Journal of Animal and Veterinary Advances 3 (6): 371-377, 2004

Digestible Energy Content of Traditional and Non-Traditional Feeds for Swine Determined Using the Mobile Nylon Bag Technique

[1]Shiyan Qiao and [2]P. A. Thacker
[1]Ministry of Agriculture Feed Industry Centre, China Agricultural University, No. 2 Yuanmingyuan West Road, Beijing, China 100094; [2]Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, Saskatchewan, S7N 5B5

Abstract: This experiment used the mobile nylon bag technique (MNBT) to determine dry matter and energy digestibility in traditional feeds as well as non-traditional feeds in order to calculate digestible energy (DE) values for use in ration formulation programs for swine. A total of 23 ingredients were tested in this experiment including six animal protein sources (blood meal, fish meal, meat meal, spray dried animal plasma, spray dried red blood cells and shrimp head flour), six oilseeds (extruded full-fat soybean, raw sunflower seeds, roasted sunflower seeds, caraway seeds, raw flaxseeds, and micronized flaxseeds), three oilseed meals (cottonseed meal, soybean meal, and borage meal), five wheat or wheat by-products (wheat, wheat distillers grains, wheat mill run, wheat bran, and dried wheat thin stillage) and three miscellaneous feeds (beet pulp, barley malt and milk-fat product). Nylon bags containing one gram of feed were placed in a 1000 mL beaker containing 500 mL of a solution made up of deionized water, 0.01 N HCl and one gram of purified activated pepsin powder and incubated for 4 h at 37°C. The bags were then inserted into the duodenum of one of five pigs through simple T-cannulae. Eight bags were administered to each pig daily. The bags were inserted into the duodenal cannulae during feeding time with four bags being inserted in the morning and four bags being inserted during the afternoon meal. With each feeding, two bags were introduced 15 minutes apart. Between five and ten nylon bags were prepared for each feed and the experiment was conducted over a seven-day period. Overall, the MNBT produced similar results to previously published DE values for 11 out of the 17 ingredients for which previous measurements have been made. For the six feeds where there was a significant discrepancy between the MNBT and previously published values, variation in chemical content provided a reasonable explanation for the discrepancy. For untreated flaxseed, caraway seed, barley malt and beet pulp, the author believes that previously published values are too high for feedstuffs containing such high neutral detergent fibre contents. In the present experiment, the MNBT generated a DE value of 4253 kcal kg^{-1} for untreated flaxseed, 1763 kcal kg^{-1} for caraway seed, 1800 kcal kg^{-1} for barley malt and 1905 kcal kg^{-1} for beet pulp, For raw sunflower seed, genetic selection has increased the ether extract content of the seed and therefore the DE value obtained here (3830 kcal kg^{-1}) is thought to more closely reflect the DE content of sunflower seeds currently being grown. Only for meat meal, did the MNBT produce a suspect result (3433 kcal kg^{-1}), which cannot be readily explained. For the remaining six feeds, there are no previously published values with which to compare the DE values determined with the MNBT. Based on their chemical analysis and the generated DE values, shrimp head flour (3473 kcal kg^{-1}), dried wheat stillage (4291 kcal kg^{-1}), roasted sunflower seed (3903 kcal kg^{-1}), micronized flaxseed (4155 kcal kg^{-1}), and milk fat product (8004 kcal kg^{-1}) all appear to have some potential for use as ingredients in swine rations. In contrast, borage meal (1562 kcal kg^{-1}) does not appear to be a useful ingredient. The overall results of this experiment indicate that the MNBT has considerable potential for use in determining the digestible energy content of swine feeds. The MNBT has several advantages compared with conventional digestibility methods in that many feeds can be tested in a relatively short duration of time with significantly fewer animals being used, only small amounts of feed are required and the test allows for energy measurements in feedstuffs that would not normally be fed to pigs as a single ingredient.

Key words: Nylon bag, pigs, digestible energy, cannulae

Introduction

The cost of feed is the greatest single expense associated with raising pigs to market weight and therefore plays a major role in determining the profitability of any swine enterprise. While corn and soybean meal are the industry standards for supplying energy and protein, there are many suitable alternatives that can be used to meet the nutritional requirements of swine while reducing ration costs (Thacker and Kirkwood, 1990).

