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THE UNIVERSITY OF ALBERTA

RAPESEED MEAL AS AN ENERGY AND PROTEIN SOURCE FOR GROWING PIGS

by

© HUGH SIMON SABEN

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled, "Rapeseed meal as an energy and protein source for growing pigs" submitted by Hugh Simon Saben, B.Sc., M.Sc., in partial fulfilment of the requirement for the degree of Doctor of Philosophy.

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ABSTRACT

Studies were undertaken to determine the digestible energy (DE) and metabolizable energy (ME) values for rapeseed meals (RM) and for soybean meals (SM) fed to growing pigs. The effects of method of determination on DE and digestible nitrogen (DN) and on ME values of RM and SM fed to growing pigs were also studied.

In the one study, 12 samples of RM of either Brassica campestris or B. napus type and commercially processed by solvent, prepress solvent or expeller processes were evaluated. Two of the meals were from RM not in commercial production, one from zero-erucic acid seed of napus type and one from Bronowski (low glucosinolate) napus type seed. Results showed that the DE value of eleven samples of RM (excluding only Bronowski meal) averaged 3.60, 3.07 and 3.05 kcal/g, for 16 kg, 33 kg and 65 kg liveweight pigs respectively. The overall average DE value for RM was 3.21 $\pm$ 0.18 kcal/g. The overall average ME value was 2.89 $\pm$ 0.19 kcal/g and the ME corrected to nitrogen equilibrium (ME_n) value was 2.64 $\pm$ 0.19 kcal/g. The average DE, ME and ME_n values for SM (50% protein) in kcal/g were 4.21 $\pm$ 0.16, 3.92 $\pm$ 0.17 and 3.64 $\pm$ 0.16 respectively.

No significant differences were observed when two different methods were used to determine the energy values. One of these was a "substitution" method where the ingredient tested replaced part of the basal diet while the other was an "addition" method, where the ingredient tested was added to the basal diet. When the test meals were fed for two different lengths of time prior to conducting the determinations, no significant differences were observed in the energy values obtained.

Comparative evaluation of some techniques used in determinations of nitrogen and energy content of feces from pigs were undertaken. Results showed that no significant differences were observed in nitrogen or energy content when measured in the wet or dry (60°C for 72 hr) feces. It may be concluded that either wet or dry fecal material may be used for nitrogen and energy determinations in pig digestion trials, without significantly influencing the results obtained.

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INTRODUCTION

Rapeseed production in Western Canada has increased dramatically in the last decade. Today Canada is the largest producer of rapeseed in the world. Two million acres were planted which produced 37 million bushels of seed in 1969, while 3.95 million acres were planted which produced 71.2 million bushels in 1970. The majority of the crop is exported, Japan and The Netherlands being the major buyers (Rapeseed Digest, 1971). Since rapeseed contains approximately 40% oil, the remainder being meal plus moisture, the extraction of oil from the seed results in the production of large quantities of rapeseed meal (RM).

RM contains on the average 36% crude protein, 13% crude fiber, 2.2% fat, 0.6% calcium and 1.0% phosphorus (Clandinin, 1967). With its relatively high protein content, RM is a potential substitute for soybean meal in pig diets. The use of RM in Canadian pig diets has been increasing, but published experimental information is not available on the digestible energy (DE) and metabolizable energy (ME) of RM for the pig.

As the formulation of animal diets becomes more precise, the need for accurate information regarding the available nutrient content of feedstuffs becomes more imperative. Since energy is one of the major components of the diet, the accurate determination of this component is of prime importance. Feed formulators have frequently been using ME values for RM derived with the chick and applying these values in the formulation of pig rations. There is evidence that for high protein feedstuffs DE or ME values for the pig are above those for the chick (Diggs et al., 1965). Researchers have shown that with the

chick, different methods of experimental procedure have resulted in significantly different ME values (Rao and Clandinin, 1970).

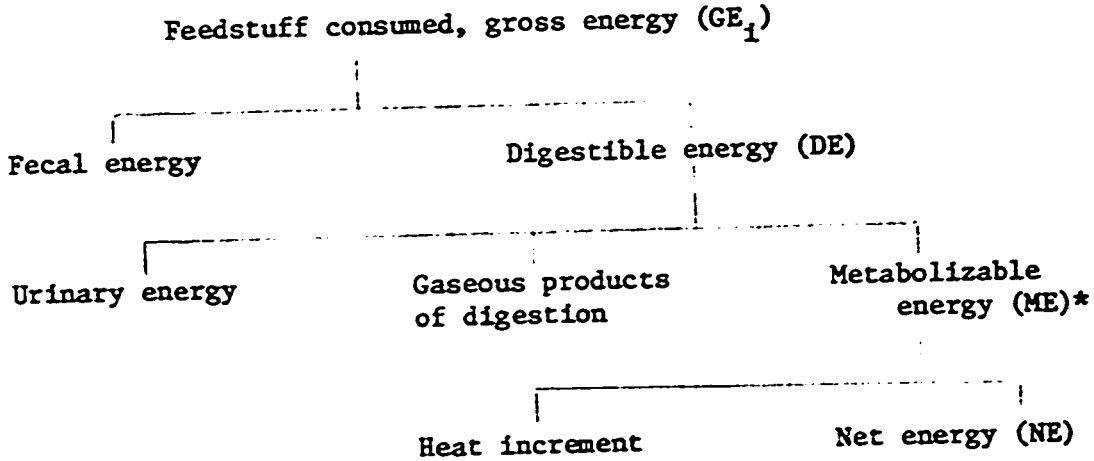
The present studies were undertaken to determine, by different experimental methods, the energy values of various rapeseed meals for the pig and to compare these values with those obtained for soybean meal. These studies were conducted in the Department of Animal Science at The University of Alberta from May 1968 to March 1971.

REVIEW OF LITERATURE

The utilization of energy:

The National Academy of Sciences - National Research Council, publication 1411 (1966), outlines the parameters of the utilization of energy of feedstuffs as feed-intake gross energy (GE_i), apparent digestible energy (DE), metabolizable energy (ME) and net energy (NE). The relationship between these measurements is shown in schematic form in Figure 1:

FIGURE 1: The utilization of energy. (conventional scheme)



* When ME is corrected to nitrogen equilibrium, it is known as nitrogen-corrected metabolizable energy (ME_n)

GE_i is defined as the dry weight of the feedstuff consumed multiplied by the gross energy (GE) of the feedstuff per unit dry weight.

DE is defined as the GE of the feedstuff consumed minus fecal energy. Fecal energy is defined as the dry weight of the feces

multiplied by the GE of the feces per unit dry weight. In this conventional scheme of energy utilization, DE refers to apparent and not true DE. Under the conventional scheme, fecal metabolic energy and endogenous urinary energy are considered part of the losses in digestion and metabolism, while in the true energy distribution scheme these fractions are part of the maintenance energy requirement. Therefore apparent DE is GE_i minus fecal energy of feed origin plus the amount of energy contained in the sloughed intestinal mucosa and digestive fluids that are not obtained from unabsorbed ration residues.

ME is defined as the GE_i of the feedstuff consumed minus fecal energy, minus urinary energy, minus the energy lost in the gaseous products of digestion. Urinary energy is defined as the GE of the urine. The gaseous products of digestion include the combustible gases produced in the digestive tract incident to the fermentation of the energy. For monogastric mammals and birds, the gaseous products of digestion are not normally considered. Bowland et al., (1970) using respiration chambers observed that methane production averaged 1.1% of total DE for male castrate pigs between 25 and 74 kg liveweight.

ME_n is defined as the GE_i of the feedstuff consumed minus fecal energy, minus urinary energy, minus the energy lost in the gaseous products of digestion; the total is then corrected for nitrogen retained or lost from the body. When nitrogen is lost from the body and animals are in negative nitrogen balance, X kcal are added to ME; when nitrogen is retained in the body and animals are in positive nitrogen balance, X kcal are subtracted from ME. This correction factor is based on the average energy content of urine per unit of nitrogen. For the pig a factor of 6.77 kcal/g nitrogen in the urine

is used as the correction factor (Diggs et al., 1959); for the chick a factor of 8.73 kcal/g is used (Titus et al., 1959). A general correction factor of 7.45 kcal/g is used for other animals, however this value was obtained with dogs and differences between species should be recognized (NAS-NRC, 1966).

NE is defined as the difference between ME and heat increment (HI) and includes the amount of energy used for either maintenance (NE_m) or for maintenance plus production ($NE_m + NE_p$). HI is defined as the increase in heat production following consumption of a feedstuff when an animal is in a thermoneutral environment.

When making up feed composition tables, the appropriate energy measure is usually expressed on a per unit weight basis. Composition may be expressed on air dry "as fed" or on a "moisture-free" basis. Expression of energy and nutrients on a moisture-free basis simplifies computation and diet formulation.

Determination of energy values:

A feedstuff may thus have separate energy values for GE, DE, ME, ME_n and NE. It is possible that NE would be the best measure of available energy for actual body use by the pig; however, NE is the most difficult energy measure to determine. In the growing pig, maintenance and production energy are seldom separated as interest is in overall performance. In addition, NE is influenced by the level of feed intake, the balance of all the nutrients in the ration, the age, breed, sex and condition of the animal used in the determination and the environmental conditions which are present during the determination (Hill and Anderson, 1958; Provatorov, 1969). It is not,

therefore, truly a measure of the energy in the feedstuff but to a considerable degree a measure of the animal and its environment.

ME is more difficult to determine than DE because urinary collection must be made. This measure is widely used with chickens where fecal and urinary excreta are voided together, hence, with avian species it is easier to determine than DE. ME has the weakness that the values are not strictly additive when feeds are combined into a diet because urinary losses may vary with the nutrient balance. On the other hand, as pigs are usually given well balanced diets in which the urinary losses of energy are reasonably constant, then variations in the ratio ME:DE should be small (ARC, 1967).

DE has the advantage that it is relatively easy to determine, and takes into account the major energy loss associated with digestion and absorption, that of the feces. Diggs et al., (1965) found that for a range of feedstuffs ME averaged 94.7 $\pm$ 5.3% of DE and ME_n averaged 91.6 $\pm$ 6.3% of DE. Nehring et al., (1960) reported that the ME of barley when added to a basal diet for adult pigs was 97.7% of DE. Tollett et al., (1961) reported that age within the range 35-160 days did not affect DE or ME_n values in full fed pigs. Thus it should be equally satisfactory to use the more easily determined DE value rather than the ME value for pigs.

The limitation of GE is obvious, as it does not take into account the energy lost in either the feces or the urine. For standard rations, differences in crude fiber markedly affect their available energy value and hence their relative feeding value. The most important consequence of substitution between standard feeds, is usually due to differences in the crude fiber of the substituted products (Crampton, 1956). For

instance, the crude fiber from whole oats is 38% digestible while from rolled oats the crude fiber is 80% digestible (Morrison, 1956a). Hence, by rolling oats the crude fiber digestibility was improved by 42%, thus improving the available energy of the standard ration.

Energy values of various feedstuffs for the pig:

Most of the values for DE and ME in feedstuffs for pigs have been mathematically derived by converting Total Digestible Nutrient (TDN) values to DE values and converting DE to ME by regression equations (NAS-NRC, 1969). The commonly used formulas are as follows:

$$\text{DE (kcal/kg)} = \frac{\text{TDN \%}}{100} \times 4409$$

$$\text{ME (kcal/kg) for swine} = \text{DE (kcal/kg)} \times \frac{96 - (0.202 \times \text{protein \%})}{100}$$

Mitchell and Hamilton (1933) conducted some of the first trials to determine by experimental means the energy values of certain feedstuffs for the pig. They reported that the ME of oat hulls was 1.12 kcal/g and that of alfalfa was 1.62 kcal/g. Forbes and Hamilton (1952) reported that the ME in kcal/g of wheat straw was 2.71; oat hulls was 2.74 and alfalfa was 2.69. These higher values, compared with values reported by Mitchell and Hamilton 19 years previously, are attributed to higher crude protein levels in the feedstuffs. Garrigus and Mitchell (1935) reported that the ME of whole corn was 3.66 kcal/g while the ME of ground corn was 3.79 kcal/g.

