

DIETARY CALORIC DENSITY AND
CALORIC UTILIZATION IN THE PIG

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ABSTRACT

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By

Somsak Vathana

The study consisted of two experiments, one an energy and nitrogen balance trial and the other a feeding trial. To evaluate feed energy density upon the performance of growth (starter, grower and finisher) rations were formulated to meet the nutrient requirements but were either high or low in energy. The low energy density rations contained 40% oats along with corn and dehulled soybean meal to meet limiting amino acid requirements. The high energy density rations contained 2% tallow along with corn and dehulled soybean meal to also meet limiting amino acid requirements. Adequate levels of minerals and vitamins were included in all rations.

Energy values which were determined for the high and low energy density grower rations (kcal/kg), respectively, were 3517 and 3260 for DE, 3473 and 3220 for ME and 3381 and 3117 for N corrected ME. Similar values (kcal/kg) for high and low energy finishing rations, respectively, were 3430 and 3093 for DE, 3389 and 3049 for ME and 3330 and



2978 for N corrected ME. Diet energy density did not appreciably influence nitrogen balance.

The feeding trial was a 2^3 factorial of a high and low energy density ration in each of the starting, growing and finishing periods. Since the starter period was only two weeks and there was no statistically significant effect of starter diet energy density upon subsequent grower performance, the overall data were treated as a 2^2 factorial of high and low energy density rations during a 6 week growing and ten week finishing period.

Dietary energy density during the growing period did not significantly influence pig performance during the growing period. Dietary energy density during this period did, however, influence subsequent performance during the finishing period which was sufficiently significant to affect overall growing and finishing performance. Pigs consuming the low energy density ration during the growing period consumed more feed and energy and tended to gain faster during the finishing period. However, they tended to be less efficient in feed and energy utilization than those pigs which consumed the high energy density ration during the growing period. Pigs which consumed the high energy density ration during the growing period followed by the low energy density ration during the finishing period were the most efficient converters of energy to gain. Furthermore, the ham plus loin weight of these pigs as a percent of their carcass weight was significantly

greater than that of the other diet energy density combinations. Dietary energy density did not significantly influence dressing percentage or the incidence of gastric ulcers.

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Somsak Vathana

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To my beloved country, Thailand
and to my parents

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VITA
SOMSAK VATHANA
CANDIDATE FOR THE DEGREE OF
MASTER OF SCIENCE

DISSERTATION: DIETARY CALORIC DENSITY AND CALORIC
UTILIZATION IN THE PIG

OUTLINE OF STUDIES:

Main Area: Swine Nutrition

Minor Area: Swine Management

BIOGRAPHICAL ITEMS:

Born: April 15, 1949, Denchai, Thailand

Education: Kasetsart University, Bangkok, Thailand
1968-1972. Animal Husbandry (B.S.)

Michigan State University, 1973-1975.
Animal Husbandry (M.S.)

MEMBER:

Alpha Zeta
Beta Beta Beta

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I. INTRODUCTION

Feed costs represent the largest portion of the expenses of producing swine. Feed ingredients which provide energy account for the largest portion of feed costs. Swine producers have become acutely aware of this with the world energy shortage raising the cost of feed energy. They are caloric cost conscious.

Feed energy is essential in all aspects of the maintenance, growth and development of swine including the operation of the vital functions to sustain life as well as the productive functions of the synthesis of a high quality product for human food.

The efficient utilization of feed energy has today become economically the single most important aspect of swine nutrition, taking on even greater significance than efficient utilization of dietary protein. Nutrition now and for years to come will emphasize nutritional balance to maximize the efficiency of feed energy utilization for product synthesis.

Modern production of meat type swine has advanced in the United States in spite of little premium to the

producer because he has recognized that this type is a more efficient converter of feed energy to product than strains of pigs predisposed to the production of more body fat. The selection of pigs which produce a lean carcass under full feeding conditions also minimizes maintenance energy needs and further contributes to maximum conversion of feed energy to product synthesis.

There are a wide variety of energy ingredients which may be incorporated into the swine diet. These may differ greatly in their digestible or metabolizable energy value. Since cellulose is largely undigested by swine, feed ingredients which contain a considerable amount of cellulose or other indigestible compounds add bulk to the diet and lower its digestible and metabolizable energy density. If dietary energy is sufficiently lowered energy intake capacity is reduced and growth rate is also reduced. This generally results in a lowered efficiency of energy utilization because a greater percent of dietary energy intake is spent on maintenance.

The efficiency of dietary energy density upon energy utilization for product synthesis is the subject of the present study. How dietary energy density in one phase of growth influences later performance and overall energy utilization was of special interest.

II. LITERATURE REVIEW

Methods of Determining Energy Values

Among the measures of energy used to evaluate feed ingredients, total digestible nutrient (TDN) has been widely used in North America. The term TDN is only an approximate measure of the food energy available to an animal after the digestion losses have been deducted and it is assumed that energy yield per gram of digested carbohydrate and protein are equal. Schneider (1947) summarized the data on total digestible nutrient (TDN) content of swine feeds.

Later, the disadvantage in expressing value of feeds and diets in terms of total digestible nutrients has been discussed by various workers (Lofgreen, 1951; Maynard, 1953; Schneider, 1954; Crampton et al., 1956). The main criticism of determination of TDN was the number of chemical analyses required and the inaccuracy of some of the methods, especially in the methods of determining the carbohydrate portion. Maynard (1947) pointed out that some of the uncertainties of the measurement of total digestible nutrients could be overcome by measuring digestible energy.

With the development of technology, the direct determination of total energy content of feed, feces and urine by means of the bomb calorimeter affords a simple, direct and accurate measure of the digestible energy and metabolizable energy values of feeds for animals. The term digestible energy is the total food energy minus total energy lost in the feces. The desirability of adopting digestible energy in place of TDN has been expressed by various workers (Lofgreen, 1951; Maynard, 1953; Schneider, 1954; Crampton et al., 1956). Swift (1957) demonstrated that one pound of TDN of roughage for sheep and cattle or mixed rations for cattle was equivalent to 2000 kilo calories of digestible energy. The term metabolizable energy refers to the measurement of energy which allows a more complete accounting for energy losses, namely the loss in urine, feces and gases. Gaseous losses in swine have been ignored in determining metabolizable energy, even though by definition they are deducted. However, this loss is minimal and rather constant. Bowland et al. (1970) reported a methane production in swine of 1.1% of the digestible energy and they also used this value to correct metabolizable energy. Both digestible energy and metabolizable energy values in energetic terms (calories) rather than percentage as in total digestible nutrients.

Some of the values of digestible energy of the feedstuffs reported by the National Research Council (NRC, 1973) were unavailable and were calculated from the

determined total digestible nutrients as follows:

$$\text{DE (kcal/kg)} = \frac{\text{TND}\%}{100} \times 4409.2$$

And most of the metabolizable energy (ME) values were calculated from the digestible energy values as follows:

$$\text{ME (kcal/kg) for swine} = \text{DE (kcal/kg)} \times [0.96 - 0.00202 (\text{crude protein}\%)]$$

In the tables of feed composition of Atlas NAS (1971) the digestible energy of feed ingredients for each kind of animal was calculated from:

- a. $\text{DE in kcal/kg} = \text{GE (kcal/kg)} \times \text{GE digestion coefficient}$
- b. The mean digestible energy in kcal/kg
- c. TDN as: $\text{DE in kcal/kg} = \frac{\text{TDN}\%}{100} \times 4409$

Metabolizable energy was calculated as follows:

- a. For each kind of animal except chickens and turkeys
From the average metabolizable energy (ME)
- b. For chickens and turkeys
From nitrogen corrected metabolizable energy
- c. For finishing cattle, sheep and horses
From DE as follows:
 $\text{ME in Mcal/kg} = \text{DE (Mcal/kg)} \times 0.82$

d. For swine

From DE as follows:

$$\text{ME in kcal/kg} = \text{DE (kcal/kg)} \times [0.96 - 0.00202 (\text{crude protein}\%)]$$

In the determination of metabolizable energy for swine, Diggs et al. (1965) suggested that it is essential to correct the urinary energy for nitrogen stored in or lost from the body during the balance trial. They found that the energy per gram of urinary nitrogen of pigs fed diets containing at least 35% protein was 6.77 kcal per gram and this value was used to adjust urinary nitrogen energy to nitrogen equilibrium. Furthermore, they showed the advantage in using metabolizable energy over digestible energy as an indicator of available energy. They showed that for all feeds the unadjusted metabolizable energy and metabolizable energy value adjusted for nitrogen retention averaged 94.7 ± 5.3 and $91.6 \pm 6.3\%$ of the digestible energy, respectively, but that for the high protein feeds, such as the slaughter-house by-products, fish-meal and soybean meal (50% CP), metabolizable energy was only 81.5% of the digestible energy value.

Using the pig, May and Bell (1971) suggested that the determination of metabolizable energy by conventional methods ($\text{DE} \times 0.98$) overestimated the metabolizable energy of high protein feeds such as fish meal. They also proposed the alternative of simply multiplying the digestible energy by about 0.98 since this would correspond with the

values expected when normal feeding levels of protein were used.

Energy Values of Diet Ingredients

It is generally agreed that the expression of available energy for nonruminant nutrition in terms of digestible energy and metabolizable energy are more precise than total digestible nutrients. The acceptance of metabolizable energy is also indicated by the number of swine nutrition studies now being reported in which nutrient allowances are related to units of metabolizable energy.

Mitchell and Hamilton (1933) reported that the metabolizable energy value of alfalfa meal was 1624 kcal per kg of dry matter for swine. Using the pig, Garrigus and Mitchell (1935) reported that whole and finely ground yellow corn contained 3662 and 3791 kcal of metabolizable energy per kg of dry matter, respectively. Table 1 contains the experimentally determined energy values including energy values of some feedstuffs reported by NRC (1968, 1973).

Factors Affecting the Energy Values

Physical Factors

According to NRC (1968), the specification for energy requirements of growing-finishing swine full-fed on corn and full-fed on wheat, barley, oats were 3,300 and 3,100 kcal of DE per kg of diets, respectively. Owusu-Domfeh and Bell (1971) indicated that the energy

Table 1. Energy Values of Diet Ingredients for Swine.

Ingredients and reference	kcal/gm dry matter		
	DE ¹	ME ²	ME _n ³
Soybean meal 50%			
Diggs <u>et al.</u> (1965)	4.39	3.88	3.72
NRC (1973)	4.46	3.98	
Young and Forshaw (1969)	4.02	3.57	
May and Bell (1971)	3.73	3.56	3.30
Saben <u>et al.</u> (1971a)	4.21	3.92	3.64
Saben <u>et al.</u> (1971b)	4.48	4.26	3.70
Soybean meal 44%			
NRC (1973)	3.75	3.70	
Saben <u>et al.</u> (1971b)	4.37	4.16	3.72
Rapeseed meal			
NRC (1973)	3.32	2.90	
May and Bell (1971)	3.34	3.11	2.98
Saben <u>et al.</u> (1971a)	3.21	2.89	2.64
Saben <u>et al.</u> (1971b)	3.37	3.13	2.76
Cottonseed meal			
NRC (1968)	3.57	3.11	
Husby and Kroening (1971)	3.01	2.74	2.56
Herring fish meat			
NRC (1968)	3.96	3.19	
May and Bell (1971)	4.64	4.07	3.86
Distillers dried grains with solubles			
Peter <u>et al.</u> (1971)			3.39
Brewers dried grain			
Kornegay (1973)	2.65	2.50	2.38
Brewers dried grains containing yeast			
Kornegay (1973)	2.84	2.63	2.50

Table 1. Continued.