The energy portion of swine diets represents the largest and most expensive portion of the diet. Although the closest estimate of the "true" energy value of a feed is given by its net energy content (Noblet *et al.*, 1994), digestible energy (DE) is still widely utilized by many swine nutritionists. The direct determination of the DE content of swine feeds typically involves either the total collection of faeces or the use of a digestibility marker (Young *et al.*, 1991). Both of these techniques are time consuming, expensive and require a large quantity of feed (Sauer *et al.*, 1989 and De Lange *et al.*, 1991).

Table 1: Chemical analysis (as fed) of traditional and non-traditional feeds used to determine digestible energy content with the mobile nylon bag technique

	International Feed Number	Moisture (%)	Crude Protein (%)	Ether Extract (%)	Ash (%)	Neutral Detergent Fiber (%)
Animal Protein Sources						
Blood meal (spray-dried)[2]	5-00-381	5.8 (7.8)	86.1 (84.7)	0.2 (1.0)	1.3 (4.7)	12.1
Blood plasma (spray-dried)[1]		7.6 (9.0)	75.2 (78.0)	0.1 (2.0)	7.1	0.6
Blood cells (spray-dried)[1]		6.1 (8.0)	85.2 (92.0)	0.3 (1.5)	2.9	0.1
Fish meal (menhaden)[2]	5-02-009	4.8 (8.6)	59.0 (60.4)	9.8 (9.8)	21.4 (19.0)	9.0
Meat meal[2]	5-00-385	5.4 (6.8)	51.7 (54.9)	11.7 (9.4)	22.8 (24.9)	28.2
Shrimp head flour		7.8	55.5	5.9	14.6	10.5
Wheat or Wheat By-Products						
Wheat (hard red spring)[2]	4-05-258	12.2 (9.8)	13.1 (13.5)	1.6 (2.0)	2.0 (1.7)	13.5
Wheat distillers grain[2]	5-05-193	6.4 (6.6)	35.1 (31.3)	4.8 (5.9)	5.2 (3.0)	27.9
Wheat mill run[2]	4-05-206	8.3 (9.9)	14.8 (15.6)	4.9 (4.3)	5.1 (5.1)	35.1
Wheat bran[2]	4-08-009	7.3 (12.0)	13.9 (13.8)	4.0 (4.0)	6.5 (5.6)	49.1
Wheat stillage (drum-dried)		10.8	46.3	3.9	7.7	8.2
Oilseeds						
Soybean (extruded)[1]	5-04-597	5.5 (10.0)	39.1 (35.2)	15.7 (18.0)	5.0	13.9
Sunflower seeds (raw)[2]	4-08-530	4.8 (6.4)	15.9 (16.8)	40.5 (25.9)	3.1 (3.1)	47.0
Sunflower seeds (roasted)		8.5	16.2	35.4	3.0	27.2
Caraway seeds[2]	5-01-130	6.8 (13.8)	19.2 (21.5)	21.4 (13.9)	4.9 (6.7)	52.5
Flaxseeds (untreated)[2]	5-02-052	4.6 (7.8)	20.5 (23.2)	41.6 (35.0)	3.3 (4.9)	38.5
Flaxseeds (micronized)		4.3	20.6	41.5	3.3	21.7
Oilseed Meals						
Cottonseed meal[2]	5-01-632	7.1 (8.6)	43.3 (41.6)	0.7 (1.6)	6.3 (6.5)	27.3
Soybean meal[2]	5-04-607	7.0 (8.7)	45.4 (46.1)	0.6 (1.0)	6.2 (5.9)	9.8
Borage meal		9.5	25.4	0.4	17.4	25.1
Miscellaneous						
Barley malt[2]	4-08-345	7.2 (9.4)	14.7 (14.3)	2.6 (1.6)	7.7 (2.3)	42.7
Milk fat product		1.7	3.4	81.3	2.1	4.8
Beet pulp (dehydrated)[2]	4-00-669	6.6 (9.4)	7.8 (8.7)	0.5 (0.5)	7.9 (4.8)	39.0

[1]Numbers in parenthesis are values published by NRC (1998) for the various feeds
[2]Numbers in parenthesis are values published by the National Academy of Sciences (1971) for the various feeds

An alternative method for the determination of DE is the mobile nylon bag technique (MNBT) originally developed by Sauer *et al.* (1983). In this method, small samples of finely ground feed are sewn into nylon bags and placed into a small beaker containing hydrochloric acid and pepsin to simulate gastric digestion. After a short incubation period, the nylon bags are removed from the beaker and inserted into the digestive tract of a pig through duodenal cannulae. The amount of material remaining in the nylon bag, after passage through the tract can be used to calculate nutrient digestibility.