Energy values for the pig and the chick of some feedstuffs relative to wheat are shown in Table 1. A comparison of the ME_n values

for the two species show some similarities, as well as some marked differences. The available energy in the high energy cereal grains, such as wheat and corn, is similar for both the pig and the chick. However, for wheat bran and for soybean meal (SM) containing 50% crude protein (N x 6.25), the ME_n values reported for the chick are substantially below those found for the pig. The difference for wheat bran could be attributed to the reduced ability of the chick, compared with the pig, to digest fiber via microbial activity in the alimentary tract. The pig varies in this regard as it becomes mature. Zivković and Bowland (1970) observed that mature sows could digest high crude fiber (9.3%) diets to a greater extent than younger pigs. They also reported that sows were most efficient in digesting organic nutrients on the 90th day of gestation, poorest on the 10th day of lactation and intermediate on the 30th day of gestation.

The reason that the ME_n value for SM is different for the two species is not known. One can speculate that perhaps the inability of the chick to utilize galactose (Rutter et al., 1953), and the differences in digestive tract capacity between the two species could account for some of the variation between the values. No experimentally determined values for DE, ME or ME_n for RM have been reported for the pig. Bowland and Schuld (1968) calculated that RM had an average ME_n of 1900 kcal/kg meal on an "as fed" basis. On the basis of work reported with feedstuffs other than RM, it is apparent that the energy values of feedstuffs should be considered as being species specific.

Digestible and metabolizable energy values for rapeseed meal:

Bowland (1966) reviewed extensively the feeding value of RM for

Table 1: Energy values of some feedstuffs relative to wheat for the pig and the chick.

(Expressed as kcal/g dry matter basis)

	Swine[x]					Poultry[+]		
	DE		ME_n			ME_n		
Feedstuff	Value	Relative Value	Value	Relative Value	% of DE	Value	Relative Value	% ME_n of pigs
Wheat (ground)	3.77	100	3.55	100	94	3.45	100	97
Corn (ground)	4.00	106	3.77	106	94	3.85	112	102
Oats	3.10	82	2.97	84	96	2.88	83	97
Alfalfa meal (17%)	1.62	43	1.40	39	86	1.78	52	127
Soybean meal (50%)	4.39	116	3.72	105	85	2.70	78	72
Fish meal (menhaden)	3.59	95	2.93	82	82	3.12	90	106
Wheat bran	2.67	71	2.47	70	92	1.29	37	52

x Values for swine derived from Diggs et al., (1965).

+ Values for poultry derived from NAS-NRC, (1971).

swine. However, DE or ME values of RM for the pig were not available then, and are still not available. Hussar and Bowland (1959) obtained no significant effect on apparent DE in pigs weighing 7, 28 or 60 kg liveweight, when receiving diets containing 0, 2 or 10% expeller-extracted RM in replacement for SM on an isonitrogenous basis. However the 10% level of the same sample of RM significantly reduced the apparent DE with rats; this observation was later confirmed by Manns and Bowland (1963).

Schuld and Bowland (1968) reported that 8% RM in the starting and growing diets for pigs, when replacing SM on an isonitrogenous basis, had no depressive effect on the energy values of the ration, but did depress feed intake and growth performance. In contrast, Bayley et al., (1969) found no effect on performance during the finishing phase by adding 11% RM to replace an equivalent level of protein from SM. Saben and Bowland (1971) found that 8% RM, when replacing SM on an isonitrogenous basis, fed to sows both in the gestation and lactation periods for two reproductive cycles, had no significant effect on feed conversion efficiency, gestation weight gains or lactation weight losses.

Bell (1965b) in studies with solvent-extracted RM of Brassica campestris origin and free of the enzyme myrosinase, obtained no reduction in energy digestibility of the diet, when the meal was fed to growing and finishing pigs. The addition of ground rapeseed screenings added as a source of the enzyme myrosinase, caused a depression in digestibility coefficients of energy and protein. Hence, myrosinase may be implicated in digestibility depression.

The development of growth-inhibiting properties in RM appears

dependent upon hydrolysis of glucosinolates (thioglucosides) into isothiocyanates (2-hydroxy-3-butenyl) and oxazolidinethione. The hydrolysis can be effected by the enzyme myrosinase, normally present in unheated rapeseed (Greer, 1956; Kjaer, 1960; Virtanen, 1965) and shown to occur in the gastrointestinal tract, where it is produced by certain bacteria, especially E. coli and A. aerogenes (Bell and Belzile, 1965).

Bell and Belzile (1965) in their review article observed that commercially produced enzyme-free RM, containing unhydrolyzed glucosinolates, is free of most of the undesirable properties if myrosinase is not reintroduced by other dietary means or by intestinal bacteria. Lodhi et al., (1970) fed diets, with and without myrosinase, and containing up to 30% RM, and showed no effect of dietary RM on the ME of the chick diets.

Studies on the energy values of RM for poultry are limited. The use of RM in poultry rations has been extensively studied by Clandinin and Robblee (1966). Sibbald and Slinger (1963b) using chicks, reported a value of 1670 kcal ME/kg RM [dry matter (DM) basis], on one sample of solvent-processed RM, which analyzed 43.1% crude protein. Sell (1966) using hens reported a value of 2290 kcal ME/kg RM (DM basis), on one sample of solvent-processed RM which analyzed 38.3% crude protein. Rao and Clandinin (1970) obtained average ME values for two RM samples analyzing 39.8% crude protein of 1347, 1468 and 1533 kcal/kg (DM basis) for 14, 28 and 42 day old chicks.

Factors influencing energy values:

Descriptions of feedstuffs are sometimes incomplete. Nutrient

differences in different sources of the same ingredient can lead to variations in energy values. For instance oats might have varying fiber percentages (NAS-NRC, 1969), for example: Oats, grain, heavy with 10.9% fiber yields 3086 DE kcal/kg, while Oats, grain, light with 16.5% fiber yields 2822 DE kcal/kg. As considerable variability exists between different sources of the same feedstuff, tables of values of energy composition do not necessarily give the correct energy value of the particular sample used in the formulation of diets for the individual pig.

The average comparative values of cereals based on DE content of the cereals when fed to pigs do not appear to vary greatly between North America and the United Kingdom (Table 2). Thus corn and wheat have about 113% the value of barley, and oats about 89% the value of barley. However, there is ample evidence (Hoppner et al., 1968; McElroy et al., 1948) that the nutrient levels of Western Canadian grains differ from average values published by NAS-NRC (1969) and that some of this variation can be attributed to soil and climatic influences. It should be recognized that variation in the nutrient composition of individual cereals may be greater than the differences in average composition between cereals (Jones et al., 1968).

The species, breeding background, sex and age of animals have been shown to affect the energy values of rations. Diggs et al., (1965) observed that the ME_n value of SM was greater for the pig than the value for the chick. Slinger et al., (1964) reported that differences existed between chickens and turkeys in their ability to metabolize energy from either a high or low energy ration.

Bowland and Berg (1959) reported that different groups of pigs

Table 2: Relative economic value of cereals for pigs[1].

Cereal	Digestible energy content from Chamberlain[2]	Digestible energy content from NRC[3]
Barley	100	100
Corn	111	112
Wheat	114	114
Oats	93	85

1 Bowland, J.P. Unpublished data.

2 Chamberlain, A.G. (1969).

3 NAS-NRC, (1969).

may have different nutrient requirements. Bell et al., (1958) found that significant differences in energy digestibility by pigs existed between stations. The differences could be associated with genetic and/or environmental factors. Skitsko and Bowland (1970a) indicated that breeding background and sex of market pigs are important considerations in formulation of energy requirements, insofar as performance is concerned, but they showed (1970b) that neither breeding background or sex significantly influenced DE or ME values. Recently O'Grady and Bowland (Personal communication, 1971) observed a sex effect in the response of rats to diets having different DE levels, but constant DE: crude protein ratios. Male rats required diets having a higher DE concentration than female rats. This is in contrast to Sibbald (1957) who showed no sex effect on DE concentration with rats. However the latter mentioned study was conducted for a short period relative to the former study.

Zivković and Bowland (1963) observed significant variation in the ability of gilts to digest organic nutrients, with the exception of protein, during growth, gestation and lactation. They obtained the highest average coefficient of 75.6% for fat digestibility during gestation, 69.6% during growth and 59.4% during lactation. The average digestion of crude fiber was 15.8% during lactation, 10.1% during growth and 9.5% during gestation. These some researchers reported (1970) that mature sows were able to digest high crude fiber diets to a greater extent than were young pigs.

Sibbald et al., (1959) showed that the ME content of several feedstuffs differed when chicks of 3 or 7 weeks of age were used for the determination. Renner and Hill (1960) showed that as age increases

so does the ability of the chick to utilize tallow. Lodhi et al., (1969) and Rao and Clandinin (1970), both observed that as age increased so did the ME values of RM when fed to chickens.

Wagner et al., (1963) reported that an increase in the energy content of pig diets resulted in a decrease in the yield of lean cuts of meat. Bell (1965a); Robinson (1965); Seerley et al., (1964) observed that at a constant energy intake level in the diet, while increasing the protein intake level, leaner carcasses were obtained.

Robinson and Lewis (1962) observed that the DE value of barley was 2.88 kcal/g, of corn 3.43 and of wheat 3.30 or 119% and 114% the value of barley respectively. In contrast Young (1971) used corn as the base index of 100 and found that barley had 85%, oats 79% and wheat 94% the DE value of corn. Using barley as a base index of 100, corn was 118%, oats 93% and wheat 111% the DE value of barley. One of the differences between these two studies was the method of determination used to ascertain the DE value of the grain. The former researchers used the method described by Hill and Anderson (1958) and Potter and Matterson (1960), which consists of feeding a basal ration containing a chemically pure material of predetermined ME content and a test ration, similar to the basal ration, but in which a portion of the reference material is replaced by the feedstuff to be determined. The latter researcher used the method described by Diggs et al., (1965), which consists of feeding the basal ration, formulated to provide adequate amounts of all nutrients except energy, and the reference material added to the basal ration, thus obtaining values of the reference material by difference between the test ration and the basal ration.

Studies have been undertaken to determine whether the balance of the nutrients in the ration affects the energy values obtained. Sibbald et al., (1962) determined the ME value of wheat, barley and corn by substituting each grain for all or part of the basal ration. The protein contents of the rations varied from 8 to 33% and the ME values of the grains were found to be unaffected by protein level in the test diets.

Sibbald and Slinger (1962) determined the ME content of SM and meat meal when they were incorporated at levels of 25, 50 or 75% of the ration. They observed that the ME of SM was unaffected by the level of inclusion in the ration, but meat meal values increased as the percent inclusion increased. However, Olson et al., (1961) found that the ME value of meat meal was reduced when either the protein level of the basal ration or the percentage inclusion of meat meal in the ration was increased. The difference in the comparative results obtained for meat meal between these two groups of research workers is not known, but indicates that a generalization on factors influencing DE and ME cannot be made.

Methods of determination of digestible and metabolizable energy for pigs:

The determination of DE and ME values for individual ingredients in pig diets have been carried out in numerous centers: Bayley and Cho (1969); Bayley and Lewis (1965a); Bayley and Lewis (1965b); Diggs et al., (1965); Nehring et al., (1963) to name a few researchers. However the method of determination has varied greatly between centers.

One procedure demonstrated by Bayley and Lewis (1965a), consisted

of feeding a basal ration containing a semi-purified material of predetermined DE and ME value and a test ration, similar to the basal ration but with the test material substituting for a portion of the basal ration. The DE and ME contents of the two rations were then determined and the energy content of the test ration calculated.

A second procedure demonstrated by Diggs et al., (1965) involved the feeding of the same basal ration to all pigs on experiment. This basal ration was formulated to provide adequate amounts of all nutrients except energy. The test material was then added to the basal ration, thus obtaining values for DE and ME by difference between the test ration and the basal ration.

A third procedure demonstrated by Bayley and Cho (1969) involved the feeding of a basal practical type ration, and a test ration obtained by substituting part of the basal ration with the material to be analyzed. The DE and ME contents of the two rations were then calculated.

