COMPARATIVE STUDY ON THE PHYSICO-CHEMICAL PROPERTIES OF MONTMORILLONITE AND KAOLINITE CLAY OBTAINED FROM OKADA AND USEN IN EDO STATE FOR PHARMACEUTICAL DRUGS FORMULATION

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Abstract: The need to maximize therapeutic activity and at the same time minimizing negative side effects have continuously led researchers to development new controlled drug delivery systems. The selected clay minerals were obtained from Okada Town and Usen Community, about 28km and 32km from Benin City, Edo State, Southwestern Nigeria, respectively; having geographical coordinates of latitude 6^0 40^l/ - 6^0 45^l/ N and longitudes 5^0 20^l/ - 5^0 25^l / E, the area is characterized by torrential rainfall, high surface runoff due to their low infiltration rates and high canopy trees. The inert samples were subjected to XRD analysis to ascertain the mineralogy compositions; and XRF analysis gave the elemental compositions from which the inherent constituents were predominant. They were purified by washing in aqueous 0.1M NaCl solutions; the resulting suspensions were sieved and dried at 35°C in an oven. The powder maize-starch was prepared from crushed grains and the slurry was sieved and dried at 35°C in an oven. The angle of repose, true density, powder porosity, bulk density, tapped density, Hausner's ratio powder retention capacity, swelling capacity, and pH were experimentally carried out to determine the physical properties of the powder: such as swell ability, flowability, void space, capillary action, acidity, and alkalinity; powder physical properties obtained for sodium-montmorillonite (Na-MMT) and Kaolinite were compared with those of reference standard of maize-starch (MS). The data revealed that Na-MMT is more effective excipient for formulation of pharmaceutical drugs than Kaolinite.

Keywords: Powder physical properties, pharmaceutical drugs, excipients, starch-maize, sodium-montmorillonite and Kaolinite. X-ray diffractogram (XRD), X-ray Fluorescence (XRF).

Introduction

The objective of this research work is to determine the best clay powder with disintegration and dissolution properties that can be exhibited by either Na-MMT or Kaolinite, required for use as alternative to the reference MS powder, which can show granulation property during wetting process prior to direct compression in drug processing. The clay minerals were obtained from areas located in Okada Town and Usen Community, which are about 28km and 32km from Benin City, Edo State, Southwestern Nigeria, respectively. Sample locations were within the geographical coordinates of latitude 6^0 40^l/ - 6^0 45^l/ N and longitudes 5^0 20^l/ - 5^0 25^l / E (Fig.1); and can be accessed by footpaths away from the major road which were well connected to the rivers. The vegetation is a rain forest region that experiences rainy season from April to October; with mean annual rainfall values range from 1500mm to 1830mm. Rainfall within the areas are usually characterized by high surface runoff due to their low infiltration rates and high canopy trees (Osadebe *et al*., 2011).