Early work indicated that the MNBT did not accurately predict in vivo nutrient digestibility when used for mixed feeds (Taverner and Campbell, 1985) or cereal grains (Graham *et al.*, 1985; Sauer *et al.*, 1989 and De Lange *et al.*, 1991). However, a modified protocol for the MNBT has recently been published which produced digestibility coefficients very similar to those obtained with conventional digestibility methods (Thacker and Qiao, 2001). Therefore, the following study was conducted using the MNBT to determine dry matter and energy digestibility in traditional feeds as well as non-traditional feeds in order to calculate digestible energy (DE) values for use in ration formulation. Where possible, the values generated were compared to industry standards to confirm the potential of the MNBT as a tool to accurately determine DE values for swine.

Materials and Methods

Acquisition of Feed Samples: A total of 23 ingredients were tested in this experiment including six animal protein sources (blood meal, fish meal, meat meal, spray dried animal plasma, spray dried red blood cells and shrimp head flour), six oilseeds (extruded full-fat soybean, raw sunflower seeds, roasted sunflower seeds, caraway seeds, raw flaxseeds, and micronized flaxseeds), three oilseed meals (cottonseed meal, soybean meal, and borage meal), five wheat or wheat by-products (wheat, wheat distillers grains, wheat mill run, wheat bran, and dried wheat thin stillage) and three miscellaneous feeds (beet pulp, barley malt and milk-fat product). Many of the feedstuffs chosen are commonly used ingredients for which DE values already exist and these values were therefore compared with the DE values generated using the MNBT. However, several non-traditional feed sources, which appear to have potential for use in swine rations, were also tested. For these feeds, no previous measurements of DE have been conducted.

Table 2: Digestible energy values for traditional and non-traditional feeds determined with the mobile nylon bag technique

	Dry Matter Digestibility (%)	Energy Digestibility (%)	Gross Energy (kcal kg^{-1})	DE MNBT (kcal kg^{-1})	DE NRC (kcal kg^{-1})[1]	DE Atlas (kcal kg^{-1})[2]
Animal Protein Sources						
Blood meal (spray-dried)	46.9 ± 6.4	45.8 ± 6.9	5362	2456	2300	2577
Blood plasma (spray-dried)	82.6 ± 4.2	82.6 ± 4.6	4782	3950	4108[3]	
Blood cells (spray-dried)	85.4 ± 3.2	85.9 ± 3.3	5315	4566	4401[3]	
Fish meal (menhaden)	72.0 ± 3.4	78.5 ± 4.7	4440	3485	3770	3282
Meat meal	64.6 ± 0.9	79.9 ± 1.5	4294	3431	2695	2957
Shrimp head flour	75.8 ± 1.5	80.3 ± 1.5	4326	3473		
Wheat or Wheat By-Products						
Wheat (hard red spring)	85.3 ± 0.7	85.3 ± 0.7	3994	3406	3400	3598
Wheat distillers grain	56.4 ± 8.5	66.7 ± 6.4	4786	3193		3445
Wheat mill run	59.3 ± 2.9	56.4 ± 3.4	4085	2303		2734
Wheat bran	53.5 ± 3.3	53.2 ± 1.3	4028	2143	2420	2654
Wheat stillage (drum-dried)	89.3 ± 1.9	90.2 ± 2.0	4758	4291		
Oilseeds						
Soybeans (extruded)	82.3 ± 1.8	83.3 ± 2.1	5257	4379	4140	
Sunflower seeds (raw)	55.3 ± 0.6	61.7 ± 0.4	6209	3830		3363
Sunflower seeds (roasted)	55.8 ± 3.1	62.5 ± 3.2	6241	3901		
Caraway seeds	41.4 ± 6.6	33.4 ± 6.7	5280	1763		3531
Flaxseeds (untreated)	69.3 ± 3.8	70.8 ± 4.0	6008	4253		4902
Flaxseeds (micronized)	66.6 ± 2.0	67.9 ± 2.2	6123	4157		
Oilseed Meals						
Cottonseed meal	54.8 ± 1.0	57.7 ± 1.0	4310	2486	2575	2999
Soybean meal	87.3 ± 4.7	86.2 ± 5.7	4308	3713	3685	3425
Borage meal	39.8 ± 1.3	45.2 ± 1.7	3453	1561		
Miscellaneous						
Barley malt	46.5 ± 6.3	44.9 ± 2.8	4010	1800		3664
Milk fat product	99.8 ± 0.1	95.6 ± 3.7	8373	8004		
Beet pulp (dehydrated)	65.2 ± 2.9	52.2 ± 4.6	3653	1907	2865	3000

