Determination and prediction of digestible and metabolizable energy concentrations in byproduct feed ingredients fed to growing pigs

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Title of the manuscript: Determination and prediction of digestible and metabolizable energy concentrations in byproduct feed ingredients fed to growing pigs.

ABSTRACT

Objective: An experiment was conducted to determine digestible energy (DE) and metabolizable energy (ME) of different byproduct feed ingredients fed to growing pigs, and to generate prediction equations for the DE and ME in feed ingredients.

Methods: Twelve barrows with an initial mean body weight of 31.8 kg were individually housed in metabolism crates that were equipped with a feeder and a nipple drinker. A 12 × 10 incomplete Latin square design was employed with 12 dietary treatments, 10 periods, and 12 animals. A basal diet was prepared to mainly contain the corn and soybean meal (SBM). Eleven additional diets were formulated to contain 30% of each test ingredient. All diets contained the same proportion of corn:soybean meal ratio at 4.14:1. The difference procedure was used to calculate the DE and ME in experimental ingredients. The *in vitro* dry matter disappearance for each test ingredient was determined.

Results: The DE and ME values in the SBM sources were greater ($p < 0.05$) than those in other ingredients except high-protein distillers dried grains. However, DE and ME values in tapioca distillers dried grains (TDDG) were the lowest ($p < 0.05$). The most suitable regression equations for the DE and ME concentrations (kcal/kg) in the test ingredients were: DE = 5,528 – (156 × ash) – (32.4 × neutral detergent fiber, NDF) with root mean square error = 232, $R^2 = 0.958$, and $p < 0.001$; ME = 5,243 – (153 × ash) – (30.7 × NDF) with root mean square error = 277, $R^2 = 0.936$, and $p < 0.001$. All independent variables are in %.

Conclusion: The energy concentrations were greater in the SBM sources and were the least in the TDDG. The ash and NDF concentrations can be used to estimate the energy concentrations in the byproducts from oil-extraction and distillation processes.

Keywords: Feedstuff; Prediction Models; Protein Supplements; Swine

INTRODUCTION

Oilseed meals are used primarily as a protein source [1], but play a role as an energy source in swine diets. Soybean meal (SBM) is one of the most commonly used oilseed meals in the swine diet. However, alternative feed ingredients, which can replace the SBM in the swine diet, are needed as the price of SBM has been continuously increasing. An accurate determination of energy concentrations of the ingredients is important to use relatively cheaper feed ingredients in the swine diet. However, studies about energy concentrations in various protein sources for pigs are limited [2-4].

The digestible (DE) and metabolizable energy (ME) concentrations of the feed ingredients are ideally determined via animal experiment, which is the most accurate method. However, because animal experiments are time-consuming and costly, equations that can predict the energy concentrations of feed ingredients can be used as an alternative method [2]. Additionally, the *in vitro* dry matter disappearance (IVDMD) of ingredients can also be useful for predicting energy concentration in ingredients for swine diets [3]. However, the use of equations can be limited to the range of nutrient compositions in the ingredients that were used to generate the equations [4, 5]. We hypothesized that energy concentrations in the feed ingredients with large range of chemical composition can be estimated using prediction equations with IVDMD as an independent variable. The objectives were to determine the DE and ME of 9 byproducts from the oil-extraction processes and 2 byproducts from distillation process fed to growing pigs and to generate equations that predict the DE and ME of byproduct feed ingredients.

MATERIALS AND METHODS

Animal care

The experimental procedure was approved by the Institutional Animal Care and Use Committee at Konkuk University (KU12062).

Diet and feeding

Twelve barrows with a mean initial body weight of 31.8 kg (standard deviation = 2.7) were used to determine the DE and ME concentrations of sesame meal produced in Korea, two sources of dehulled.

Statistical analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC, USA). Outliers (difference from median > 2 × interquartile range) were removed from the dataset for the final statistical analysis. The model included dietary treatment as a fixed variable and animal and period as random variables. Least squares means of each treatment were calculated, and the difference in means was tested using the PDIFF option with the Tukey's adjustment. The experimental unit was a pig, and the statistical significance was set at p-value < 0.05.

