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Evaluation of prediction equations to estimate gross, digestible, and metabolizable energy content of maize dried distillers grains with solubles (DDGS) for swine based on chemical composition[☆]

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ABSTRACT

The objective of this study was to cross-validate prediction equations to estimate the concentration of GE, DE, and ME among sources of corn distillers dried grains with solubles (DDGS) with variable chemical composition in growing pigs. Published concentrations (DM basis) of GE, CP, ether extract (EE), NDF, and total dietary fiber (TDF) along with particle size (PS, μm), bulk density (BD, g/cm^3) and *in vivo* determinations of DE and ME from 45 sources of DDGS samples were obtained from 5 published studies. Prediction equations for GE (5 equations), DE (20 equations), and ME (19 equations) from published studies were used to calculate the concentration of GE, DE, and ME among DDGS sources and compare with experimentally determined *in vivo* values. Each equation was evaluated using the entire data set, and data sets that excluded data from which the equation was developed (cross-validation). Equations were compared for their overall explanation of variance (R^2), precision for reduction in prediction error (PE, kcal/kg DM), and accuracy in deviation of the predicted mean from the overall observed mean (bias, kcal/kg DM). Prediction of GE concentrations among DDGS sources was poor (PE < 200 and biases > 150) despite moderate explanation of overall variance (R^2 < 0.6). Therefore, we tested DE and ME equations that included GE as an input using the actual analyzed GE concentration of samples. Under this condition, the most precise (PE = 144) and accurate (bias = 19) DE equation was DE = −2,161 + (1.39 × GE) − (20.7 × NDF) − (49.3 × EE). The most precise (PE = 149) and accurate (bias = −82) ME equation was ME = −261 + (1.05 × GE) − (7.89 × CP) + (2.47 × NDF) − (4.99 × EE). Predicting GE with

Abbreviations: ADF, acid detergent fiber; AOAC, Association of Official Analytical Chemists; CP, crude protein; DDGS, maize dried distillers grains with solubles; DE, digestible energy; DM, dry matter; EE, ether extract; GE, gross energy; ME, metabolizable energy; NDF, neutral detergent fiber; NSP, non–starch polysaccharides; TDF, total dietary fiber.

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equation GE = 4,583 + (50.6 × EE) − (0.1 × PS), and using this estimate in the equation of ME = −261 + (1.05 × GE) − (7.89 × CP) + (2.47 × NDF) − (4.99 × EE), resulted in moderate precision (PE = 134) and accuracy (bias = 48). Cross-validation of equations that require PS, BD, or TDF as inputs was not possible because these inputs were only measured in 1 of the 5 published studies used in this evaluation.

1. Introduction

Maize dried distillers grains with solubles (DDGS) produced by dry-grind fuel ethanol plants is being used in large quantities in swine diets due to increased supply and significant diet cost savings (Stein and Shurson, 2009; Cromwell et al., 2011). However, the energy and nutrient content in DDGS is more variable (Spiehs et al., 2002) than in maize (*Zea mays*) and soybean (*Glycine max*) meal (Cromwell et al., 1999a,b). Anderson et al. (2012) showed that the concentration of metabolizable energy (ME) among DDGS sources can range from 3,414 to 4,141 kcal/kg DM. As a result, variability in energy and nutrient content among DDGS sources has created significant challenges for determining relative economic value and establishing accurate nutrient loading values when formulating swine diets.

Energy is the most expensive nutritional component in animal feeds. Nutritionists need rapid, inexpensive, and accurate methods to determine energy content among highly variable ingredients like DDGS. Although NRC (2012) provides gross energy (GE), digestible energy (DE), metabolizable energy (ME), and net energy (NE) values with standard deviations (except for ME and NE) for various classifications of maize DDGS co-products, these estimates can quickly become outdated due to evolving production technologies being implemented in the U.S. ethanol industry. *In vivo* determinations of DE and ME in DDGS are expensive, tedious, and time consuming, but provide the most accurate estimates of all methods. Near infrared spectroscopy (Rathore et al., 2005) offers the advantages of being fast and inexpensive, but a database in excess of 200 estimates of *in vivo* DE or ME estimates would likely be required in order to develop good calibrations. As a result, development and use of accurate prediction equations with chemical analysis appears to be the most promising approach for rapid, inexpensive, and accurate estimation of GE, DE, ME, and NE content of DDGS.

Energy prediction equations have been developed for barley (Fairbairn et al., 1999), meat and bone meal (Adedokun and Adeola, 2005; Olukosi and Adeola, 2009), wheat DDGS (Cozannet et al., 2010), and complete diets (Just et al., 1984; Noblet and Perez, 1993) and are likely accurate for the nutrient matrices from which they were derived, but are not likely precise nor accurate for estimating DE and ME for maize DDGS. Pedersen et al. (2007) developed prediction equations specifically for maize DDGS while equations from Anderson et al. (2012) were developed using a wide variety of maize co–products, including DDGS, but these have not been validated. Many of the DDGS DE and ME prediction equations from Pedersen et al. (2007) and Anderson et al. (2012) for DDGS require a GE estimate as one of the predictive factors. Gross energy (GE) determinations of feedstuffs are relatively inexpensive, accurate, and the methodology is well accepted, but not commonly conducted by commercial laboratories. Prediction equations for GE based on chemical composition of a feed ingredient or diets are available (Ewan, 1989; INRA, 2008), but their precision and accuracy in predicting GE among sources of DDGS needs validation. Therefore, the objectives of this study were to compare GE, DE, and ME prediction equations from various published sources for their accuracy and precision in predicting experimentally determined GE and *in vivo* DE and ME estimates for maize DDGS using data sets from other studies, in an across study validation.

2. Materials and methods

All of the maize DDGS data used in this study were obtained from the previous studies which had approved Animal Care and Use Protocols.

2.1. Sources of nutrient and energy composition

A database of 45 maize DDGS samples with comprehensive analyzed GE and chemical composition data, as well as *in vivo* DE or ME values were obtained from Stein et al. (2006), Pedersen et al. (2007), Stein et al. (2009), Anderson et al. (2012), and Kerr et al. (2013). All data presented are on a DM basis. Some data sets did not included values for specific composition measures (*e.g.* crude fiber, particle size, bulk density, ME), and as a result, these data were omitted from the evaluation rather than calculating estimated values despite their potential impact on model selection (Maroto-Molina et al., 2013). The deletion method was utilized because of the relatively small size of the data set and the difficulty of predicting chemical composition values in maize DDGS.

2.2. Calculated GE, DE and ME estimates

Prediction equations for GE (5 equations), DE (20 equations), and ME (19 equations) from published studies were used to calculate the concentration of GE, DE, and ME among 45 maize DDGS sources and compare with experimentally determined