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Prediction of the digestible and metabolizable energy content of wheat milling by-products for growing pigs from chemical composition

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ABSTRACT

Thirty samples of wheat milling by-products (wheat bran, wheat middlings, wheat shorts, wheat red dog, wheat feed flour), collected from 11 flour mills, were fed to growing pigs to determine their digestible energy (DE) and metabolizable energy (ME) content and to establish equations for predicting their DE and ME content based on chemical analysis. The basal diet was based on corn and soybean meal while the other 30 experimental diets contained 290.4 g/kg wheat milling by-products added at the expense of corn and soybean meal. The 31 diets were fed to 96 growing pigs (BW = 61.9 ± 3.2 kg) according to a completely randomized design during two successive periods. During each period, the 30 experimental diets were fed to three pigs and the basal diet was fed to six pigs, resulting in 6 replications per experimental diet and 12 replications for the basal diet over the two periods. The chemical composition of the 30 samples was variable, and starch and fiber content had a strong negative correlation ($r = -0.96$ to -0.99 for CF and ADF, respectively). The DE content of wheat feed flour, wheat red dog, wheat shorts, wheat middlings and wheat bran averaged 17.4, 16.9, 15.2, 12.5 and 12.0 MJ/kg DM, respectively. From the stepwise regression analysis, a series of DE and ME prediction equations were generated. The best fit equations for wheat milling by-products were: DE (MJ/kg DM) = 19.2 − (0.016 × aNDF) with $R^2 = 0.94$, RSD = 0.58 and $P<0.01$; and ME (MJ/kg DM) = 16.9 − (0.0136 × aNDF) with $R^2 = 0.94$, RSD = 0.50 and $P<0.01$. Few additional variables came into the equation models because of the strongly correlated relationships among chemical components. The results indicate that DE and ME content varied substantially and various correlated single predictors (aNDF, ash, CF, starch, etc.) can be used to accurately predict the DE and ME content when fed to growing pigs.

1. Introduction

During the production of flour from wheat, 25–30% wheat milling by-products can be produced (Blasi et al., 1998). Wheat milling by-products are widely used in commercial pig production as they provide a source of energy, amino acids (AA) and

Abbreviations: AA, amino acid; ADF, acid detergent fiber expressed inclusive of residual ash; aNDF, neutral detergent fiber assayed with a heat stable amylase and expressed inclusive of residual ash; ATTD, apparent total tract digestibility; CF, crude fiber; CV, coefficient of variation; DE, digestible energy; GE, gross energy; ME, metabolizable energy; NDF, neutral detergent fiber; RSD, relative standard deviation.

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phosphorus (P) (Nelson, 1985; Erickson et al., 1985). These by-products are commonly referred to as wheat bran (course and fine outer layer, CF > 95 g/kg, as fed), wheat middlings (70 g/kg < CF ≤ 95 g/kg), wheat shorts (40 g/kg < CF ≤ 70 g/kg), wheat red dog (15 g/kg < CF ≤ 40 g/kg) and wheat feed flour (CF ≤ 15 g/kg) according to AAFCO (1996).

There is a considerable amount of variation in the chemical composition of wheat by-products because of differences in the variety of wheat being processed, environmental factors (production and storage) as well as differences in processing techniques used for production (Nelson, 1985; Blasi et al., 1998; Kim et al., 2005). Energy is the most expensive components in pig diets (Myer and Brendemuhl, 2001). Previous publications for DE and ME content of wheat by-products were not comprehensive and comparable for using the chemical analysis to generate energy prediction equations. More comprehensive data about the chemical composition and energy content of these series of by-products will enable nutritionists to formulate diets more accurately and economically (Cromwell et al., 2000). Therefore, the present work was conducted to determine the chemical composition of 30 samples of variable wheat milling by-products. These values were then utilized to establish prediction models to estimate DE and ME content based on chemical composition.

2. Materials and methods

The experimental protocol used in this study was approved by the Institutional Animal Care and Use Committee of China Agricultural University (Beijing, China). This study was conducted in the Swine Nutrition Research Center of the National Feed Engineering Technology Research Center (Chengde, Hebei, China).