[1]Numbers in parenthesis are values published by NRC (1998) for the various feeds
[2]Numbers in parenthesis are values published by the National Academy of Sciences (1971) for the various feeds
[3]DE values f or spray dried animal plasma and spray dried cells were provided by American Protein Corporation.

Surgical Procedures: Simple T-cannulae were inserted into the duodenum of six pigs (Camborough Line 15, Pig Improvement Canada Ltd, Acme Alberta; 43.5 kg initial weight) following the surgical procedures described by Sauer *et al.* (1983) with some modifications. The rigid T-cannulae (24 mm i.d. x 65 mm length) were fabricated from Delrin nylon rod (Johnston Industrial Plastics, Edmonton, Alberta) according to the specifications outlined by McBride *et al.* (1983).

The pigs were fasted for 12 h prior to surgery, but water was freely accessible. A long-acting antibiotic (Liquamycin, 0.5 mL, Rogar/STB Inc., London, Ontario) was administered intramuscularly 8 h before surgery. The pigs were brought under general anaesthesia using a gas mixture of oxygen (500 to 1000 mL/min) and halothane (0.5 to 2.0%). The right side of the pig, starting from the second last rib caudally across the flank region, was shaved with an electric clipper, cleaned with Betadine (Purdue Frederick Inc., Toronto, Ontario) and draped leaving the surgical area exposed. An incision of approximately 7 cm in length was made parallel and caudal to the last rib leaving a space of approximately 3 cm between the incision and the last rib for subsequent suturing.

The duodenum was identified and a site approximately 5 to 10 cm posterior to the pyloric sphincter was chosen for insertion of the cannulae. A purse-string suture (2-0 catgut; Cyanamid Canada Inc., Baie D'Urfe, Quebec) was inserted into the serosal layer of the intestine to outline the positioning and length of the incision. An incision was made between the two parallel sutures using a No. 25 scalpel blade and the flanges of the cannulae were inserted into the lumen of the intestine through the incision. The purse-string suture was tightened and a second purse-string suture was placed around the base of the cannulae approximately 2 mm below the original suture to further secure the cannulae.

A fistula was created between the two last ribs by surgically removing a small piece of skin and penetrating the muscle layers and peritoneum using finger manipulation and a pair of Rochester Pean Forceps. The barrel of the cannulae was then pulled through the fistula. Terramycin (0.5 mL) was administered into the abdominal cavity and the incision closed by suturing the peritoneum as well as the inner and outer muscle layers using 2-0 catgut. The skin was sutured with 2-0 silk. A retaining ring was then threaded down the barrel of the cannulae and tightened

as close as possible to the skin. An analgesic (Butorphenol Tartate, 0.1 mg kg^{-1} bodyweight) was administered intra-muscularly immediately after surgery and again 24 h following the surgery.
Following surgery, the pigs were placed in metabolic crates and allowed a 2-week recuperation period to regain their normal appetite. From d 3 onwards, the area around the cannulae was washed with warm water and then zinc oxide cream (H. J. Sutton Industries, Vaughan, Ontario) was applied under and around the retaining ring to minimize skin irritation and reduce the potential for infection. Pigs were not fed the day following surgery, but received about 150 g of feed the day thereafter. The daily feed intake was then gradually increased until the pigs were consuming approximately 1.6 kg feed per day. The skin sutures were removed 10 d after surgery.