Similar procedures have been used to determine the ME_n of feedstuffs for the chick; the semi-purified method as described by Hill and Anderson (1958) and Potter and Matterson (1960); and the difference method as described by Nehring et al., (1963). The substitution method has been used extensively by workers including Rao and Clandinin (1970) and Sibbald and Slinger (1963a).

PART 1

Introduction:

A preliminary study, experiment 441A, using a modification of the method used by Diggs et al., (1965) was designed to obtain values for DE, ME and ME_n for a sample of RM for growing pigs at two weight periods, 15 and 32 kg liveweight. This experiment was designed mainly to determine if 25% of the total feed could consist of RM, as variable results regarding palatability of RM have been reported by Bowland (1957) and Morrison (1956b).

Materials and Methods:

Twelve female pigs of Yorkshire x Lacombe breeding were involved. Four pigs were fed the basal diet, 4 pigs were fed the SM supplemented diet and 4 pigs were fed the RM supplemented diet. At 15 kg liveweight, the basal diet (Table 3) was fed to the appropriate experimental pigs at a level of 450 g/day. The basal diet was based on SM and wheat and thus differed from that used by Diggs et al., (1965) which was based on SM and corn. The two test ingredients (RM and SM) were added to the basal diet at a level representing 25% of the total feed intake by weight. Therefore pigs fed the RM test ration consumed 450 g basal diet and 150 g RM per day. It was found that at 15 kg liveweight all the basal ration or rations with RM or SM added were consumed by the pig. No problems as to palatability or rejection of RM by the pig were observed.

At the 32 kg liveweight period, it was found that the RM pigs consumed 1200 g/day of the diet, which was made up of 900 g basal

Table 3: Composition of the basal diet fed in energy studies with pigs.

Ingredient	Composition %
Soybean meal (50%)	67.35
Wheat	23.00
Stabilized tallow	3.50
DL-methionine	0.50
Dicalcium phosphate	3.50
Ground limestone	1.00
Iodized salt	0.40
Zinc sulfate	0.05
Trace mineral mix[1]	0.25
Vitamin B-complex mix[2]	0.35
Vitamins A, D & E[3]	+
Terramycin supplement[4]	0.10

1 The mineral mix supplied the following per 100 kg diet: cobalt carbonate, 570 mg; copper sulfate, 6.12 g; ethylene diamine dihydroiodide, 320 mg; ferrous carbonate, 58.7 g; manganous oxide, 11.9 g; zinc oxide, 740 mg; ground limestone, 171.6 g.

2 The vitamin B-complex mix supplied the following per 100 kg diet: riboflavin, 1.1 g; calcium pantothenate, 2.2 g; niacin, 4.95 g; choline chloride, 5.35 g; folic acid, 34.0 mg; vitamin B_{12}, 2.2 mg.

3 Vitamin A was fed at 500,000 I.U.; vitamin D_2 at 50,000 I.U. and vitamin E at 500 I.U. per 100 kg diet.

4 Terramycin supplement supplied 2.2 g of antibiotic per 100 kg of diet.

ration and 300 g RM. Higher levels were offered to the RM group; however these higher amounts were not entirely consumed each day. The amount of 1200 g/day was considered to be the optimum daily amount that the experimental pigs would consume. No problems were encountered at either weight by feeding pigs from the SM group the same levels of basal and SM as were fed to the RM group.

The RM was of B. campestris type and purchased locally. The SM was a 50% crude protein commercially available meal purchased locally.

Six metabolism cages, described by Castell and Bowland (1968) were available, so that each metabolism trial contained two pigs from each diet. The same pigs were used for metabolism studies at the two weights (15 and 32 kg liveweight).

Seven days after receiving the basal diet or the basal diet plus the respective test ingredient, pigs were placed in metabolism cages. Collection of feces and urine commenced at 8 A.M. on the 10th day with collection for a 72-hour period. Water was available at all times.

Feces were collected daily and stored in a refrigerator at approximately 0°C until the end of the collection period, when an aliquot of the combined fecal collection was dried in a forced-air oven at 60°C for 72 hours. After drying the samples were allowed to equilibrate with air moisture, weighed and ground through a 40-mesh screen in a Wiley mill. Urine was filtered through glass wool into collection vessels containing 25 ml of concentrated H_2SO_4. Total urine production was measured and an aliquot was taken for analytical determination.

Combustible energy was measured for feed, feces and urine using a Parr adiabatic oxygen bomb calorimeter. Nitrogen determination was

carried out on feed, feces and urine using the Kjeldahl method (AOAC, 1965) with protein being calculated from N x 6.25. Diggs et al., (1959) determined that the caloric value of urinary nitrogen for the pig was 6.77 kcal/g, and this value was used to adjust urinary energy to nitrogen equilibrium.

Data were analyzed statistically using an analysis of variance program available from The University of Alberta Computing Center.

Results and Discussion:

One sample of RM was used in this preliminary study. No evidence of lack of acceptability was encountered when RM was fed to growing pigs at two weight ranges, 15 and 32 kg liveweight, and when RM made up 25% of the total diet. Metabolism determination proved successful using a modification of the method proposed by Diggs et al., (1965). The study indicated that growing pigs in metabolism cages would readily consume diets containing up to 25% RM.

Energy values are reported for RM, SM and the basal diet in Table 4 for the combined weight; however limited significance should be attached to the actual values, as this was a preliminary study. The average DE values were 3.94 kcal/g for RM and 4.31 kcal/g for SM. The average ME values were 3.62 kcal/g for RM and 4.18 kcal/g for SM. Greater differences between RM and SM were obtained for the ME_n values, which were in kcal/g, 3.33 for RM and 4.08 for SM. The values for the basal diet are included for comparative purposes.

The four RM fed pigs were continued on trial to 65 kg. At this weight it was found that the maximum amount that all pigs would consume was 1500 g/day of total feed, of which 25% or 375 g was RM.

Table 4: Means for gross energy, digestible energy and metabolizable energy (kcal/g dry matter) for rapeseed meal, soybean meal and the basal ration for two combined weights (15 and 32 kg) of pigs fed a basal ration or a basal ration with rapeseed meal or soybean meal.

Diet	No. of pigs	Gross energy (GE)	Digestible energy (DE)[1]	Metabolizable Energy Unadjusted (ME)	Metabolizable Energy Adjusted (ME_n)
Rapeseed meal	4	4.92	3.94	3.62	3.33
Soybean meal	4	4.70	4.31	4.18	4.08
Basal diet	4	4.49	4.07	3.78	3.62

1 Analysis of variance indicated that rapeseed meal had a lower DE than SM ($P < 0.05$).

Therefore 600, 1200 and 1500 g/day of feed for 15, 32 and 65 kg weight pigs respectively, were selected as the amounts to be fed to each pig in further studies.

PART 2 [1]

Introduction:

Most of the values for digestible energy (DE) and metabolizable energy (ME) in feedstuffs for pigs have been mathematically derived by converting Total Digestible Nutrient values to DE values and converting DE to ME by regression equations (NAS-NRC, 1969). Published information on the DE and ME from rapeseed meal (RM) for pigs is not available. Feed formulators have frequently been using ME values derived with the chick and applying these values to pig feeds. There is evidence that for high protein feeds, values for DE or ME for the pig are above those for the chick (Diggs et al., 1965).

The present study was conducted to determine the DE, ME, ME corrected to nitrogen equilibrium (ME_n) and digestible nitrogen (DN) from RM of different types and processed by different methods. Soybean meal (SM) containing 50% protein was used as a positive control throughout the experiments.

Materials and Methods:

Ten samples of RM (Table 5) of either Brassica campestris of B. napus type and commercially processed by solvent, prepress-solvent or expeller processes were evaluated for DE, ME, ME_n and DN by a modification of the method of Diggs et al., (1965). An eleventh sample of

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[1] The material in Part 2 of this thesis has been accepted for publication in the August 1971 issue of the Canadian Journal of Animal Science:
Saben, H.S., J.P. Bowland and R.T. Hardin. 1971. Digestible and metabolizable energy values for rapeseed meals and for soybean meal fed to growing pigs. 51: (in press).

RM from zero-erucic acid seed of napus type and a twelfth sample from Bronowski (low glucosinolate) napus type seed were also evaluated. These RM samples were those that were supplied to the various co-operators under a Rapeseed Utilization Assistance Program and were crushed during July to October, 1968 but were from seed produced during 1967 and 1968.

A basal diet (Table 3) was fed to experimental pigs at a level of 450 g/day at 16 kg, 900 g/day at 33 kg and 1125 g/day at 65 kg liveweight. This basal diet was based on SM and wheat and therefore differed from that used by Diggs et al., (1965) which was based on SM and corn. The test ingredients (RM or SM) were added to the basal diet at a level representing 25% of the total feed intake by weight. Therefore pigs fed the test ingredients consumed 600 g, 1200 and 1500 g/day at 16, 33 and 65 kg liveweight respectively. Seven days after receiving the basal diet or the basal diet plus the test ingredient, pigs were placed in metabolism cages as described by Castell and Bowland (1968). Collection of feces and urine commenced at 8 A.M. on the 10th day with collection for a 72-hour period. Water was available at all times.

A total of 64 barrows of Yorkshire x Lacombe breeding were involved in the study, 4 pigs were fed each of the RM diets and 8 pigs fed each of the basal diet and the SM diet. Eight metabolism cages were available so that each metabolism trial contained one pig fed the basal diet, one pig fed the SM diet and 6 pigs fed six different RM diets. Therefore SM served as a positive control in each metabolism trial. The same pigs were used for metabolism studies at three different weights (16, 33 and 65 kg). Two replications totalling 32 pigs were on experiment between June and September 1969 and a further two

Table 5: Rapeseed meal samples identified by manufacturing process and seed types.

Rapeseed meal Sample No.[1]	Manufacturing process	Seed type
1	Solvent	B. campestris
3	Solvent	B. campestris
4	Prepress-solvent	B. campestris
5	Prepress-solvent	B. campestris
6	Prepress-solvent	B. napus
7	Expeller	B. campestris
8	Prepress-solvent	B. campestris
9	Expeller	B. campestris
10	Prepress-solvent	B. campestris
11	Prepress-solvent	B. napus
2	Solvent	Zero-erucic acid (B. napus)
12	Solvent	Bronowski (B. napus)

[1] Samples 1 to 11, excluding 2 were produced from commercial seed. Samples 2 and 12 were produced from seed not available at that time for commercial use.

replications totalling 32 pigs between December 1969 and March 1970.

Feces were collected daily and stored in a refrigerator at approximately 0°C until the end of the collection period, when an aliquot of the combined fecal collection was dried in a forced air oven at 60°C for 72 hours. After drying the samples were allowed to equilibrate with air moisture, weighed and ground through a 40-mesh screen in a Wiley mill. Urine was filtered through glass wool into collection vessels containing 25 ml of concentrated H_2SO_4. Total urine production was measured and an aliquot was taken for analytical determinations.

Combustible energy was measured for feed, feces and urine using a Parr adiabatic oxygen bomb calorimeter. Nitrogen determinations were carried out on feed, feces and urine using the Kjeldahl method with protein being calculated from N x 6.25. Diggs et al., (1959) determined that the calorific value of the urinary nitrogen for the pig was 6.77 kcal/g, and this value was used to adjust urinary energy to nitrogen equilibrium.

Data were analyzed statistically using an analysis of variance program available from The University of Alberta Computing Center. Preliminary statistical analyses indicated no differences in the values of DE, ME, ME_n and DN derived using the overall means for the basal diet compared with the values obtained using the individual means for the basal diet applicable to each specific metabolism trial. As an overall mean may be considered to be a more reliable estimate, the overall basal diet means were used in deriving the energy and nitrogen values reported. Means were compared using Duncan's multiple range test (Steel and Torrie, 1960).

Data were missing for one pig fed rapeseed meal number 5 at 33 kg liveweight. These missing data were replaced by the average value of this group, with error degrees of freedom being reduced by one for each missing value. A probability of 0.05 was selected as the point of significance for data.

