta).

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REFERENCES

[1] S. Caillère, S. Héni, M. Rautureau. Minéralogie des argiles : I- Structures et propriétés physico-chimiques, 2nd Edition, Masson, Paris, **1982**, 184p.
[2] M.I. Carretero, *Appl. Clay Sci.*,**2002**, 21, 155-163.
[3] W.B. Jepson, *Phil. Trans. R. Soc. Lond. A.*, **1984**, 311, 411-432.
[4] M.S. Prasad; K.J. Reid; H.H. Murray, *Appl. Clay Sci.*, **1991**, 6, 87-119.
[5] M.A. Siddiqui; Z. Ahmed; A.A. Saleemi, *Appl. Clay Sci.*, **2005**, 29, 55-72.
[6] M.I. Carretero; M. Pozo, *Appl. Clay Sci.* ,**2009,** 40, 73-80.
[7] M.I. Carretero; M. Pozo, *Appl. Clay Sci.*, **2010**, 40: 171-181.
[8] M. Beers, R. Berkow. The merk manual of diagnostic and therapy, 10th Edition, Merk & Co, Madrid, **1999**, 254-255.
[9] A.C. Guyton. Medical Physiology, 6th Edition, W.B. Saunders Company, U.S.A, 1981, 1074p.
[10] C. Visera; A. Lopez-Galindo, *Appl. Clay Sci.*, **1999**, 14, 69-82.
[11] H.G. Vogel. Drug Discovery and Evaluation Pharmacological Assays. 2nd Edition, Springer; Berlin Heidelberg, **2002**, 1221p.
[12] R.L. Jone, H.C. Hanson. Mineral Licks, Geophagy and Biogeochemistry of North American Ungulates, 1st Edition, Iowa State University Press, Ames, **1985**.
[13] D. Njopwouo; E. Tejiogap; F. Sondag; B. Volkoff; R. Wandji R, *Annales de la Faculté des Sciences, Université Yaoundé I*, **1998,** 31(2), 319-334.
[14] I. Tonle Kenfack. Capteurs électrochimiques à base d'argiles smectitiques camerounaises fonctionnalisées par les groupements thiol et amine : Elaboration, caractérisation et application au piégeage de métaux lourds à effet polluant. Thèse de Doctorat/PhD, Université Yaoundé I, Yaoundé, **2004**.
[15] T.P. Boulleys. Contribution à la caractérisation physico-chimique des argiles de Mayouom : cas des puits 3 et 4. Mémoire de D.E.A., Université Yaoundé I, Yaoundé, **2005**.
[16] W.E. Djoufac; C. Djiogue; D. Njopwouo, *Annales de la Faculté des Sciences, Université. Yaoundé I*, **1999**, 32 (1), 125-135.
[17] C.F. Linares; L. Alfonso; M. Rosa-Brussin, *J. Appl. Sci.*, **2004**, 4 (3): 472-476.
[18] J.R. Odilon Kikouama; N. Yagoubi; B. Legendre; L. Baldé, *Appl. Clay Sci.*, **2007**, 1-2, 1-10.
[19] T-H. Wu; I-C. Chen I-C.; L-C. Chen, *World J. Gastroenterol*., **2010**, 16 (35), 4455-4459.
[20] P.N. Maton; M.E. Burton, *Drugs*., **1999**, 57(6), 855-870.

[21] S. Kong. Contribution à l'étude de la purification des argiles kandiques tropicales et de leurs charges superficielles. Thèse de Doctorat, Université de Yaoundé I, Yaoundé **1989**.
[22] H. Chamayou, J.P. Legros, Agence de Coopération Culturelle et Technique. Les bases physiques, chimiques et minéralogiques de la science du sol, Presses Universitaires de France, Paris, **1989**, 71-167.
[23] J. Rigaud, Traitements thermiques. E.N.S.C.I, Limoges, **1993**, 38p.
[24] C. Ma; R.A. Eggleton, *Clays Clay Miner.*, **1999**, 47 (2), 174-180.