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Effects of increasing levels of pea hulls in the diet on productive performance, development of the gastrointestinal tract, and nutrient retention of broilers from one to eighteen days of age

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ABSTRACT

The effects of inclusion of pea hulls (PH) in the diet on growth performance, development of the gastrointestinal tract and nutrient retention were studied in broilers from 1 to 18 d of age. There were a control diet based on low fibre ingredients (69.3 total dietary fibre (16.1 g crude fibre/kg)) and three additional diets that resulted from the dilution of the basal diet with 25, 50 and 75 g PH/kg (81.2, 93.2, and 105.1 g total dietary fibre/kg diet, respectively). Each treatment was replicated six times and the experimental unit was a cage with 12 chicks. Growth performance, development of the gastrointestinal tract and the coefficients of total tract apparent retention (CTTAR) of nutrients were recorded at 6, 12 and 18 d of age. In addition, jejunal morphology was measured at 12 and 18 d and the coefficients of apparent ileal digestibility (CAID) of nutrients at 18 d of age. Pea hulls inclusion affected all the parameters studied. The inclusion of 25 and 50 g PH/kg diet improved growth performance as compared to the control diet. The relative weight (g/kg body weight) of proventriculus ($P \leq 0.01$), gizzard ($P \leq 0.001$) and ceca ($P \leq 0.05$) increased linearly as the level of PH in the diet increased. The inclusion of PH affected quadratically ($P \leq 0.01$) villus height:crypt depth ratio with the highest value shown at 25 g PH/kg. In general, the CTTAR and CAID of nutrients increased linearly and quadratically ($P \leq 0.05$) with increasing levels of PH, showing maximum values with PH level between 25 and 50 g/kg diet. We conclude that the size of the digestive organs increases with increasing levels of PH in the diet. In general, the best performance and nutrient digestibility values were observed with levels of PH within the range of 25 and 50 g/kg. Therefore, young broilers have a requirement for a minimum amount of dietary fibre. When pea hulls are used as a source of fibre, the level of total dietary fibre required for optimal performance is within the range of 81.2–93.2 g/kg diet (25.6–35.0 g crude fibre/kg diet). An excess of total dietary fibre (above 93.2 g/kg diet) might reduce nutrient digestibility and growth performance to values similar to those observed with the control diet.

Abbreviations: ADFI, average daily feed intake; AME_n, apparent metabolisable energy nitrogen corrected; BW, body weight; BWG, body weight gain; CAID, coefficient apparent ileal digestibility; CTTAR, coefficient of total tract apparent retention; DF, dietary fibre; GIT, gastrointestinal tract; PH, pea hulls.

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1. Introduction

The inclusion of moderate amounts of fibre in the diet improved growth performance in chicks fed low-fibre diets (Jiménez-Moreno et al., 2009b; González-Alvarado et al., 2010), an effect that may result from an improvement in gizzard function (González-Alvarado et al., 2008). A well-developed gizzard increases intestinal refluxes and facilitates the mixing of the digesta with HCl and enzymes. Consequently, the inclusion of dietary fibre may improve the digestibility of protein and other dietary components (Svihus and Hetland, 2001; Jiménez-Moreno et al., 2009c) as well as the solubility of the mineral fraction of the diet (Guinotte et al., 1995). However, an excess of dietary fibre reduced feed intake and might hinder nutrient digestibility and growth performance (Jørgensen et al., 1996b; Sklan et al., 2003).

The effects of dietary fibre on gastrointestinal tract (GIT) development, nutrient digestibility and growth performance depends on the level of inclusion and the physicochemical characteristics of the fibre source (Guillon and Champ, 2000; Schneeman, 2001; Mateos et al., 2002; Amerah et al., 2009). Water holding capacity, viscosity, bulk, particle size, fermentability and the ability to bind bile acids of the fibre fraction of the diet have nutritional implications on feed intake, organ development and nutrient digestibility (Bach Knudsen, 2001; Montagne et al., 2003). The mechanisms by which dietary fibre increase viscosity of the digesta or physically trap components of the diet depends largely on the physical properties of the fibre rather than on its chemical composition (Tosh and Yada, 2010). However, the susceptibility to fermentation of the dietary fibre in the ceca, depends primarily on the chemical structure of the fibre source (Morris, 2001).

