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Nutrient composition, digestibility and energy value of distillers dried grains with solubles and condensed distillers solubles fed to growing pigs and evaluation of prediction methods

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This study had two objectives: (1) to determine the nutritional value of 13 batches of distillers dried grains with solubles (DDGS) and 5 batches of condensed distillers solubles (CDS), and (2) to evaluate the prediction of the nutritional value of DDGS by using either mean values per DDGS type or lab measurements as potential predictors of nutrient content. The DDGS batches were derived from either wheat ($n = 3$), corn ($n = 3$) or a mixture of grains ($n = 7$). The CDS batches were mainly wheat-based. The batches were collected from 11 European ethanol plants. Six barrows per dietary treatment were placed in individual metabolism cages and fed either a basic diet or a diet in which 30% of the basic diet was replaced by DDGS or CDS. Chromium oxide (4 g/kg) was included in the feed as an external marker. Fecal and ileal samples were collected and the apparent fecal digestibility (AFD) and apparent ileal digestibility (AID) of the diets were calculated using the indicator method. Consequently, AFD and AID values for DDGS and CDS were calculated through difference. Nutrient components, color measurements and *in vitro* protein values were evaluated as variables to predict the AFD, AID and net energy (NE) value of DDGS by means of multiple regression analysis. The DDGS corn samples had a higher gross energy and crude fat (CFAT) content ($P < 0.001$) and were more red (a^*; $P = 0.002$) and yellow (b^*; $P = 0.003$) than the DDGS wheat and DDGS mix samples. The NE value was also higher for DDGS corn ($P < 0.001$). Large variation existed between DDGS samples in amino acid digestibility (particularly of Lysine), even when DDGS was produced from the same type of grain. Hence, the use of mean values for each DDGS type did not result in a good estimation of the nutritional value. The NE value of DDGS could be predicted by the color parameter b^* ($R^2 = 71.1$; $P < 0.001$) and CFAT ($R^2 = 76.2$; $P < 0.001$), or by combining CFAT and acid detergent fiber ($R^2 = 94.0$; $P < 0.001$). No good prediction equations could be established for the amino acid digestibility. The CDS samples also showed high variation in nutrient and amino acid composition and digestibility, which limits their usability in practical pig feed formulation.

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Abbreviations: AA, amino acid; ADFom, acid detergent fiber expressed exclusive of residual ash; ADICP, acid detergent insoluble crude protein; AFD, apparent fecal digestibility; AID, apparent ileal digestibility; aNDFom, neutral detergent fiber assayed with a heat stable amylase and expressed exclusive of residual ash; BPSCP, solubility of crude protein in borate-phosphate buffer; CDS, condensed distillers solubles; CF, crude fiber; CFAT, crude fat; CP, crude protein; CV, coefficient of variation; DDGS, distillers dried grains with solubles; DM, dry matter; GE, gross energy; GOS, glucose-oligosaccharides; NE, net energy; NSP, non-starch polysaccharides; OM, organic matter; PDIKOH, protein dispersibility index in potassium hydroxide; PHSCP, solubility of crude protein in a solution of pepsin in hydrochloric acid; SGd1, SGd6, SGd24, crude protein degradability with *Streptomyces griseus* after 1, 6 and 24 h of incubation; WSCP, water solubility of crude protein.

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1. Introduction

Distillers dried grains with solubles (DDGS) and condensed distillers solubles (CDS) are byproducts of the bio-ethanol industry, formed after fermenting the starch from grains. Interest in the use of DDGS and CDS for pig feeding has been steadily increasing. Including these byproducts in the pig diet results in a more sustainable way of feeding, not only by upgrading waste products, but also by saving on soybean meal import and by using ingredients that are not in competition with the human diet. To accurately formulate pig diets, reliable values for nutrient composition and digestibility of DDGS and CDS are essential. Until now, research has mainly focused on the nutritional value of DDGS derived from corn, which is the grain used in most bio-ethanol plants in the US (Stein and Shurson, 2009). Wheat and mixtures of grains are also used to produce bio-ethanol, but less is known about their nutritional value in pig diets. Furthermore, very little research has been reported on the nutritional value of CDS in pig diets. In addition, the nutritional value of the byproducts can vary considerably depending on the processing plant, the production process, and the grain type used (Pahm et al., 2008b; Urriola et al., 2009, 2010). Due to this variation, the use of mean values can result in an inaccurate formulation of pig diets, which could lead to suboptimal performance and/or reduced cost effectiveness. It would therefore be valuable to estimate the nutritional value of each batch of DDGS using simple lab measurements. The first objective of this study was to determine the nutritional value of different batches of DDGS (derived from either wheat, corn or a mixture of grains) and CDS sampled from different production plants. The second objective was to evaluate the prediction of the nutritional value of DDGS using either mean values per DDGS type (according to the grain type used) or simple and fast lab measurements as potential predictors, in order to more accurately include them in pig diets.

