EFFECTS OF FEEDING OATS AND OAT HULLS ON PIG PERFORMANCE AND RATION DIGESTIBILITY OF WEANLING PIGS

by

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GENERAL INTRODUCTION

In recent years, dramatic changes have taken place in commercial pork production. Each year more and more hog producers are going to total confinement operations. There is a trend toward weaning pigs at three to four weeks of age. This earlier weaning allows for increased production of more litters per sow per year. These new management systems along with the addition of new feedstuff by-products and grain varieties creates a need to continually evaluate nutritional programs to optimize pig performance.

Problems facing many of today's swine operations are weaning stress and getting pigs started on feed without developing scours or edema. Management of the pigs' environment plays an important role in their survival and ability to get off to a "good start." The type of diet fed to start the early weaned pigs is equally important.

Several recent reports indicate that diets higher in fiber reduce the incidence of scours in early weaned pigs. However, these reports have been inconsistent and somewhat conflicting due to the variability of pig weight and age at weaning. Hence, the purpose of this study is to determine the effects of various levels of dietary oats and oat hulls in practical swine rations on pig performance, ration digestibility and incidence of diarrhea in pigs weaned at four to five weeks of age.

REVIEW OF LITERATURE

The inhibitory effect of high levels of dietary fiber on growth rate and feed efficiency of growing-finishing swine was first reported over fifty years ago. Vestal (1922) indicated that diets high in fiber (7.5%) resulted in slow and unprofitable gains with growing-fattening pigs. Bohstedt and Fargo (1933) indicated that adding oats (5.7% crude fiber diet) resulted in little difference in feed efficiency, but above 7.7% fiber in the diet the efficiency of gain decreased at a more rapid rate. Carroll et al. (1937) concluded that oats could be fed to growing-finishing swine to the extent of nearly one-half the diet for 27.3 to 31.8 kg pigs without appreciably affecting growth rate, although feed required per unit of gain increased slightly as the percentage of oats increased. These researchers also suggested that any method of preparation that made the hulls less noticeable increased palatability of oats for pigs. Robison (1939) reported that ground oats had a feed value of approximately 79% that of corn when fed as the only grain in drylot, and 82% when fed as one-fourth of the grain in the diet on pasture.

More recently, the effects of high levels of dietary fiber on growing-finishing swine have been re-evaluated repeatedly (Axelsson and Erickson, 1953; Coey and Robison, 1954; Crampton et al., 1954; Teague and Hanson, 1954; Bohman et al., 1955; Merkel et al., 1958a;

Jensen et al., 1959a,b; Hochstetler et al., 1959; Larsen and Oldfield, 1960; Pond et al., 1962).

Crampton and Bell (1946) and Forbes and Hamilton (1952) reported the pig has a limited ability to utilize crude fiber and there was no indication that the pigs attempted to eat more feed to compensate for the lower energy value of diets with added fiber. However, Axelsson and Ericksson (1953) reported a slight increase in daily feed intake with increased crude fiber level. However, the apparent increased consumption did not compensate for the decreased total metabolizable energy value of the diets. They further suggested crude fiber levels (calculated on a dry-matter basis) of 6.57% and 7.26% as optimum for rate of gain and feed efficiency, respectively. In contrast, Jensen et al. (1959a) reported crude fiber levels (on dry-matter basis) above the approximate 3.0% in the basal diets did not improve gain or efficiency, while levels of only approximately 5.3% on drylot and 3.5% on pasture apparently reduced performance.

Recommendations for specific quantities of oats in diets for swine must be general because of the extreme variation in quality of grain which may be encountered. For instance, oats of a standard test weight of 32 pounds would have a high hull percentage and lower feeding value for the pig when compared to oats which are 38 pounds standard test weight. Jensen et al. (1959a) compared 24 lb. standard test weight oats and 32 lb. standard test weight oats in diets containing 20 and 40% oats. The authors concluded that for 27.3 kg pigs, growth rates were reduced approximately the same on oats of the two test weights when compared to the control corn-soybean meal diet. However,

