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Research paper

Thermal properties of some Egyptian kaolin pastes for pelotherapeutic applications: Influence of particle geometry on thermal dosage release

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ABSTRACT

The present study aims to evaluate the potentiality of 7 selected structural highly ordered kaolinite-rich samples from Egyptian Carboniferous sedimentary deposits (located at Abu Zenima district, west central Sinai peninsula) to use them in medicinal semisolid formulations as peloids. The effect of particle geometry and kaolinite crystallite size are studied to check their influence on thermal dosage performance.

The studied samples exhibit a variable mineralogy. Kaolinite is the main constituent (ranging from 81 to 94%), followed by quartz (up to 14%), lesser amounts of anatase and halite, and traces of hematite, magnetite, alunite and gypsum. The kaolinite order “Hinckley Index” varies from 1.28 to 1.50. 1:1 (w/w) kaolin mud pastes were prepared with purified water in Eppendorf tubes using a touch vibration vortex mixer for 2 min. The cooling kinetics of pastes were measured by using a differential scanning calorimetry equipment (Shimadzu DSC-50Q). Specific heats were calculated, following Cara et al. (2000). The granulometry and geometric surface area were measured by laser diffraction (Mastersizer 2000LF, Malvern Instruments) in the range 0.02 and 1500 μm.

All analyzed samples showed a clear predominance of particles under 4 μm (ranging from 82 to 94%), with median size (D_{50}) ranging from 0.93 to 1.35 μm. The heat retention time during cooling from 50 °C to 32 °C reached up to 30.82 min, oscillating around an average of 28.72 min, and the temperature corresponding to the minimal dosage time (T_{20}) was not exceed below 34.7 °C. A good correlation (R^2 = 0.875) was found between heat retention time and specific heats. There is no correlation between kaolinite content and thermal properties, but R^2 values around 0.6 are found with granulometry (finer the particles, greater the heat retention time t_{32} and the specific heat). Even if sample H5 (Gabal Hazbar deposit) is not the richest in kaolinite, it exhibits the best thermal dosage performance, in accordance with the granulometry (D_{50} = 0.93 μm), and geometric surface area (3.73 m^2/g).

1. Introduction

Thermotherapy is a recognized medicinal strategy based on the analgesic and anti-inflammatory effects that heat application produces on the human body. Clearly, the treatment route is attempted by applying exogenous local or whole changes in the heat content of body tissues for a certain time to alleviate inflammations and pains associated with rheumatic and skeletomuscular disease, or also to stimulate other therapies. In such method, the intensity of the heat that applied directly to the skin on the painful site is limited by about 44 °C with gradient of < 10 °C; that is available for heating deeper subcutaneous tissue layers from the outside. Subsequently, there are essentially three different physiological modes of temperature action: (1) beneficial increase of blood flow and control of nervous signal transduction; that could be attained by biophysical properties and biochemical processes influence local cellular activities, (2) elicit reflex responses of complexity that feedback from the central nervous system through the skeletomuscular strains by producing specific nervous signals or altering hormone levels, or (3) maintain and regulate heat balance of the body between heat production and loss; that could change various physiological activities (Kosaka et al., 2001; Brosseau et al., 2011).

Pelotherapy, or mud therapy, has received much attention in physical therapy field because clays are ubiquitous, cheap, and exhibit good heat retention capacity (Veniale et al., 2007; Gomes et al., 2015). From

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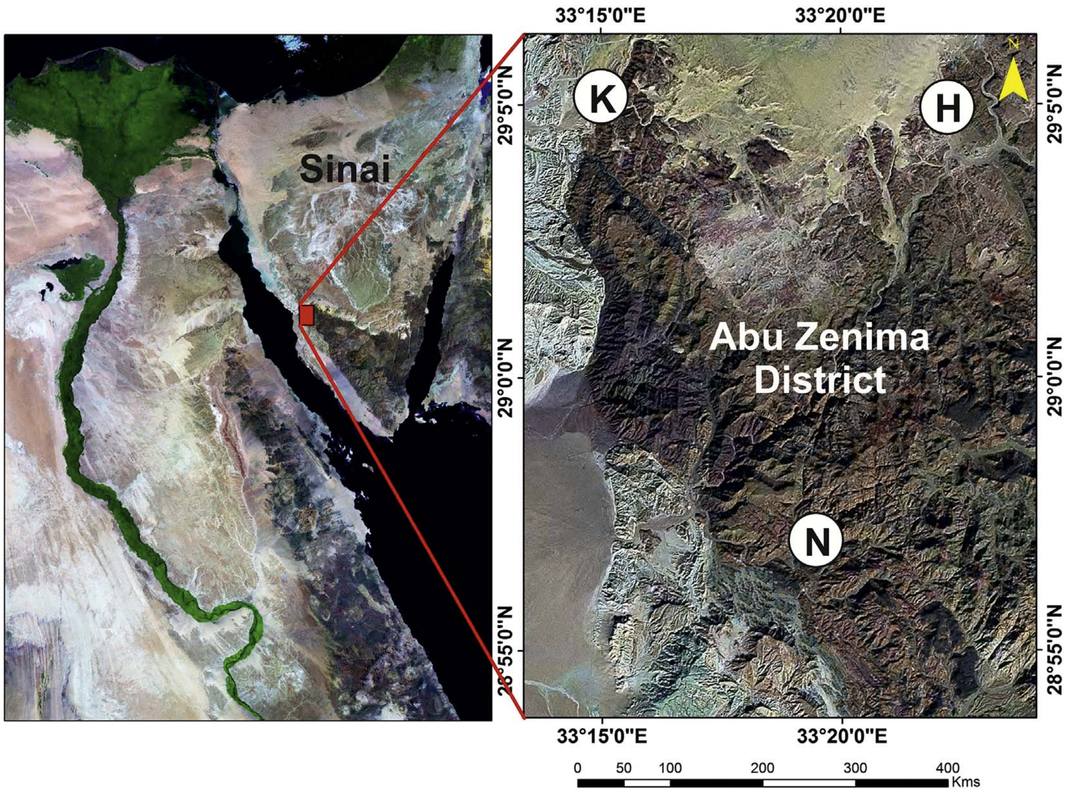

