RESEARCHREPORT

ANIMAL SCIENCE

Title: Development of a Practical Net Energy System (productive energy) that allows for the Capture of Ingredient Cost Savings Expected from NE systems with Predictable Performance
- **NPB #11-**127 revised

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Industry summary:

The purpose of the current study was to determine if the NE system proposed in the NRC, 2012 can be an effective replacement for the ME system. The overall plan was to evaluate the NE system in different situations when diverse rations are formulated. We conducted two experiments: In the first one, we placed 2,054 pigs in a commercial setting from 40 kg to market weight (130kg). Pigs were tested for growth and carcass data. Diets included a simple corn soy diet, diets with corn DDGS, and diets with DDGS+Corn Germ Meal (CGm). These diets were formulated to a constant NE content or a constant ME content. The second experiment, which looked at how the pig utilizes nutrient in the diet involved collection fecal and urine samples from 40 gilts during the growing (39-70kg BW) and the finishing period (70-110kg BW). Digestibility of gross energy (GE) and nitrogen utilization were measured in diets with an increasing amount of each of corn DDGS, CGm, and wheat middlings (0, 12, or 12% inclusion in combination for a total of 0, 18 or 36% co-products). Diets with co-products were fixed to a constant NE content relative to the corn-soy diet by adding fat at 1.6 or 3.3% respectively, or were allowed to decline (no fat added). Results showed that the addition of co-products did not have a negative impact in growth performance when diets are formulated to a constant ME or NE. However some carcass characteristics were impaired when co-products were added at 40%. This seems to have the least impact on the constant NE compared to the constant ME diets. Digestibility of GE decreased when co products were added to the diet, and the inclusion of fat (1.6 and 3.3%) did not help to improve digestibility. Performance in pigs declined with the addition of co-products to the diet using either energy system. However, the decline was smallest when the diets were formulated using the NE system. The effectiveness of any energy system will be dependent on our ability to generate accurate energy values on ingredients and on diets. While the NE system showed advantages over the ME system, neither system was shown to be completely satisfactory in predicting animal performance.

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Implications

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- Performance in pigs declined with the addition of co-products to the diet using either energy system. However, the decline was smallest when the diets were formulated using the NE system.
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- The effectiveness of any energy system will be dependent on our ability to generate accurate energy values on ingredients and diets. While we have more experience with the ME system, and thus more confidence in our ME ingredient values, this does not translate into more predictable animal performance when the ME system is used side-by-side with the NE system.
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- While the NE system showed advantages over the ME system, neither system was shown to be satisfactory in predicting animal performance. Therefore, it appears that while NE may be slightly superior to ME, a system of formulating diets better than NE is required to achieve our ultimate objective of accurately predicting animal performance based on diet composition.

Keywords:

Metabolizable energy, Net energy, growing-finishing pigs.

Scientific abstract:

The net energy (NE) system describes the useful energy for growth better than the metabolizable energy (ME) system. Therefore NE system should demonstrate a more reliable animal response when a diverse set of ingredients are used, but this fact needs to be demonstrated in practice. Two experiments were conducted. The first experiment compare growth performance, carcass characteristics and financial returns in diets with a cumulative addition of co-products and formulated with the ME and the ME systems. 944 gilts and 1,110 castrates (BW=40.8±0.5 kg) were allotted to separate pens and assigned to one of 5 different feeding programs according to a randomized complete block design. A simple corn-soybean meal control (CTL1) served as the basis to establish ME and NE specifications for both programs. The following two treatments included DDGS (CTL1+DDGS, ME) and (CTL1+DDGS, NE), the last set of two diets contained both DDGS and corn germ meal (CTL1+DDGS+CGm, ME) and (CTL1+DDGS+CGm, NE). Fat varied to achieve either ME or NE targets. Pigs were harvested at a mean BW of 130.3+4.0 kg., growth performance, feed efficiency and carcass data were collected. Data generated were analyzed using the Mixed procedure of SAS. No differences were observed among treatments for whole-body ADG (P=0.18), ADFI (P=0.12) or G:F ratio (P=0.18). Total carcass gain was different among treatment programs (P<0.03) with the greatest difference between CTL1 (66.7 kg) and CTL1+DDGS+CGm ME and NE treatments (64.6 kg). Although not statistically different (P > 0.05), carcass gain tended to be greater for the NE vs. ME DDGS (66.4 vs. 65.1 kg) and for CTL1+DDGS+CGm programs (65.0 vs. 64.3 kg). Carcass G:F ratio behaved similarly for CTL1, CTL+DDGS ME-NE and CTLl+DDGS+CGm ME-NE respectively: 0.258, 0.254, 0.257 and 0.256, 0.259 (SEM 0.001, P=0.133). FOM lean percent was similar among treatments (P=0.43).In the second experiment apparent total tract digestibility of GE and Nitrogen utilization was calculated in diets with a constant or declining NE content. 40 gilts (BW=38.5±0.4 kg) were randomly assigned to 5 treatments. A control corn-soy based control diet (CTL2), a diet similar to the CTL2 but containing 6% each of corn DDGS, corn germ meal and wheat middlings with NE constant relative to CTL2 (18NE-CON), or allowed to decline (18NE-DEC), or similar diets but with 12% each of the same co-products and NE held constant (36NE-CON) or allowed to decline (36NE-DEC). Constant NE in the CON treatments was achieved by adding fat. Diets were formulated for both growing (40 to 70 kg) and finishing (70 to 110 kg) periods. For each period urine and feces were collected. Data were analyzed using the

MIXED procedure of SAS. In growing period, ATTD of GE decreased in all co-product diets compared to the CTL (85.3 vs. 79.9% for average of 18NE and 36NE; $P<0.01$). There were no differences between NE-CON and NE-DEC (80.5 vs. 79.3%; $P>0.05$). In finishing period, ATTD of GE also decreased in co-product diets compared to the CTL2 (87.1 vs. 82.6% for average of 18NE and 36NE; $P<0.01$). Unlike growing period, the 18NE diets had a higher ATTD of GE compared to 36NE diets ($P<0.05$). There were no differences between NE-CON and NE-DEC (82.7 vs. 82.5%; $P>0.05$). Nitrogen retention declined on all co-product diets in the growing period (40.6 vs. 35.5% for average of 18NE and 36NE; $P=0.01$) and tended to decline in the finishing period (35.0 vs. 30.2% for average of 18NE and 36NE; $P=0.08$). There were no differences between CON and DEC diets at 18NE or 36NE ($P>0.05$).

Introduction:

The adoption of more complex formulations and the growing need to lower feed costs in the U.S. swine rations has given rise to questions about the most effective energy system to use. The NE system has been advanced by some due to its consideration of the biochemical cost of converting dietary energy into forms that are available for metabolic uses. Actually efficiencies (k, %) of ME for NE varies according to the chemical characteristics of the feed 60, 90, 82 and 58%, for digestible crude protein, fat, starch, sugar and fiber, respectively (Noblet, 1994). As a result the ME values are proportionally higher for ingredients with high concentration of protein or fiber and proportionally lower for ingredients with a high level of starch or fat than to the correspondent NE values. The NE system has been successfully used in Europe where diets are more diverse than in North America. The question about adopting the NE system has become relevant mainly because U.S. producers have limited or no experience with it, prompting the necessity of its evaluation

A practical way to evaluate the NE system is to provide constant response independently of the number of ingredients (Simple vs. complex diets) when a constant energy value is formulated. In this purpose feed efficiency may be a simple response measurement that may provide evidence of how well the energy is utilized.

Objectives

Main:

- To validate the concept of productive energy (PE), an energy system based on the INRA (French) net energy system but “corrected” for application in an American context

Specific objectives:

1) To determine the degree of error that occurs when applying the NRC 2012 values (INRA based) to diets formulated and fed under good commercial conditions
2) To determine if adjustment of the NRC 2012 NE values can be undertaken in growth studies using feed conversion as the as the primary and most accurate outcome criterion.