Results and Discussion:

Of the 12 RM samples used in this study, 2 meals were produced from rapesced that was not in commercial production. Therefore, these two meals have been excluded from the overall mean values (Table 6). The Bronowski meal number 12 was a different type meal containing low glucosinolate levels, while the meal number 2 from zero-erucic acid seed seemed to be typical in composition to other napus meals. The DE, ME, ME_n and DN values for 10 meals indicated no significant differences between meals. Means with their standard errors for the 10 meals expressed in kcal/g dry matter were 4.74 $\pm$ 0.12 for GE, 3.21 $\pm$ 0.18 for DE, 2.89 $\pm$ 0.19 for ME and 2.64 $\pm$ 0.19 for ME_n. Average values for DE, ME and ME_n for Bronowski meal and for zero-erucic acid meal were not significantly different from the average of the other meals. Soybean meal contained 4.81 $\pm$ 0.08, 4.21 $\pm$ 0.16, 3.92 $\pm$ 0.17 and 3.64 $\pm$ 0.16 kcal/g dry matter for GE, DE, ME and ME_n, the latter three values being significantly higher than those obtained for RM. The coefficient for DN averaged 75.9 $\pm$ 2.9% for RM and 89.2 $\pm$ 1.9% for SM.

Diggs and coworkers reported DE, ME and ME_n for a wide range of feedstuffs for the young, 15.4 kg, pig, but RM was not included in their study. For SM containing 50% protein they obtained values in

kcal/g dry matter of 4.39 for DE, 3.88 for ME and 3.72 for ME_n.

The ten RM samples had unadjusted ME and ME_n values of 90 and 82% of the DE respectively, while the SM had ME and ME_n values that were 93 and 86% of DE. These values for SM compare with 88 and 85% obtained by Diggs et al., (1965). The standard errors for DE and for ME were similar suggesting that there is little difference in accuracy between these two energy measures for pig diets.

The values obtained for the basal diet are given in Table 3 for reference purposes. The observed energy values of the basal diet were 4.56 ± 0.01, 3.99 ± 0.03, 3.70 ± 0.04 and 3.63 ± 0.04 kcal/g for GE, DE, ME and ME_n while the calculated values derived from NAS-NRC (1969) were 4.60, 4.14, 3.87 and 3.68 kcal/g respectively.

The values for GE, DE, ME, ME_n and the coefficients for DN at the three experimental weights of 16, 33 and 65 kg have been grouped by manufacturing process and seed type (Table 7). Average values are based on 11 samples (excluding only the Bronowski meal), because of the similarity of the zero-erucic acid meal to the average of the other meals. There were no significant differences in the values for DE, ME and ME_n in the RM samples for 16, 33 or 65 kg pigs. However, there was a trend toward a decrease in these values between 16 and 33 kg liveweight. The SM decreased in DE, ME and ME_n as weight increased with differences being significant for DE and ME between 33 and 65 kg liveweight. The coefficients for DN in RM and SM were similar throughout. The basal diet showed no trend toward a change in DE, ME, ME_n or DN throughout the three weight ranges. As indicated by the low standard errors (Tables 6 and 7), the basal diet gave very uniform results throughout the trials.

Table 6: Overall means for gross, digestible and metabolizable energy (kcal/g dry matter) and digestible nitrogen (%) for two seed types and different processed rapeseed meals and for soybean meal as determined at three weights (16, 33 and 65 kg) of growing pigs.

Rapeseed meal number	No. of pigs	Gross energy		Digestible energy		Metabolizable energy				Digestible nitrogen	
						ME		ME n			
		Mean	±SE[1]	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE
1	4	4.85	0.11	3.44	0.22	3.06	0.21	2.93	0.19	79.3	2.8
3	4	4.78	0.10	3.30	0.17	2.84	0.18	2.59	0.19	78.0	2.4
4	4	4.80	0.10	3.36	0.08	3.17	0.13	2.98	0.12	78.6	2.3
5	4	4.66	0.13	3.03	0.16	2.67	0.16	2.37	0.17	74.7	3.4
6	4	4.66	0.13	2.99	0.19	2.64	0.19	2.30	0.20	70.7	1.9
7	4	4.85	0.14	3.32	0.28	3.10	0.29	2.88	0.27	76.1	3.8
8	4	4.66	0.10	2.91	0.20	2.55	0.22	2.27	0.22	74.1	2.7
9	4	4.89	0.14	3.31	0.18	3.09	0.15	2.80	0.16	73.9	2.9
10	4	4.67	0.13	3.17	0.18	2.73	0.16	2.51	0.17	74.9	2.5
11	4	4.59	0.13	3.30	0.18	3.05	0.20	2.76	0.21	78.4	4.2
Averages: (10 meals)	40	4.74	0.12	3.21^{ab}	0.18	2.89^{ab}	0.19	2.64^{a}	0.19	75.9^{a}	2.9
2	4	4.80	0.14	3.26^{ab}	0.20	2.94^{ab}	0.22	2.57^{a}	0.24	77.2^{a}	2.8
12	4	4.76	0.11	2.82^{a}	0.18	2.57^{a}	0.20	2.34^{a}	0.17	70.5^{a}	2.7
Soybean meal (50%)	8	4.81	0.08	4.21^{c}	0.16	3.92^{c}	0.17	3.64^{b}	0.16	89.2^{b}	1.9
Basal diet	8	4.56	0.01	3.99^{bc}	0.03	3.70^{bc}	0.04	3.63^{b}	0.04	90.6^{b}	0.5

[1] Standard error
Values in each column with a common letter or with no letter in their superscript are not significantly different ($P < 0.05$).

Table 7: Means for gross, digestible and metabolizable energy (kcal/g dry matter) and digestible nitrogen (%) for three weights of pigs for rapeseed meals of different seed types and different methods of processing, and for soybean meal.

Weight kg	Manufacturing process	Seed type	Quantity fed/day g	No. of meal samples	No. of pigs	Gross energy Mean	Gross energy ±SE	Digestible energy Mean	Digestible energy ±SE	Metabolizable energy ME Mean	Metabolizable energy ME ±SE	Metabolizable energy ME_n Mean	Metabolizable energy ME_n ±SE	Digestible nitrogen Mean	Digestible nitrogen ±SE
16	Solvent	campestris	150	2	8	5.08	0.09	3.75	0.17	3.37	0.21	3.16	0.23	76.7	4.1
	Prepress-solvent	campestris	150	4	16	4.88	0.07	3.25	0.07	2.82	0.11	2.60	0.12	71.3	2.6
	Expeller	campestris	150	2	8	5.18	0.18	3.71	0.24	3.36	0.22	3.14	0.24	73.9	4.6
	Prepress-solvent	napus	150	2	8	4.65	0.16	3.31	0.20	3.00	0.24	2.57	0.29	74.0	4.7
	Solvent	(zero-erucic acid) napus	150	1	4	5.00	0.15	3.98^{ab}	0.40	3.51^{ab}	0.40	3.15^{ab}	0.47	83.5	2.6
				AV (11 meals)		4.96	0.13	3.60^{ab}	0.22	3.21^{ab}	0.24	2.92^{ab}	0.23	75.9^{a}	3.7
	Solvent	(Bronowski) napus	150	1	4	4.92	0.19	3.07^{a}	0.28	2.75^{a}	0.20	2.54^{a}	0.14	69.4^{a}	7.6
			150	1	8	5.03	0.09	4.60^{c}	0.24	4.21^{c}	0.28	3.96^{c}	0.26	90.3^{b}	3.5
	Soybean meal Basal diet	(50%)	450		8	4.54	0.00	3.98^{bc}	0.03	3.73^{bc}	0.05	3.62^{bc}	0.05	90.2^{b}	0.7
33	Solvent	campestris	300	2	8	4.70	0.10	3.28	0.23	2.76	0.23	2.66	0.21	81.1	2.3
	Prepress-solvent	campestris	300	4	16	4.63	0.08	3.11	0.12	2.82	0.16	2.64	0.16	77.2	1.9
	Expeller	campestris	300	2	8	4.77	0.13	3.12	0.28	2.98	0.32	2.67	0.29	73.4	3.6
	Prepress-solvent	napus	300	2	8	4.56	0.12	3.10	0.24	2.87	0.20	2.58	0.23	74.9	5.1
	Solvent	(zero-erucic acid) napus	300	1	4	4.71	0.33	2.72^{ab}	0.32	2.44^{ab}	0.34	1.97^{a}	0.41	69.8^{a}	5.8
				AV (11 meals)		4.67	0.15	3.07^{ab}	0.24	2.77^{ab}	0.25	2.50^{a}	0.26	75.3^{a}	3.7
	Solvent	(Bronowski) napus	300	1	4	4.70	0.20	2.82^{a}	0.27	2.54^{a}	0.23	2.42^{a}	0.21	69.8^{a}	3.7
			300	1	8	4.74	0.17	4.12^{c}	0.28	3.87^{c}	0.33	3.62^{b}	0.29	89.1^{b}	1.8
	Soybean meal Basal diet	(50%)	900		8	4.58	0.00	3.98^{bc}	0.07	3.71^{bc}	0.09	3.63^{b}	0.08	90.3^{b}	1.0
65	Solvent	campestris	375	2	8	4.67	0.11	3.06	0.22	2.73	0.23	2.45	0.21	78.1	3.1
	Prepress-solvent	campestris	375	4	16	4.58	0.12	2.99	0.21	2.70	0.19	2.36	0.20	78.3	2.3
	Expeller	campestris	375	2	8	4.66	0.11	3.11	0.30	2.94	0.29	2.69	0.27	77.6	4.4
	Prepress-solvent	napus	375	2	8	4.67	0.10	3.02	0.26	2.67	0.30	2.45	0.28	74.7	3.0
	Solvent	(zero-erucic acid) napus	375	1	4	4.60	0.28	3.08^{ab}	0.23	2.88^{ab}	0.24	2.59^{ab}	0.20	78.2^{ab}	3.6
				AV (11 meals)		4.65	0.14	3.05^{ab}	0.24	2.78^{ab}	0.25	2.51^{ab}	0.23	77.4^{ab}	3.2
	Solvent	(Bronowski) napus	375	1	4	4.67	0.18	2.56^{a}	0.40	2.41^{a}	0.56	2.08^{a}	0.48	72.3^{a}	2.3
			375	1	8	4.64	0.13	3.91^{b}	0.30	3.67^{b}	0.26	3.32^{bc}	0.25	88.1^{bc}	4.6
	Soybean meal Basal diet	(50%)	1125		8	4.57	0.00	4.02^{b}	0.06	3.67^{b}	0.08	3.65^{c}	0.07	91.2^{c}	0.6

Values in each column with a common letter or with no letter in their superscript are not significantly different ($p < 0.05$).

A statistical comparison was made between processing methods and seed types for the eleven RM samples and no significant differences were observed.

The eleven RM meals used in the present study varied in oxazolidinethione levels from 1.82 to 10.37 mg/g, while the Bronowski meal contained essentially no oxazolidinethione (0.25 mg/g). As the meals did not differ significantly in DE, ME, ME_n or DN, the data suggest that the available energy and the N digestibility of RM are not markedly influenced by glucosinolate levels. The crude fiber levels of all 12 meals ranged from 13.7 to 16.0% with Bronowski meal containing 14.3% crude fiber. Thus it appears that the energy levels of Bronowski meal, which had the lowest DE and ME of all the meals, although not significantly lower than the other meals, was not directly associated with the crude fiber level of the meal.

Lodhi et al., (1969) studied nine samples of RM and reported that that average ME was 1,203, 1,313 and 1,782 kcal/kg, respectively, for 4 week old chicks, 6 week old chicks and hens fed diets containing 30% RM for at least 21 days. A comparison of the ME values of RM observed in this trial with those reported by Lodhi et al., (1969) show that the values for the pig are substantially higher than the values for the chick. It is evident that the ME values for RM obtained with chicks should not be used in feed formulation for the pig. The DE and ME values of feeds, especially high protein feedstuffs, should be considered as being species specific.