Ingredients and reference	kcal/gm dry matter		
	DE ¹	ME ²	ME _n ³
Corn gluten feed			
Yen <u>et al.</u> (1974)		2.77	2.60
Wheat shorts			
May and Bell (1971)	3.10	3.01	2.95
NRC (1973)	3.25	3.00	
Corn			
Diggs <u>et al.</u> (1965)	3.67	3.64	3.55
NRC (1973)	4.05	3.81	
Young and Forshaw (1969)	4.04	3.87	
Grain sorghum			
Diggs <u>et al.</u> (1965)	3.76	3.76	3.55
NRC (1973)	3.89	3.66	
Wheat			
Diggs <u>et al.</u> (1965)	3.77	3.63	3.55
NRC (1973)	4.16	3.86	
May and Bell (1971)	4.04	3.92	3.87
Oats			
Diggs <u>et al.</u> (1965)	3.10	3.05	2.97
NRC (1973)	3.08	2.88	
May and Bell (1971)	2.96	2.90	2.85
Barley			
NRC (1973)	3.51	3.27	
Young and Forshaw (1969)	3.41	3.21	
Barley, heavy			
May and Bell (1971)	3.27	3.22	3.15

Table 1. Continued.

Ingredients and reference	kcal/gm dry matter		
	DE ¹	ME ²	ME _n ³
Coconut meat (sol-extd grnd)			
NRC (1973)	3.63	3.31	
Creswell and Brooks (1971)	3.6		
Coconut oil			
Creswell and Brooks (1971)	8.9		
Tallow (bleachable stabilized, fancy grade, 100)			
Diggs <u>et al.</u> (1965)	8.13	7.90	7.83

¹Digestible energy

²Metabolizable energy

³Metabolizable energy corrected for N retention

specification in the NRC (1968) diets could be reduced by about 10% without any significant decrease in performance of the pigs. This agreed well with the findings of Robin and Lewis (1964) who fed pigs on diets containing 68 or 76% total digestible nutrients. Although the feed conversion was slightly poorer on the low energy diet than on the high energy diet, the difference was not statistically significant. In addition, they also pointed out that the NRC (1968) protein level appeared to be inadequate to permit the most efficient utilization of high energy diets. This idea is well in agreement with Seerley et al. (1964) who reported that the energy efficiency in swine was decreased

as the level of energy increased (from 1825 to 2036 kcal of GE/lb diet) in low protein rations (12.5% crude protein).

The availability of fats for animal feeding has made it more practical to increase the energy density in animal rations. Many research workers have reported that poultry performance was influenced by the ratio of protein to energy in the diet (Baldini and Rosenberg, 1955; Leong et al., 1955; Matterson et al., 1955; Scott and Staheli, 1955; Lockhart and Thayer, 1955).

Some researchers have demonstrated that the addition of fat to increase energy in the basal swine diets improved rate and efficiency of gains (Day et al., 1953; Sewell et al., 1958; Brooks and Thomas, 1959; Pond et al., 1960; Clawson et al., 1962; Greeley et al., 1964; Hale et al., 1968). In other trials, efficiency of gain was increased without an increase in rate of gain (Kropf et al., 1954; Seerley et al., 1964; Brooks 1967a).

Reports by Sewell et al. (1957), Abernathy et al. (1958), Clawson et al. (1962), Brooks and Thomas (1959), Boenker and Tribble (1960) and Pond et al. (1960) indicated that there was a required relationship between energy level and crude protein level in corn-protein supplement rations for optimum performance.

Wagner et al. (1963) fed growing-finishing pigs corn-soy diets containing 0 or 10% fat (choice white grease) with 3 different protein levels (25, 19 and 13% crude protein). They found that there were no significant

interactions between energy and protein for average daily gain, feed efficiency, carcass backfat, dressing percent, percent yield of lean cuts and intramuscular fat. The same group of workers was unable to demonstrate a consistent improvement in daily gain due to the additional 10% fat. However, a significant improvement in feed efficiency due to the addition of 10% fat was demonstrated in their study. Feeding growing pigs 16% protein diets containing 0, 5, 10 or 15% stabilized lard, stabilized animal tallow or crude corn oil, Greeley et al. (1964) found that neither source nor level of dietary fat significantly affected apparent digestibility of protein or dry matter. Zivkovic and Bowland (1963) fed gilts diets containing 15% fat (stabilized tallow). They found that the digestibilities of dry matter, crude protein and crude fat were improved and the digestibility of nitrogen free extract depressed. Another report by Boenker et al. (1969) revealed that the addition of 7% fat (stabilized animal grease) to increase the gross energy of a corn-soy meal diet of 3870 kcal/kg to 4210 kcal/kg had very little effect on the digestibility of various components. They also indicated that if one assumed that the differences in the ratio of corn and soybean meal did not seriously alter the digestibility of the components of the feedstuff, it could be estimated from their data that the digestibility of added fat was about 88% and that of the added energy was 87.5%.

Cooke et al. (1972c) fed gilts diets containing four protein levels (15%, 18%, 21% and 24% CP) at each of four energy levels (2850, 3075, 3300 and 3525 kcal DE/kg air dry basis) and the daily feed allowance was limited according to a scale which increased linearly with live weight from 1.14 kg/day at 20 kg to 2.43 kg/day at 59 kg. They found no significant interactions between the effects of dietary energy and protein on growth rate, efficiency of feed conversion or carcass characteristics. However, there was a tendency for maximum growth rate and best efficiency of feed conversion with 18% crude protein level on two lower energy diets (2830 and 3100 kcal DE/kg air dry basis). The only significant interaction between energy and protein effects was the killing-out percentage, which was significantly lower on the combination of lowest energy and lowest protein than on any other diet. This result disagrees with the findings of Lodge et al. (1972b) who showed no significant influence of a low energy and low protein combination on killing-out percentage and of Cooke et al. (1972a) who reported a nonsignificant increased killing-out percentage in pigs fed a high energy diet (3500 kcal/kg DE) with a low protein level (15% CP). Waterman et al. (1973) demonstrated that 3% tallow supplementation to a corn-soy meal finisher diet resulted in reduction in time to market weight by about 4 days. Metabolizable energy consumed per unit gain was reduced by approximately 4%. Carcass backfat thickness was

reduced by about 4% and fat trim was approximately 2% less in pigs fed diets containing 3% tallow.

Brooks (1972) fed growing-finishing swine a molasses-soy diet, sugar-soy diet or corn-soy diet containing 0, 10 or 20% soybean oil, tallow or mixed (food waste fats) fat. They found that with the exception of the low energy molasses diet, the source of basal energy affected rate of gain to a greater extent than energy level. Pigs fed high sucrose diets gained faster than pigs fed corn diets, while pigs fed high corn diets gained at a faster rate than pigs fed high molasses diets. The addition of 10 or 20% fat increased rate of gain only when added to the low energy molasses diet. They found that feed/gain was negatively correlated ($r = -.95$) to energy concentration. As regard to the source of fats, they concluded that the three fats appeared equal as energy sources for pigs. According to the review of A.R.C. (1967) fats varied in percent digestibility. The digestibility coefficients for pigs of a hydrolyzed fat mixture or beef tallow added as 5% of the diet were 76% and 86% respectively, and that of stabilized white grease added as 10-20% of the diet was 87-90%. There was also an inverse relation between the mean molecular weights of the fatty acids in fats and oils and their digestibility. For 7-week old pigs the average coefficients were 78%, 90% and 96% for fats with long, medium and short chain lengths, respectively.

Recently, Hanke et al. (1974-75) fed growing pigs diets containing 25% rolled oats substituted for corn. The diets were formulated to contain 16, 20 or 24% crude protein with 0, 3 or 6% supplemental tallow. They concluded that there were no protein level x supplemental tallow interactions for either rate of gain or feed/gain ratio. Another observation on the use of fat as a source of energy has been reported by Moser (1975) who fed growing-finishing pigs normal corn diets (16-14% protein) or high lysine corn diets (14-12% protein) with or without 5% added fat. They found that 5% added fat to growing-finishing diets increased average daily gain of the pigs by 7.5%, decreased feed required per pound of gain by 13%, increased backfat thickness by 6.2% and slightly decreased, but not significantly, percent ham and loin.

The Effect of Fiber Content

The inhibitory effect of high levels of dietary fiber on growth rate of growing-finishing swine has been demonstrated by many workers (Hochstetler et al., 1959; Jensen et al., 1959 a, b; Larsen and Oldfield, 1961; Pond et al., 1962; and Seerley et al., 1962).

Seerley et al. (1964) fed growing-finishing pigs a corn-soy meal ration and a ration with 40% finely ground oats replacing corn and each of the rations contained 0, 4 or 8% fat (yellow grease). They found that the average daily gains of pigs fed all the corn rations with or

without added fat showed faster gains than those which received all corn-oat ration with or without added fat. Pigs fed corn rations without added fat required 0.22 lb less feed per pound of gain than was required by pigs fed corn-oat rations with no additional fat. They also found that feed efficiency of pigs fed corn-oat rations was improved by 0.22 and 0.39 lb with supplemental fat at 4 and 8% levels, respectively, as compared with those fed the no added fat ration. About the same amount of feed was required to produce a pound of gain with the no-fat corn ration as with the corn oat ration to which 4% fat had been added and the addition of 8% fat to the corn-oat ration improved feed efficiency 5% over the non-fat corn ration. This was primarily due to the difference in fiber content of the diets because the gross calorie content of the corn and corn-oat rations was similar with each of the energy levels fed. The fiber content of the corn rations was only 2.7%, while the corn-oat rations contained about 6.2% fiber. This report agrees with the work of Becker (1960) who demonstrated that the metabolizable energy content of corn and corn-oat rations could be made equal with the addition of fat to the corn-oat rations at the rate of 1% fat to 10% oats.

Replacing 10% of corn in a corn-soy diet with ground corn cobs, Boenker (1969) found that the coefficient of digestibility of crude fiber, nitrogen free extract and dry matter were significantly lower than in the basal diet and

the basal diet containing 7% fat. Likewise, Pond et al. (1962) reported that apparent digestibilities of dry matter, crude fiber and nitrogen free extract were significantly reduced by the addition of 12.4% corn cobs to low protein rations.

In more recent work, Baird et al. (1974) reported that crude protein digestibility was significantly depressed with the addition of citrus pulp to the diet but there was no significant difference in dry matter digestibility due to the level of citrus pulp in the diet. The depression of protein digestibility was 1.6% for each 1% increase in crude fiber content of the diet and an 0.75% decrease for each 1% increase in cellulose contained in the diet.

The Effect of Pelleting

Jensen (1956) reported that pelleting usually improved gain/feed of pigs fed corn-soybean meal diets. Troelsen and Bell (1962) indicated that pelleting resulted in increased intake of digestible energy which was due to improved digestibility of the energy components in pelleted diets. Chamberlain et al (1967) also reported the same result that there was an improvement in feed efficiency in pigs fed with the diet in pelleted form but Gamble et al. (1967) were unable to demonstrate such a benefit.

The NCR-42 Committee on Swine Nutrition (1969) did not demonstrate a consistent benefit to rate of gain or gain/feed due to pelleting corn-soybean meal diets for

growing pigs. They found that the average daily gain and gain/feed were 0.77 vs. 0.78 kg and 0.31 vs. 0.32, respectively for pigs fed the meal and pelleted diets. Similar results have been reported by Owusu-Demfeh and Bell (1971) who demonstrated that the NRC (1968) and ARC (1967) diets in pelleted form did not produce better growth than the diets in the meal form. Although, the growth rates and feed intakes of pigs fed the pelleted diets improved during the finishing period, the feed efficiency was still below that obtained with the meal type diets. The same group of workers also gave an explanation for the relatively poor performance of the pigs fed the pelleted diet during the grower period suggesting that may be the pellets may have been too hard for young pigs to utilize.

The effect of form of diet on the performance of finishing pigs has been studied by Hanke et al. (1972) who reported that pelleting of corn-soybean meal diets resulted in a significant ($P < .01$) increase in daily gain while regrinding of the pelleted diets apparently exerted a deleterious effect on rate of gain. Likewise, pelleting of the diets resulted in a significant ($P < .05$) improvement in gain/feed compared with that resulting from feeding the diet in meal form.