Materials & Methods:

Experiment 1

Title: *Development of a Practical Net Energy System (productive energy) that allows for the Capture of Ingredient Cost Savings Expected from NE systems with Predictable Performance*

Objectives:

- To determine the degree of error that occurs when applying the NRC 2012 NE values to diets formulated and fed under typical commercial conditions in the

- To determine if adjustment of the NRC 2012 NE values can be undertaken in growth studies using feed conversion as the as the primary and most accurate outcome criterion.

Materials and methods:

The protocol for this experiment was approved by the Institutional Animal Care and Use Committee of Iowa State University. U.S. 6-12-7396-S

Animals, Housing and Experimental Design:

This experiment was conducted at Hanor's Illinois Research finisher facility; two barns equipped with the Howeema feed delivery system were utilized. 2054 pigs (944 gilts and 1110 barrows Camborough derivative x TR4 sire, initial BW 40.8±0.5 kg) were placed in pens (21 to 23 pigs per pen). Gilts and barrows were placed separately, and divided in 10 different average pen weight blocks. During the experimental period, pigs had free access to feed and water.

Throughout the 84 d growth trial, strict protocols were in place for individual pig medication and removal. Each pen and the feed present in the feeders were weighed at days 0, 21, 42, 63 and 84. After day 84, the animals were marketed in 4 cuts at Triumph Foods' packing plant (average body weight 130.3+0.9 kg) where carcass characteristics were measured.

Dietary treatments:

A simple corn-soybean meal control (CTL1) served as the basis to establish the control ME and NE levels. The next two treatments included DDGS and were formulated with to an ME value equal to that of the control diet or to an NE level equal to that of the control (CTL1+DDGS, ME) and (CTL1+DDGS, NE). The last set of two treatments contained both DDGS and CGm and were also formulated with either constant ME or NE content (CTL1+DDGS+CGm, ME) and (CTl1+DDGS+CGm, NE). Fat was varied to achieve either constant ME or NE levels as required. All diets were delivered in meal form.

Each feeding program involved three dietary phases; barrows and gilts received the same diets and switched dietary phases using the PIC–Hanor Lysine curve (PIC 2012) that is based on body weight.

Data and Samples:

Prior to formulating the diets, samples of corn, soybean meal, corn distillers drains and corn germ meal were analyzed at the Agricultural Experiment Station Chemical Laboratories (University of Missouri-Columbia, MO) or the Iowa State University Monogastric Nutrition Laboratory (Iowa State University-Ames, IA)

Body weight and feed disappearance were computed on a pen basis in order to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (G:F). Pigs were harvested at Triumph Foods where carcass data were collected.

Loin depth and back fat thickness were measured using a fat-o-meter (FOM). Measurements were taken between the 3-4th last rib. Lean percentage was calculated using the Triumph Foods prediction equation.

Statistical Analysis:

Data were analyzed as a randomized block design with 19 replicates per treatment, and analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Pen was the experimental unit. Differences were considered statistically significant with $P < 0.05$ and trends with $P < 0.10$.

Experiment 2

Title: *Evaluation of the net energy system in comparison with the metabolizable energy system when alternative ingredients and fat are added.*

Objectives:

The overall objective of this experiment was to compare diets that contained an increasing level of distiller grains, corn germ, and wheat middlings when the diets are formulated to a constant or declining NE value

Materials and methods:

The procedures followed in this experiment were approved by the Institutional Animal Care and Use Committee of Iowa State University under number: 12-12-7478-S

Animals Housing and Experimental Design:

This experiment was conducted at the Swine Nutrition Farm in Iowa State University. 40 gilts (initial BW 38.5±0.4 kg) of the progeny of PIC 337 sires x C22 orC29 dams (Pig Improvement Company, Hendersonville, TN) were randomly assigned to one of the five treatments for a period of 69 days. The experiment was divided into two periods: A growing period from 39 to 70 kg, and a finishing period from 70 to 110 kg. Within each period, pigs were placed in individual pens for 21 days. Each pen included a partially slatted concrete floor, an automatic self-feeder and a cup drinker. At day 21 of each period, pigs were weighed and transferred to metabolism crates for 13 days. Each crate had a fully slatted floor, stainless steel feeder, and a nipple drinker. Fecal and urine samples could be taken by placing a metal tray, a screen and a plastic jug under the crate. Pigs had a three day adaptation period, then total urine and fecal samples were collected during days 4-6 and 11-13; at the end of the metabolism period, pigs were weighed. Animals had access to feed and water ad libitum.

