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Research paper

An evaluation of palygorskite inclusion on the growth performance and digestive function of broilers

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ABSTRACT

Palygorskite (Pal), a natural non-toxic silicate clay mineral with abundant resource reserve on the Earth, has received increasing attention in animal nutrition either as an efficient and safe feed additive or ingredient to promote the growth of animals. The current study was conducted to evaluate the effects of Pal supplementation on the growth performance and digestive function of broilers. 144 one-day-old Arbor Acres broiler chicks were allocated into 3 dietary treatments consisting of 6 replicates with 8 chicks each. Birds in the 3 treatments were given a basal diet supplemented with 0, 0.5 mass% and 1.0 mass% of Pal for 42 days, respectively. The broilers fed diets containing either 0.5 mass% or 1.0 mass% Pal showed similar growth performance to those given the basal diet. Compared with the control group, the relative weight of the pancreas was increased by Pal inclusion at 42 days. 1.0 mass% Pal supplementation increased nitrogen retention and organic matter digestibility of broilers during 32 to 34 days. Similarly, 0.5 mass% Pal inclusion significantly enhanced pancreatic and jejunal lipase activity at 21 days. In addition, birds fed diet supplemented with 1.0 mass% Pal showed a higher level of jejunal trypsin activity at 42 days compared with the control group. The results indicated that dietary Pal supplementation could enhance relative weight of pancreas, nitrogen retention and organic matter digestibility (1.0 mass% Pal only), and the activities of digestive enzymes of broilers, which may account for the similar growth performance.

1. Introduction

Palygorskite (Pal) is a naturally available magnesium–aluminum silicate clay mineral with nanorod-like crystal morphology and reactive —OH groups on its surface (Bergaya and Lagaly, 2013; Galán and Carretero, 1999). It is composed of ribbons of 2:1 phyllosilicate units. Each ribbon is connected to the next by the inversion of SiO_4 tetrahedra along a set of Si—O—Si bonds, forming zeolite-like channels with the size of 0.37 nm × 0.64 nm (Chisholm, 1990, 1992; Mckeown et al., 2002). The special crystal structure, stacking mode and nanometric dimension of the rod crystals of Pal endow it with plentiful pores, high aspect ratio, and good ion-exchange capacity (Gonzalez et al., 1989; Murray, 2000). So, Pal has been widely used as a colloidal agent (Wang et al., 2015b; Xu et al., 2014), an adsorbent (Gupta and Bhattacharyya, 2014; Ouali et al., 2015; Tian et al., 2015; Wang et al., 2015a; Zhang et al., 2015), a carrier of active components (Papoulis et al., 2010; Yan et al., 2016) and nanocomposites (Chae et al., 2015; Sarkar et al., 2015; Wang and Wang, 2016; Zhou and Keeling, 2013). By virtue of the excellent properties, non-toxic, safe and biocompatible advantages, Pal shows great prospect in biological fields (Ghadiri et al., 2015) and is widely used as an active ingredient in pharmaceutical applications, including as gastrointestinal protectors and anti-diarrhetic drugs (Lopez-Galindo et al., 2007; Viseras et al., 2007). The therapeutic action of Pal is highly associated with its high specific area and adsorption capacity (Carretero, 2002). Also, the adsorption of H^+ ions onto the surface of Pal can induce gastric acidity reduction, which in turn enables Pal to be a potential antacid (Carretero and Pozo, 2010).

Aside from its application in human health and many other industrial uses, Pal can also exert beneficial effects in animal nutrition mainly due to its high adsorption capacity, large specific surface area, good rheological and catalytic properties (Murray, 2000; Yan et al., 2016). The Pal entered for the first time the European Union Community Register of Feed Additives being classified as silage additive functional group in 2005 (Chalvatzi et al., 2014), and has been included in the catalogue of feed materials in European Union since 2011 (EU Commission, 2011). In China, Pal, classified as a raw feed material (Ministry of Agriculture of China, 2013), finds extensive usage either as pellet binder of animal feed or as animal feed supplement.

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Dietary Pal inclusion can increase growth performance, decrease diarrhea rate, and improve intestinal morphology and barrier function in weaned piglets (Zhang et al., 2013). Additionally, Pal exhibited prominent effectiveness in counteracting the detrimental injury induced by aflatoxin-contaminated diets in weanling pigs (Schell et al., 1993). For laying hens, Chalvatzi et al. (2014) showed that the supplementation of 1.0 mass% Pal into the Lohmann Brown hens' diets for 24 weeks improved laying percentage, feed conversion ratio and egg quality except eggshell and yolk color. In broilers, Pappas et al. (2010) reported that dietary 1.0 mass% Pal incorporation, used as a pellet binder, increased hardness of pellets without adverse effect on the growth performance of broilers during 6 weeks. Recently, Qiao et al. (2015) found that dietary 2.0 mass% Pal supplementation, especially the natural Pal, could improve the digestive function of laying hens, and did not have any adverse effect on the laying performance and egg quality, which in turn suggested that Pal inclusion could also improve the digestive function of broilers. However, little was known about the use of Pal on the digestive function of broilers. The current study was therefore conducted to investigate the effects of Pal inclusion on the growth performance and digestive function of broilers fed mash diets, and it is expected that this research may pave a foundation for extending the application of Pal in animal nutrition.