more feed was required per pound of gain on the 24 lb. than on the 32 lb. oats diet. Meade et al. (1966) reported a decrease in efficiency of feed utilization with diets of 20, 30 and 40% oats and a reduced rate of gain due to the use of 40% oats in one experiment but not in a second study. However, Hochstetler et al. (1959) did not obtain significant differences in gain or efficiency with diets containing 20 or 40% oats. Using a high-protein oat with a 33 lb. test weight in diets of growing and finishing swine, Wahlstrom and Libal (1975) reported that levels of 0, 20, 40 and 60% oats in the diets did not affect rate of gain, but feed efficiency at the 60% oat addition reduced feed efficiency by about 3%. This suggests that a lower dietary fiber level is necessary for optimum feed efficiency than for optimum rate of gain. Also, their results indicate that crude fiber levels of 9.1% (60% oat diet) did not effect rate of gain, in contrast to the study by Axelsson and Eriksson (1953) in which they suggested a crude fiber level of 6.59% was optimum for gain.

Several reports (Teague and Hanson, 1954; Cole et al., 1967b; Henry, 1969; Baird et al., 1970; and Baird et al., 1975) have confirmed that the pig can tolerate wide ranges of crude fiber in the diet provided energy density is adequate. Jensen et al. (1959a) reported that adding hulls to hulled oat diets decreased growth rate and feed efficiency. However, the addition of corn oil to equate the diets for energy resulted in gains comparable to those on the control diet. These reports support the hypothesis that the pig tends to eat until it satisfies its energy requirement unless prevented by bulk or possibly palatability of the diet.

Increased daily feed consumption associated with reduced energy has been reported by Merkel et al. (1958), Haugse et al. (1962), Troelsen and Bell (1962), Cole et al. (1967a,b), Dinusson et al. (1956), and Dinusson et al. (1969). Kornegay (1978), using soybean hulls as a fiber source, reported similar results as the above reports; however, pigs fed 24% hulls were not able to maintain a growth rate equal to that of the other pigs, although feed intake was increased.

It has been well documented that leaner pork carcasses can be produced by restricting the energy intake of pigs. Crampton et al. (1954), Coey and Robinson (1954), Bohman et al. (1955), Merkel et al. (1958b) and Bell et al. (1958) have reported the production of leaner pork carcasses by replacing part of a high energy diet with fibrous feeds. However, Teague et al. (1954) reported that when a cellulose product (Ruffex) replaced corn starch in a purified basal diet at levels of 5, 10, 15 and 20%, carcass characteristics could not be correlated with the level of fibrous material fed.

Research on utilization of different kinds of fiber indicates that the source of fiber may be a factor in the observed effects (Bohstedt and Fargo, 1933; Forbes and Hamilton, 1952). Hochstetler et al. (1959) reported no significant differences in feedlot performance of carcass characteristics between pigs fed diets containing 0, 20 and 40% oats. The authors also found a non-significant decrease in rate of gain and backfat thickness as alfalfa meal was increased in the diet, and a significant decrease in rate of gain, feed efficiency, dressing percentage and percent of fat trim in pigs fed a

diet containing 40% wheat bran. The diet containing 40% wheat bran also was accompanied by a similar increase in lean and primal cuts.

Bohman et al. (1953) determined that when 10, 30 and 50% ground alfalfa was added to the basal diet no significant differences were seen in backfat thickness, length or dressing percentages between groups. Cunningham et al. (1961) reported that diets diluted with cellulose resulted in a variable degree of feed restriction, lowered dressing percentage, and produced slightly softer fat. Clausen and Ludvigsen (1960) reported that, in addition to reducing the thickness of the backfat of pigs, fillers such as fibrous feeds may also produce a softer fat.

Dinusson et al. (1969) reported a trend toward decreased backfat thickness as the fiber level of the diet increased, although backfat thickness was not significantly affected by levels of fiber.

Research on the utilization of the fibrous portion of feeds by swine indicates that the apparent digestibility of crude fiber may vary widely (Mangold, 1934; Axelsson, 1947; Woodman and Evans, 1947a). The digestibility of crude fiber by swine may vary from zero (Mitchell and Hamilton, 1933) to over 90% (Breirem et al., 1958). Much of the variability has been attributed to the source of fiber such as oat hulls, corn cobs, alfalfa, soybean hulls, wheat straw and woodflock (Mitchell and Hamilton, 1933; Poijarvi, 1944; Breirem et al., 1958; Forbes and Hamilton, 1952; Quicke et al., 1959; Pond et al., 1962; Kornegay, 1978).