2.1. General procedures

Thirty samples of wheat milling by-products (wheat feed flour, $n = 6$; wheat red dog, $n = 7$; wheat shorts, $n = 5$; wheat middlings, $n = 7$; wheat bran, $n = 5$), classified by CF content, were collected from 11 commercial flour mills located in the main wheat flour production areas of HeNan, HeBei, FuJian, JiangSu, LiaoNing, TianJin and ShangDong in China.

Thirty-one diets were fed to 96 crossbred (Duroc×Landrace×Yorkshire) barrows (Initial BW, 61.9 ± 3.2 kg) according to a completely randomized design conducted during two successive periods. The basal diet was based on corn and soybean meal with the remainder of the diet comprising vitamins and minerals, while the other 30 diets contained 290.4 g/kg wheat milling by-product which replaced 30% of the basal diet weight supplied by corn and soybean meal. On the basis of reduce the risk of feed refusals and to use dietary inclusion levels that are representative of what is used in the pig diets, increasing inclusion levels of test ingredients in experimental diets can decrease variation between replications when assessing energy content, can thereby improve the precision in determinations of energy content (Huang et al., 2013). In addition, wheat by-products can be recommended to use as high as 30% in growing-finishing pigs. Corn and soybean meal were ground in a hammer mill using a 2 mm screen. The ingredient composition of the diet used in the study is presented in Table 2.

The 96 crossbred pigs were individually housed in stainless steel metabolism cages (1.4 m×0.45 m×0.6 m) located in eight environmentally controlled rooms. All of the rooms were situated in one building and each room had 12 cages.

During each period, the 30 experimental diets were fed to three pigs while the basal diet was fed to six pigs, resulting in 6 replications per experimental diet and 12 replications for the basal diet over the two periods. Each period lasted 12 days comprised of a 7 days adaptation period followed by a 5 days total collection of feces and urine. Feces were collected immediately as they appeared in the metabolism crates and were placed in plastic bags to be stored at −20 °C. Urine was collected in a bucket placed under the metabolic crate. The bucket contained 10 ml of 6 N HCl for every 1000 ml of urine. Each day, the total urine volume was measured and a 10% aliquot was filtered through gauze and 50 ml of the mixed urine samples were transferred into a screw-capped tube and stored immediately at −20 °C until needed for analysis. At the end of the collection period, feces were thawed, pooled by pig, homogenized, sub-sampled, dried for 72 h in a 65 °C drying oven and ground through a 1-mm screen.

Vitamins and minerals were supplemented in all diets to meet or exceed the estimated nutrient requirements for growing pigs recommended by NRC (1998). Pigs were weighed at the beginning of each period. The diets were provided at a rate of 2.8 times maintenance energy (i.e., 106 kcal/kg of ME/kg $BW^{0.75}$; NRC, 1998) determined at the initiation of each adaptation period. The daily feed allowance was divided into two equal meals fed at 0800 and 1700 h. If one pig had feed refusals greater than 20% of the supplied feed, another pig was substituted to meet the replication requirement. Water was freely available from a low-pressure drinking nipple to avoid water contamination of the urinary collection bucket. The diets were provided in mash form.

2.2. Chemical analysis

The methods used to analyze the diets and wheat milling by-products were similar to the descriptions provided by Huang et al. (2012). Dry matter (procedure 4.1.06; AOAC, 2000), ether extract (Thiex et al., 2003), crude protein (Thiex et al., 2002), crude fiber (procedure 978.10; AOAC, 2000), neutral detergent fiber, acid detergent fiber (procedure 4.6.03; AOAC, 2000), ash (procedure 4.1.10; AOAC, 2000), calcium (procedure 4.8.03; AOAC, 2000) and total phosphorus (procedure 3.4.11; AOAC, 2000) content were analyzed. Neutral detergent fiber and acid detergent fiber were determined using fiber bags and fiber analyzer equipment (Fiber Analyzer, Ankom Technology, Macedon, NY). The concentration of aNDF was analyzed using heat stable α-amylase and sodium sulfite without correction for insoluble ash. The ADF fraction was analyzed directly in