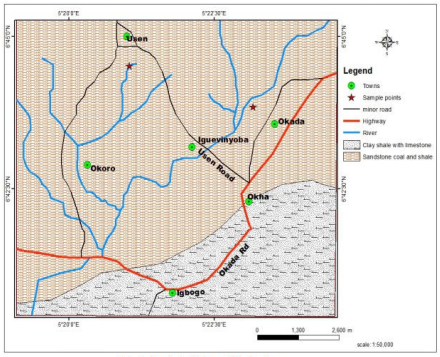


Fig. 1: Geological Map of Study Area

Figure 1: Geological Map of Study Area

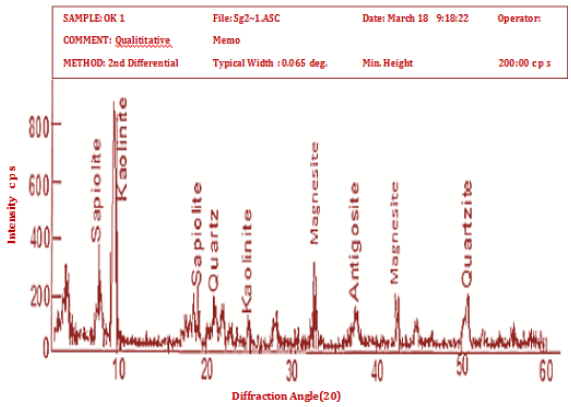
The clay minerals selected for this study are Montmorillonite predominant and Kaolinite prevalence, Montmorillonite consist of alumina octahedral sheet between two layered silica tetrahedral sheets, Kaolinite made up of single layered alumina octahedral sheet and silica tetrahedral sheet, and these clay minerals were modified with NaCl solution. The imperfection of the crystal lattice and the isomorphous substitution induce a net negative charge that leads to the adsorption of alkaline earth metal ions in the interlayer space (Ghanshyam *et al*, 2009). Such imperfection is responsible for the activity and exchange reaction with organic compounds. The clay minerals also contain hydroxyl end-groups on the surfaces and they have large surface areas; exhibit good adsorption property, cation exchange capacity, outstanding adhesive ability and drug-carrying capability, (Khalil *et al*., 2005). Clay minerals are common ingredients used as both excipients and active substance in pharmaceutical products, (Ghanshyam *et al*, 2009). Starch is the second most abundant renewable polymer in nature that is inexpensive, fully biodegradable and widely studied for many years in the field of materials. Starch $(-C_6H_{10}O_5-)_n$ a combination of amylase and amylopectin (Odeniyi *et al*., 2011); being the most familiar of the natural hydrophilic carbohydrate polymers. Starch use for this study is derived from commercially sold maize grain seeds (Zea mays L.). Chemical modification involves the introduction of functional groups into maize-starch molecule resulting in alteration of physical properties (Odeniyi *et al*., 2011).

Materials and Method

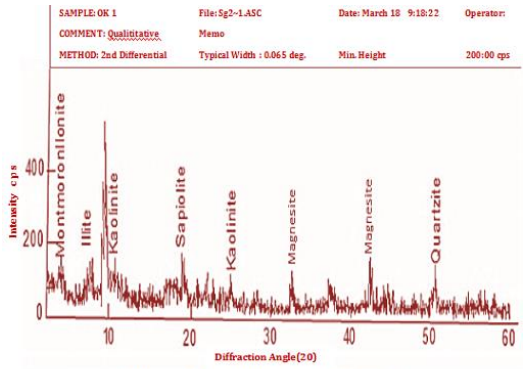
Materials

The Sample clay minerals (namely Montmorillonite and Kaolinite) were obtained from areas located in Okada Town and Usen Community, covering distance of about 28km and 32km from Benin City, Edo State, Southwestern Nigeria respectively. X-ray diffractogram (XRD) analysis was used to determine the mineralogy of the clay samples from which the percentage compositions of the clay types were calculated. X-ray Fluorescence (XRF) analysis was used to determine the

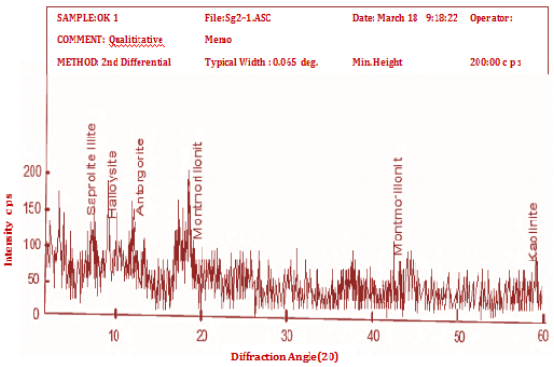
elemental composition of the clay samples from which the inherent constituents of the clay minerals were determined. The XRD and XRF results are shown in graphs 1(a-d) and table 1 respectively. Sodium-Montmorillonite contains sodium magnesium aluminum silicate hydroxide. Kaolinite contains aluminum silicate hydroxide.