Jensen and Becker (1965) evaluated the effects of pelleting a diet and its cereal component upon its utilization and concluded that there were no significant effects on rate of gain and that daily feed intake was variably affected,

with no definite trend established. In contrast, Hintz and Garrett (1967) demonstrated that the pelleting of barley for growing and finishing swine increased the rates of gain and intake and seemed to improve feed efficiency.

Substituting corn with corn gluten feed up to 30% in a 16% protein ration, Yen et al. (1971) found that pigs fed pellets had daily gain and gain/feed significantly ($P < .05$) greater than those fed meal. They also noticed that, pelleting of corn gluten feed significantly ($P < .01$) improved nitrogen absorption from 4.9 to 5.1 gm/day in growing pigs. Baird et al. (1974) reported that the replacement of corn with either 10 or 20% citrus pulp in the diet with adding energy caused a slight reduction in daily gain with the reduction at the 20% level being significant ($P < .01$) in finishing swine. They also found that simply pelleting the diet would not compensate for the loss of energy when corn was replaced with citrus pulp and no other energy made to replace the energy loss due to less corn in the diet.

Physiological Factors

The effects of protein level, energy level and sex on growth, feed efficiency and carcass characteristics of swine have been reported by Wagner et al. (1963). They reported that increasing the energy level in basal diet by the addition of 9-10% choice white grease had no significant effect on rate of gain but did significantly improve

feed efficiency. However, barrows gained significantly faster and contained significantly more intramuscular fat than gilts. This finding is in agreement with Mulholland et al. (1960) who reported that barrows grew significantly faster than gilts and pigs marketed at 195 lb. grew faster than those slaughtered at 145 lb. of body weight. In the second trial of Wagner et al. (1963), the pigs were fed with diets of two different levels of metabolizable energy (1310 and 1640 kcal/lb of diet). They found that gilts fed to 200 lb. gained slightly faster than boars and had a significant higher dressing percent. However, boars were significantly more efficient in feed conversion and had significantly less carcass backfat. They also noted that boars yielded a higher percent of lean cuts and slightly less intramuscular fat but neither were statistically significant.

Owusu-Domfeh and Bell (1971) demonstrated that feed consumption of barrows was significantly higher than that of the gilts during the grower period. The barrows reached market weight faster than the gilts, as their growth rate was significantly faster than that of the gilts for overall test.

Allee et al. (1972) evaluated the effect of sex on performance, body composition and lipogenesis. The concluded that females gained at a slower rate and were more efficient in feed utilization than castrated males. Females had a lower rate of glucose-U-¹⁴C incorporation into fatty

acids and oxidation to $^{14}\text{CO}_2$ than castrated males. The activities of malic enzyme and citrate cleavage enzyme were also lower in females. Carcass analysis revealed that castrated males had more backfat, perirenal fat and fat brim and a lesser percent of carcass as lean cuts than females.

Maintaining a constant ratio of each nutrient in the diet to the metabolizable energy concentration, Allee et al. (1971a) found that young pigs 6 weeks of age were capable of utilizing the fat of corn oil as effectively as carbohydrates, which is in agreement with Sewell and Miller (1965) who reported a higher efficiency in pigs weaned at 21-26 days fed corn oil, beef tallow and lard as source of dietary fat.

Feeding a high fat diet has been shown to depress fatty acid synthesis in liver and adipose tissue of the laboratory rat (Whitney and Roberts, 1955; Hill et al., 1958; Marsoro, 1962; Diller and Harvey, 1964; Leveille, 1967 a, b) and in hepatic tissue of the chicken (Weiss et al., 1967; Yeh and Leveille, 1969; Yeh et al., 1970). Korchak and Mosoro (1964) found that saturated long chain fatty acids decreased the degree of incorporation of acetyl CoA and malonyl CoA into fatty acids in rat-liver homogenates, with myristic acid being the most inhibitory. Allee et al. (1971, a, b, c) reported that increasing of the level of dietary fat in the swine diet resulted in a linear depression of glucose-U- ^{14}C incorporation into fatty acid and oxidation to $^{14}\text{CO}_2$. They also found that the

activities of malic enzyme and citrate cleavage enzyme also decreased linearly as dietary fat level increased. O'Hea and Leveille (1969) demonstrated that fatty acid synthesis and $^{14}\text{CO}_2$ production from glucose- $\text{U-}^{14}\text{C}$ were virtually abolished in biopsy adipose tissue samples obtained from pigs subjected to a 4- or 7-day fast. Refeeding the animals for 2 days fully restored lipogenesis to the prefasting level, and refeeding for 4 days was associated with a two-fold overshoot in the capacity for glyceride-glycerol synthesis. No overshoot in fatty acid synthesis could be detected after 4, 6 or 12 days of refeeding. They also noticed that in pigs refed diets high in protein or fat after a 4-day fast, the restoration of the lipogenic capacity of the adipose tissue was limited to about 50% of that observed in animal refed a high carbohydrate diet.

The investigation of the effect of source of dietary fat on the capacity of pig adipose tissue to synthesize fat, and the influence of source of dietary fat on the activities of malic enzyme and citrate cleavage enzyme have been demonstrated by Allee et al. (1972) who found that the addition of 10% dietary fat as corn oil, lard, tallow or coconut oil, resulted in a marked depression in the conversion of glucose- $\text{U-}^{14}\text{C}$ into fatty acids. They also found that the activities of malic enzyme and citrate cleavage enzyme were depressed in adipose tissue homogenates of pigs fed diets containing 10% dietary fat, regardless of source. From these findings, the same group of workers suggested

that all dietary fats, saturated and unsaturated, were equally effective in inhibiting fatty acid synthesis.

Energy x Mineral Interaction

The relationship of dietary fat to calcium and magnesium in the rat has been reported by some investigators (French, 1942 and Cheng et al., 1949). The effect of fat on calcium and phosphorus metabolism has been studied by Calverley and Kennedy (1949) who fed rats an egg albumin (cooked) -dextrinized starch ration containing 5% of completely hydrogenated cottonseed oil, peanut oil or coconut oil. They found that the inclusion of 5% of fat in the diet increased fecal excretion of calcium when compared to those fed no supplemental fat. Fecal calcium increased with the increase in the melting point of the fat used. The excretion of fecal phosphorus showed no constant relationship either to the characteristics of the fat used or to the presence of fat in the diet. They also noted that the excretion of calcium and phosphorus in the urine was affected only indirectly by the presence of fat in the diet. When the fecal excretion of calcium was considerably increased, there was a decrease in the urinary excretion of calcium but a marked increase in the urinary excretion of phosphorus.

Using the pig, Newman et al. (1967) studied the effects of added animal fat (tallow) on the utilization of calcium and phosphorus. The animals were fed diets

containing various level of calcium (0.20, 0.40, 0.60 or 0.80% dietary calcium) and phosphorus (0.35, 0.45, 0.55 or 0.65% dietary phosphorus) with or without 10% tallow. They found that feed intake and average daily gain increased linearly ($P < .01$) up to 0.6% dietary calcium and 0.45% dietary phosphorus. The addition of tallow had no effect on rate of gain but significantly decreased feed intake and improved feed efficiency and significantly decreased breaking strength of femurs but had no effect on femur moisture, percent ether extract or calcium when compared to pigs fed no supplemental fat. In their digestibility study, they found that added tallow had no consistent effect on calcium digestibility, but depressed the apparent digestibility of dietary phosphorus. The endogenous fecal calcium loss was greater in pigs fed the high calcium diets, but was not affected by the level of dietary tallow.

Study of the influence of added fat (graded lard) in the basal diet on the utilization of zinc has been reported by Babatunde (1972). The diets used consisted of corn, groundnut cake, 3.0% blood meal, 3.2% fish meal, 2.0% rice bran, 1.5% bone meal and 0.75% oyster shell containing four levels of zinc (0, 100, 200 or 300 ppm in the form of zinc oxide powder) and three levels of fat (0, 2.5 or 5.0% lard). This worker found that pigs receiving the basal diet without the additional fat or supplemental zinc (estimated to contain 0.8% calcium and 50 ppm zinc) provided the best growth rate when compared to those fed no

fat diets with supplemental zinc. Pigs fed a basal diet containing 2.5 or 5.0% fat without supplemental zinc developed signs of zinc deficiency after a 17-week feeding trial. However, it was concluded that supplementation with about 100 ppm zinc to the basal diet containing 2.5% lard appeared to give the best performance, while with 5.0% added lard, 200-300 ppm of zinc supplementation appeared to give the best results in growing pigs.

Maust et al. (1972) evaluated the feeding value of diets consisting of cassava flour and rice bran (approximate 29.0 and 40.0% of the diet, respectively) as major sources of energy compared with a diet consisting of corn as the major source of energy for growing pigs. They found that pigs fed the corn diet gained more weight and had a higher efficiency of feed utilization than pigs fed the cassava-rice bran diet. Pigs fed the cassava-rice bran diet developed zinc deficiency signs including parakeratosis and depressed serum alkaline phosphatase levels, despite the similar zinc content of the two diets (40 and 48 ppm for the cassava-rice bran diet and corn diet, respectively). With the supplemental zinc (52 ppm of Zn as ZnCO_3), pigs showed improvement in both daily gain and feed efficiency and serum alkaline phosphatase was restored to a level not significantly different from the pigs fed the corn diet. The same group of workers also explained that the poor performance and the occurrence of parakeratosis in pigs fed the cassava-rice bran diet were primarily due to free

phytic acid in the rice bran which was reported to contain 5.1% free phytic acid by Nelson et al. (1968). Phytic acid is known to chelate cations such as zinc.

In the report of Babatunde (1972) there is no indication of the effect of phytic acid in the rice bran on the utilization of zinc (50 ppm of the basal diet) which is the minimum requirement according to the recommendation of NRC (1968). The possible explanation could be that the amount of rice bran (2% rice of the diet) is too small to affect the utilization of zinc by pigs. Even though the level of calcium of the basal diet (0.8% Ca) was higher than that (0.65% Ca) recommended by NRC (1968), the pigs still performed well with no sign of parakeratosis.

Requirements for Vitamins

The requirements for vitamins of young pigs (Table 2) are presented in the review of Lucas and Lodge (1961). The requirement for vitamin A of young 10 lb. pigs is 220 ug of vitamin A acetate or 550 ug of β -carotene, per pound of dry matter of the diet. For older pigs over 40 lb. liveweight the requirements per pound feed dry matter are about 60 ug vitamin A acetate or about five times as much β -carotene. The rest of the vitamin requirements reported in Table 2 indicate the amount of each vitamin per unit of energy digested feed (EDF). The values of EDF have been calculated from the gross energy of mixed diets. The same group of workers reported that the EDF of sow's

milk was 97% of gross energy. Synthetic or semi-synthetic liquid milk substitutes for pigs under 20 lb. liveweight and synthetic meal mixtures for pigs over 20 lb. liveweight have EDF of 90% of gross energy.

Two trials at Michigan State University (Miller et al., 1971) indicated that half the supplemental levels in MSU 16 ration (Table 3) provided by the premix (Table 4) were adequate to support maximum gains of pigs weaned at 30 lb. and fed for 16 weeks. The MSU 16 ration contains about 3450 kcal per kg of diet. The nutrient composition of MSU 16 ration and the requirements (NRC-recommendations) are shown in Table 5.

Recently, some swine nutrition studies were reported in which nutrient allowances were related to units of metabolizable energy. In studies on the effects of fat as a source of energy for young pigs, Allee et al. (1971 a, b) and Allee et al. (1972) formulated rations which maintained a constant ratio of each nutrient in the diet to the concentration of metabolizable energy.

Table 2. Requirements for Vitamins of Young Pigs.