Preparation of Nylon Bags: Nylon bags measuring approximately 25 x 40 mm, were prepared from monofilament nylon cloth (Sefar Canada Inc., Scarborough, Ontario) with a pore size of 48 um. The bags were sealed on three sides using heat (Sealboy, Packaging Aids Corporation, San Rafael, California). A 1 g sample of feed, ground through a 1.0 mm mesh screen, was placed in the bag and the remaining side of the bag was then also heat-sealed. Between five and ten nylon bags were prepared for each feed.
The bags were grouped in blocks of 10 and placed in a 1000 mL beaker containing 500 mL of a solution made up of deionized water, 0.01 N HCl and one g of purified activated pepsin powder (377.4 IU/g; Sigma-Aldrich Canada Ltd, Oakville, Ontario). The beaker was then placed into a shaking water bath (65 oscillations/min) and incubated for 4 h at 37°C. After incubation, the bags were removed from the beaker, washed with deionised water and frozen in small plastic bags until required. Most of the pre-digestion factors (i.e. pepsin concentration, pH, duration of pre-digestion, pore size, bag shape) were chosen because they had been shown in previous work to produce results most similar to those obtained with conventional digestibility studies (Cherian *et al.*, 1988 and 1989). A larger sample size was chosen to ensure sufficient residue to conduct needed chemical analyses.

MNBT Digestibility Study: The pigs (average weight 45.5 kg at initiation of study) were individually housed in 135 x 65 cm stainless steel metabolic crates. They received 750 g of a grower diet (15.9% crude protein and 12.1 MJ/kg DE) containing 70.25% barley, 26.5% canola meal and 3.25% vitamin-mineral premix during each of two daily feedings (09:30 and 16:30 h). The stainless steel feeder was filled with water so that water was available at all times except during feeding.
Prior to insertion, nylon bags were removed from the freezer and thawed for 5-min in a 37°C water bath. Eight bags were administered to each pig daily. The bags were inserted into the duodenal cannulae during feeding time with four bags being inserted in the morning and four bags being inserted during the afternoon meal. With each feeding, two bags were introduced 15 minutes apart (i.e. two bags at the initiation of feeding and a further two bags 15 minutes later). Only five of the pigs were used during this trial with one barrow acting as a spare.
The nylon bags were recovered in the feces during searches conducted every four hours. Most of the nylon bags were excreted within 24 ± 4 hours of insertion. Nylon bags were carefully isolated from faeces and any faeces sticking to the bags were scrapped off with a dry paper towel. The bags were not washed. All nylon bags were then frozen (-20°C) until needed for chemical analysis. The search for nylon bags was terminated 72 h after the insertion of the last nylon bag. Any bags that were chewed or otherwise damaged were discarded and not used in the experiment.

Chemical Analysis and Digestibility Calculations: Analyses for dry matter, crude protein, ash and ether extract in the feed ingredients were conducted according to the methods of the Association of Official Analytical Chemists (1980). An adiabatic oxygen bomb calorimeter was used to determine the gross energy content. Neutral detergent fibre was analysed using the method of Van Soest *et al.* (1991).
In order to measure dry matter digestibility using the mobile nylon bag technique, frozen nylon bags and residues were freeze-dried for 48 h in a Lyph-Lock 12 Freeze Dry System (Labconco, Kansas City, Missouri). Dry matter digestibility was calculated by subtracting the dried weight of the ingredient originally placed in the bag (sample weight corrected for moisture content of ingredient) from the dried weight of the residue after passing through the digestive tract (freeze dried residue) and expressing the difference as a percentage of the original dried sample weight.
Digestibility coefficients for gross energy were determined by tightly rolling the freeze-dried nylon bags and placing them into a colorimeter cup fitted for a Parr Adiabatic Bomb Calorimeter Model 1200 (Parr Instrument Company, Moline, Illinois). The nylon bag and the residue were combusted but the energy value was corrected by subtracting the energy value of an empty nylon bag. The gross energy of the residue was subtracted from the gross energy of the original dried sample and the difference was expressed as a percentage of the gross energy of the original dried sample. DE values were calculated by multiplying the gross energy of the feed by the digestibility coefficient for energy.

Results and Discussion

The chemical composition of the ingredients tested for digestible energy is shown in Table 1. Since the chemical composition of a feed has a major effect on nutrient digestibility, it is important to point out where the chemical composition of the ingredients used in the present trial differ from previously published values. For this reason, where they are available, the chemical analyses of similar feed ingredients published by the National Research Council (NRC, 1998) and the National Academy of Sciences (1971) are provided for comparison purposes.