Dietary treatments:

Diets were formulated for the growing and the finishing period using the following specifications:

- Control diet containing only corn and soybean meal (CTL2)
- Control diet plus middle level (6% each) of each of 3 alternative ingredients (corn germ meal, 9^{+}% fat DDGS and wheat middlings) with the NE of the diet formulated to be the same as diet #1 by using fat (18NE-CON).
- Same as diet #2 except no fat is added and NE is allowed to float downward (18NE-DEC).
- Control diet plus higher level (12% each) of each of 3 alternative ingredients (corn germ meal, higher fiber DDGS and wheat middlings) with the NE of the diet formulated to be the same as diet #1 by using fat (36NE-CON).
- Same as diet #4 except no fat is added and NE is allowed to float downward (36NE-DEC).

Amino acids, phosphorous and calcium level were set at 6% above NRC 2012 requirements for both growing (40 to 70 kg) and finishing (70 to 110 kg) gilts. Titanium dioxide was added at 0.4%, salt at 0.5%, vitamin premix 0.16 and mineral premix to 0.15 for all the diets. Diets 1 through 5 had a constant level of amino acids.

Data and samples:

Prior to formulating the diets, samples of corn, soybean meal, corn distillers grains, corn germ meal and wheat middlings were analyzed at the Agricultural Experiment Station Chemical Laboratories (University of Missouri-Columbia, MO) and at the Iowa State Monogastric Nutrition Laboratory (Iowa State University-Ames, IA)

Feed samples were taken at the feed mill at the time of mixing and then again during the feeding period. Urine and feces were collected twice a day at 8:00 and 16:00 h for 72 h. Feces were collected in a pre-labeled plastic bag, while all the urine was collected in a plastic jug (with ≈20ml of 6N hydrochloric acid in order to minimize nitrogen losses). For urine collections total weight of the urine was recorded, then it was mixed prior to sampling (in order to have a homogenized urine subsample), pH was measured using a pH paper indicator to ensure the collection pH was sufficiently low to minimize N losses, urine was filtered and subsampled. Finally 10% of the total urine weight was kept for Nitrogen analysis.

Urine and fecal samples were immediately frozen at -20°C after collections and were kept at this temperature until chemical assays.

Statistical analysis:

Pigs, pens and crates were randomly assigned to treatment. Data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Pig was the experimental unit for all analyses. Differences were considered statistically significant with $P < 0.05$ and trends with $P < 0.10$.

Net energy calculation:

To estimate NE for both experiments, ingredients were analyzed for dry matter, ash, starch (ST), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and ether extract (EE), values of these assays were used in the following equation (NRC 2012 Eq1-7):

$$NE = 0.726xME + 1.33xEE + 0.39xST - 0.62xCP - 0.83xADF$$

Energy in Kcal/kg, Nutrient components are in gr/kg.

ME values utilized to feed this equation were mainly NRC, 2012 values. NE values generated from this equation as well as the nutrient profile were analyzed for each ingredient and compared with the values of ingredient composition published in the NRC, 2012 and the values developed and used in practice by The Hanor Company.

Results:

Objective: *To validate the concept of productive energy (PE), an energy system based on the INRA (French) net energy system but "corrected" for application in an American context*

Both experiments were designed to meet this objective. To validate the NE system, we evaluated key aspects such as growth performance and carcass characteristics, calculation of NE based in ATTD determination and nitrogen utilization.

Calculation of the NE content of ingredients after chemical analysis:

Most NE values calculated in the equation (corn, corn DDGS, wheat middlings, and soybean oil) were in agreement to the NRC, 2012, while values for CWG, corn germ meal (in the first experiment) and the soybean meal were re-considered and replaced with empirical values developed by The Hanor Company.