Correlation coefficients (r) between nutrient compositions and energy concentrations were determined using the CORR procedure of SAS. A Multiple linear regression analysis was conducted by the REG procedure of SAS in order to generate regression equations for DE and ME of the ingredients based on nutrient contents and IVDMD of the ingredients as independent variables. The most representative prediction equation was selected based on the STEPWISE procedure of SAS. A prediction equation for the DE:GE ratio was developed using the REG procedure of SAS with IVDMD as an independent variable.

RESULTS

Nutrient composition

Values for the GE of the ingredients ranged from 3,875 to 4,924 kcal/kg on an as-is basis (Table 1). The CP concentration of the ingredients ranged from 15.3 to 50.0%, and the NDF concentration ranged from 7.35 to 61.4% on an as-is basis.

Digestible and metabolizable energy

Feed intake during the collection period was greater ($p < 0.05$) for the basal, palm kernel expellers, and TDDG diets than that for the HPDDG and canola meal diets (Table 3). Energy digestibility of the basal and SBM-containing diets was greater ($p < 0.05$) than that of the other diets. The DE concentration in the SBM-KD1 diet was greater ($p < 0.05$) than that in the other experimental diets except the SBM-KD2 diet. The ME concentration in the SBM-KD1 diet was also greater ($p < 0.05$) than that in the other diets except the SBM-KD2 and SBM-I diets. The DE and ME in the TDDG diet were the lowest ($p < 0.05$).

DISCUSSION

Most nutrient compositions of ingredients were within range of previous studies [2, 4]. In this study, the lowest DE and ME values in the TDDG diet can be explained mainly by the largest fecal energy output in the pigs fed the TDDG diet. Although GE intake by pigs fed the TDDG diet was not different from most of the other experimental diets, the dry feces output of pigs fed the TDDG diet was the greatest among the experimental diets. The large quantity of fecal output may be caused by the high fiber concentration in the TDDG, which increases passage rate of digesta and lowers time for digestion and absorption of nutrients [16, 17]. Therefore, fecal GE output of pigs fed the TDDG diet was greater than that of pigs fed the other experimental diets except the PM diet despite being the lowest GE in dry feces. For these reasons, the DE in the TDDG diet may be less than that in the other experimental diets. The TDDG diet had the lowest ME value, which may have occurred because the TDDG diet had the lowest DE and the urinary GE output of pigs fed the TDDG diet was not different from most of the other experimental diets.

The DE and ME in the sesame meal were less than values in the literature [2, 4], which appear to be due to the greater NDF and ADF concentrations in the sesame meal used in this experiment than the fiber concentrations in the literature [2, 4]. Dietary fiber negatively affects the energy utilization [16, 18]. Thus, although the GE of sesame meal in this experiment was similar to values in the literature, the DE:GE ratio was less in this experiment than that reported in the literature [2, 4].

The GE, DE, and ME in the two sources of SBM-KD were within the range of previous values [2, 4, 19, 20]. The DE, ME, and DE:GE ratio in the SBM-I were similar to the previous values [2, 4].