Vitamins	Liveweight of pig (lb)	Vitamin A acetate $\mu\text{g/lb}$ dry matter	β carotene $\mu\text{g/lb}$ dry matter
A	10	220	550
	20	60	300
	40	60	300
<u>Per Mcal EDF (energy of digested feed)</u>			
D	10	100 IU	
	20	100 IU	
	40	100 IU	
Thiamin	<20	0.35 mg	
	20-45	0.35 mg	
Riboflavin	<20	0.55 mg	
	20-45	0.40 mg	
Nicotinic acid	<20	4.5 mg	
	20-45	4.5 mg	
Pantothenic acid	<20	2.9 mg	
	20-45	1.7 mg	
Pyridoxine	<20	0.2 mg	
	20-45	0.2 mg	
B ₁₂	<20	4.0 μg	
	20-45	3.0 μg	

Table 3. MSU Corn-Soy Rations.

Ingredients	Grower MSU 16	Finisher MSU 13
Ground shelled corn	1560	1710
Soybean meal	380	230
Ground Limestone	20	20
Dicalcium phosphate	20	20
Salt	10	10
MSU VTM premix	10	10
	2000	2000

Table 4. MSU VTM Premix.

Nutrient	Amount in 10 lb. of premix
Vitamin A, million	3.0 IU
Vitamin D, million	0.6 IU
Vitamin E, thousand	10.0 IU
Riboflavin	3.0 g
Niacin	16.0 g
D-pantothenic acid	12.0 g
Choline chloride	100.0 g
Vitamin B ₁₂	18.0 mg
Zinc	68.0 g
Manganese	34.0 g
Iodine	2.5 g
Copper	9.0 g
Iron	54.0 g
Autioxidant (BHA and/or BHT)	45.0 g
Carrier (ground yellow corn)	To bring total to 10 lb.

Table 5. Nutrient Values of MSU 16 Compared to Requirements.

Nutrient	MSU 16 ^a	Requirements ^b
Digestible energy, kcal/kg ^c	3450	3300
Crude protein %	16.0	16.0
Arginine	0.99	0.20
Histidine	0.36	0.20
Isoleucine	0.76	0.50
Leucine	1.32	0.60
Lysine	0.73	0.70
Methionine + Cystine	0.51	0.50
Phenylalanine	0.93	0.50
Threonine	0.56	0.45
Tryptophan	0.16	0.13
Valine	0.69	0.50
Vitamins		
A, IU/kg	480* (3780) ^g	1300
D, IU/kg	0* (660)	200
E, IU/kg	9* (20)	11
Thiamin, ppm ^d	4	1.1
Riboflavin, ppm	1.6* (4.9)	2.6
Niacin, ppm ^e	5.4* (23)	14.0
Pantothenic acid, ppm	5.4* (18)	11.0
Pyridoxine, ppm	6.4	1.1
Choline, ppm	850* (960)	900
B ₁₂ , ppb ^f	0* (19)	11
Minerals		
Calcium, %	0.68	0.65
Phosphorus, %	0.52	0.50
Sodium, %	0.26	0.10
Chlorine, %	0.36	0.13

Table 5. Continued.

Nutrient	MSU 16 ^a	Requirements ^b
Potassium, %	0.58	0.30
Magnesium, ppm	1150	400
Iron, ppm	39* (98)	80
Zinc, ppm	20* (100)	50
Manganese, ppm	7* (44)	20
Copper, ppm	4* (14)	6
Iodine, ppm	<0.2* (2.7)	0.2
Selenium, ppm	0.04* (.14)	0.1

^aExcluding nutrients supplied by MSU VTM premix.

^bNational Research Council listed requirement for 40 lb. pig.

^cKilocalories per kilogram.

^dParts per million.

^eAvailable niacin.

^fparts per billion.

^gValues with 10 lb/ton supplemental VTM premix.

*Inadequate to meet requirement.

III. EXPERIMENTAL PROCEDURE

A feeding trial through the entire swine feeding period and one balance trial with growing-finishing swine were conducted to evaluate low and high energy density rations. Corn and 2% stabilized tallow were used as the main source of energy for the high energy rations and corn with 40% oats were used as the main source of energy for the low energy rations.

Animals used in the studies were Yorkshire, Hampshire and crossbred Yorkshire-Hampshire pigs obtained from the Michigan State University swine research center.

Experiments

Experiment 1. Feeding trial: Effect of Energy Density of Diets During Starting-Growing-Finishing Period on the Performance of Pigs

In this experiment, all pigs were randomly allotted from weight, sex and litter outcome groups to experimental treatments. The design of experiment was a 2^3 factorial with replication (Table 9). Eight possible treatment combinations were obtained: Low-Low-Low, Low-Low-High,

Low-High-Low, Low-High-High, High-Low-Low, High-High-Low, High-Low-High, and High-High-High in which each treatment combination represents energy density in the starter, grower and finisher diets, respectively. The compositions of all the rations used in this experiment are shown in Tables 6, 7 and 8. During the starting period, all the pigs were housed in pens with aluminum slatted floors. After this period, they were moved to pens with cement slatted floors until the end of the experiment. Feed was provided ad libitum in self feeders, and water was continuously available from automatic waterers. All housing had thermostatically controlled temperature and ventilation.

The animals were weighed individually at the beginning of the experiment and at biweekly intervals thereafter. Following each weighing, feed remaining in the self feeders were measured. Feed consumption for the period was recorded and then average daily gain, average daily feed consumption and feed/gain were calculated and recorded.

The length of the experiment was 126 days with 1 period (2 wk) for starter, 3 periods (6 wk) for grower and 5 periods (10 wk) for finisher. After the end of the experiment the animals were kept on the same finishing diets for a few days until they reached market weight of approximately 100 kilograms. Some animals from each treatment were slaughtered at either a commercial slaughtering plant or the meats laboratory of Michigan State University. Dressing percentage and percent ham + loin were measured.

Table 6. Composition of Starter Rations.

Ingredients	Energy Density	
	Low	High
Corn	769	1527
Oats	800	0
SBM 49	360	360
Limestone	15	15
Dicalcium phosphate	30	30
Salt	5	5
Vit-TM	15	15
Lysine (50%)	6	8
Tallow	0	40
	2000	2000
<u>Nutrient Composition*</u>		
ME, kcal/kg	2962	3387
Crude protein, %	17.0	15.8
Calcium, %	.72	.70
Phosphorus, %	.60	.58
Lysine, %	.95	.95
Methionine + Cystine, %	.53	.52
Tryptophan	.20	.17

*Estimated.

Table 7. Composition of Grower Rations.

Ingredients	Energy Density	
	Low	High
Corn	881	1639
Oats	800	0
SBM 49	260	260
Limestone	15	15
Dicalcium phosphate	20	20
Salt	5	5
Vit-TM	15	15
Lysine (50%)	4	6
Tallow	0	40
	2000	2000
<u>Nutrient Composition*</u>		
ME, kcal/kg	2975	3400
Crude, protein, %	15.0	13.8
Calcium, %	.60	.58
Phosphorus, %	.50	.48
Lysine, %	.75	.75
Methionine + Cystine	.46	.47
Tryptophan	.17	.14

*Estimated.

Table 8. Composition of Finisher Rations.

Ingredients	Energy Density	
	Low	High
Corn	983	1741
Oats	800	0
SBM 49	160	160
Limestone	15	15
Dicalcium phosphate	20	20
Salt	5	5
Vit-TM	15	15
Lysine (50%)	2	4
Tallow	0	40
	2000	2000
<u>Nutrients Composition*</u>		
Metabolizable energy kcal/kg	2971	3396
Crude protein, %	13.0	11.7
Calcium, %	.58	.56
Phosphorus, %	.48	.46
Lysine, %	.55	.55
Methionine + Cystine, %	.42	.42
Tryptophan, %	.14	.11

*Estimated.

Table 9. Design of Experiment 1.

Period	Treatment Combination		Length
	<u>Energy Density</u>	<u>Energy Density</u>	
Starter (14-24 kg)	Low	High	2 wk
	↓	↓	
Grower (24-54 kg)	Low	High	6 wk
	↓	↓	
Finisher (54-94 kg)	Low	High	10 wk

At the same time the animals were checked for the incidence of stomach ulcer.

Experiment 2. Balance Trial

The balance trial was conducted in the metabolism area at the Michigan State University swine farm. Eight crossbred growing pigs obtained from one litter averaging 46.1 kg bodyweight were involved in the experiment. They were randomly assigned within sex to two lots of 4 pigs each. The same diets used for growing and finishing swine in Experiment 1 (Tables 7 and 8) were used in this experiment. The diets were provided ad libitum using self feeders. The pigs and feeders were weighed individually at the beginning and at the end of each period and recorded.

The average daily gain and feed consumption were calculated on the basis of the period of collection (3 days).

Feces and feed wastage were collected on a metal plate beneath the fully slotted floor, urine was collected in plastic containers through a fine mesh metal screen. Approximately 100 ml of 50% hydrochloric acid was added to the urine container prior to collection. Feces, urine and feed wastage were collected daily and weighed. A feces sample was taken daily and kept in a well sealed plastic container and a few drops of 50% HCl was added before storing in a cool room. A urine sample was also taken daily and stored in a plastic vial in the same location. At the end of each period, feces samples for the period (3 days) were put together in an aluminum pan and dried at 50°C for approximately 12 hours. The feces were weighed prior to and after drying and percent dry matter was calculated. Dried feces were ground with a hand meat grinder and samples were taken and stored in air tight polyethylene bags at room temperature.

Each collection period was 3 days long and all the pigs were provided at least a 2 day adjustment period prior to the 3 day collection period. In the growing period each group of animals was on both high and low energy ration with a 2 day adjustment period prior to and between the collection periods. In the finishing period both pens were kept on the finishing rations of the same energy density which they had received for the second growing

period balance trial and then were switched to the alternative energy density of the finishing diets for the final energy balance. These pigs were also provided the same adjustment period as the growing period balance trials.

Analytical Procedures

Feed and Feces

Feed samples were ground twice through a screen with 2 mm diameter openings. The feed samples were stored in air-tight polyethylene bags before and after grinding. The feces samples were reground again through a 2 mm diameter screen in a Wiley mill.¹ All the feed and feces samples were stored at room temperature.

Crude protein of feed and feces samples was determined by the semi-micro Kjeldahl technique, using a Sargent Spectro-Electro Titrator.² Gross energy was determined by the use of a Parr adiabatic oxygen bomb calorimeter.³

Approximately 0.5 gm each of feed and feces samples was digested in concentrated sulphuric acid in the determination of crude protein (duplicates for each sample). Approximately 1 gm of each feed and feces sample (in duplicate) was made into pellets and used for gross energy determination in the Parr adiabatic oxygen bomb calorimeter.

¹Arthur H. Thomas Co., PA.

²E. H. Sargent and Co., IL.

³Parr Corp., Moline, IL.

Urine

Daily urine samples were stored in well-sealed vials at 4°C and each of them was analyzed for crude protein and gross energy in duplicate.

Approximately 0.5 gm of each urine samples was used in the determination of crude protein and the general procedure was the same as for determination of fecal crude protein. For gross energy determination of urine samples, the general procedure and instrument were the same as the determination of feed or fecal gross energy with the exception of the preparation of the samples. A urine sample of approximately 5 ml was absorbed on cotton dried at 45°C for about 12 hours and incinerated in the Parr adiabatic oxygen bomb calorimeter for gross energy determination.

Statistical Analysis

All the data were subjected to analysis of variance by the use of a CDC 6500⁴ computer at the Michigan State University computer laboratory with the exception of the summary data of pig performance in the starting period. The performance of pigs in the starting period were analyzed by the student t-test through the use of a Hewlett-Packard calculator.⁵ The individual treatment values were compared by Duncan's (1955) multiple range test.

⁴Control Data Corp., Minneapolis, Minn.

⁵Hewlett-Packard hp 9100 A.

IV. RESULTS

In experiments 1 and 2, average daily gain, average daily feed, feed efficiency, average daily energy and energy efficiency were considered on the lot basis for each group of animals of all experimental treatments.

Nitrogen corrected metabolizable energy values for both grower and finisher low and high energy density rations determined during the balance trial in the experiment 2 were used to evaluate the utilization of energy in the experiment 1 during both growing and finishing periods.