Net energy evaluation: Growth performance and carcass characteristics:

The first experiment showed that in a commercial setting, whole body growth performance (ADG, $P=0.18$, ADFI, $P=0.12$ and G:F ratio, $P=0.18$) were not affected when either the ME or the NE system was utilized to formulate constant energy diets. Mortality was not related to energy system or co-product addition ($P=0.59$). At the carcass level, total carcass gain was statistically different among treatment programs ($P=0.03$) with the greatest difference between CTL1 (66.7 kg) and CTL1+DDGS+CGm, ME and NE treatments (64.6 kg). Although not statistically different ($P > 0.05$), carcass gain tended to be greater for the NE vs. ME program for CTL1+DDGS diets (66.4 vs. 65.1 kg) and for CTL1+DDGS+CGm (65.0 vs. 64.3 kg). Carcass G:F ratio behaved similarly for CTL1, CTL+DDGS ME-NE and CTLl+DDGS+CGm ME-NE respectively: 0.258, 0.254, 0.257 and 0.256, 0.259 (SEM 0.001, $P=0.133$). FOM lean percent was similar among treatments ($P=0.43$).

Net energy evaluation: Calculation of NE after ATTD determination, and nitrogen utilization:

In the growing period, ATTD of GE decreased in all co-product diets compared to the CTL2 (85.3 vs. 79.9% for average of 18NE and 36NE; $P<0.01$). There were no differences between NE-CON and NE-DEC (80.5 vs. 79.3%; $P>0.05$). In the finishing period, ATTD of GE also decreased in the co-product diets compared to the CTL (87.1 vs. 82.6% for average of 18NE and 36NE; $P<0.01$). Unlike in the growing period, the 18NE diets had a higher ATTD of GE compared to 36NE diets ($P<0.05$). There were no differences between NE-CON and NE-DEC (82.7 vs. 82.5%; $P>0.05$)

The NE content was confirmed to be constant for the NE-CON diets ($P>0.10$), despite a lower digestibility coefficient for these diets.

Nitrogen retention declined on all co-product diets in the growing period (40.6 vs. 35.5% for average of 18NE and 36NE; $P=0.01$) and tended to decline in the finishing period (35.0 vs. 30.2% for average of 18NE and 36NE; P=0.08). There were no differences between CON and DEC diets at 18NE or 36NE ($P>0.05$).

Objective: *To determine the error when applying the NRC 2012 NE values to diets formulated and fed under good commercial conditions*

Both experiments were designed to meet this goal, Results showed that at the formulation level, as well as after calculating NE and ME (using a equation based in DE), the NE: ME ratio remained similar for constant, and even for declining NE diets with an increasing amount of co-products.

ATTD improved from growing to finishing pigs; therefore the NE values in finishing pigs may be underestimated. Since the NE system does not account for this change this may become a source of error.

Nitrogen utilization suggests that diets with co-products did not achieve the same rate of nitrogen retention as the simple corn-soy diet.

Objective: *To determine if adjustment of the NRC 1012 NE values can be undertaken in growth studies using feed conversion as the primary and ultimate method to validate NE estimates*

The first experiment was designed to meet this goal; results showed that feed efficiency is not the most precise method to evaluate NE values. In this study feed efficiency was not statistically different among diets formulated with the NE or the ME system

Discussion:

The quality of an energy system is given by its ability to predict the performance of animals independent of the ingredient composition of the diet (Kil, 2013; Noblet and Henry, 1993). In this study the ME and the NE systems responded adequately at the level of whole body growth performance when simple and complex diets were compared. In contrast, NE and ME complex diets resulted in a poorer performance for some carcass variables than a simple corn–soy diet (hot carcass weight, total carcass grain, loin depth and back fat). This drop was more accentuated for diets formulated with the ME system. This finding supports the theoretical advantage of the NE system over the ME system.