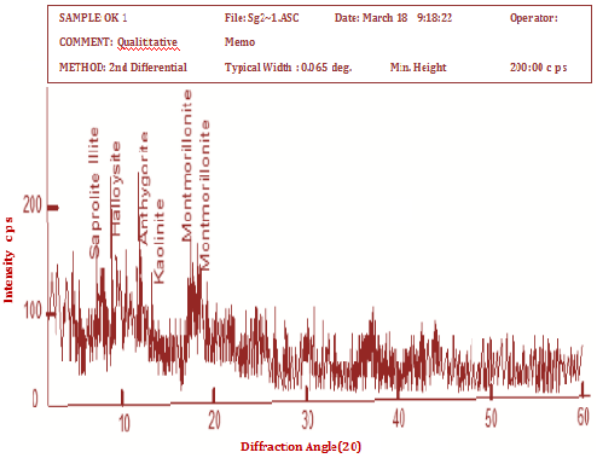
XRD graph 1a : XRD Diffractogram of Sample 1



XRD graph 1b: XRD Diffractogram of Sample 2



XRD graph 1c : XRD Diffractogram of Sample 3



XRD graph 1d : XRD Diffractogram of Sample 4

Table 1: Tablets physical properties (TPP) for Na-MMT, kaolinite and MS

Parameters (% Oxide)	% COMPOSITION					
	Sample 1 US 1	Sample 2 US 2	Mean Value	Sample 3 OK 1	Sample 4 OK 2	Mean Value
$Si0_2$	63.34	62.26	62.80	55.71	55.80	55.76
Al_20_3	28.25	28.21	28.23	20.60	20.68	20.64
K_20	3.27	3.50	3.39	0.31	0.29	0.30
Fe_20_3	2.56	2.54	2.55	0.72	0.75	0.74
Ca0	0.51	0.54	0.53	0.28	0.28	0.28
$Ti0_2$	0.23	0.29	0.26	1.04	0.93	0.99
Na_20	0.34	0.22	0.28	1.88	1.72	1.80
Mg0	0.17	0.20	0.19	0.16	0.17	0.17
Cr_20_3	0.13	0.11	0.12	0.12	0.09	0.11
Ba0	0.15	0.22	0.19	0.15	0.19	0.17
Ni0	0.04	0.03	0.04	0.02	0.02	0.02
Sr0	0.01	0.03	0.02	0.03	0.02	0.03
Mn0	0.02	0.02	0.02	0.01	0.01	0.01
$Mo0_3$	0.01	0.01	0.01	0.01	0.01	0.01
Y_20_3	0.01	0.01	0.01	0.01	0.01	0.01

KEY:

US 1: Usen Clay of Sample Point 1.

US 2: Usen Clay of Sample Point 2.

OK 1: Okada Clay of Sample Point 3

OK 2: Okada Clay of Sample Point 4

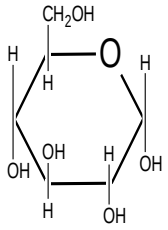


Figure 1: Sturctural formula of Maize Starch (Dextrose) or Glucose Anhydrous.
Source: Handbook of Pharmaceutical Excipients 5th Edition. Rowe *et al*., (2006)

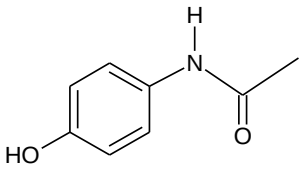


Figure 2: Chemical Structure of Paracetamol (acetaminophen $C_8H_9NO_2$) 4-hydroxyacetanilide
Source: wikipedia.org/wiki/file.Paracetamol_skeletal.svg.