Summary:

Twelve samples of rapeseed meal (RM) and one sample of soybean

meal (50% protein) (SM) were evaluated for digestible energy (DE), metabolizable energy (ME), nitrogen-corrected ME (ME_n) and digestible nitrogen (DN). RM samples were of Brassica campestris and B. napus origin and contained meals processed by solvent, prepress-solvent or expeller processes. Two of the meals were from rapeseeds not in commercial production, one a Bronowski (low glucosinolate) napus meal and one a meal from zero-erucic acid rapeseed of napus type. Energy studies were conducted with 64 pigs at 16, 33 and 65 kg liveweight, adding 25% by weight of the test ingredient to the total diet.

The overall means and standard errors for all weight groups for Gross Energy (GE), DE, ME and ME_n in kcal/g of dry matter, for 10 RM (excluding Bronowski and zero-erucic acid RM) were 4.74 $\pm$ 0.12, 3.21 $\pm$ 0.18, 2.89 $\pm$ 0.19 and 2.64 $\pm$ 0.19 respectively, while the values obtained for SM were 4.81 $\pm$ 0.08, 4.21 $\pm$ 0.16, 3.92 $\pm$ 0.17 and 3.64 $\pm$ 0.16. There were no significant differences in DE, ME or ME_n among the 12 RM samples, or between weight periods. The values for the basal diet were uniform throughout. The overall mean coefficient for DN was 75.9 for RM and 89.2% for SM. The DE, ME and ME_n values for RM should be considered as being species specific.

PART 3 [1]

Introduction:

Most of the values for DE and ME in feedstuffs for pigs have been mathematically derived by converting Total Digestible Nutrient values to DE values and converting DE to ME by regression equations (NAS-NRC, 1969). Soybean meal has been the most extensively studied of the various protein supplements commonly used in pig diets. Although the use of rapeseed meal (RM) in Canadian pig rations has been increasing there are few experimentally determined values on the digestible energy (DE), metabolizable energy (ME), nitrogen-corrected ME (ME_n) or digestible nitrogen (DN) for RM. Saben et al., (1971a) have recently reported DE, ME, ME_n and DN values for 12 samples of RM.

Rao and Clandinin (1970) determined the ME_n value of RM for the chick using two methods, the dilution with RM of a practical type ration, described by Sibbald and Slinger (1963a) and the substitution of RM for a portion of the glucose in a semi-purified ration, described by Hill and Anderson (1958). Using the Sibbald and Slinger method they obtained a significantly higher ME value for RM, 1654 kcal/kg of dry matter, than was obtained by using the Hill and Anderson method, 1245 kcal/kg of dry matter. Average ME_n values, based on fecal collections taken at 14, 28 and 42 days of age showed an increase in ME_n as the age at which collections were taken increased. This is in agreement with the observation of

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[1] The material in Part 3 of this thesis has been accepted for publication in the August 1971 issue of the Canadian Journal of Animal Science:
Saben, H.S., J.P. Bowland and R.T. Hardin. 1971. Effect of method of determination on digestible energy and nitrogen and on metabolizable energy values of rapeseed meal and soybean meals fed to growing pigs. 51: (in press).

Lodhi et al., (1969), that the ME_n value of RM was higher for 6 week old chickens than for 4 week old chickens.

The objective of the present study was to determine the DE, ME, ME_n and DN values for the pig of a commercial solvent-extracted Brassica campestris RM and of two SM samples using two methods: (1) A modification of the method of Diggs et al., (1965) and (2) A modification of that of Sibbald and Slinger (1963a). These will be referred to as an 'addition' method and 'substitution' method respectively. The effect of conducting the determinations for DE, ME, ME_n and DN following feeding the meal for different periods during which time pigs were kept in the metabolism cages was also studied.

Materials and Methods:

Thirty two castrate male pigs of Lacombe x Yorkshire breeding, weighing an average of 18.0 kg liveweight were allotted to the experiment. In the 'addition' method (A) a basal diet (Table 8) was fed to each of 16 pigs at a level of 450 g/day for 21 days. This basal diet was based on soybean meal (SM) and wheat and thus differed from that used by Diggs et al., (1965) which was based on SM and corn. The 4 treatments were basal, RM, SM (44% protein) and SM (50% protein). The three test ingredients were added to the basal diet at a level representing 25% of the total feed intake by weight. Thus pigs fed the test ingredients consumed 600 g/day of feed, 450 g of basal feed and 150 g of their respective test ingredient.

In the 'substitution' method (S) a basal diet (Table 8) was fed to a second group of 16 pigs for 21 days. This basal diet differed in several ingredients from that used by Sibbald and Slinger (1963a). The

Table 8: Formulation and composition of basal diets fed in energy studies with pigs.

Ingredient	Basal Diet A[1]	Basal Diet S[2]
Wheat	23.00	35.00
Soybean meal (50%)	67.35	7.00
Stabilized tallow	3.50	5.00
Corn		24.35
Barley		17.00
Alfalfa meal		4.00
Fish meal (72%)		5.00
Dicalcium phosphate	3.50	0.50
Ground limestone	1.00	1.00
Iodized salt	0.40	0.40
Zinc sulfate	0.05	0.05
Trace mineral mix[3]	0.25	0.25
Vitamin B-complex mix[4]	0.35	0.35
Vitamins A, D & E[5]	+	+
Terramycin supplement[6]	0.10	0.10
DL-methionine	0.50	
COMPOSITION		
Gross energy kcal/g (analysis)	4.2	4.2
Crude protein % (calculated)	36.7	17.0
Crude protein % (analysis)	39.1	18.0
Lysine % (calculated)	2.0	0.8
Methionine + Cystine & (calculated)	1.5	0.6

[1] Diet, modified from Diggs et al., (1965). Air-dry basis.

[2] Diet, modified from Sibbald and Slinger, (1963a). Air-dry basis.

[3] The mineral mix supplied the following per 100 kg diet: cobalt carbonate, 570 mg; copper sulfate, 6.12 g; ethylene diamine dihydroiodide, 320 mg; ferrous carbonate, 58.7 g; manganese oxide, 11.9 g; zinc oxide, 740 mg; ground limestone, 171.6 g.

[4] The vitamin B-complex mix supplied the following per 100 kg diet: riboflavin, 1.1 g; calcium pantothenate, 2.2 g; niacin, 4.95 g; choline chloride, 5.35 g; folic acid, 34.0 mg; vitamin B_{12}, 2.2 mg.

[5] Vitamin A was fed at 500,000 I.U., vitamin D_2 at 50,000 I.U. and vitamin E at 500 I.U. per 100 kg diet.

[6] Terramycin supplement supplied 2.2 g of antibiotic per 100 kg of diet.

4 basal pigs received 900 g of feed/day. The treatment pigs received 60% by weight of the basal diet plus 40% of the respective test ingredient. For example, pigs fed RM received 540 g/day of the basal diet plus 360 g/day of RM.

Eight metabolism cages were available so that each metabolism trial contained 4 pigs from each method (Table 9). Nine days after receiving the basal diet or the basal diet and their respective test ingredient, pigs were placed in metabolism cages as described by Castell and Bowland (1968). Water was available at all times.

Feces and urine were collected on the 12th, 13th and 14th days and again on the 19th, 20th and 21st days, for a total of two 72-hour collection periods. After the first collection period, the pigs were taken out of the cages and weighed. The cages were cleaned and the pigs were returned to the cages that same day.

Feces were collected daily and stored in a refrigerator at approximately 0°C until the end of the collection period, when an aliquot of the combined fecal collection was dried in a forced air oven at 60°C for 72 hours. After drying the samples were allowed to equilibrate with air moisture, weighed and ground through a 40-mesh screen in a Wiley mill. Urine was filtered through glass wool into collection vessels containing 25 ml of concentrated H_2SO_4. Total urine production was measured and an aliquot was taken for analytical determinations.

Combustible energy was measured for feed, feces and urine using a Parr adiabatic oxygen bomb calorimeter. Nitrogen determinations were carried out on feed, feces and urine using the Kjeldahl method with protein being calculated from N x 6.25. Diggs et al., (1965) determined

Table 9: Allotment of pigs for metabolism trial[1].

METHOD A: Addition method	Basal
	Basal plus RM
	Basal plus SM (44% protein)
	Basal plus SM (50% protein)
METHOD S: Substitution method	Basal
	Basal diluted by RM
	Basal diluted by SM (44% protein)
	Basal diluted by SM (50% protein)

[1] Trial was replicated 4 times.

that the caloric value of the urinary nitrogen for the pig was 6.77 kcal/g, and this value was used to adjust urinary energy to nitrogen equilibrium.

Data were analyzed statistically using an analysis of variance program available from The University of Alberta Computing Center. Means were compared using Duncan's multiple range test (Steel and Torrie, 1960). A probability of 0.05 was selected as the point of significance between means.

Results and Discussion:

The overall means for gross energy (GE), DE, ME and ME_n in kcal/g dry matter and %DN (Table 10) for RM, SM (44% protein) and SM (50% protein) were 4.87, 3.37, 3.13, 2.76 and 79.2; 4.86, 4.37, 4.16, 3.72 and 92.6; and 4.76, 4.48, 4.26, 3.70 and 93.1 respectively. GE values for RM and SM (44% protein) were higher than that for SM (50% protein), which would be indicative of the higher oil content expected in the former meals. RM was significantly lower than either of the two SM samples in DE, ME, ME_n and DN. The values for SM (50% protein) were similar to the values obtained by Diggs et al., (1965) for DE and ME_n, however the value for ME is somewhat higher, 4.26 kcal/g dry matter in the present study while Diggs et al. reported a value of 3.88 kcal/g dry matter. The DE for RM of 3.37 kcal/g and ME_n of 2.76 kcal/g dry matter are in close agreement with that reported in a previous paper (Saben et al., 1971a) where the average DE for 12 samples of RM was observed to be 3.21 kcal/g and ME_n to be 2.64 kcal/g dry matter. For RM, the unadjusted ME and the ME_n averaged 92.5 and 81.9% of the DE respectively, while the SM samples averaged 95.2 and 83.8% of the DE

Table 10: Overall means of feeds for gross energy (GE), digestible energy (DE), metabolizable energy (ME), nitrogen-corrected ME (ME_n) as kcal/g dry matter and for % digestible nitrogen (DN).

Feeds	GE ± S.E.[1]	DE ± S.E.	ME ± S.E.	ME_n ± S.E.	DN ± S.E.
Rapeseed meal	4.87 ± 0.06^{a}	3.37 ± 0.14^{c}	3.13 ± 0.16^{c}	2.76 ± 0.15^{b}	79.2 ± 2.19^{b}
Soybean meal (44%)	4.86 ± 0.06^{a}	4.37 ± 0.14^{a}	4.16 ± 0.13^{a}	3.72 ± 0.14^{a}	92.6 ± 1.42^{a}
Soybean meal (50%)	4.76 ± 0.05^{b}	4.48 ± 0.11^{a}	4.26 ± 0.12^{a}	3.70 ± 0.11^{a}	93.1 ± 1.22^{a}
Basal	4.62 ± 0.02^{c}	3.97 ± 0.05^{b}	3.77 ± 0.05^{b}	3.64 ± 0.04^{a}	87.6 ± 1.40^{a}

1 Standard error

a b c Means without a common superscript are significantly different at $P < 0.05$.

respectively. The standard errors for DE, ME and ME_n are similar suggesting that there is little difference in accuracy between these three energy measurements. The average values obtained for both basal diets are included in Table 10 for reference purposes.

There were no significant differences (Table 11) between the means for GE, DE, ME and ME_n and DN for the 'addition' and 'substitution' methods or for the two periods of collection. Period 1 refers to values obtained for the 12th, 13th and 14th days on trial and period 2, the values obtained for the 19th, 20th and 21st days on trial. Observed values for GE, DE, ME and ME_n in kcal/g dry matter for the 'addition' method were 4.77 $\pm$ 0.06, 4.07 $\pm$ 0.14, 3.90 $\pm$ 0.17 and 3.42 $\pm$ 0.16 respectively, while the values for the 'substitution' method were 4.80 $\pm$ 0.08, 4.02 $\pm$ 0.14, 3.76 $\pm$ 0.14 and 3.49 $\pm$ 0.14 respectively. Overall averages for period 1 in kcal/g dry matter for GE, DE, ME, ME_n and for %DN were 4.76 $\pm$ 0.07, 4.11 $\pm$ 0.15, 3.88 $\pm$ 0.17, 3.51 $\pm$ 0.16 and 88.8 $\pm$ 1.95 respectively, while values for period 2 for the same measurements were 4.80 $\pm$ 0.06, 3.98 $\pm$ 0.16, 3.78 $\pm$ 0.16, 3.40 $\pm$ 0.16 and 87.4 $\pm$ 2.46 respectively. Using the Student-t test (Steel and Torrie, 1960) there was a significant difference between the two methods for the %DN in the basal diets. The protein intake of pigs fed the two basal diets was similar on a g/day basis (176 g for the 'addition' vs 162 g for the 'substitution' method). The difference could be associated with a greater feed intake by the pigs on the 'substitution' method, or with the wider calorie to protein ratio of the basal diet in this method.