If we look to the NE:ME ratio across ingredients, we see a wide range with lower values for high protein and high fiber ingredients and higher for high fat ingredient (i.e. 0.64 for soybean meal, 0.63 for corn germ meal and 0.88 for soybean oil); however, the ratio between NE and ME in mixed diets seems to remain relatively constant at 0.74 for a corn soy diet vs. 0.73 for a highly diverse diet. In practical terms, the NE system has a particular advantage in pricing ingredients that vary widely in chemical composition (especially protein, fiber and fat). For example, we know from the French and the Dutch that the main advantage of the NE system is in relative pricing of ingredients. The benefit of the NE system in terms of predicting animal performance is more modest as we saw in this study.

As expected, the addition of co-products to a corn-soybean diet decreased digestibility, due to the increasing fiber content. Inclusion of fat in order to achieve a constant NE diet did not significantly affect the digestibility coefficient, although it did increase the energy density of the diet. Therefore, more energy per kg of feed is available for metabolic purposes, and consequently the calculation of NE (Noblet, 1994) appeared to be superior to ME in this instance as well.

One of the challenges of an energy system is related to the additivity of individual NE or ME values. It is assumed in the diet that indeed this values are additive; however, we also know that individual components of ingredients such as fiber, interact with the other components of the diet to alter digestibility. This potential lack of additivity at the level of the chemical composition of the diet affects the NE system as much as the ME system., Therefore, we cannot expect any current energy system (including the NE system) to provide perfectly predictable performance outcomes.

Implications

- Performance in pigs declined with the addition of co-products to the diet using either energy system. However, the decline was smallest when the diets were formulated using the NE system.

- The effectiveness of any energy system will be dependent on our ability to generate accurate energy values on ingredients and diets. While we have more experience with the ME system, and thus more confidence in our ME ingredient values, this does not translate into more predictable animal performance when the ME system is used side-by-side with the NE system.

- While the NE system showed advantages over the ME system, neither system was shown to be satisfactory in predicting animal performance. Therefore, it appears that while NE may be slightly superior to ME, a system of formulating diets better than NE is required to achieve our ultimate objective of accurately predicting animal performance based on diet composition.

Table 1.1 Energy values utilized in both experiments

Ingredient/ Kcal/kg	First experiment		Second experiment	
	NE	ME	NE	ME
Corn	2.664	3.395	2713	3395
Corn Germ meal	1.888	2.830	2102	2830
Corn DDGS	2.343	3396	2298	3434
SBM 47.5% CP	2.131	3294	2170	3376
Wheat Midds	-	-	2020	2968
Fat CWG	7.365	8.124	-	-
Soybean oil	-	-	7512	8527

Table 1.2. Overall growth Performance of ad libitum fed pigs, diets where formulated using the ME or the NE systems[1]

		CTL1+DDGS		CTL1+DDGS+CGm			
Phase	CTL1[2]	ME[3]	NE[4]	ME[5]	NE[6]	SEM	*P*-Value
Day 0-84							
ADG kg	0.983	0.969	0.986	0.960	0.966	0.009	0.1779
ADFI kg	2.727	2.697	2.717	2.643	2.646	0.029	0.1167
G:F ratio	0.361	0.360	0.363	0.364	0.366	0.002	0.1809

[a,b,c] Assess significant differences (*P*>0.05) or statistical trends (*P*>0.10) between dietary treatments

[1] Data are least mean squares (2054 pigs in 95pens), analyzed using the Mixed procedure of SAS®

[2] Control= Corn-soy based diet.

[3] Ctl+DDGS, ME= Control plus 30% of corn DDGS (25% for phase 1), ME equal to the control diet.

[4] Ctl+DDGS, NE= Control plus 30% of corn DDGS, (25% for phase 1) NE equal to the control diet.

[5] Ctl+DDGS+CGm= Control plus 20% each of corn DDGS and Corn germ Meal, (25 and 15% respectively for phase 1), and ME equal to the control diet.

[6] Ctl+DDGS+CGm= Control plus 20% each of corn DDGS and Corn germ Meal, (25 and 15% respectively for phase 1), and NE equal to the control diet.