2. Materials and methods

All trials and feed evaluation procedures were conducted between 2010 and 2012 at the Institute for Agricultural and Fisheries Research (ILVO, Melle, Belgium). The national and institutional guidelines for the care and experimental use of animals were adhered to. All experimental procedures involving animals were approved by the Ethical Committee of ILVO (approval number 2010/123).

2.1. Experimental procedures

Thirteen batches of DDGS and five batches of CDS were collected from 11 European ethanol plants (Table 1). The DDGS batches were derived from the fermentation of 100% wheat (DDGS wheat; 3 batches), 100% corn (DDGS corn; 3 batches), or a mixture of grains (DDGS mix; 7 batches). The nutritional value of the 13 DDGS batches was determined in three digestibility trials, conducted as described by CVB (2005, 2009). Each digestibility trial consisted of three series, with three weeks between the start date of the series. In each of the series, two barrows (Ra-Se Genetics Hybrid sow × Piétrain boar) per dietary treatment were used, resulting in six animals per dietary treatment. Barrows were fed either a basic diet (Table 2) or a diet in which 30% of the basic diet was replaced by one of the 13 DDGS batches. Two basic diets (A and B) were used, as the supply of ingredients varied during the time span of the three trials. Chromium oxide (4 g/kg) was included in all basic diets as an external marker. In digestibility trial 1, basic diet A was compared with diets containing 70% basic diet A and 30% DDGS 1, 2, 3, 4, or 5. In digestibility trial 2, basic diet A was compared with diets containing 70% basic diet A and 30% DDGS 6, 7, 8, 9, or 10, and in digestibility trial 3, basic diet B was compared with diets containing 70% basic diet B and 30% DDGS 11, 12, or 13.

Table 1
Starting material and origin of the 13 batches of distillers dried grains with solubles (DDGS) and 5 batches of condensed distillers solubles (CDS).

Source (commercial name)	Starting material	Company, Country
DDGS 1	60% wheat, 30% sorghum, 10% triticale	Alco Bio Fuel, Belgium
DDGS 2	70% wheat, 20% corn, 10% triticale	Alco Bio Fuel, Belgium
DDGS 3	55% wheat, 20% corn, 20% barley, 5% triticale + sugar syrup	Crop Energies, Germany
DDGS 4	100% wheat	Tereos, France
DDGS 5	55% wheat, 20% corn, 20% barley, 5% triticale + sugar syrup	Crop Energies, Germany
DDGS 6	65% wheat, 25% corn, 10% triticale	Alco Bio Fuel, Belgium
DDGS 7	100% corn	Pannonia Ethanol, Hungary
DDGS 8	100% corn	Abengoa Bioenergy, Spain
DDGS 9	50% wheat, 50% corn	Agrana, Austria
DDGS 10	100% wheat	Abengoa Bioenergy, The Netherlands
DDGS 11	100% wheat	Tereos, France
DDGS 12	80% wheat, 20% corn	Alco Bio Fuel, Belgium
DDGS 13	100% corn	Abengoa Bioenergy, The Netherlands
CDS 1 (Protisyr)	Mainly wheat-based, with other grains added	Alco Bio Fuel, Belgium
CDS 2 (Alcomix)	100% wheat-based	Syral, Belgium
CDS 3 (Protiwanze)	Mainly wheat-based, with some sugar beet syrup added	Biowanze, Belgium
CDS 4 (Grainpro)	Mixture of grains	Verbio, Germany
CDS 5 (Sastapro)	100% wheat-based	Cargill, The Netherlands

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