No differences were observed between the two periods of collection, one week apart. This observation suggests that the possible stress of

Table 11: Means for gross energy (GE), digestible energy (DE), metabolizable energy (ME) and nitrogen-corrected ME (ME_n) (kcal/g dry matter) and percentage digestible nitrogen (DN), for the "addition" (A) and "substitution" (S) methods and for two periods (1 and 2).[a]

Ingredient	Period	GE			DE			ME			ME_n			DN		
		A	S	Av	A	S	Av	A	S	Av	A	S	Av	A	S	Av
Rapeseed meal	1	4.74	4.96	4.85	3.34	3.72	3.53	3.17	3.41	3.29	2.80	3.11	2.96	79.9	82.1	81.0
	2	4.83	4.96	4.90	3.06	3.35	3.20	3.05	2.89	2.97	2.46	2.68	2.57	77.6	76.9	72.2
	Av	4.78	4.96		3.20	3.54		3.11	3.15		2.63	2.90		78.8	79.5	
Soybean meal (44% protein)	1	4.86	4.80	4.83	4.49	4.31	4.40	4.32	4.06	4.19	3.92	3.71	3.82	93.2	91.8	92.5
	2	4.95	4.80	4.88	4.36	4.31	4.34	4.20	4.04	4.12	3.53	3.72	3.62	92.0	93.2	92.6
	Av	4.90	4.80		4.42	4.31		4.26	4.05		3.72	3.72		92.6	92.5	
Soybean meal (50% protein)	1	4.72	4.77	4.74	4.68	4.40	4.54	4.38	4.08	4.23	3.64	3.65	3.64	95.4	92.3	93.8
	2	4.80	4.77	4.78	4.45	4.40	4.42	4.42	4.16	4.29	3.69	3.81	3.75	92.1	92.6	92.4
	Av	4.76	4.77		4.56	4.40		4.40	4.12		3.66	3.73		93.8	92.4	
Basal	1	4.61	4.64	4.62	4.10	3.84	3.97	3.83	3.74	3.78	3.64	3.62	3.63	92.0	83.3	87.6
	2	4.58	4.64	4.61	4.11	3.82	3.96	3.79	3.72	3.76	3.69	3.61	3.65	92.7	82.3[b]	87.5
	Av	4.60	4.64		4.10	3.83		3.81	3.73		3.66	3.62		92.4[a]	82.8[b]	
Overall means with standard error																
Method	A	4.77 ± 0.06			4.07 ± 0.14			3.90 ± 0.17			3.42 ± 0.16			89.4 ± 1.87		
	B	4.80 ± 0.08			4.02 ± 0.14			3.76 ± 0.14			3.49 ± 0.14			86.8 ± 2.35		
Period	1	4.76 ± 0.07			4.11 ± 0.15			3.88 ± 0.17			3.51 ± 0.16			88.8 ± 1.95		
	2	4.80 ± 0.06			3.98 ± 0.16			3.78 ± 0.16			3.40 ± 0.16			87.4 ± 2.46		

[a] Fecal and urinary collection was conducted on the 12th, 13th and 14th days after feeding of the respective diet for period 1 and on the 19th, 20th and 21st days for period 2.

[a] [b] Average for addition method greater ($P < 0.05$) than average for substitution method.

keeping pigs of this age in metabolism cages over a 2-week period has no observable influence on the results obtained. Lodhi et al., (1969) and Rao and Clandinin (1970) using chickens observed an increase in ME values as the chicks grew older. However, in both instances the time between the initial and final collection periods was greater and the age spread of the chickens was greater than used in this experiment. The present study was not designed to compare energy values for pigs differing markedly in age. However, Saben et al., (1971a) observed no significant difference between DE, ME or ME_n for pigs at 16, 33 and 65 kg liveweight.

The data show that the values for DE, ME, ME_n and DN were similar for the two methods of determination, and that either method could be used satisfactorily.

Summary:

Commercial samples of solvent-extracted rapeseed meal (RM), 44% crude protein soybean meal (SM) and 50% crude protein SM were evaluated for digestible energy (DE), metabolizable energy (ME), nitrogen-corrected ME (ME_n) and digestible nitrogen (DN), using two methods of evaluation. A comparison of results from feeding the test meals for two different lengths of time prior to conducting the determinations was also made. Sixteen male castrate pigs were allotted to each of the two evaluation methods, with 4 pigs assigned to each of 3 treatment groups, and 4 pigs assigned to the basal control group for each method.

The two SM samples had higher DE, ME, ME_n and DN than the RM sample. The DE, ME and ME_n values in kcal/g dry matter for RM were 3.37, 3.13 and 2.76 while for SM they were 4.42, 4.21 and 3.71

respectively. The overall mean coefficient for DN was 79.2 for RM and 92.8% for SM. There were no significant differences observed between methods or between the two time periods. The values for the basal diets were uniform throughout the trial, as indicated by low standard errors.

PART 4 [1]

Introduction:

Several reports (Blem, 1968; Manoukas et al., 1964; Shannon and Brown, 1969) of studies with avian species have observed nitrogen (N) and energy losses when excreta were dried prior to N and energy determination. Bratzler and Swift (1959) reported N loss from cow feces dried for 22 hr at 65°C in a forced-air oven. To the authors' knowledge, there are no similar reports on feces from the pig.

Studies were undertaken to evaluate some techniques used in swine digestibility studies: (1) Comparison of N content as determined on wet or dry feces from pigs fed either high or low protein diets, (2) Comparison of energy content as determined on wet and dry feces, and (3) Effect of length of digestion time, using the Kjeldahl method, on the determined N content of fecal material.

Materials and Methods:

A diet containing 39% crude protein was fed to 64 castrate male pigs (Saben et al., 1971a). Metabolism studies were conducted for 3-day periods at 16, 33 and 65 kg liveweight. The 192 samples of feces obtained in this study were separated into two portions. One portion was analyzed for N on the same day that each metabolism study was terminated, using the Kjeldahl method (AOAC, 1965) utilizing a

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[1] The material in Part 4 of this thesis has been submitted for publication in the Canadian Journal of Animal Science:
Saben, H.S. and J.P. Bowland. 1971. Comparative evaluation of some techniques used in determinations of nitrogen and energy content of feces from pigs. (Submitted for publication).

commercial 'Kel-Pak' catalyst, with boric acid being used to retain the ammonia. A sample of approximately 2 g was used.

The other portion of wet fecal material was dried in a forced-air oven at 60°C for 72 hours. After drying the samples were allowed to equilibrate with air moisture, weighed and ground through a 40-mesh screen in a Wiley mill. N determinations were then conducted using the same method as described above. A sample of approximately 1 g was used. Duplicate N determinations were made on each wet and dry sample.

A diet containing 18% crude protein and analyzing 4.2 kcal gross energy/g was fed to 14 castrate male pigs (Saben et al., 1971b). Metabolism studies were conducted for two 3-day periods at 18 kg liveweight. Samples of feces obtained in this study were separated into two portions. One portion was used for wet and dry fecal N comparisons as described above. The other portion was split into two parts, one part from 16 samples was used for wet and dry fecal energy determinations, using a Parr adiabatic oxygen bomb calorimeter. In order to obtain complete combustion on the wet feces in the calorimeter, 1 g samples were wrapped in no. 1 Whitman filter paper; the energy of the filter paper was found to be approximately 3.83 kcal/g. This amount was subtracted from the total combustion figure. The dry fecal samples were combusted as outlined (Parr, 1960). Duplicate energy determinations were made on each wet and dry sample.

The other 12 samples of fecal material were dried by the procedure described previously and analyzed for N following various lengths of digestion. All 12 samples were analyzed at 1 and 4 hours, while 6 samples were analyzed at 2 hr and the other 6 samples at 3 hr. Mean values for N were calculated for each hour. The times refer to the

length of digestion after the contents of the Kjeldahl digestion flask had become clear. AOAC (1965) recommends that the digestion solution should boil briskly until the solution clears, and samples containing organic material should than boil for 2 hr after clearing.

Figures 2 to 5 and the values presented in Table 12 were derived using IBM 360/67 computer programs available from The University of Alberta Computing Center.

Results and Discussion:

Analysis of variance indicated no significant difference between the mean values for N content determined from wet fecal material or dry (dried at 60°C for 72 hr) fecal material in diets containing either 39% of 18% crude protein (Table 12). The determined N content of feces from 192 pigs fed the high crude protein diet is given in Figure 2. The linear regression Y = A(intercept) + B(slope) X was used to compare the grams of fecal N excreted over a 3-day metabolism period, obtained from the wet and dry fecal determinations. Y (wet fecal N/pig/3 days) = A 1.47 + B 0.99 X (dry fecal N/pig/3 days). The determined N content of feces from 28 pigs fed the practical type 18% crude protein diet is given in Figure 3. Y = 0.59 + 0.91(X). The combined linear regressions for pigs fed either the high or low protein diets is given in Table 12: Y = 0.89 + 1.00(X). The highly significant Student-t values (Table 12) indicate that the slopes are significantly different from zero for both the high protein and lower protein diets. As r^2 = 0.83, 83% of the variation in wet feces is accounted for by the relationship between wet and dry feces.

Based on the combined data, the mean N loss between wet and dry

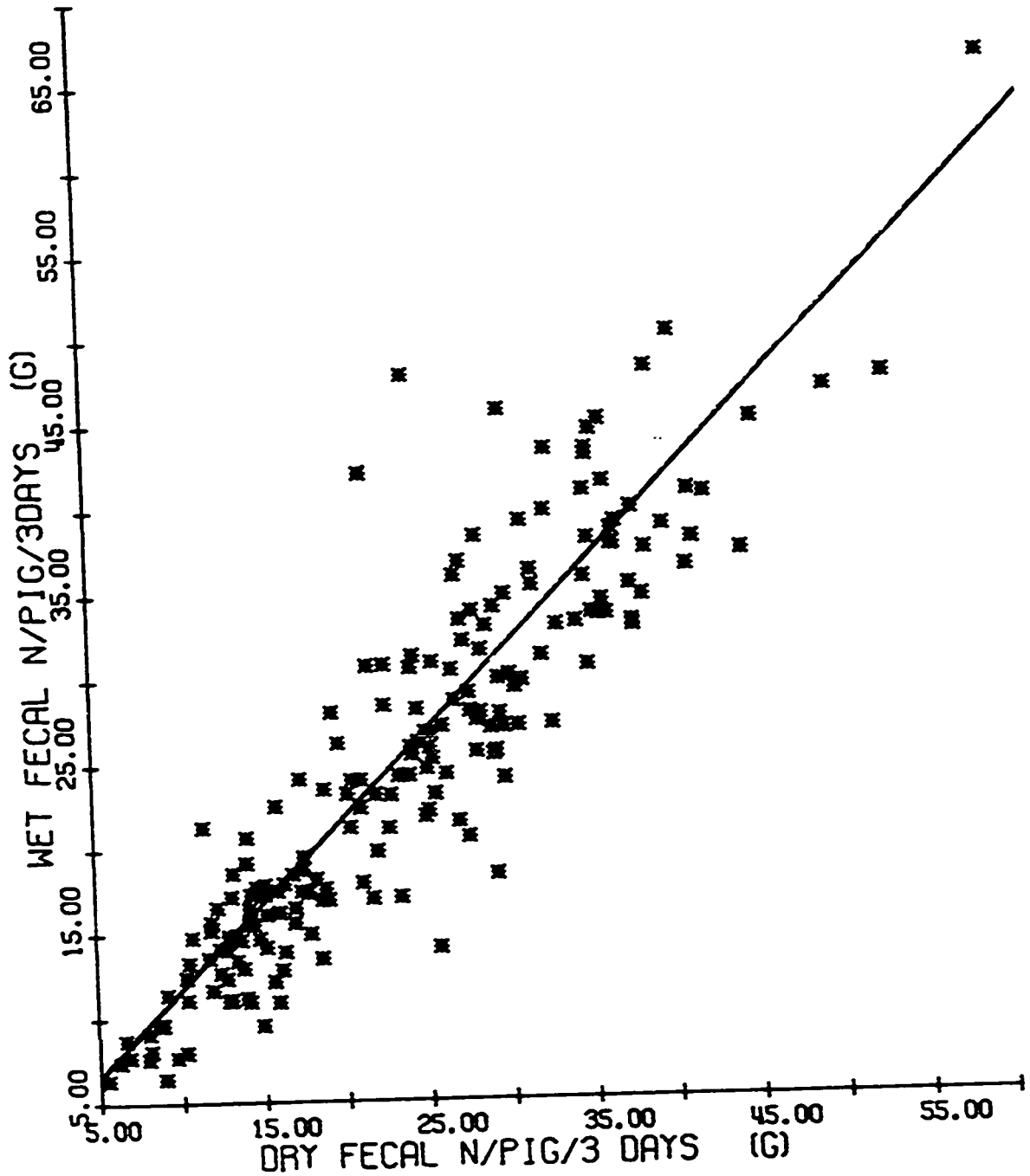

FIGURE 2: Fecal nitrogen (g/pig/3 days) as determined on wet fecal material compared with dry (72 hr at 60°C) fecal material, when pigs were fed a high crude protein diet.