Method

Dry Sieve Analysis: Particle size distribution of clay minerals, paracetamol bulk powders and powder mixtures were determined using a stack of metal sieve plates from largest to the finest aperture in the following order 500, 350, 250, 150, 90, 64 and 45 µm (PASCALL ENG. CO. LTD.). The weight of powders retained on the surface of each sieve plate was divided by the total sample weight to obtain the corresponding weight oversize for each sieve fraction. Clay minerals of 90µm size particles were stored in 2 separate air tight containers, from which they were taken to determine their physical properties.
Modification and Purification of clay minerals: To obtain clay minerals in Na-form by ion-exchange method, 850g of MMT and Kaolinite were dispersed in 0.1M NaCl solutions (which was prepared by dissolving 8.5g NaCl in 1000cm^3 of distilled H_2O), stirred for 12hrs and centrifuged, this process is repeated thrice. Finally, the slurries were centrifuged and washed in with de-ionized water until free from chloride ion as tested by $AgNO_3$ solution (Bergaya *et al*., 2006). To purify, 420g of each Na-MMT and Kaolinite were dispersed in de-ionized water left standing for 10 hrs, the supernatant dispersion of particles < 2µm were collected 10cm from the top surface at 30°C, (Patel *et al*., 2007).

Powder Physical Properties

Flowability: The flow characteristics of the clay minerals and starch were studied by determining the angle of repose of the samples (Iwuagwu & Okoli, 1992). True density and powder porosity were determined using standard method as described in an earlier work done by Azubuike *et al*., 2011,. Hausner ratio also defined flowability as the ratio of tapped density over the bulk density of each of the samples was determined before and after 100 taps of a known weight of powder, (Biljana et al., 2011) & (Iwuagwu & Okoli, 1992).

Powder Retention Capacity: Powder retention capacity was determined based on the method of Ring (1985). The weight of the residue (W_x) determined, and residue was dried to constant weight (W_y) at 65ºC in the hot air oven. The mean powder retention capacity was computed as [W_x/W_y] (Iwuagwu & Okoli, 1992).

Swelling Capacity: The swelling capacity of the powders was determined by the method of Bowen and Vadino (1984) (Iwuagwu & Okoli, 1992). The volume of the sediment V_x and increase in volume V_y were recorded; then to obtain swelling capacity (%) the expression $V_y/V_x \times 100$ was applied (Azubuike *et al*, 2011; Bergaya *et al*., 2006; Iwuagwu & Okoli, 1992).
pH: 10g of starch powder was slurried in 10ml of ethanol and diluted to 100ml with deionized water; the 10g of clay minerals was slurried in deionized water only. The various suspensions were agitated for 5 min., thereafter their pH at 25°C were determined with pH meter (Phywe, W. Germany) (Iwuagwu & Okoli, 1992).

RESULTS AND DISCUSSION
The results of the experimental determination of powder physical properties of the maize-starch, Na-MMT and Kaolinite carried out are shown in Table 2.
Results
Table 2: Powder Physical Properties for Na-MMT, KAO and MS

S.N.	Physical Characteristic	MS	Na-MMT	KAO
1	Angle of Repose (degree)	56.00°	34.40°	28.20°
2	True Density (g/cm^3)	1.72	2.00	2.50
3	Powder Porosity (%)	31.94	30.00	20.00
4	Bulk Density (g/cm^3)	0.56	0.50	0.40
5	Tapped Density (g/cm^3)	0.71	0.73	0.83
6	Hausner's Ratio	1.27	1.46	1.72
7	Powder Retention Capacity (%)	3.04	2.90	1.80
8	Swelling Capacity	1.96	1.91	1.72
9	pH	8.67	8.70	4.95

MS = Maize Starch, Na-MMT = Sodium Montmorillonite, KAO = Kaolinite

Discussions

Angle of Repose: Angle of repose 56.00º of the Maize Starch (MS) was higher than that of the Na-MMT and Kaolinite 34.40º and 28.20º respectively. This indicates that MS and NaMMT exhibited better flow properties than the Kaolinite. This may be partly due to its relatively high moisture content. The larger the Angle of Repose the better powder physical properties (PPP) obtained. Kaolinite formed poorer angle of repose than that of NaMMT. (Carter, 1972; Iwuagwu & Okoli, 1992; Okhamafe *et al*., 1991).