Table 1.3. Growth Performance at market weight and carcass traits of ad libitum fed pigs, diets where formulated using the ME or the NE systems[1]

		CTL1+DDGS		CTL1+DDGS+CGm			
Item	CTL1[2]	ME[3]	NE[4]	ME[5]	NE[6]	SEM	*P*-Value
Mortality %	2.5	2.38	2.17	1.89	3.48	0.72	0.5941
Growth performance day 0-94							
WB ADG, kg	0.955	0.954	0.963	0.945	0.946	0.009	0.6105
WB ADFI, kg	2.761	2.743	2.759	2.688	2.688	0.030	0.2186
G:F ratio	0.346	0.349	0.350	0.352	0.353	0.002	0.2045
Carcass Traits							
Hot Carcass Weight, kg	96.95	95.30	96.60	94.49	95.20	0.699	0.0788
Carcass Yield, (Avg cuts)%	73.8^{a}	73.2^{bc}	73.6^{ab}	72.8^{c}	73.1^{c}	0.2	0.0005
Carcass Yield, (Avg Pen) %	73.9^{a}	73.1^{bc}	73.5^{b}	72.8^{c}	73.0^{bc}	0.2	0.0001
Carcass Gain, kg	66.73^{a}	65.07^{bc}	66.39^{ab}	64.28^{c}	64.98^{bc}	0.600	0.0247
Carcass ADG, kg/d	0.712^{a}	0.694^{bc}	0.708^{ab}	0.686^{c}	0.693^{bc}	0.007	0.031
Carcass G:F ratio	0.258	0.254	0.257	0.256	0.259	0.001	0.1332
FOM Backfat, mm	21.7	20.6	21.3	20.9	20.7	0.296	0.058
FOM Loin Depth, mm	60.2^{a}	59.3a^{bc}	59.6^{ab}	58.3^{c}	58.6^{bc}	0.419	0.015
FOM Lean, %	51.8	52.1	51.8	51.9	51.9	0.1	0.433

[a,b,c] Assess significant differences (*P*>0.05) or statistical trends (*P*>0.10) between dietary treatments

[1] Data are least mean squares, (2054 pigs in 95pens), analyzed using the Mixed procedure of SAS®

[2] Control= Corn-soy based diet.

[3] Ctl+DDGS, ME= Control plus 30% of corn DDGS (25% for phase 1), ME equal to the control diet.

[4] Ctl+DDGS, NE= Control plus 30% of corn DDGS, (25% for phase 1) NE equal to the control diet.

[5] Ctl+DDGS+CGm= Control plus 20% each of corn DDGS and Corn germ Meal, (25 and 15% respectively for phase 1), and ME equal to the control diet.

[6] Ctl+DDGS+CGm= Control plus 20% each of corn DDGS and Corn germ Meal, (25 and 15% respectively for phase 1), and NE equal to the control diet

Table 1.4.Apparent total tract digestibility, energy content and nitrogen utilization determined for growing period, diets contained 0, 18 or 36% of co-products, with a constant or declining NE content[1]

Item	CTL2[2]	Cons-18[3]	Decl-18[4]	Const-36[5]	Decl-36[6]	SEM	*P*-Value
Digestibility							
ATTD od GE	85.3^{a}	81.8^{b}	80.5^{bc}	79.2^{bc}	78.1^{c}	0.7	0.005
Energy Mcal/kg, DM							
GE	4.34	4.50	4.41	4.62	4.42	-	-
DE	3.70^{a}	3.68^{a}	3.55^{bc}	3.66^{ab}	3.45^{c}	0.032	0.011
ME NRC[7]	3.60^{a}	357^{a}	344^{bc}	355^{ab}	3.34^{c}	0.031	0.009
ME Calculated[8]	3.53^{a}	3.50^{a}	338^{b}	349^{a}	327^{b}	0.029	0.007
NE [9]	2.66^{a}	2.64^{a}	2.53^{bc}	2.62^{ab}	2.45^{c}	0.027	0.011
ME: NE ratio	0.74	0.74	0.73	0.74	0.73	-	-
Nitrogen utilization							
N excreted %	59.4^{b}	65.2^{a}	64.0^{a}	63.4^{a}	65.6^{a}	0.70	0.01
N retained %	40.6^{a}	34.8^{b}	36.0^{b}	36.6^{b}	34.4^{b}	0.70	0.01