Individual feed ingredients can vary widely in chemical composition because of variation in cultivars, growing conditions, processing and storage conditions (NRC, 1998). As such, discrepancies between the chemically determined values for the ingredients used in the present experiment and those of previously published values are to be expected. Most of the variation which was observed is within the range that might be expected and were not considered to be large enough to have a major impact on the DE values of the ingredients tested. However, there are two instances where variation in chemical content was thought to impact on the DE values obtained. This occurred with raw sunflower seeds and untreated flax seeds.

The National Academy of Sciences (1971) reports that the ether extract content of raw sunflower seeds is 25.9%. This varies considerably from the 40.5% ether extract determined for sunflower seeds in the current experiment. However, more recent studies by Wahlstrom (1985) reported that the ether extract content of sunflower seeds was 42.4% while Dinusson *et al.* (1982) reported a value of 41% ether extract for sunflower seed. These values support the findings of the current experiment and are thought to more closely resemble the ether extract content of sunflower seeds currently being fed.

The National Academy of Sciences (1971) reports that the ether extract content of untreated flax is 35.0%. This value also varies considerably from the 41.6% ether extract determined for flax seeds in the current experiment. However, DeClercq and Daun (2002) report the oil content of flaxseed has increased significantly over the past decade and reported a value of 40.4% as the average for the 2002 flaxseed harvest.

The digestible energy values determined with the MNBT are presented in Table 2. Where possible, the values are compared to previously reported digestible energy values in NRC (1998) and in the Altas of Nutritional Data on United States and Canadian Feeds (National Academy of Sciences, 1971). Obviously some variation is to be expected between the values presented in the current paper and previously published values due to variation in chemical composition. As a result, differences of less than 5% were considered to be within acceptable limits and only those situations where differences between previously published values and those in the current paper exceeded 5% will be discussed.

For the animal protein sources, there was good agreement between previously published values and those determined with the MNBT for all feeds except meat meal (3433 kcal kg^{-1}). For meat meal, the MNBT generated a DE value 17.6% higher than previously reported values. There is nothing in the chemical analysis of meat meal to validate such an increase and the accuracy of this value is suspect. The dramatically higher digestibility coefficient for energy in comparison with dry matter for meat meal suggest that an error might have occurred in the measurement of energy digestibility for meat meal using the MNBT. The chemical analysis of shrimp head flour in conjunction with a DE value of 3473 kcal kg^{-1} suggest that this ingredient may have some potential as a protein source for use in swine production.

For wheat or wheat by-products, there was generally good agreement between the DE values generated with the MNBT and previously published values. The hierarchy of the DE values for wheat (3406 kcal kg^{-1}), wheat distiller's grains (3193 kcal kg^{-1}), wheat mill run (2303 kcal kg^{-1}) and wheat bran (2143 kcal kg^{-1}), correlated well with the neutral detergent fibre content of these ingredients. Drum-dried wheat stillage had a protein content of 46.3%, a neutral detergent fibre content of 8.2% and a DE value of 4291 kcal kg^{-1} which in combination with the fact that it has found use as a palatability enhancer in rainbow trout rations (Thiessen *et al.*, 2003), suggest that this product may also be a useful feed ingredient in swine rations.

For the oilseeds, there was good agreement between the MNBT and previously published values for extruded soybeans (4379 kcal kg^{-1}). For sunflower seeds, the DE value generated by the MNBT (3830 kcal kg^{-1}) was dramatically higher than previously reported values. However, as previously indicated, the oil content of sunflower seeds has increased substantially since the initial DE values were generated and therefore, the DE value determined in the present experiment is more likely going to reflect the energy content of sunflower seeds currently being fed. The DE value of untreated flaxseed determined with the MNBT (4253 kcal kg^{-1}) was 15.2% lower than the 4902 kcal kg^{-1} value published in the Atlas of Nutritional Data on United States and Canadian Feeds (National Academy of Sciences, 1971). However, the current value seems reasonable when one compares the chemical composition of flaxseed and sunflower seed. Given the fact the ether extract content of the two feeds was similar and the neutral detergent fibre content was slightly less for flaxseed, the DE value of 4253 kcal kg^{-1} would rank the two feeds in the appropriate order while the DE value published in the Atlas seems inordinately high for a feed with a neutral detergent fibre content of 38.5%.