Fig. 1. Location map showing the section sites (K: Wadi Khaboba, H: Gabal Hazbar and N: wadi Abu Natash) of the collected Abu Zenima Carboniferous kaolin samples.

pharmaceutical point of view, it has received much pioneer technological developments by Spanish and Italian scientists in the recent decades; however it was known since antique periods, hence becoming a trend of thermotherapy for competing with the other thermal methods that based on biomedical heating techniques such as microwave devices (Bird et al., 1985; Moros, 2013). In this regard, peloids or medicinal thermal mud are pharmaceutically considered as semisolid products (pastes and poultices) that can be formulated by mixing of geomaterials (mainly pure clay minerals or associated by non-clay mineral phases) of variable composition and size with saline water brought from the sea or lakes, or thermo-mineral water erupted form springs (45–50 °C) and then these mixtures are subjected to maturation (i.e., beneficial microbiological metabolic activity) process (Sánchez et al., 2002; Veniale et al., 2004; Gomes and Silva, 2007; Gomes, 2013; Gomes et al., 2013).

These medicinal products, either artificially designed mainly from clay minerals or formed in situ, can be administrated topically as facial masks or body bathing for healing pains and inflammations of skeletomuscular disorders, rheumatic (arthrosis, arthritis and fibromyalgia) and also skin diseases (acne, psoriasis and seborrhea). Hence, pelotherapy has a dual therapeutical action based on the original physical and chemical characteristics of the mineral and thermal water fractions. These agents are represented in heat treatment and/or transdermal delivery of chemical elements with other beneficial dermatological activities due to clay mineral behaviors (Grassi et al., 2003; Veniale et al., 2007; Evcik et al., 2007; Giacomino and De Michele, 2007; Tateo and Summa, 2007; Tateo et al., 2009 and 2010; Carretero et al., 2010; Fraioli et al., 2011; Rebelo et al., 2011; Beer et al., 2013; Espejo-Antúnez et al., 2013; Sánchez-Espejo et al., 2014; Suárez Muñoz et al., 2015; Awad et al., 2017b).

The quality of peloids for healing activity are mainly influenced by specific heat, heat capacity, thermal conductivity, heat diffusiveness and cooling kinetics, maturation time, chemical compositions of solid (minerals and organic matter) and fluid phases, viscosity, plasticity, adhesivity, abrasivity, solid/liquid ratio and ion exchange capacity. In the pelotherapeutic route of administration, the temperature of the paste required at the beginning of the treatment dosage is between 45 °C and 50 °C, with heat retention time in the range of 20–30 min throughout the cooling to reach 32 °C. The final temperature usually considered as 32 °C in all calculations, because the skin temperature normally reached to this degree at the equilibrium state due to the heat exchange between the skin and the sample. Therefore, the considered temperature range of 50–32 °C are used, in comparative studies, for evaluating the therapeutic performance of clay materials in hot mud-packs formulations for healing the painful chronic skeletomuscular diseases (Cara et al., 2000a,b; Legido et al., 2007; Gámiz et al., 2009; Casás et al., 2011 and 2013; Quintela et al., 2012; Fernández-González et al., 2013; Caridad et al., 2014; Khiari et al., 2014; Gomes et al., 2015; Sánchez-Espejo et al., 2015).

The water content has been attributed by Cara et al. (2000b) as a controlling factor in prolongation of heat retention time in case of using montmorillonite-formulated mud. However, the thermal behaviour of kaolin-based mud could not be significantly influenced by the formulation water content, as well as the undesirable consistency and performance are expected to the product with high water contents, because kaolinite is a non-swelling and relatively low water absorption clay mineral, if compared to montmorillonite.

In pharmacopoeia quality, the 1:1 kaolin-water system exhibits the highest clinical absorptive feature amongst other common pharmaceutical materials used in hydrophilic paste preparations (Juch et al., 1994). Technologically, the 1.0 solid/liquid ratio of the kaolin aqueous dispersions showed the optimal water content 50% in the preparations of easily molded, consistent, and desirable adhesive pastes (Ramasamy et al., 2015). Therefore, the other effects of the solid particle geometric properties of kaolin powders on the thermal behaviour translated from this hypothesized context into testing considerations.

With these premises, the present study aims to evaluate the potentiality of some highly ordered kaolinite-rich samples belong to the economic Egyptian Abu Zenima kaolin deposits, in semisolid formulations of medicinal peloids; with diagnosing the influence of granulometric characteristics (particle size distribution and geometric surface