[a,b,c] Assess significant differences (*P*>0.05) or statistical trends (*P*>0.10) between dietary treatments

[1] Data are least mean squares of 40 gilts, with 8 animals per treatment, analyzed using the Mixed procedure of SAS®

[2] Control= Corn-soy based diet.

[3] Const-18= Control plus 6% each of corn DDGS, Corn germ Meal, and wheat middlings, and NE equal to the control diet.

[4] Decl-18= Const-18, without fat added, NE content lower than Control diet,

[5] Const-36= Control plus 12% each of corn DDGS, Corn germ Meal, and wheat middlings, and NE equal to the control diet

[6] Decl-36= Const-36, without fat added, NE content lower than Control diet.

[7] NRC 1998 equation 1-7, May and bell, (1971): ME = DE *(1.012 1 (0.0019 2 % CP))

[8] ME= DE-urinary energy. Urinary energy was calculated using Noblet et al., (2004) equation Urinary energy = 192 + 31 x urinary nitrogen

[9] Noblet et al., (1994) equation 3: NE = 0.843 x DE - 463

Table 1.5.Apparent total tract digestibility, energy content and nitrogen utilization determined for finishing period, diets contained 0, 18 or 36% of co-products, with a constant or declining NE content[1]

Item	CTL2[2]	Cons-18[3]	Decl-18[4]	Const-36[5]	Decl-36[6]	SEM	*P*-Value
Digestibility							
ATTD of GE	87.1^{a}	83.9^{b}	84.3^{b}	81.4^{c}	80.6^{c}	0.4	0.0006
Energy Mcal/kg, DM							
GE	4.28	4.46	4.37	4.62	4.44	-	-
DE	3.72^{ab}	3.74^{ab}	3.68^{b}	3.76^{a}	3.58^{c}	0.018	0.0056
ME NRC[7]	3.65^{a}	3.66^{a}	3.60^{a}	3.66^{a}	3.49^{b}	0.018	0.0044
ME Calculated [8]	3.56^{a}	3.57^{ab}	3.51^{b}	3.58^{a}	3.41^{c}	0.017	0.0041
NE[9]	2.68^{ab}	2.69^{ab}	2.64^{b}	2.70^{a}	2.56^{c}	0.015	0.0055
ME: NE ratio	0.73	0.74	0.73	0.74	0.73		
Nitrogen utilization							
N excreted %	65.0^{b}	70.0^{a}	68.8^{ab}	70.6^{a}	69.7^{a}	1.12	0.08
N retained %	35.0^{a}	30.0^{b}	31.2^{ab}	29.4^{b}	30.3^{b}	1.12	0.08

[a,b,c] Assess significant differences (*P*>0.05) or statistical trends (*P*>0.10) between dietary treatments

[1] Data are least mean squares of 40 gilts, with 8 animals per treatment, analyzed using the Mixed procedure of SAS®

[2] Control= Corn-soy based diet.

[3] Const-18= Control plus 6% each of corn DDGS, Corn germ Meal, and wheat middlings, and NE equal to the control diet.

[4] Decl-18= Const-18, without fat added, NE content lower than Control diet,

[5] Const-36= Control plus 12% each of corn DDGS, Corn germ Meal, and wheat middlings, and NE equal to the control diet

[6] Decl-36= Const-36, without fat added, NE content lower than Control diet.

[7] NRC 1998 equation 1-7, May and bell, (1971): ME = DE *(1.012 1 (0.0019 2 % CP))

[8] ME= DE-urinary energy. Urinary energy was calculated using Noblet et al., (2004) equation Urinary energy = 192 + 31 x urinary nitrogen

[9] Noblet et al., (1994) equation 3: NE = 0.843 x DE – 463