Due to the limitation of the number of young pigs, only 12 lots of pigs were available for assignment to the starting rations, instead of the 16 lots called for by the design of the experiment. The numbers of lots of experimental animals were equally subjected to low and high energy starting rations with 6 lots on each treatment. On the study of the interaction of age and treatments due to the starting period, the data were tested by the use of analysis of variance. The results indicated that there was no effect of treatments during the starting period on the performance of the following period (growing period).

Based on these results, the starting period was studied separately and was not included in the overall performance, which included only the growing and finishing periods. At this point, the design of experiment turned into a 2^2 factorial.

Experiment 1

Starter: The performance of the pigs on the starting diets is shown in Table 10. There were no significant differences due to treatments between any parameters reported herein. Even though young pigs on the high energy starting diet showed a slightly better daily gain (590 vs. 550 g) this was primarily due to the higher feed consumption by the high energy group. Meanwhile, the efficiency of feed conversion was slightly better (1.93 vs. 1.97) in groups receiving the high energy ration as expected. Feed energy conversion to gain, however, was more efficient by pigs on the low energy starter ration.

Grower: In this period, animals on both low and high energy growing rations showed almost the same average daily gain (653 vs. 644 g, for low vs. high energy ration, Table 11). The average daily feed consumption for pigs fed the low energy diet was somewhat higher than for those fed the high energy ration (1701 vs. 1599 g for low energy vs. high energy). Feed/gain was thus less for pigs fed the high energy growing ration. Nitrogen corrected metabolizable energy consumed per day was almost equal in both

Table 10. Summary of Pig Performance on Starting Period.¹

Item	Low Energy Ration	High Energy Ration	Significance
No. of Lots	6	6	
Average daily gain, g	550 (±13.2)	590 (±17.0)	NS
Average daily feed, g	1083 (±40.1)	1136 (±38.7)	NS
Feed/gain	1.97 (±.04)	1.93 (±.06)	NS

¹Values represent $\bar{X} \pm SE$

Table 11. Summary of Pig Performance on Growing Period.

Item	Low Energy Ration	High Energy Ration	
No. of Lots	8	8	±SE ¹
Average daily gain, g	653	644	20.5
Average daily feed, g	1701	1599	66.6
Feed/gain	2.60	2.47	0.38
Av. daily energy cons., ² kcal	5302	5406	217.7
Energy ² eff. kcal/kg gain	8092	8357	122.8

¹Standard error of the mean.

²Nitrogen corrected metabolizable energy.

treatments. In contrast to feed/gain, the efficiency in utilizing energy for gain was slightly better for pigs on the low energy growing ration (8092 vs. 8357 kcal/kg of gain for low and high energy diets, respectively). However, the differences among the treatments reported in this period were statistically non-significant.

Finisher: The results of the finishing period are reported on the basis of the consequence of the effects of the diet during the growing period. The performance of pigs on the low energy finishing ration is shown in Table 12. The data show that there were slight effects of energy density of the growing rations on the performance of pigs fed the low finishing energy ration. None of the effects were statistically significant. Pigs which were fed the low energy finishing ration and had been on the low energy growing ration gained slightly faster (645 vs. 626 gm) and consumed approximately 211 gm more feed per day but feed conversion (feed/gain) was slightly poorer (3.85 vs. 3.62) than those fed the low energy finishing ration after being fed the high energy growing ration. The nitrogen corrected metabolizable energy consumption per day was also higher in the groups of pigs which had been on the low energy grower ration. These groups of pigs also had a lower ability to utilize calories of low energy finishing ration (11,495 vs. 10,775 kcal/kg).

The performance data of pigs on the high energy finishing ration are shown in Table 13. The energy density

Table 12. Summary of Pig Performance on Low Energy Finishing Ration.¹

Item	Low Energy Grower	High Energy Grower	
No. of	4	4	±SE ²
Average daily gain, g	645	626	25.6
Average daily feed, g	2480	2268	99.6
Feed/gain	3.85	3.62	0.10
Av. daily energy cons. ³ kcal	7385	6755	295.6
Energy eff., kcal/kg gain	11495	10775	289.4

¹On the basis of type of ration during growing period.

²Standard error of the mean.

³Nitrogen corrected metabolizable energy.

Table 13. Summary of Pig Performance on High Energy Finishing Ration.¹

Item	Low Energy Grower	High Energy Grower	
No. of	4	4	±SE ²
Average daily gain, g	655	627	19.7
Average daily feed, g	2374*	2050	78.7
Feed/gain	3.62	3.29	0.12
Av. daily energy cons. kcal	7904*	6826	262.1
Energy eff., kcal/kg gain	12055	10964	397.6

¹On the basis of type of ration during growing period.

²Standard error of the mean.

*Significantly higher than the value in the same line
(P < .05)

of the growing ration had a slight effect on the average daily gain of pigs fed the high energy finishing diet. Pigs receiving the low energy ration during the growing period gained slightly faster (655 vs. 627 gm) on the high energy finishing ration. Both average daily feed and average daily energy consumption were greater ($P < .05$) in pigs which had been on the low energy growing ration before being placed on the high energy finishing ration. Even though the efficiency in feed and energy conversion tended to be poorer for those pigs which had been on the low energy ration during the growing period this effect was not statistically significant.

Finishing period: The effects of both low and high energy finishing rations on the performance of pigs are shown in Table 14. Pigs during the finishing period did not show a consistent effect on average daily gain due to energy level in the ration being more dependent on the type of ration received during the growing period. Energy density in the rations had a great impact on the amount of feed consumption. Pigs fed the low energy ration which had been on the low energy growing ration consumed a significantly ($P < .05$) greater amount of feed per day than those which were on the same low energy finishing ration but which had been on the high energy growing ration. The groups which were on the high energy ration during both periods as expected, consumed the least feed. Pigs fed the high energy finishing ration which had been on the high

Table 14. Summary of Pig Performance of Finishing Period.¹

Item	(L) ² L ³	(L)H ⁴	(H)L	(H)H	
No. of Lots	4	4	4	4	±SE ⁵
Av. daily gain, g	645	654	626	627	16.2
Av. daily feed, g	2478 ^{aa,b}	2374 ^{aa}	2268 ^a	2050	63.5
Feed/gain	3.86 ^{aa}	3.62 ^a	3.62 ^a	3.29	0.08
Av. daily energy, kcal	7385 ^a	7904 ^{aa,bb}	6755	6826	197.9
Energy eff., kcal/kg gain	11495	12055 ^{aa,bb}	10775	10964	245.9

¹On the basis of type of ration during growing period.

²(...) = type of ration during growing period.

³L = Low energy finishing ration.

⁴H = High energy finishing ration.

⁵Standard error of the mean.

^aSignificantly greater than least value ($P < .05$).

^bSignificantly greater than next to least value ($P < .05$).

^{aa} $P < .01$.

^{bb} $P < .01$.

energy ration during the growing period showed significantly better feed efficiency than those which received the low energy finishing ration regardless of the energy density received during the growing period as well as those which were on the high energy finishing ration but which had been on the low energy growing ration. The efficiency of feed conversion for (H)L and (L)H groups was identical. For the consumption of nitrogen corrected metabolizable energy, pigs on the high energy finishing ration which had received the low energy grower ration consumed significantly ($P < .01$) more calories per day than those which had received the high energy grower ration and received either a low or high energy finishing ration. Meanwhile, pigs fed the low energy finishing ration and the low energy growing ration consumed more ($P < .05$) calories per day than those fed the low energy finishing ration which had been on the high energy growing ration. Pigs which had received the high energy growing ration and then received either low or high energy rations during the finishing period utilized energy for gain significantly ($P < .01$) more efficiently than those fed the high energy finishing ration which had been on the low energy growing ration.

Overall feed trial (growing-finishing period):

Pigs which received the low energy growing ration and continued with either low or high energy finishing ration (LL and LH) tended to produce a faster gain than those which received the high energy ration during the growing

period and continued with either low or high energy ration during finishing period (HL or HH). Feed consumption of pigs fed the low energy rations during both the growing and finishing period (LL) was significantly higher than those fed the high energy ration during the growing period and continued with either low or high energy finishing rations (HL or HH). Pigs on the LH treatment also consumed a significantly higher ($P < .05$) amount of feed per day than the HH group. Pigs fed the high energy growing ration and continued with either the low or high energy finishing ration required significantly less feed per pound of gain. Feed efficiency of pigs fed high energy rations for both the growing and finishing period was greater ($P < .05$) than that of pigs on the combinations of low and high energy rations for either the growing or finishing period. The average daily consumption of nitrogen corrected metabolizable energy in the groups of pigs fed low energy rations for both growing and finishing period was greater than that of pigs receiving the high energy ration during the growing period. However, the differences were not statistically significant. Pigs fed the low energy ration during the growing period and continued with the high energy finishing ration (LH) consumed a significantly ($P < .01$) higher amount of calories per day than the two groups which received the high energy ration during the growing period with either the low or high energy finishing ration. The calories consumed by pigs fed the high energy growing ration with the

Table 15. Summary of Overall Pig Performance.¹

Item	LL	LH ²	HL	HH	
No. of Lots	4	4	7	4	±SE ³
Av. daily gain, g	651	652	636	630	10.2
Av. daily feed, g	2191 ^{aa,b}	2118 ^{aa}	2015 ^a	1883	43.7
Feed/gain	3.37 ^{aa,b}	3.25 ^a	3.17 ^a	3.00	0.05
Av. daily energy, kcal	6614	6918 ^{aa,bb}	6241	6302	138.6
Energy eff., kcal/kg gain	10167	10605 ^{aa,b}	9805	10031	164.6
<u>Carcass characteristics</u>					
Number of Pigs	15	15	13	13	...
Dressing %	73.50	74.21	73.65	74.60	0.46
% Ham + Loin	40.70	40.10	42.60 ^{cc}	40.72	0.33
No. with stomach ulcer	3/12	5/12	1/11	1/8	...

¹Excluding starting period.

²L = Low energy ration

H = High energy ration.

First letter is growing period and second is finishing period.

³Standard error of the mean.

^aSignificantly greater than least value ($P < .05$).

^bSignificantly greater than next to least value ($P < .05$).

^{aa} $P < .01$.

^{bb} $P < .01$.

^{cc}Significantly greater than least 3 values ($P < .01$).

low energy finishing ration (HL) and that of those fed high energy rations for both growing and finishing periods (HH) were almost the same. Efficiency in utilizing calories by pigs fed the high energy grower and continued with either low or high energy finishing ration (HL or HH) was significantly greater than for pigs fed the treatment combination of the low energy growing ration and the high energy finishing ration (LH). Energy efficiency of pigs fed low energy rations for the growing-finishing period (LL) was similar to that of pigs fed high energy all the way (HH).

Carcass characteristics: Dressing percents of pigs were similar among the four treatment combinations. However, pigs fed the high energy finishing ration with the low or high energy growing ration appeared to produce slightly higher dressing percent but it was not statistically significant. Pigs on the high energy growing ration with low energy ration during the finishing period had a significantly ($P < .01$) higher percent of ham + loin than animals from any other treatment combinations.

Stomach ulcers occurred in pigs of every treatment combination and the incidence was not related to treatment.

Experiment 2

The results of the balance trial for the growing period are shown in Table 16. From the results of daily energy balance the digestible energy and metabolizable

Table 16. Summary of Balance Trial of Growing Rations.