Peas (*Pisum sativum* L.) are an alternative to soybean meal and cereals in non-ruminant diets (Valencia et al., 2008; Parera et al., 2010). Pea hulls (PH) represent between 90 and 140 g/kg of the mature seed and consist mainly of insoluble non-starch polysaccharides such as cellulose, together with some amounts of pectins and xylans, and small amounts of lignin (Daveby et al., 1993; Castell et al., 1996). Commercial PH contains also a variable proportion of starch and protein that cannot be removed entirely during the air-classification process that separates the different fractions of the peas (Czukor et al., 2001; Valencia et al., 2009). We hypothesized that the inclusion of a moderate amount of PH to diets low in fibre, may improve the development of the GIT of young broilers, increasing nutrient digestibility and growth performance but that high levels of PH may have detrimental effects on some of these traits. The objective of this experiment was to study the effects of increasing levels of PH in the diet on digestive traits, nutrient digestibility and productive performance in broilers from 1 to 18 d of age.

2. Materials and methods

2.1. Pea hulls and diets

A batch of PH was obtained from a supplier of pea protein concentrate destined to the animal feed industry (Esasa, Valladolid, Spain). The batch was ground through a rotor mill (Retsch GmbH Model ZM 200, Haan, Germany) fitted with a 2.0-mm screen, and used as such in the manufacturing of the feeds. The chemical composition of the PH used is shown in Table 1. The basal diet was formulated using low-fibre ingredients and contained 13.7 MJ apparent metabolisable energy nitrogen corrected (AME_n)/kg and 69.3 g total dietary fibre (DF)/kg (FEDNA, 2003). Celite, an acid-washed diatomaceous earth (Celite Hispánica S.A., Alicante, Spain) was added (20 g/kg) to the basal diet as an acid insoluble ash source. The remaining diets had similar ingredient composition to the basal diet but 25, 50 or 75 g PH/kg substituted (weight/weight) identical amounts of the basal diet. All diets met or exceeded the nutritional recommendations of FEDNA (2008) for broilers (Table 2).

2.2. Husbandry and experimental design

All procedures used in this research were approved by the Animal Ethics Committee of the Universidad Politécnica de Madrid and were in compliance with the Spanish guidelines for the care and use of animals in research (Boletín Oficial del Estado, 2005).

In total, 288 1 d-old female broiler (Ross-308) chicks with an initial body weight (BW) of 43.0 ± 3.1 g were obtained from a commercial hatchery (Avimosa, Moraleja de Enmedio, Spain), allocated in a windowless, environmentally controlled room and randomly placed in groups of 12 in 24 battery cages (1 m × 0.9 m; Avícola Grau, Madrid, Spain). Chicks were divided into six blocks by BW and diets were randomly assigned to cages within each block. The cages had complete wire flooring and were equipped with two drinker cups and an open trough feeder. Room temperature was kept at 33 °C during the first 3 d of life and then, was reduced gradually according to age until reaching 24 °C at 18 d. Chicks received a 23 h/d light program and had free access to feed in mash form and tap water throughout the trial.

2.3. Laboratory analysis

Pea hulls, diets, excreta and ileal digesta were analysed for total ash using the muffle furnace (method 942.05) and for nitrogen by Dumas (method 968.06) using a LECO analyser (model FP-528, Leco Corporation, St. Joseph, MI) as described by AOAC International (2000). Dry matter was determined by oven-drying (method 6) and ether extract by Soxhlet fat analysis after 3N HCl acid hydrolysis (method 4.b) as described by Boletín Oficial del Estado (1995). Gross energy was measured with an isoperibol bomb calorimeter (model 356, Parr Instrument Company, Moline, IL) and acid insoluble ash was analysed as