2. Materials and methods

2.1. Palygorskite

The Pal used in the current study was taken from Huangnishan Mine located on Xuyi county of Jiangsu province, China. The chemical composition is listed in Table 1. Before use, the raw Pal mineral was rolled on a three-roller machine for one time, and then dispersed in water at solid/liquid ratio of 1/10 (mass/mass). The aqueous dispersion was passed through a 300-mesh sieve to remove the large grains of quartz or aggregates. The solid was separated from the dispersion by filter-pressing process, and then dried and smashed as powder (particle size <75 μm) for further use.

The structure, morphologies and specific surface area of the used Pal were characterized using the following techniques. X-ray diffraction (XRD) patterns were collected on a X'pert PRO X-ray power diffractometer equipped with a Cu-Kα radiation source (n = 0.1541 nm; 40 kV, 40 mA) (PAN analytical Co., Netherlands) from 3 to 80° (2θ) at a scanning rate of 8.34°/min, with a step interval of about 0.017°, divergence slit of 0.5° and anti-scatter slit of 1°. The surface morphologies were observed using a field emission scanning electron microscope (FESEM, JSM-6701F, JEOL, Japan) at an accelerating voltage of 5 kV, and the transmission electronic microscopic (TEM) images were taken on a JEM-1200 EX/S transmission electron microscope (TEM, JEOL, Tokyo, Japan) at an accelerating voltage of 200 kV. Before imaging, the sample for scanning electron microscope (SEM) observation was fixed on copper stub and coated with gold film, and the sample for TEM observation was dispersed in ethanol and a drop of the dispersion was took and put on a copper grid. The specific surface area was measured on an ASAP 2010 analyzer (Micromeritics, USA) at 77 K by the N_2 adsorption–desorption isotherms. All the samples were degassed at 90 °C for 10 h to remove moisture. The specific surface area was calculated by the BET equation. The XRD pattern, SEM and TEM images of the used Pal are shown in Fig. 1. The (110), (200), (130) and (040) reflections of Pal were observed at 2θ = 8.44° (d = 1.0476 nm), 2θ = 13.76° (d = 0.6436 nm), 2θ = 16.51° (d = 0.5369 nm) and 2θ = 19.78° (d = 0.4488 nm), respectively (Fig. 1a). The rod-like crystals of Pal were clearly observed in the SEM and TEM images (Fig. 1b, c). In addition, the BET specific surface area of the pre-treated Pal was determined to be 203.71 m^2/g.

Table 1
Chemical composition of used Pal.

Composition	Content (%)
SiO_2	52.29
Al_2O_3	12.29
Fe_2O_3	8.65
MgO	5.67
CaO	2.60
K_2O	2.38
Na_2O	0.18

2.2. Bird husbandry, diets and experimental design

All procedures were approved by Nanjing Agricultural University Institutional Animal Care and Use Committee. A total of 144 one-day-old Arbor Acres broiler chicks (body weight, 39.00 ± 0.20 g) obtained from a commercial hatchery were randomly allocated into 3 dietary treatments consisting of 6 replicates with 8 chicks each (4 males and

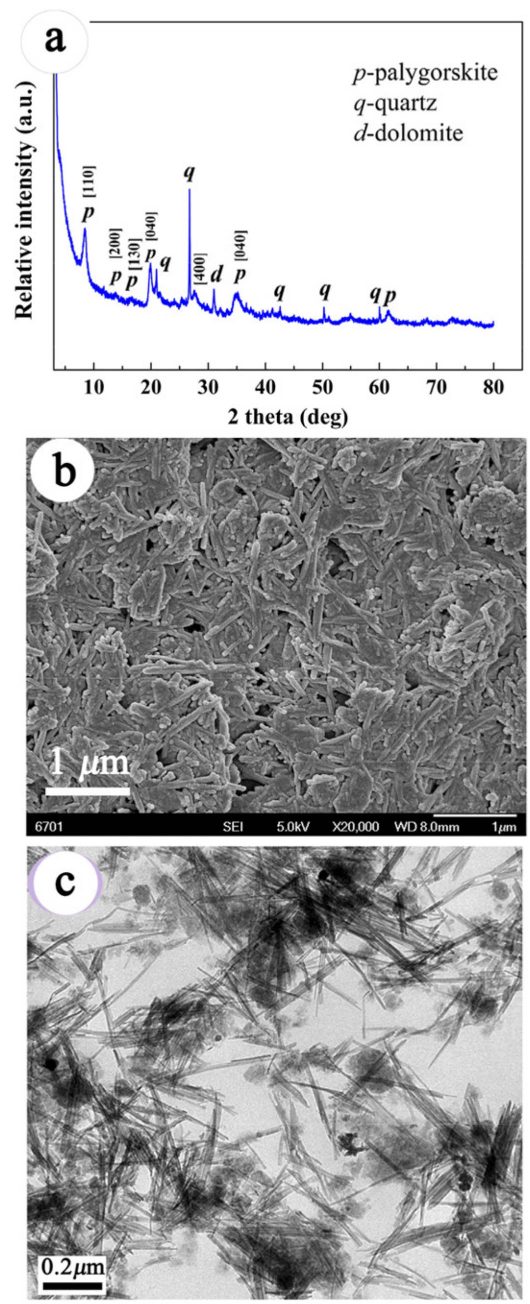

Fig. 1. (a) XRD pattern, (b) SEM image and (c) TEM image of the used Pal.