Item	High Energy Ration	Low Energy Ration
<u>Daily energy balance</u>		
Feed intake, g	2333	2391
Gross energy intake, kcal	9202	9268
Fecal energy, kcal	996	1473
Digestible energy, kcal	8206	7795
Urine energy, kcal	104	95
Metabolizable energy, kcal	8102	7700
<u>Daily N Balance</u>		
Intake N, g	47.45	54.18
Fecal N, g	8.08	10.56
Net N, absorbed	39.37	43.62
Apparent N dig. %	83	81
Urine N, g	7.77	7.31
N retention, g	31.60	36.31
Apparent BV	80	83
Apparent NPU	67	67

energy concentration of low and high energy rations were obtained. In a determination of metabolizable energy, Diggs et al. (1965) indicated that it was necessary to correct the urinary energy for nitrogen stored in or lost from the body during the balance trial and reported the energy for urinary nitrogen to be 6.77 kcal/gm. This value was used to adjust metabolizable energy and nitrogen corrected metabolizable energy was obtained. The determined energy values of the low energy growing ration were 3260, 3220 and 3117 dcal/kg for digestible energy (DE), metabolizable energy (ME), and nitrogen corrected metabolizable energy (N-cor ME), respectively, on the as-fed basis (Table 18). The determined energy values of the high energy growing ration were 3517, 3473 and 3381 kcal/kg for DE, ME and N-cor ME, respectively, on the as-fed basis. The results of the balance trial for pigs on the finishing ration are shown in Table 17. The determined energy values for the low energy finishing ration were 3093, 3049 and 2978 for DE, ME and N-cor ME, respectively, and for the high energy finishing ration were 3430, 3389 and 3330 kcal/kg for DE, ME and N-cor ME, respectively, on the as-fed basis.

Apparent biological value (ABV) and apparent net protein utilization (ANPU) reported in Tables 16 and 17 for daily nitrogen balance were calculated as follows:

$$ABV = \frac{N \text{ intake} - (\text{fecal N} + \text{urinary N})}{N \text{ intake} - \text{fecal N}}$$

Table 17. Summary of Balance Trial of Finishing Rations.

Item	Low Energy Ration	High Energy Ration
<u>Daily energy balance</u>		
Feed intake, g	2163	2031
Gross energy intake, kcal	8828	8228
Fecal energy, kcal	1407	1946
Digestible energy, kcal	7421	6282
Urine energy, kcal	88	90
Metabolizable energy, kcal	7332	6192
<u>Daily N Balance</u>		
Intake N, g	35.50	38.81
Fecal N, g	10.01	10.41
Net N absorbed, g	25.49	28.40
Apparent N dig., %	72	73
Urine N, g	6.84	7.17
N retention, g	18.65	21.23
Apparent BV	73	74
Apparent NPU	52	54

Table 18. Determined Energy Values of Growing and Finishing Rations.

Item	GE ¹ kcal/kg	DE ² kcal/kg	ME ³ kcal/kg	N coreME ⁴ kcal/kg
<u>Grower</u> (as-fed basis)				
Low energy ration	3881	3260	3220	3117
High energy ration	3969	3517	3473	3381
<u>Finisher</u> (as-fed basis)				
Low energy ration	4052	3093	3049	2978
High energy ration	4081	3430	3389	3330

¹Gross energy.²Digestible energy.³Metabolizable energy.⁴Nitrogen corrected metabolizable energy.

Table 19. Metabolizable Energy Values of Feed Ingredients (As-fed Basis).*

Ingredients	Est.	Calculated (balance data)	
		Grower	Finisher
Tallow	7920	7920	7920
Corn + SBM 49	3500	3491	3399
Oats	2548	3070	2588

*kcal/kg.

$$\text{ANPU} = \frac{\text{N intake} - (\text{fecal N} + \text{urinary N})}{\text{N intake}}$$

Assuming that metabolizable energy of stabilized tallow to be 7920 kcal/kg (Diggs et al., 1965) in both high energy grower and finisher rations, calculated ME values of corn + SBM 49 and oats were obtained for each growing and finishing period. The calculated ME values of corn + SBM 49 and oats were 3491, 3070 and 3399 and 2588 kcal/kg on as-fed basis, respectively, for the growing and finishing rations.

V. DISCUSSION

Starter: The performance of pigs during the starting period did not significantly respond to different dietary energy density. Feed consumed per unit of gain by pigs fed the high energy starting ration was slightly less than that of those fed the low energy starting ration. Using the estimated metabolizable energy values, pigs fed the high energy starting ration consumed more calories per day (3845 vs. 3205 kcal) but were less efficient in energy conversion (6521 vs. 5831 kcal ME/kg of gain) than pigs fed the low energy starting ration. It appears that incorporating 2% of stabilized tallow into the corn-soy starting ration depressed energy utilization efficiency by young pigs, perhaps due to poor digestibility of the added fat. These results differ from the findings of Allee et al. (1971a) who reported that young pigs 6 weeks of age were capable of utilizing fat as corn oil as efficiently as carbohydrates.

Grower: None of the results of the growing period were significantly different between treatments but several trends were apparent. The incorporation of 2% of stabilized

tallow into a corn-soy growing ration resulted in the limiting of feed (but not energy) consumption with a slight reduction in gain per day in growing pigs when compared to pigs fed the corn-oats ration. Pigs fed the high energy growing ration required approximately 5% less feed per unit of gain. Nitrogen corrected metabolizable energy consumption per day was approximately 2% higher in pigs fed the high energy growing ration but they were less efficient in energy utilization.

Finisher: Treatments of the growing period appeared to effect the performance of pigs during the finishing period. Pigs with the influence of a low energy growing ration tended to gain faster in the finishing period than those under the influence of a high energy growing ration, regardless of the energy density during the finishing period. However, the differences in gain were not statistically significant. Pigs fed a low energy growing ration consumed significantly more feed during the finishing period. Feed required per unit of gain was significantly higher in pigs which received the low energy finishing or high energy finishing ration under the influence of low energy growing ration than the animals fed the high energy finishing ration under the influence of the high energy ration during the growing period. It also appeared that the treatment of low energy during the growing period encouraged animals to consume more energy during the finishing period.

Pigs which consumed a higher amount of calories were less efficient than those groups that consumed less energy per day.

Overall performance (growing-finishing period):

Pigs fed low energy during the growing period with low or high energy during the finishing period (LL or LH) gained slightly better than the other two treatment combinations HL and HH. Different results for gain of pigs which received similar types of ration has been demonstrated by Seerley et al. (1964) who reported that pigs fed an all corn ration with or without added fat showed faster gains than those which received a corn-oats ration with or without fat. Waterman et al. (1973) and Moser (1975) indicated that pigs showed better gains when fed high energy rations during the growing-finishing period. Improvement in feed efficiency in pigs fed high energy ration has been reported by several workers (Clawson et al., 1962; Greeley et al., 1964; Seerley et al., 1964; Brooks, 1967a; and Hale et al., 1968). The same results for feed efficiency has been established in this experiment. Waterman et al. (1973) indicated that metabolizable energy consumed per unit of gain was reduced by approximately 4% when pigs received a basal diet with 3% added fat. In this study, pigs fed HH treatment combination consumed approximately 1% less (non-significant) N-cor ME per unit of gain when compared with pigs fed LL treatment combination. The highest N-cor ME/gain reported herein was among the pigs which received the low energy

ration during the growing period and the high energy ration during the finishing period, approximately 5.7% higher than the HH treatment combination.

Dressing percents of pigs were not significantly different among the treatment combinations. Percent ham + loin was highest in pigs treated by the HL treatment combination and significantly ($P < .01$) higher than any other treatment combination. Waterman et al. (1973) reported the addition of 3% tallow to the basal diet did not adversely affect the percent ham and loin. The HL combination was also the treatment which utilized energy for gain most efficiently.

The incidence of stomach ulcer of pigs was variable among the 4 treatment combinations and no specific trend was apparent from the results. On the LL treatment combination there were three out of twelve pigs which showed the incidence of stomach ulcer and only one out of eight pigs which received the HH combination showed the sign of stomach ulcer. The feeding of the low energy (high fiber) diet containing 40% oats appeared to have no effect in preventing the incidence of stomach ulcer as claimed by Riker III et al. (1967) who reported that oats had a protective property for stomach ulcer which was primarily due to the increase in particle size (Mahan et al., 1964) and fiber content (Rease et al., 1966b). In the current study finely ground oats were used.

Balance trial: For the growing rations, ME and N-cor ME values were 98.77, 95.61% and 98.75, 96.13% of DE, respectively, for the low and high energy rations. Metabolizable energy and N-cor ME for the low and high energy rations were 98.58, 96.28% and 98.80 and 97.08% of DE, respectively, during the finishing period. Diggs et al. (1965) reported that the unadjusted metabolizable energy and the metabolizable energy adjusted for nitrogen balance averaged $94.7 \pm 5.3\%$ and $91.6 \pm 6.3\%$ of the digestible energy, respectively, in young pigs fed with rations containing at least 35% protein. For the normal levels of protein feeding (11 to 16% protein), Bowland et al. (1970) estimated ME to be 96.5% of DE. May and Bell (1971) suggested 0.98 as a factor to convert DE to ME values.

The experimentally determined ME values for low energy rations of both grower and finisher were higher than the estimated values due to the actual energy value of oats being somewhat higher than the expected value (NRC, 1973). Calculations were based on the assumption that tallow was equally utilized during both the growing and finishing period by pigs fed the high energy ration and that energy values of corn and soybean meal 49 were equal. Younger pigs apparently utilized feed energy more efficiently than at an older age. The energy values of oats were reported to be 2730 kcal/kg (Diggs et al., 1965) and 2596 kcal/kg (Young and Bell, 1971) on the as-fed basis. There appears to be more variation in the energy values of oats between

grower and finisher in the balance trial (3070 vs. 2588 kcal/kg for grower and finisher, respectively).

VI. CONCLUSIONS

Two experiments were conducted to evaluate the feeding values of low and high dietary caloric density in pigs. The first experiment was a feeding trial in which the response of the pigs to the treatments were measured. The other experiment was a balance trial in which the metabolizable energy values of the low and high energy rations of both grower and finisher were experimentally determined. The results of the experiments led to the following conclusions:

1. The performance of the pigs during the starting period did not significantly respond to widely different dietary energy densities.
2. Dietary energy density during the starting period had no effect on the performance of the pigs in the following period (growing period).
3. The incorporation of 2% stabilized tallow into a corn-soy growing ration resulted in the limiting of feed consumption with a slight reduction in gain in the growing pigs but approximately 6.4% higher feed efficiency than pigs on a 40% oat ration.

4. Nitrogen corrected metabolizable energy consumption per day was approximately 2% higher in pigs fed the high energy diet but they were less efficient in energy utilization.

5. Treatments of the growing period appeared to affect the performance of pigs during the finishing period. With the influence of low energy growing ration, pigs tended to gain faster and consumed significantly more feed per unit of gain during the finishing period when compared to that of those which were under the influence of the high energy growing ration.

6. It appeared that the treatments of the low energy ration during the growing period encourage pigs to consume more nitrogen-corrected metabolizable energy during the finishing period but they were less efficient in energy utilization.

7. The overall (grower-finisher) average daily gain was not improved by increasing the energy density in the ration. Pigs fed the high energy rations for the growing-finishing period consumed significantly less feed per day but were more efficient in feed conversion than those which received any of the other treatment combinations.

8. The energy density in the diets had no effect on dressing percentage of swine. Percent ham and loin was significantly improved in the pigs receiving the high energy grower and low energy finisher treatment combination.

9. The incorporation of finely ground 40% oats in a corn-soy ration appeared to have no effect in preventing the incidence of stomach ulcer.