True Density: in table 1 the true density data are as follows: MS 1.72 g/cm^3, Na-MMT 2.00 g/cm^3 and Kaolinite 2.50 g/cm^3. True Density of MS is less than that of Na-MMT and Kaolinite. True Density consists of Bulk, Tapped Densities, and Void Space (porosity) in a given volume of powder. Hence the higher true density of Kaolinite suggests that Na-MMT and MS exhibit good compressibility, because smaller particles occupy more of the void space than large clay particles. (Carter, 1972; Okhamafe et al., 1991).

Powder Porosity (%): The porosity of MS (31.94) was only slightly better than NaMMT (30.00) and Kaolinite (20.00) had the least measured porosity. MS show slightly better consolidation (densification) properties than Na-MMT, and Kaolinite had the lowest consolidation properties. Porosity can vary between wide limits depending on the extent to which void filling occurred between the larger particles (Carter, 1972;

Okhamafe et al., 1991).. Powder porosity affects the rate and extent of water uptake into the powder layer, and as such the higher porosity value, the more rapid rate and extent of water uptake; this also contributed to the higher moisture content. [2].

Bulk Density: MS exhibited the highest bulk density of 0.56 gcm^{-3} followed by NaMMT 0.50 gcm^{-3} and the lowest Kaolinite 0.40gcm^{-3}. The higher bulk density of MS and Na-MMT form better tablet disintegrant than Kaolinite, thus at higher bulk density of a disintegrant, the lower the quantity required for compression in tablet manufacture. Generally, a disintegrant with a high bulk density will exhibit a high dilution potential on a weight basis (Azubuike *et al*., 2011).

Tapped Density: The low tapped densities of MS (0.71gcm^{-3}) and Na-MMT (0.73 gcm^{-3}) indicated that void spaces in both powder beds are easily filled by the fine particles, which signifies better flowability property than the tapped density values of 0.83 gcm^{-3} shown by Kaolinite. The high densities are recorded when void spaces created by larger powder particles are not filled by smaller particles (Iwuagwu & Okoli, 1992).

Hausner's Ratio: Hausner's ratio 1.27 and 1.46 obtained for MS and Na-MMT respectively are low indicating better flow properties than 1.72 obtained for Kaolinite, hence it is said that powder possesses better-flow property because of its low inter-particle friction (Iwuagwu & Okoli, 1992).

Powder Retention Capacity (%): Powder retention capacity of 3.04% for MS was relatively high compared to 2.90% and 1.80% for Na-MMT and Kaolinite respectively. This indicates that MS and Na-MMT are more hygroscopic compared to Kaolinite. Powder flowability increases with increasing moisture content (Lieberman *et al*., 1989).

Swelling Capacity: Na-MMT show higher swelling capacity of 1.91 than that of Kaolinite 1.72 and MS had highest swelling capacity of 1.96. The swelling capacity reflects increase in volume of which MS had the highest volume increase followed by Na-MMT and Kaolinite the least swelling volume. (Olayemi *et al*., 2009).

pH: MS, Na-MMT and Kaolinite exhibited pH 8.67, 8.70 and 4.95 at 25°C respectively. This implies that MS and Na-MMT equilibrate easily in aqueous medium of 0.1M HCl during disintegration and dissolution processes, whereas Kaolinite will not easily equilibrate in the acidic medium. Thus bulk clay particles are made up of a definite ionizable compound which forms true equilibrium and whose charge is built up due to ionization of those compounds (Marshal & Gupter, 1933).

Conclusion

Kaolinite exhibits lowest value of angle of repose which indicates poor flow property and may contain far less moisture content. Its value of high true density makes it to be less compressible and as such its densification or consolidation property is poor. Kaolinite shows low bulk density value which implies that much quantity is required for compression. Kaolinite tapped density value is high due large powder particles creating void space not filled by smaller particles. High Hausner's ratio value shown by Kaolinite is an indication of its poor flow property, it also shows poor powder retention capacity and poor swelling capacity. Its acidic character make it unsuitable disintegrant for solid dosage forms. It can be generalized that the Na-MMT has great prospects of being used as alternative powder disintegrant to Maize-Starch (MS) in the formulation of certain solid pharmaceutical dosages; since Kaolinite failed most of the powder physical property tests.