There is very little published information on the nutritive value of caraway seeds for swine and the only published

DE value for caraway seed is 3531 kcal kg^{-1} (National Academy of Sciences, 1971). The MNBT generated a value of 1763 kcal kg^{-1}, which seems more appropriate for a feedstuff with 52.5% neutral detergent fibre. For oilseed meals, there was generally good agreement between the DE values generated using the MNBT and previously published values with the values of 3713 and 2486 for soybean meal and cottonseed meal showing excellent agreement particularly with the previously published values of NRC (1998). The exceeding low DE value for borage meal (1561 kcal kg^{-1}) is consistent with the extremely poor performance observed when pigs were fed borage meal (Mustafa *et al.*, 1997) and likely reflect the high ash and high neutral detergent fibre content of this ingredient. For the miscellaneous category, there was little agreement between the DE values generated using the MNBT and previously published DE values for barley malt (1800 kcal kg^{-1}) and dehydrated beet pulp (1905 kcal kg^{-1}). In the opinion of the author, the DE values published in the Atlas of Nutritional Data on United States and Canadian Feeds (National Academy of Sciences, 1971) for barley malt (3664 kcal kg^{-1}) and beet pulp (3000 kcal kg^{-1}) are too high for feedstuffs with neutral detergent fibre contents of 42.7 and 39.0% respectively. Dehydrated alfalfa has a similar fibre content to these two ingredients and has a DE of only 1830 kcal kg^{-1} (NRC, 1998) giving some validation to the values generated by the MNBT in the current experiment. The DE content of milk fat product has not been previously measured but the 8004 kcal kg^{-1} determined in the current experiment is similar to the 8000 kcal kg^{-1} reported for beef tallow (NRC, 1998), which would have a similar fatty acid composition as milk fat. Overall, the MNBT produced similar results to previously published DE values for 11 out of the 17 ingredients for which previous measurements have been made. For the six feeds where there was a significant discrepancy between the MNBT and previously published values, variation in chemical content provided a reasonable explanation for the discrepancy with most feeds. For untreated flaxseed, caraway seed, barley malt and beet pulp, the author believes that previously published values are too high for feedstuffs containing their high neutral detergent fibre content as fibre is know to have negative effects on nutrient digestibility (Fernandex and Jorgensen, 1986). For raw sunflower seed, genetic selection has increased the ether extract content of the seed and therefore the DE value obtained here is thought to more closely reflect the DE content of sunflower seeds currently being grown. Only for meat meal, did the MNBT produce a suspect result, which cannot be readily explained.

For the remaining six feeds, there are no previously published values with which to compare the DE values determined with the MNBT. Based on their chemical analysis and the generated DE values, shrimp head flour (3473 kcal kg^{-1}), dried wheat stillage (4291 kcal kg^{-1})) roasted sunflower seed (3903 kcal kg^{-1}), micronized flaxseed (4155 kcal kg^{-1}) and milk fat product (8004 kcal kg^{-1}) all appear to have some potential for use as ingredients in swine rations. In contrast, borage meal does not appear to be a useful ingredient due to its extremely low energy content (1562 kcal kg^{-1}).

It is important to point out that although the present experiment did not compare DE values determined with the MNBT with conventional digestibility studies, our previous work (Thacker and Qiao, 2001) did compare our modified MNBT with conventional digestibility methods and there was excellent agreement between the two techniques. The results of the present experiment provide additional evidence that the MNBT is a useful technique for measuring DE in swine as for most of the feeds tested in the current experiment, the DE values determined using the MNBT compared favourably with previously published values. Where differences were obtained, variation in chemical content provided a reasonable explanation for the discrepancy.

Although the MNBT cannot completely replace conventional digestibility studies, the technique has several advantages compared with conventional digestibility methods. The prime advantage of the MNBT is that the test allows for energy measurements in feedstuffs that would not normally be fed to pigs as a single ingredient. In addition, many feeds can be tested in a relatively short duration of time with significantly fewer animals being used and only small amounts of feed are required.

References

AOAC, 1980. Official Methods of Analysis (13th Ed.) Association of Official Analytical Chemists, Arlington VA.

Cherian, G., W. C. Sauer and P. A. Thacker, 1988. Effect of predigestion factors on the apparent digestibility of protein for swine determined by the mobile nylon bag technique. J. Anim. Sci., 66:1963-1968.