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APPENDIX

Table A-1. Performance Data, Experiment 1, Energy Schedules, Low-High-Low.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig. No.	Weight, kg												
105- 8 F	14.6	20.9	29.6	38.2	50.5	54.1	64.6	71.8	80.0	87.7			
120- 2 M	11.8	18.2	27.3	37.7	48.2	57.3	64.1	75.9	85.9	96.8			
120- 4 M	14.1	22.3	32.7	41.4	51.4	60.0	61.8	70.0	76.4	83.6			
123-10 F	15.5	23.2	31.4	39.5	48.6	56.8	62.3	72.7	82.3	90.9			
133- 8 M	13.2	19.6	29.1	38.2	48.7	58.6	64.6	73.2	83.2	94.1			
117-10 F	13.6	20.5	30.5	40.0	51.4	58.2	55.5	68.2	79.2	89.5			
122- 1 M	14.6	21.4	31.8	42.3	51.8	61.8	65.5	76.8	86.4	95.5			
128- 1 M	16.8	24.1	35.0	47.3	58.6	71.4	79.1	86.4	95.9	105.0			
132- 3 M	15.5	23.2	32.7	42.7	53.2	62.3	66.8	74.1	73.2	77.6			
Av. daily gain, gm		506	688	692	747	628	348	673	583	621			
Feed cons. to date, kg		129.09	321.82	548.18	805.00	1068.64	1242.27	1530.91	1848.18	2159.55			
Av. daily feed, gm		1025	1530	1797	2038	2092	1378	2291	2518	2471			
Feed/gain		2.03	2.22	2.60	2.73	3.33	3.96	3.40	4.32	3.98			

Table A-2. Performance Data, Experiment 1, Energy Schedules, High-High-Low.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig. No.	Weight, kg												
105- 1 M	15.9	23.6	33.6	42.7	54.6	65.9	72.3	79.6	-	-	-	-	-
104- 1 M	14.1	22.7	32.3	44.1	56.8	70.0	83.6	87.7	102.3	115.0			
120- 9 F	15.5	23.2	33.2	41.8	51.4	60.5	66.4	71.8	81.3	87.7			
120- 1 M	14.1	22.7	31.8	42.7	54.6	66.8	70.0	78.6	89.6	95.5			
123- 8 F	14.1	22.7	31.8	40.9	50.0	60.9	66.8	75.0	85.0	93.2			
125- 6 F	16.8	25.5	35.9	43.2	55.5	66.8	70.5	80.5	91.4	96.4			
117- 7 M	12.7	20.9	30.0	37.7	50.0	60.0	63.6	75.0	87.3	97.3			
128-11 F	15.0	23.6	32.7	43.6	55.6	63.2	67.3	72.7	83.6	90.0			
152- 6 F	15.9	23.6	30.0	36.4	44.1	53.2	58.6	67.3	69.9	78.6			
Av. daily gain, gm		590	657	649	774	767	411	548	735	561			
Feed cons. to date, kg		149.09	345.91	572.27	832.73	1117.73	1329.09	1636.82	1907.27	2214.09			
Av. daily feed, gm		1183	1562	1797	2067	2262	1677	2442	2415	2739			
Feed/gain		2.00	2.38	2.77	2.67	2.95	4.08	4.45	3.29	4.89			



Table A-3. Performance Data, Experiment 1, Energy Schedules, Low-High-High.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig. No.	Weight, kg												
120- 3 M	15.5	24.6	33.6	45.9	57.3	70.0	77.3	83.2	91.4	99.6			
120- 6 F	15.5	24.6	34.6	44.6	53.6	61.8	68.2	78.6	87.7	98.2			
123- 7 M	12.3	19.1	29.1	39.1	48.6	58.2	60.5	69.6	77.3	85.0			
125- 5 F	16.4	22.7	31.8	40.9	49.6	57.7	63.6	67.3	71.4	85.5			
117- 3	17.3	24.6	34.1	42.7	50.5	57.7	69.1	76.4	76.8	78.4			
128- 4	15.0	21.8	31.4	39.6	48.6	58.6	63.2	71.8	78.6	87.3			
128-10	13.2	20.9	30.0	41.8	51.4	61.8	65.5	72.7	82.7	88.6			
132- 9	13.6	20.9	28.6	36.4	43.6	52.7	56.4	63.2	69.6	75.5			
105- 7	20.5	28.2	39.1	51.8	61.4	71.8	78.6	87.7	95.9	106.4			
Av. daily gain, gm		540	674	718	647	680	413	540	483	580			
Feed cons. to date, kg		142.27	346.36	579.55	829.55	1087.27	1287.73	1583.18	1875.00	2158.18			
Av. daily feed, gm		1129	1620	1851	1984	2045	1591	2345	2316	2247			
Feed/gain		2.09	2.40	2.58	3.06	3.01	3.85	4.34	4.79	3.87			

Table A-4. Performance Data, Experiment 1, Energy Schedules, High-Low-Low.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig No.	Weight, kg												
120-10	18.2	27.3	38.2	48.6	59.1	69.6	73.6	80.9	89.6	98.2			
120-11	13.2	20.0	28.6	36.4	46.4	55.0	55.9	66.4	76.8	81.8			
133- 3	15.0	22.7	33.2	43.6	54.6	63.6	68.2	76.4	88.6	91.8			
117- 4	17.3	26.4	37.3	45.5	55.9	66.4	70.9	73.2	82.7	95.5			
117- 6	15.9	23.6	35.9	45.5	56.4	68.6	65.5	77.3	88.6	99.1			
128- 3	12.3	19.6	28.6	37.7	49.1	59.1	65.5	76.4	70.0	95.9			
132- 8	14.6	22.7	30.9	39.1	45.9	52.7	57.7	67.3	75.9	83.2			
132- 7	16.8	26.4	35.0	44.6	54.6	64.6	69.6	79.6	73.2	69.1			
105- 6	15.9	23.2	32.7	41.4	49.1	59.1	68.2	76.8	85.9	94.6			
Av. daily gain, gm		577	702	651	704	698	287	629	452	618			
Feed cons. to date, kg		151.82	330.00	540.46	796.82	1072.27	1280.00	1582.27	1888.18	2195.91			
Av. daily feed, gm		1205	1414	1670	2035	2186	1649	2399	2428	2442			
Feed/gain		2.09	2.01	2.57	2.89	3.14	5.71	3.82	5.34	3.95			

Table A-5. Performance Data, Experiment 1, Energy Schedules, High-Low-Low.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig No.	Weight, kg												
105-9	10.9	18.2	26.4	35.9	45.9	55.0	65.9	73.6	84.6	93.6			
104-7	13.6	21.4	29.6	38.6	47.7	57.3	65.5	74.6	83.2	94.1			
120-5	14.6	23.2	31.8	42.9	53.2	65.0	68.6	80.9	90.5	101.4			
133-4	15.5	22.7	32.7	42.3	51.4	62.3	68.6	77.3	86.8	97.3			
117-2	15.9	25.0	35.9	45.5	55.9	66.4	72.7	81.8	93.2	102.3			
122-7	12.7	19.6	29.6	38.6	50.5	60.9	72.7	83.2	93.6	99.1			
128-9	12.3	19.6	27.7	35.0	43.6	53.2	55.9	66.4	75.9	84.1			
128-5	15.9	24.6	35.0	45.9	55.5	61.4	69.6	78.6	90.0	98.2			
132-1	19.6	28.6	38.6	49.1	59.6	70.5	76.8	88.6	94.1	103.2			
Av. daily gain, gm		571	670	685	712	704	510	704	690	646			
Feed cons. to date, kg		141.36	321.36	547.73	820.46	1109.55	1369.09	1687.28	2047.73	2396.37			
Av. daily feed, gm		1122	1429	1797	2165	2294	2060	2525	2861	2767			
Feed/gain		1.97	2.13	2.62	3.05	3.26	4.02	3.59	4.15	4.28			

Table A-6. Performance Data, Experiment 1, Energy Schedules, High-Low-High.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig No.	Weight, kg												
105-5	19.1	28.2	39.1	49.6	58.6	68.2	76.4	86.4	95.0	105.5			
133-5	16.4	24.1	33.6	43.6	55.0	63.2	70.5	78.6	86.4	96.4			
120-7	12.3	20.9	31.4	40.5	51.8	60.5	64.6	75.5	85.5	92.3			
123-11	12.3	19.6	27.3	35.9	45.5	55.0	56.4	64.1	73.2	78.2			
117-9	12.3	20.5	29.6	35.9	44.1	50.5	51.8	60.0	70.0	77.3			
122-4	12.7	20.0	28.2	36.4	46.8	55.5	68.6	78.2	87.7	96.8			
128-2	14.1	21.4	28.6	37.3	48.2	55.0	57.3	67.3	78.6	89.1			
132-4	16.4	25.0	32.7	40.9	50.5	61.4	62.7	69.6	77.7	82.7			
132-2	13.6	21.4	30.0	39.1	48.2	55.9	54.6	65.9	75.0	84.6			
Av. daily gain, gm		571	630	625	710	607	299	656	663	586			
Feed cons. to date, kg		140.91	310.45	497.73	753.64	995.00	1211.82	1503.64	1802.73	2078.64			
Av. daily feed, gm		1.96	2.14	2.38	2.86	3.16	5.75	3.53	3.58	3.74			

Table A-7. Performance Data, Experiment 1, Energy Schedules, Low-Low-High.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig. No.	Weight, kg												
129-2	17.3	25.0	34.1	44.6	54.6	63.2	72.3	82.7	98.7	98.2			
126-1	13.6	21.8	31.8	42.3	56.4	67.7	71.8	82.3	93.2	99.6			
127-8	15.0	21.4	30.0	39.1	50.5	60.9	71.4	83.2	90.9	97.7			
101-4	12.7	20.0	29.6	40.9	54.1	59.1	70.0	82.3	93.6	98.6			
101-8	14.4	20.0	28.6	35.9	45.9	55.9	60.0	69.1	80.0	83.6			
137-4	13.6	20.9	30.5	38.6	47.7	54.1	63.2	69.1	79.6	80.0			
117-5	20.5	28.6	40.5	51.4	62.7	68.2	76.4	86.4	98.6	101.4			
126-5	10.5	16.4	25.5	34.1	42.7	49.1	55.5	67.3	79.6	85.0			
104-4	10.9	16.8	24.6	32.3	41.4	52.3	62.7	75.0	86.4	92.3			
Av. daily gain, gm	498	669	667	768	591	578	747	771	663				
Feed cons. to date, kg	115.46	332.73	564.55	840.00	1087.73	1314.55	1657.73	1992.73	2164.55				
Av. daily feed, gm	916	1724	1840	2186	1966	1800	2724	2659	2727				
Feed/gain	1.84	2.58	2.76	2.85	3.33	3.12	3.65	3.44	4.11				

Table A-8. Performance Data, Experiment 1, Energy Schedules, High-Low-Low.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig No.	Weight, kg												
129-1	15.9	24.6	33.2	40.9	51.8	59.6	66.8	77.7	89.6	94.6			
126-2	14.6	23.2	34.6	45.0	56.8	62.7	72.3	82.3	92.3	97.7			
127-9	14.1	21.8	31.4	40.0	49.1	57.3	63.6	70.9	80.9	84.1			
104-5	13.6	21.4	29.6	38.6	49.6	60.0	65.9	77.3	90.0	96.4			
101-7	15.9	25.9	37.7	48.2	58.6	70.0	76.4	87.7	101.8	106.4			
135-5	13.2	20.9	31.4	41.4	56.4	70.0	74.6	87.7	102.3	110.5			
126-8	11.4	17.7	25.9	35.0	44.6	54.1	60.0	69.6	79.1	80.0			
122-10	13.6	21.4	30.5	40.5	50.9	60.0	70.0	74.6	86.8	90.9			
Av. daily gain, gm		577	688	676	788	678	499	698	848	675			
Feed cons. to date, kg		130.91	336.82	540.45	802.27	1046.36	1241.82	1553.64	1899.09	2070.91			
Av. daily feed, gm		1169	1838	1818	2338	2179	1745	2784	3084	3068			
Feed/gain		2.03	2.67	2.69	2.97	3.22	3.50	3.99	3.64	4.55			