It is well established that increasing crude fiber level depresses the digestibility of a diet for swine (Lloyd and Crampton, 1955; Pond

et al., 1962; Troelsen and Bell, 1963; Henry, 1968; Boenker, Tribble and Pfander, 1969; Bowland et al., 1970). Bowland et al. (1970) used finely ground oat hulls as the crude fiber source for diets containing 3.1, 6.1, 9.1, and 12.1% crude fiber. They found for pigs weighing approximately 50 kg, the digestion coefficients for crude fiber were 43.2, 35.0, 28.4, and 20.2%, respectively.

Cunningham et al. (1962) reported that increasing the crude fiber level of swine diets with solka-floc lowered the digestibility of crude fiber when the diets were fed ad libitum. However, when the intake was reduced to maintenance levels, digestibility of the crude fiber in the high and low fiber diets was equal.

An inverse relationship between level of crude fiber and apparent digestibility of crude protein is well documented (Teague and Hanson, 1954; Lloyd and Crampton, 1955; Whiting and Bezeau, 1957a; Pond et al., 1962; Glover and Duthie, 1958; Likuski et al., 1961; Boenker et al., 1969; Bowland et al., 1970; Keys et al., 1970). Lloyd and Crampton (1955) observed that increasing the percentage of protein or decreasing the percentage of crude fiber in a diet had a tendency to increase the apparent digestibility of protein. Cunningham et al. (1962) found a decrease of about 1.1% in crude protein digestion for each 1% increase in crude fiber content of the diet, when using cellulose as the fiber source. Baird et al. (1974) found a decrease of 1.6% in crude protein digestion for each 1% increase in crude fiber, when using citrus pulp as the fiber source. Kornegay (1978) reported about a 1% decrease in crude protein digestion for each 1% increase in crude fiber content of the diet when using soybean hulls as the crude fiber source. Whiting

and Bezeau (1957a,b), Cunningham et al. (1962) and Boenker et al. (1969) reported that increased fiber in the diet increased the metabolic fecal nitrogen but had no effect on the biological value. Whiting and Bezeau (1957b) reported that the type and amount of fiber affected the metabolic fecal nitrogen excretion, whether expressed on dry matter intake or fecal dry matter output. Likuski et al. (1961) found, using rats and pigs, that nitrogen retention as a percentage of gross or digested nitrogen was lower for a high fiber-low energy diet than for low fiber-high energy diet. Kornegay (1978), using soybean hulls as a fiber source, reported nitrogen retention as a percentage of gross nitrogen tended to decrease; but, as a percentage of digested nitrogen, nitrogen retention increased as hulls were substituted.

DeGoey and Ewan (1975) and Bowland et al. (1970) found that digestible and metabolizable energy were reduced by increasing level of fiber in the diet. DeGoey and Ewan (1975) found that metabolizable energy as a percentage of digestible energy was not affected by fiber in the diet. Also, these authors reported that percentage of body nitrogen decreased as the level of cellulose was increased; but no significant differences were observed in body gain of nitrogen ether extract, energy or ash.

Cunningham et al. (1962) indicated that crude fiber digestibility is influenced both by level of feeding and body weight and that changes in age without simultaneous changes in body weight have little effect. These authors also suggested that the length of time that a pig receives

a high level of crude fiber has very little effect on the ability to digest it.

Numerous experiments have demonstrated that increasing the caloric content of swine diets has generally resulted in reduced daily feed consumption and improved efficiency of gain (Pond et al., 1960; Noland and Scott, 1960; Clawson et al., 1962; Kuryvial et al., 1962; Lowrey et al., 1962; Wagner et al., 1963; Greeley et al., 1964a; Greeley et al., 1964b; Hale et al., 1968; Allee et al., 1971c; Allee and Hines, 1972; Allee et al., 1972). Brooks (1972) demonstrated the high correlation (r=.95) of gain/feed to dietary energy density.