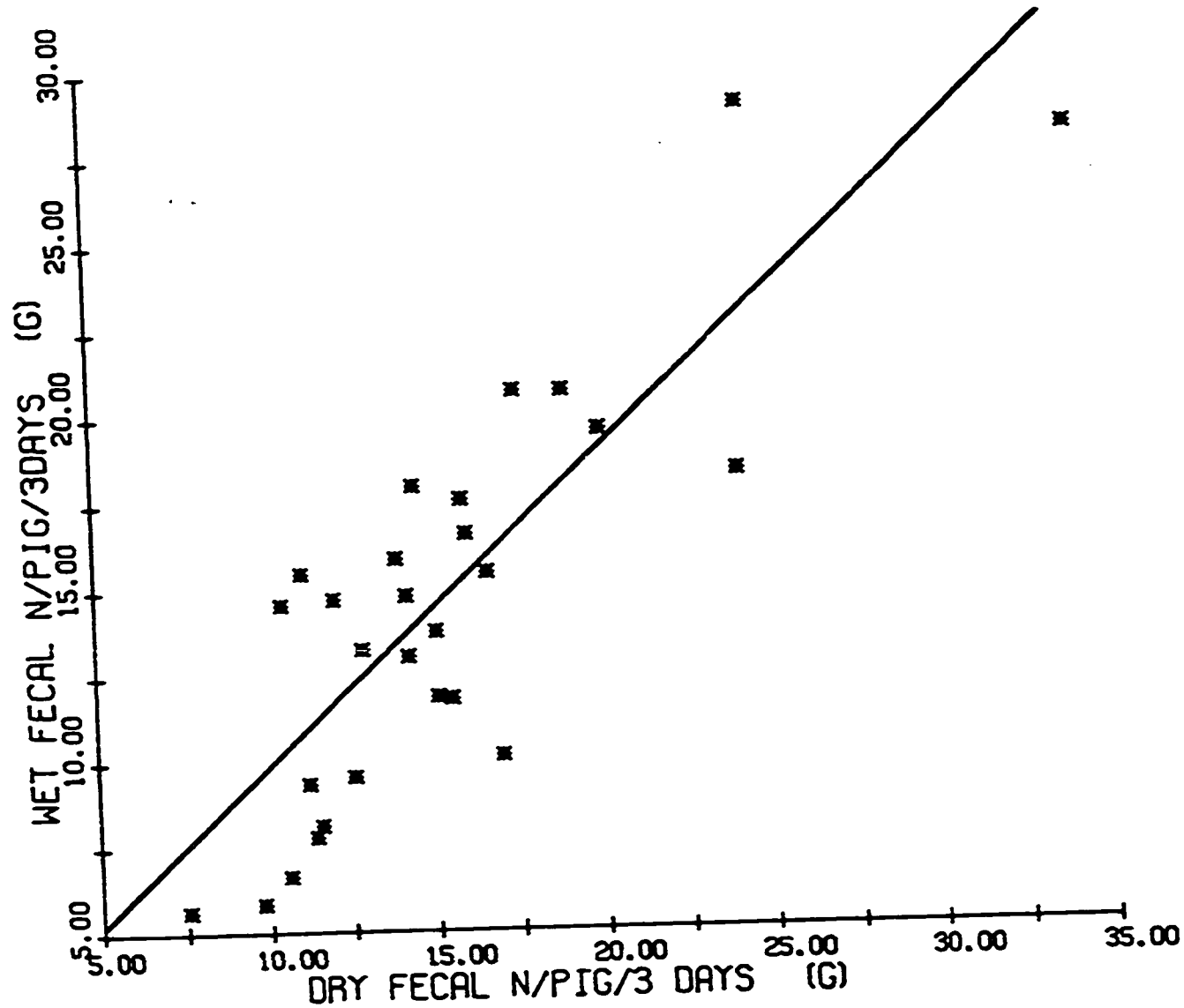

FIGURE 3: Fecal nitrogen (g/pig/3 days) as determined on wet fecal material compared with dry (72 hr at 60°C) fecal material, when pigs were fed a practical type diet.

determinations was 0.87 g/pig over the 3-day sampling period (Table 12), which represents a 3.7% N loss. This observation is in general agreement with Bratzler and Swift (1959) who reported that when cow feces were dried for 22 hr at 65°C in a forced-air oven, they obtained a N loss of 5.2%. Shannon and Brown (1969) observed a 4.6% N loss when poultry excreta were dried in a forced-air oven for 24 hr at 60°C. Shannon and Brown observed that N losses of excreta dried in a forced-air oven increased in a stepwise fashion from 4.6% to 10.6% as the drying temperature was increased from 60°C to 120°C. It should be recognized that avian excreta also contain urine in which N may differ in lability from that in mammalian feces. However, the results from the studies with the different species are similar.

Feces from 16 pigs were analyzed for fecal energy in either the wet or dry (dried at 60°C for 72 hr) form (Figure 4). The data indicate (Table 12) that no significant differences were observed between the fecal energy excreted, when analyzed in either the wet or dry form. The regression for wet fecal energy compared with dry fecal energy in kcal/g (Table 12) gave the following values: $Y = 0.74 + 1.00(X)$. The data indicate that a large percentage (96%) of the variation in wet feces is accounted for by the relationship between wet and dry feces. The highly significant Student-t value indicates that the slope is significantly different from zero.

The mean energy loss (kcal/g) was 5.0% between the wet and dry material (Table 12). Shannon and Brown (1969) reported a mean energy loss of 5.5%, which is in agreement with our observations, when they dried poultry excreta in a forced-air oven for 24 hr at 60°C. However, the loss observed in our study is lower than that reported by

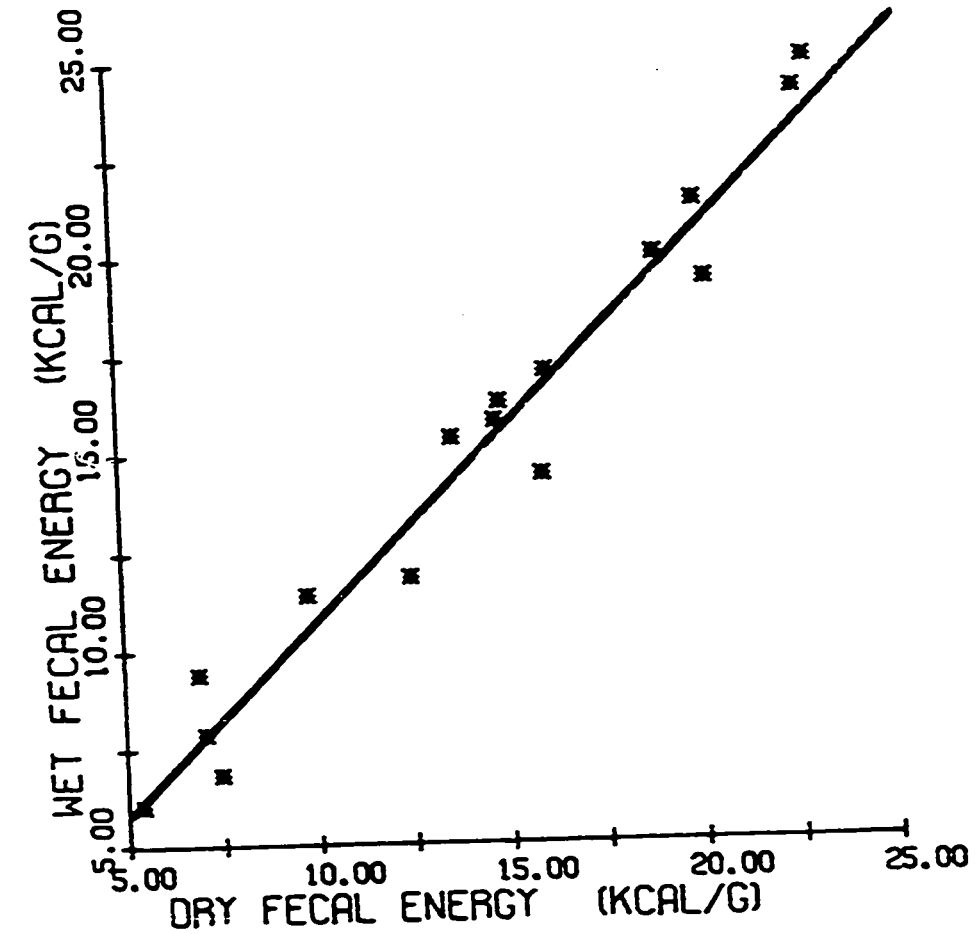

FIGURE 4: Fecal energy (kcal/g) as determined by bomb calorimetry on wet fecal material compared with dry (72 hr at 60°C) fecal material.

Manoukas et al., (1964) who reported a mean loss in energy of 12.0% on a dry matter basis for poultry feces dried in a convection oven for 24 hr at 65°C. In excreta voided by the Blue-winged Teal or the House Sparrow, Blem (1968) obtained no loss in energy, when wet excreta collected at 20°C were compared with excreta dried in a convection oven for 48 hr at 65°C.

The difference between the duplicate sample determinations never exceeded 3% for N or 2% for energy, but N and energy determinations on wet fecal material gave consistently greater standard errors (Table 12) than those on dry fecal material. These results indicate slightly greater sampling error from wet feces compared with dry feces.

The fecal N loss between the wet and dry material in our observations, would explain only a small part of the total energy loss obtained on the same fecal samples. Loss of other volatile compounds, probably associated with fermentation, must occur. Considering that fecal energy in pigs is not likely to be more than 20% of the dietary energy value, then the error associated with the digestible energy value when feces are dried would be approximately 1 percent. This loss is relatively insignificant and is less than losses from methane production reported by Bowland et al., (1970) to average 1.1% of the energy in digestible energy. This latter loss is ignored in digestibility and metabolism trials with pigs.