References

1. CC. Osadebe, SE. Obrike, and NA. Sulymon, 2011. Evaluation of Imo Clay-Shale Deposit (Paleocene) from Okada, Edo State, Southwestern Nigeria, as Drilling Mud Clay. *J. of Appl. Technol*. In Environ. Sanitation. **1**(4):311-316.
2. C. P. C.Azubuike, A. O., Okhamafe, & A. Falodun, 2011. Some Pharmacopeial and Diluent-Binder Properties of Maize Co-derived from α-Cellulose in Selected Tablet Formulations. *J. Chem.Pharm. Res*., **3**(3):481-488.
3. F. Bergaya, BKG. Theng, and G. Lagaly 2006. Handbook of Clay Science, 1st edition Elsevier Publication, Amsterdam.
4. G. Biljana, I. Rade., D. Rok, & S. Stane, 2011. Formulation and evaluation of immediate release tablets with different types of paracetamol powder prepared by direct compression. *Africa Journal of Pharmacy and Pharmacology* **5** (1); 31 – 41.
5. SJ. Carter 1972. Tutorial Pharmacy, 6th Edition, Pitman Medical Publising Co. Ltd., Tumbridge Well Kent England, 211- 233.
6. VJ. Ghanshyam, DK.. Bhavesh, AP. Hasmukh, CB. Hari, and VJ. Raksh, 2009. Montmorillonite as a drug delivery system: Intercalation and in vitro release of timolol maleate. *International journal of pharmaceutics* **374**: 53 -57.
7. http//en.wikipedia.org/wiki/file.Paracetamol_skeletal.svg
8. MA. Iwuagwu & PO. Okoli, 1992. Disintegrant properties of pregelatinized cassava and white maize starches. *Pharmacy World Journal* **9** (2): 49-53.
9. H. Khalil, D. Mahajan, & M. Rafailovich, 2005. Polymer-Montmorillonite clay nanocomposites, Part 1: complexation of montmorillonite clay with vinyl monomer, *Polym. Int* 54: 423 – 427.
10. HA. Lieberman, L. Lechman, & JB. Schwarz, 1989. Pharmaceutical Dosage Forms: Tablets. 2th Edition Marcel Deckker, Inc; New York, 1, 75-130.
11. Marshall CE. & Gupta RS. 1933. Base exchange equilibria in clays. *Soc.Chem Industry Jour*. **52**:433T.
12. MA. Odeniyi, RN. Onu, & OA. Adetunji, 2011. Evaluation of bioadhesive properties of natural and modified banana starches. *East and Central African Journal of Pharmaceutical Sciences.***14:** 34 – 42.
13. AO. Okhamafe, AC Igboechi & Obaseki.TO 1991. *Pharmacy World Journal*, **8**(4): 120–123.
14. OJ. Olayemi, TS Allagh., & AR Oyi. 2009. Comparative binding effects of Wheat, Rice and Maize Starches in Chlorquine Phosphate Tablet Formultions. *Res. J. of Appl. Sci., Engineering and Technology* **1**(2):77-80.
15. HA. Patel, RS. Somani, HC. Bajaj, & RV. Jasta, 2007a. Synthesis and characterization of organic Bentonite using Gujarat and Rajasthan clays. *Curr. Sci*. **92**: 1004.
16. SG. Ring 1985. Some studies on gelatine. Starch, **37**, 80 – 87.
17. RRC. Rowe, PJ.. Sheskey, & SC. Owen 2006. Handbook of Pharmaceutical Excipients 5th Edition, Pharmaceutical Press (PhP), Grayslake, USA: 231-232.