Table A-9. Performance Data, Experiment 1, Energy Schedules, Low-Low-High.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig No.	Weight, kg												
126-6	15.0	22.3	32.3	42.7	54.1	60.5	68.2	77.3	84.1	88.2			
127-3	14.1	23.2	32.7	40.9	52.3	62.3	72.3	82.3	96.8	101.4			
101-6	15.5	25.0	34.1	43.6	55.9	65.9	73.6	85.0	98.2	106.8			
122-11	13.6	23.2	32.3	40.9	51.8	61.8	66.4	76.8	91.4	97.7			
137-5	10.5	15.0	23.2	30.5	40.0	48.6	50.9	60.0	70.5	74.1			
131-6	11.4	17.7	25.5	31.4	41.8	52.3	56.8	65.9	78.2	84.1			
104-8	14.6	23.6	33.2	42.7	52.7	61.4	69.1	78.2	89.6	92.3			
122-5	15.0	25.5	35.5	44.1	55.5	67.3	76.4	88.6	101.8	107.7			
Av. daily gain, gm		588	654	607	779	679	479	718	862	745			
Feed cons. to date, kg		123.64	322.73	516.82	755.45	980.91	1165.45	1491.36	1855.00	2041.36			
Av. daily feed, gm		1104	1778	1733	2131	2013	1648	2910	3247	3328			
Feed/gain		1.88	2.72	2.85	2.73	2.97	3.44	4.05	3.77	4.47			

Table A-10. Performance Data, Experiment 1, Energy Schedules, High-High-High.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig No.	Weight, kg												
129-9	12.7	20.0	26.8	34.1	40.9	48.6	56.4	62.3	71.8	75.9			
126-4	10.9	19.1	28.6	37.3	50.0	62.7	67.3	76.4	87.3	92.7			
127-1	15.0	24.1	35.5	46.4	60.5	71.4	76.8	86.8	99.6	109.1			
101-10	17.7	28.2	39.6	48.2	57.7	67.3	71.8	80.0	89.6	95.9			
101-2	11.4	16.8	25.9	34.6	45.0	54.6	58.6	65.9	76.8	85.5			
140-9	11.4	20.0	30.0	40.0	49.1	58.6	65.5	71.4	82.7	88.6			
137-7	15.5	25.0	35.9	45.5	56.8	67.3	70.5	76.4	89.1	93.2			
135-9	16.4	25.5	36.4	47.7	60.9	70.0	75.0	86.4	101.4	106.8			
144-1	14.6	18.6	27.3	35.5	45.5	58.2	70.5	80.9	93.2	100.5			
Av. daily gain, gm		569	704	661	771	734	425	588	833	900			
Feed cons. to date, kg		120.00	322.73	584.18	808.64	1063.82	1226.82	1548.18	1866.36	2040.46			
Av. daily feed, gm		952	1609	1789	2067	2020	1299	2551	2525	2763			
Feed/gain		1.67	2.29	2.71	2.68	2.76	3.05	4.34	3.03	3.07			

Table A-11. Performance Data, Experiment 1, Energy Schedules, Low-High-High.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig. No.	Weight, kg												
126-3	16.4	25.0	36.8	48.2	59.6	62.3	75.0	85.5	98.6	106.4			
127-10	15.9	25.0	35.0	45.9	54.1	58.6	67.3	74.6	85.9	90.9			
101-11	12.3	20.2	30.5	39.1	45.5	48.2	53.6	61.4	71.8	76.4			
127-2	13.2	21.4	31.8	40.9	54.1	59.1	63.2	74.1	83.2	91.4			
101-4	16.4	25.9	37.7	47.7	56.8	60.9	65.5	74.6	80.0	85.5			
144-8	13.2	20.9	29.6	37.7	42.7	50.5	56.8	62.7	70.0	75.9			
122-3	13.2	20.9	29.1	39.1	51.8	56.8	65.5	76.4	87.3	92.3			
104-10	14.6	22.7	32.7	41.8	49.6	56.4	67.7	75.9	87.3	92.3			
Av. daily gain, gm		595	727	689	659	345	552	630	704	839			
Feed cons. to date, kg		134.09	298.18	485.00	687.73	801.36	900.45	1082.27	1370.91	1509.09			
Av. daily feed, gm		1197	1465	1668	1810	1015	885	1623	2577	2468			
Feed/gain		2.01	2.02	2.42	2.75	2.94	1.60	2.58	3.65	2.94			

Table A-12. Performance Data, Experiment 1, Energy Schedules, High-High-Low.

Period	Initial	Starter				Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk	18 wk			
Pig No.	Weight, kg												
126-7	16.8	25.9	35.5	44.5	53.2	56.4	63.6	72.3	81.8	85.5			
127-7	11.8	20.5	29.6	38.6	48.2	52.3	60.5	68.2	75.9	81.8			
101-9	12.7	21.8	31.8	40.9	50.0	54.1	62.7	75.5	87.3	93.2			
101-5	13.2	23.2	34.1	44.6	56.4	59.1	70.0	80.9	91.4	99.1			
127-6	10.9	20.0	27.7	36.8	43.6	46.4	55.5	64.1	74.1	78.6			
135-11	15.5	25.5	36.4	45.5	50.0	55.0	63.6	74.6	84.6	90.0			
127-11	10.9	19.6	30.0	39.1	50.5	55.0	59.1	68.2	74.6	84.1			
122-12	14.1	23.2	33.2	42.3	48.6	51.4	60.5	69.6	72.7	78.6			
122-6	13.2	21.8	32.3	41.8	50.9	56.4	68.2	77.3	86.4	89.6			
Av. daily gain, gm	654	707	663	613	275	616	690	821					
Feed cons. to date, kg	149.55	355.91	563.64	744.55	902.27	1041.36	1265.00	1550.45	1740.91				
Av. daily feed, gm	1187	1638	1649	1436	1252	1104	1775	2266	3023				
Feed/gain	1.82	2.32	2.49	2.34	4.57	2.65	2.58	3.65	3.68				

Table A-13. Performance Data, Experiment 1, Energy Schedules, (...) -Low-Low.

Period	Initial	Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk
Pig No.		Weight, kg							
109-10	31.4	39.6	44.1	51.8	60.5	72.7	83.2	91.8	99.1
145-1	30.0	38.2	47.7	58.2	67.7	79.6	87.3	100.9	104.6
129-4	29.1	36.8	41.4	52.7	61.8	72.3	85.0	95.5	100.9
109-11	28.6	38.2	43.6	53.6	57.3	68.6	80.0	86.6	91.8
122-9	28.2	35.5	40.0	47.3	55.5	65.0	69.6	77.7	83.6
144-6	30.5	38.2	43.6	53.2	53.2	59.1	68.6	80.0	92.7
135-4	27.3	35.9	39.1	45.5	55.0	65.5	78.2	90.9	94.6
123-1	29.6	39.1	46.8	55.9	63.6	77.3	90.9	105.0	110.5
Av. daily gain, gm	596		400	642	556	796	755	741	725
Feed cons. to date, kg	166.82	280.91	449.55	660.00	938.18	1237.27	1551.82	1735.91	
Av. daily feed, gm	1489	1019	1506	1879	2484	2670	2808	3287	
Feed/gain	2.50	2.55	2.35	3.38	3.12	3.54	3.79	4.53	

Table A-14. Performance Data, Experiment 1, Energy Schedules, (...) - Low-High.

Period	Initial	Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk
Pig No.		Weight, kg							
109-6	22.7	30.0	35.5	43.6	45.5	53.2	62.7	73.6	81.4
144-4	29.1	37.7	39.1	46.8	45.0	51.4	60.9	71.4	78.2
129-6	24.6	31.4	39.6	47.7	50.9	60.9	69.1	81.8	87.7
109-8	29.6	36.8	43.6	53.2	60.0	70.9	80.0	88.6	95.0
No-No	25.9	33.2	41.4	46.8	55.9	64.6	72.7	81.8	86.8
137-10	27.3	33.6	40.5	46.8	47.7	54.1	60.9	70.4	73.2
104-2	30.5	38.6	50.0	61.4	65.9	78.6	92.7	104.6	110.5
123-4	29.6	39.1	47.7	57.3	63.6	75.9	90.0	104.6	110.5
Av. daily gain, gm		546	509	591	276	671	709	784	830
Feed cons. to date, kg		118.18	275.91	454.09	641.82	889.55	1187.73	1469.55	1630.00
Av. daily feed, gm		1055	1408	1591	1676	2212	2662	2516	2865
Feed/gain		1.93	2.77	2.69	6.08	3.30	3.76	3.21	3.45

Table A-15. Performance Data, Experiment 1, Energy Schedules, (...) -High-Low.

Period	Initial	Grower				Finisher			
		2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk
Pig No.		Weight, kg							
109-9	29.6	38.2	47.3	58.2	65.9	75.5	84.1	93.2	98.6
133-7	22.3	29.6	36.8	46.4	57.7	68.8	80.5	90.9	97.3
129-10	30.0	37.3	45.5	55.5	63.6	74.6	86.4	96.4	102.7
109-2	29.6	38.2	40.9	52.3	58.2	62.7	74.6	85.9	90.9
109-4	23.6	30.0	34.6	40.9	48.6	59.6	76.4	90.0	96.8
140-5	25.5	33.6	40.5	51.8	54.6	64.1	70.0	79.6	86.4
127-11	29.1	35.5	39.1	46.8	54.6	63.6	74.1	84.1	90.9
Av. daily gain, gm	538		432	686	523	668	790	755	888
Feed cons. to date, kg	114.09	215.91	352.27	533.18	815.73	1075.09	1347.73	1519.55	
Av. daily feed, gm	1164	1039	1391	1846	2885	2644	2783	3506	
Feed/gain	2.16	2.41	2.03	3.53	4.32	3.35	3.69	3.95	

Table A-16. Performance Data, Experiment 1, Energy Schedules, (···)-High-High.

Period	Grower				Finisher				
	Initial	2 wk	4 wk	6 wk	8 wk	10 wk	12 wk	14 wk	16 wk
Pig No.	Weight, kg								
109-12	25.0	30.5	40.5	51.4	60.0	68.6	78.6	89.1	92.7
144-7	25.5	29.1	31.8	40.0	45.5	50.9	58.6	68.2	74.1
129-7	25.0	30.9	39.1	47.7	55.9	65.9	75.9	85.5	86.8
109-1	23.2	29.1	30.9	36.4	41.4	47.7	56.4	66.4	72.7
140-2	29.6	35.9	36.4	47.3	58.6	70.5	81.8	92.7	97.3
140-8	30.0	37.3	39.6	47.7	56.4	66.8	75.9	85.5	91.8
140-10	23.2	29.6	38.2	46.8	54.1	61.8	71.4	79.6	85.0
109-7	35.0	41.8	45.5	53.6	64.1	75.5	85.9	92.7	99.1
Av. daily gain, gm		426	338	615	581	640	686	671	711
Feed cons. to date, kg		124.09	240.00	380.91	576.82	823.82	1075.82	1311.82	1447.27
Av. daily feed, gm		1108	1035	1258	1749	2204	2248	2110	2419
Feed/gain		2.60	3.07	2.05	3.01	3.44	3.28	3.14	3.40

Table A-17. Balance Trial, Experiment 2.

Period Ration	Grower		Finisher	
	High	Low	Low	High
Pig No's	Weight, kg			
148-4	40.5	43.2	45.9	49.5
			50.5	53.2
			54.1	55.9
148-3	41.4	43.6	45.9	49.5
			50.5	52.7
			54.1	55.9
148-10	52.3	55.0	59.5	63.6
			66.4	69.5
			70.5	73.6
148-7	44.1	46.8	49.5	53.2
			55.5	58.2
			60.5	63.2
Av. daily gain, gm	858	938	892	783
Av. daily feed, gm	2239	2384	2139	2064
Feed/gain	2.61	2.54	2.40	2.63

Table A-18. Balance Trial, Experiment 2.

Period Ration	Grower		Finisher					
	High	Low	High	Low				
Pig No's	Weight, kg							
148-1	44.5	44.7	48.2	52.7	55.9	58.6	58.6	60.0
148-5	42.7	41.8	44.1	47.3	49.5	51.4	52.3	54.1
148-8	52.7	55.0	58.2	63.2	65.9	68.6	69.1	73.2
148-12	50.5	52.7	55.5	60.5	62.7	65.5	65.5	69.1
Av. daily gain, gm	567		1106		842		908	
Av. daily feed, gm	2400		2426		2263		1922	
Feed/gain	4.24		2.19		2.69		2.12	

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