Fecal material from 12 pigs was analyzed for N over varying periods of time (Figure 5). The data indicate (Table 12) that no significant differences were observed between %N obtained when pig fecal material was digested for 1, 2, 3 or 4 hours, after the contents of the Kjeldahl digestion flask first became clear. The N content, scaled to an index

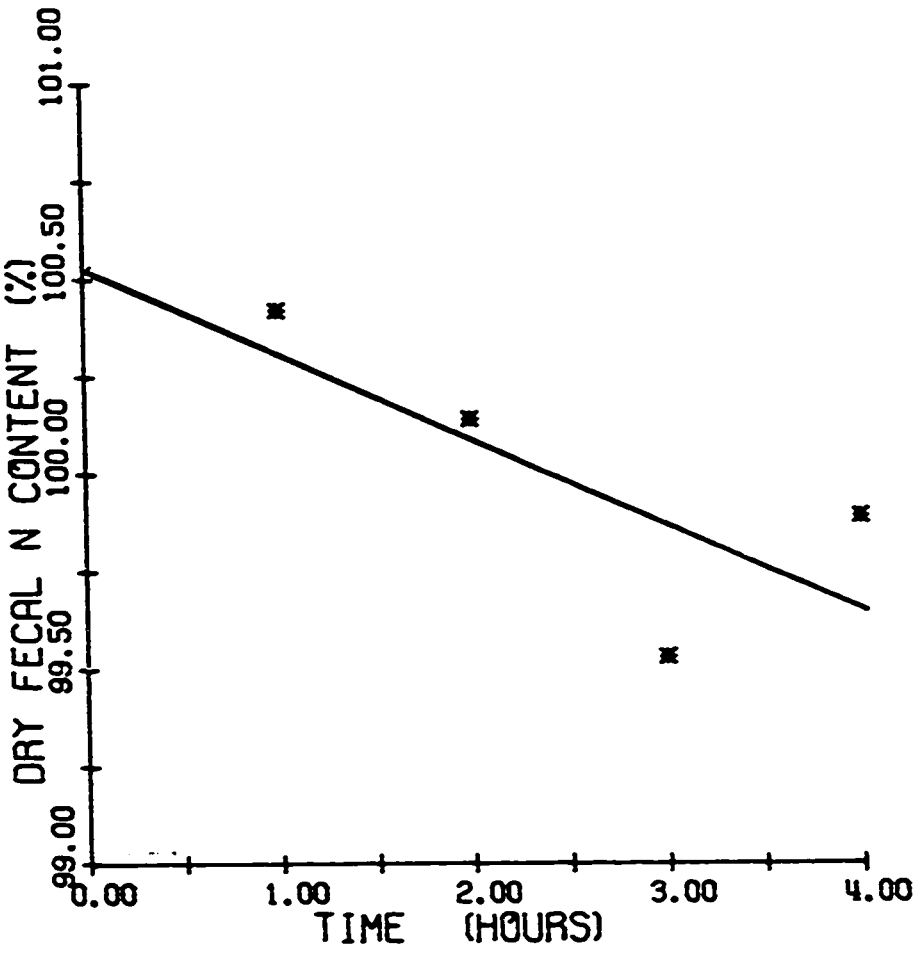

FIGURE 5: Nitrogen content (scaled to a mean of 100%) of dry (72 hr at 60°C) fecal material obtained following Kjeldahl digestion for one, two, three or four hr after the contents of the flask became clear.

Table 12: Results of analysis of variance and linear regressions.

Criteria evaluated	Fecal N[1] High (39%) crude protein diet (g/pig/3 days)	Fecal N Practical type (18%) crude protein diet (g/pig/3 days)	Fecal N (g/pig/3 days)	Fecal energy (kcal/g)	Length of digestion time (100% scale)
Figures	1	2	1 & 2	3	4
No. of observations	192	28	220	16	4
F test N.S.[2]	1.10	0.31	0.42	0.13	0.08
Y values	Wet	Wet	Wet	Wet	% N
Mean value	24.89	14.50	23.56	15.12	100.00
± S.E.[3]	0.80	1.11	0.72	1.48	0.19
Minimum	6.38	5.62	5.62	6.05	99.53
Maximum	66.29	28.95	66.29	24.93	100.42
X values	Dry	Dry	Dry	Dry	Time
Mean value	23.74	15.33	22.69	14.37	2.50
± S.E.	0.74	1.02	0.69	1.45	0.21
Minimum	5.52	7.57	5.52	5.38	1
Maximum	59.35	34.02	59.35	23.05	4
Regressions:					
Intercept A	1.47	0.59	0.89	0.74	100.54
Slope b	0.99	0.91	1.00	1.00	-0.22
± S.E. of b	0.03	0.12	0.03	0.05	0.14
Student t	29.69	7.66	32.64	19.07	-1.61
Variation r^2	0.83	0.69	0.83	0.96	0.56

1. Nitrogen.
2. Non-significant differences for comparisons between wet and dry fecal material and percent N on time.
3. Standard error.

of 100 compared with the time in hours gave the following regression value: $Y = 100.54 - 0.22(X)$. The AOAC (1965) recommendation that for samples containing organic material, a 2 hr digestion time after the solution clears is sufficient to obtain the N in the sample, therefore appears to be satisfactory.

Although there are some N and energy losses from pig feces dried for 72 hr at 60°C, in standard digestibility studies these losses are not sufficiently large to justify the problems associated with attempting to sample and analyze wet feces for N and energy.

Summary:

Statistical procedures were used to compare some techniques used in digestibility studies with pigs. No significant differences were observed in fecal nitrogen (N) content when measured in the wet or dry (dried at 60°C for 72 hours) form, or in fecal energy when measured in the wet or dry form. There was, however, an average 3.7% N loss and 5.0% caloric loss from dry feces compared with wet feces.

When dry fecal material was subjected to 1, 2, 3 or 4 hours of digestion after the sample became clear using the Kjeldahl method, no significant difference was observed between the length of digestion time and the %N obtained.

It may be concluded that either wet or dry pig fecal material may be used for N and energy determinations in pig digestion trials, without significantly influencing results obtained. Digestion time of dry fecal material, within the limits studied, did not alter N as determined in the feces.

GENERAL DISCUSSION

Results of the experiments conducted herein show that the DE and ME values of RM are lower than those of SM. For instance, the average DE of RM was found to be 3.21 kcal/g DM, while the value for SM was found to be 4.21 kcal/g DM. The higher crude fiber content of the RM and its lower protein content no doubt contribute to its lower available energy value when compared with SM. However, the growth-inhibiting properties in RM, the glucosinolates, appear to have little effect on the available energy of RM. The Bronowski RM used in this study contained essentially no oxazolidinethione (0.25 mg/g), while the other meals varied in oxazolidinethione levels from 1.82 to 10.87 mg/g, and no significant differences in DE, ME or ME_n were observed between the Bronowski meal and the other meals.

Feed formulators have frequently been using ME_n values derived with the chick and applying these values to the pig. Results show that the ME_n value of RM for the pig is higher, 2.64 versus 2.20 kcal/g, than for the chick. Similarly, results show that the ME_n value of 50% crude protein SM for the pig is higher, 3.64 versus 2.42 kcal/g, than for the chick. Thus for high protein feeds, values for DE and ME for the pig are higher than those for the chick. Therefore energy values must be considered as being species specific when used in diet formulation.

For example, feed formulators using the ME_n value for the chick and applying this value to the pig, underestimate the available energy of RM by 12 percent. On the basis of ME values for the pig, and ignoring nutrients other than energy and protein, if 50% crude protein SM sells for $100.00 per ton, then the feed formulator should not be

prepared to pay more than $72.50 per ton for RM.

The lower crude protein and higher crude fiber content of RM compared with SM, resulted in the digestible nitrogen (DN) content of RM being significantly lower than the DN content of SM. However if the plant geneticist could change the protein and fiber content of rapeseed to be more comparable with soybean, then RM should become a direct competitor with SM for use in formulation of animal feeds.

Researchers have found with the chick that different methods of determining the energy values will give different results. The results obtained in this study with pigs show no evidence of difference in DE, ME or ME_n when two different methods were used to determine the energy values. Results for this study show that there are some nitrogen and energy losses from pig feces dried for 72 hr at 60°C, but in standard digestibility studies these losses are not sufficiently large to justify the problems associated with attempting to sample and analyze wet fecal material for nitrogen and energy.

Two recommendations are submitted for consideration:

1. That research by plant breeders, nutritionists, processors and others be continued to increase the available energy of RM, in order that it may be competitive with SM, and
2. That energy studies continue to be conducted on RM in view of the fact that new varieties of rapeseed, low in erucic acid and/or low in glucosinolate levels, will be commercially available within the next few years in Canada.

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APPENDIX A

Analysis of variance at ($P < 0.05$)* level, for means in Table 6, page 30.

Overall means for combined weights:

Gross Energy (GE)

Source	df	M.S.
Treatment (T)	15	0.1491
Weight (W)	2	1.3671*
T x W	30	0.1044
Error	144	0.1252

Digestible Energy (DE)

Source	df	M.S.
T	15	2.5212*
W	2	3.3805*
T x W	30	0.2523
Error	144	0.3909

Metabolizable Energy (ME)

Source	df	M.S.
T	15	2.7121*
W	2	2.0319*
T x W	30	0.2796
Error	144	0.4428

Nitrogen-corrected ME (ME_n)

Source	df	M.S.
T	15	3.2097*
W	2	2.1461*
T x W	30	0.3337
Error	144	0.4157

Digestible Nitrogen (DN)

Source	df	M.S.
T	15	589.01 *
W	2	73.76
T x W	30	60.28
Error	144	67.92

APPENDIX B

Analysis of variance at ($P < 0.05$)* level, for means in Table 7, page 31.

(a) Overall means for 16 kg liveweight:

GE

Source	df	M.S.
T	15	0.2398
Error	48	0.0969

DE

Source	df	M.S.
T	15	1.0443*
Error	48	0.2203

ME

Source	df	M.S.
T	15	1.1449*
Error	48	0.3205

ME_n

Source	df	M.S.
T	15	1.3044*
Error	48	0.3596

DN

Source	df	M.S.
T	15	315.23 *
Error	48	116.08

Analysis of variance at ($P < 0.05$)* level, for means in Table 7, page 31.

(b) Overall means for 33 kg liveweight:

GE

Source	df	M.S.
T	15	0.0561
Error	48	0.1426

DE

Source	df	M.S.
T	15	0.9026*
Error	48	0.3205

ME

Source	df	M.S.
T	15	1.0277*
Error	48	0.3888

ME_n

Source	df	M.S.
T	15	1.1848*
Error	48	0.4423

DN

Source	df	M.S.
T	15	209.17 *
Error	48	82.42

APPENDIX C

Analysis of variance at ($P < 0.05$)* level, for means in Table 10, page 40.

Overall means for feeds:

GE

Source	df	M.S.
T	3	0.2202*
Error	48	0.0407

DE

Source	df	M.S.
T	3	4.0595*
Error	48	0.2418

ME

Source	df	M.S.
T	3	4.1759*
Error	48	0.2821

ME_n

Source	df	M.S.
T	3	3.4133*
Error	48	0.2546

DN

Source	df	M.S.
T	3	665.69 *
Error	48	41.32

APPENDIX D

Analysis of variance at ($P < 0.05$)* level, for means in Table 11, page 42.

Means for GE, DE, ME, ME_n and DN for two methods and two periods:

GE

Source	df	M.S.
T	3	0.2202*
Method (M)	1	0.0137
T x M	3	0.0627
Period (P)	1	0.0169
T x P	3	0.0048
M x P	1	0.0169
T x M x P	3	0.0048
Error	48	0.0407

DE

Source	df	M.S.
T	3	4.0595*
M	1	0.0492
T x M	3	0.2873
P	1	0.2574
T x P	3	0.0770
M x P	1	0.0133
T x M x P	3	0.0212
Error	48	0.2418

ME

Source	df	M.S.
T	3	4.1759*
M	1	0.2746
T x M	3	0.0807
P	1	0.1377
T x P	3	0.1026
M x P	1	0.0124
T x M x P	3	0.0526
Error	48	0.2821

Analysis of variance at ($P < 0.05$)* level, for means in Table 11, page 42.

ME_n

Source	df	M.S.
T	3	3.4133*
M	1	0.0778
T x M	3	0.0763
P	1	0.2004
T x P	3	0.1852
M x P	1	0.0339
T x M x P	3	0.0509
Error	48	0.2546

DN

Source	df	M.S.
T	3	665.69 *
M	1	103.16
T x M	3	88.45
P	1	27.71
T x P	3	12.35
M x P	1	0.5295
T x M x P	3	10.00
Error	48	41.32