The DE and ME in the HPDDG were less than previous values [4, 11, 21, 22], but were similar with a previous value [23]. The GE in the HPDDG used in this experiment was within the range of previous values, but the DE:GE ratio was less than that in previous studies, resulting in a lower DE and ME in the HPDDG used in this experiment. We cannot clearly explain why energy digestibility was less compared with previous studies; however, it may be a result of unknown factors, such as region, variety, manufacturing process, or the presence of anti-nutritional factors.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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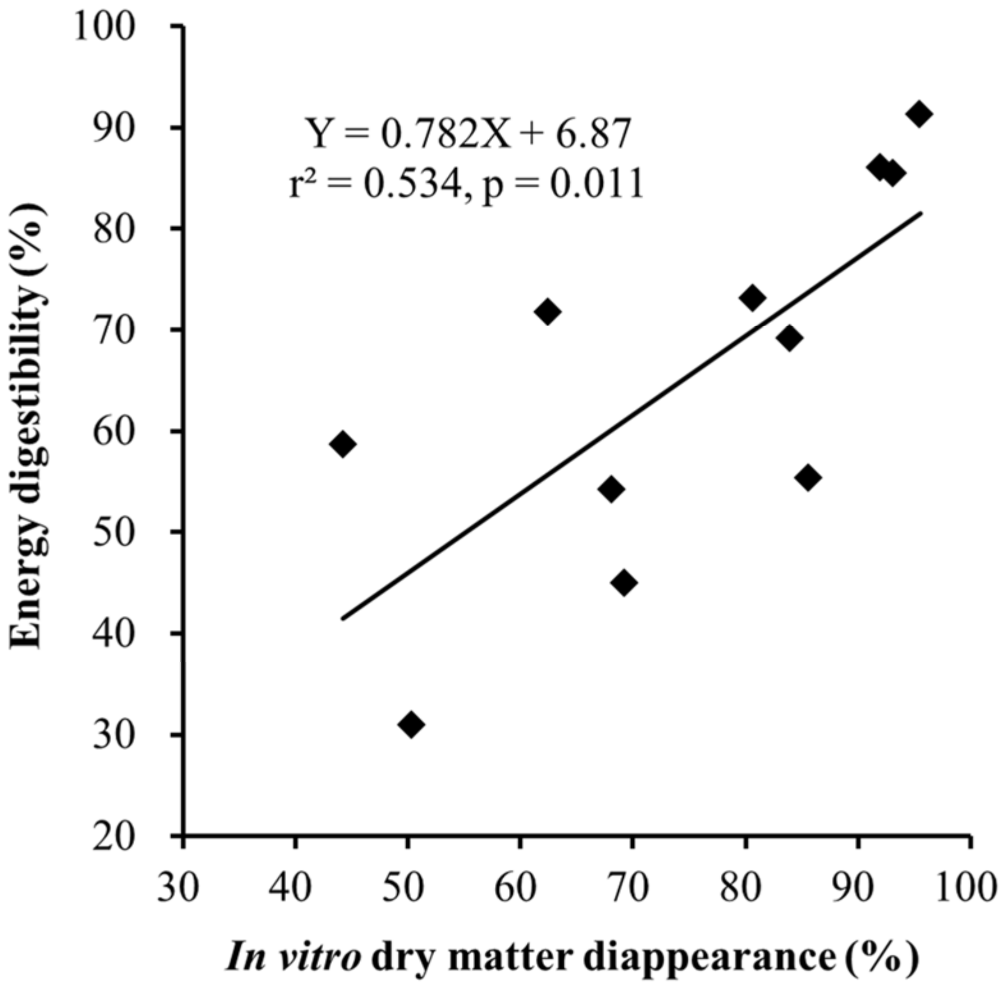
Table 1. Energy and nutrient composition of experimental ingredients[1)] (as-is basis)

Item	Ingredient										
	Sesame meal	Soybean meal-dehulled-Korea 1	Soybean meal-dehulled-Korea 2	Soybean meal-India	High-protein distillers dried grains	Perilla meal	Canola meal	Copra meal	Corn germ meal	Palm kernel expellers	Tapioca distillers dried grains
Dry matter (%)	97.0	90.2	90.2	90.1	91.5	90.3	91.4	90.2	94.1	89.6	93.3
Gross energy (kcal/kg)	4,688	4,299	4,332	4,221	4,924	4,240	4,235	4,095	4,699	4,407	3,875
Crude protein (%)	50.0	47.1	47.4	39.6	38.0	43.2	37.5	21.8	21.4	15.3	18.4
Ether extract (%)	6.05	2.46	0.74	0.84	5.24	1.08	1.85	1.76	8.27	6.97	3.12
Crude fiber (%)	9.3	4.6	5.7	5.1	7.3	18.8	9.6	13.6	10.4	17.0	22.7
Ash (%)	11.0	6.2	6.3	6.3	1.4	9.0	9.5	6.7	2.4	4.7	14.9
Neutral detergent fiber (%)	28.1	7.4	8.7	9.6	39.0	44.7	24.7	55.1	43.4	61.4	56.2
Acid detergent fiber (%)	17.5	7.2	9.1	8.2	20.1	25.9	18.1	32.2	14.6	36.8	47.3
Calcium (%)	2.15	0.64	0.67	0.70	0.13	1.71	1.01	0.62	0.13	0.43	0.77
Phosphorus (%)	1.32	0.64	0.62	0.53	0.25	1.25	0.95	0.54	0.53	0.55	0.22

[1)] Data are the mean of duplicate analyses of each ingredient.



Figrue 1. Relationship between energy digestibility and *in vitro* dry matter disappearance for growing pigs. An equation for energy digestibility….