Cherian, G., W. C. Sauer and P. A. Thacker, 1989. Factors affecting the apparent digestibility of protein for swine when determined by the mobile nylon bag technique. Anim. Feed Sci. Technol., 27:137-146.

DeClercq, D. R. and J. K. Daun, 2002. Quality of western Canadian flaxseed-2002. Grain Research Laboratory, Canadian Grain Commission, Winnipeg, MB.

De Lange, C. F. M., W. C. Sauer, L. A. Den Hartog and J. Huisman, 1991. Methodological studies with the mobile nylon bag technique to determine protein and energy digestibilities in feedstuffs for pigs. Livest. Prod. Sci., 29: 213-225.

Dinusson, W. E., J. N. Johnson, R. L. Harrold and R. Zimprich, 1982. Sunflower seeds in swine rations. North Dakota Agric. Exper. Stat. Farm Res., 40:13-14.

Fernandez, J. A. and J. N. Jorgensen, 1986. Digestibility and absorption of nutrients as affected by fibre content in the diet of the pig. Quantitative aspects. Livest. Prod. Sci., 15:53-71.

Graham, H., P. Aman, R. K. Newman and C. W. Newman, 1985. Use of a nylon-bag technique for pig feed digestibility studies. Brit. J. Nutr., 54:719-726.

McBride, B. M., R. Berzins, L. P. Milligan and B. W. Turner, 1983. Development of a technique for gastrointestinal endoscopy of domestic ruminants. Can. J. Anim. Sci., 63:349-354.

Mustafa, A. F., J. J. McKinnon, P. A. Thacker and D. A. Christensen, 1997. Effect of borage meal on nutrient digestibility and performance of ruminants and pigs. Anim. Feed Sci. Technol., 64:273-285.

National Research Council, 1998. Nutrient Requirements of Domestic Animals. No. 2. Nutrient Requirements of Swine. 10th ed. NAS-NRC, Washington, DC.

National Academy of Sciences, 1971. Atlas of Nutritional Data on United States and Canadian Feeds. NAS-NRC, Washington, DC.

Noblet, J., H. Fortune, X. S. Shi and S. Dubois, 1994. Prediction of net energy value of feeds for growing pigs. J. Anim. Sci., 72:344-354.

Sauer, W. C., H. Jorgensen and R. Berzins, 1983. Modified nylon bag technique for determining apparent digestibilities of protein in feedstuffs for pigs. Can. J. Anim. Sci., 63:233-237.

Sauer, W. C., L. A. Den Hartog, J. Huisman, P. van Leeuwen and C. F. M. De Lange, 1989. The evaluation of the mobile nylon bag technique for determining the apparent protein digestibility in a wide variety of feedstuffs for pigs. J. Anim. Sci., 67:432-440.

Taverner, M. R. and R. G. Campbell, 1985. Evaluation of the mobile nylon bag technique for measuring the digestibility of pig feeds. In: A. Just, H. Jorgensen and J. A. Fernandez (Eds.). Proc. 3rd Intern. Seminar on Digestive Physiology in the Pig. Copenhangen, Denmark, pp: 385-388.

Thacker, P. A. and S. Qiao, 2001. Further modifications to the mobile nylon bag technique to determine nutrient digestibility for swine. Asian-Aust. J. Anim. Sci., 14:1149-1156.

Thacker, P. A. and R. N. Kirwkood, 1990. Nontraditional Feed Sources for Use in Swine Production. Butterworth Publishers, Stoneham, MA., pp:551.

Thiessen, D. L., G. L. Campbell and R. T. Tyler, 2003. Utilization of thin distillers' solubles as a palatability enhancer in rainbow trout (Oncorhynchus mykiss) diets containing canola meal or air-classified pea protein. Aquaculture Nutr., 9:1-10.

Van Soest, P. J., J. B. Robertson and B. A. Lewis, 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74:3583-3597.

Wahlstrom, R. C., 1985. Sunflowers in pig nutrition. Pig News Inform., 6:151-154.

Young, L. G., A. G. Low and W. H. Close, 1991. Digestion and metabolism techniques in pigs. Pages 623-630 In: E. R. Miller, D. E. Ullrey and A. J. Lewis (Eds). Swine Nutrition. Butterworth-Heinemann, Boston, Mass.