Seerley et al. (1964) compared corn-oat diets with 0, 4, and 8% fat additions. The authors concluded that fat added to the diets did not significantly influence daily gain; however, the addition of fat decreased daily feed consumption an average of about .23 kg per day. Cole et al. (1967b) compared isocaloric diets with different levels of crude fiber (8.9% and 12.9%) and concluded that there was no significant differences between diets in voluntary feed intake, rate of gain or carcass quality. Baird et al. (1970) compared six diets which contained 3.5, 7.5, or 11.5% crude fiber with two levels of calculated energy at each fiber level. Energy values differed approximately 15% between the two diets at each fiber level. The authors concluded that energy increases of about 15% in the diet increased gains. Jensen, Becker and Terrill (1959) showed that additions of oat hulls to a diet inhibited growth rate; however, when the energy of the diet was increased by addition of corn oil, the gains were equal to those obtained with the control diets. Hines et al. (1975) reported that

feeding up to 30% alfalfa meal in a fortified finishing pig diet did not significantly reduce average daily gain or change feed efficiency when tallow was also added to maintain the caloric density of the diet. Hines (1977) reported that pigs fed diets containing 40% oats and 5% fat gained 5% faster and were 10% more efficient than pigs fed a fortified corn-soybean meal control diet.

Miller (1975) conducted experiments to study the additions of 40% oats and 3% animal fat to a fortified corn-soybean meal diet for starting and growing-finishing pigs. The author concluded that the addition of 3% fat to the corn-soybean meal basal diet depressed feed consumption and rate of gain while the addition of 40% oats to the basal diet tended to increase starter gain. However, addition of 3% tallow to the growing-finishing control diet tended to improve rate of gain and feed efficiency while adding 40% oats in the growing-finishing diets depressed rate of gain and feed efficiency. Vathana (1975) fed fortified corn-soybean meal diets which were made low or high in caloric density by additions of either 40% oats or tallow, to starting and growing-finishing pigs. He concluded that in the starting period, pigs did not significantly respond to dietary energy density. Also, in the growing period pigs with widely different dietary energy densities gained at a similar rate with poorer feed efficiency but better energy conversion by pigs on the low energy density diet. Other workers have reported the same general conclusion that the digestibility of fat is low after weaning (Eusebio et al., 1965; Frobish et al., 1969; Ewan, 1970; Leibbrandt et al., 1975).

It has been shown that as the calorie:protein ratio widens, daily gains may be reduced on diets deficient or marginal in protein. The importance of a constant calorie:protein ratio has been demonstrated by Clawson et al. (1962); Allee et al. (1971b); Allee and Hines (1972) and Allee (1977).

Methods of processing diets or individual diet components affect their acceptability and utilization by swine. Carroll et al. (1937) suggested that any method of preparation that made the hulls less noticeable increased palatability of oats for pigs. Crampton and Bell (1946) reported that a fine grind was more advantageous than a medium or coarse grind because the physical identity of the hull was more completely destroyed and the product was more acceptable to the pig. Becker et al. (1963) reported that pigs fed a medium ground diet containing corn had better feed efficiency than pigs fed a coarse ground similar diet. These authors also showed evidence that growing pigs (11.4-18.2 kg) were less responsive to different particle sizes than were the heavier pigs (27.3-56.8 kg). Schneider and Flatt (1975) concluded "that there are pronounced differences in the extent in which pigs are able to digest oats depending on the degree of fineness. The digestion coefficient of organic matter of crushed oats is low, but is improved by coarse grinding and further improved by fine grinding."

There has been a considerable amount of research done on pelleting swine feeds. Early studies on pelleting of swine diets generally resulted in improved growth, feed consumption and feed utilization. A summary of 30 comparisons at seven different agricultural experiment

stations covering the period 1953-1964 showed variable results (Meade, 1965). However, on the average, pigs consuming pellets gained 6% faster and produced 5% more gain per unit of feed fed than did pigs fed meal. The NCR-42 Committee on Swine Nutrition (1969) using nine experiment stations, carried out a cooperative evaluation of meal versus pellet fortified corn-soybean meal diets for growing-finishing pigs. They concluded that rate of gain was similar on both diets but gain per unit of feed consumed was significantly higher for pelleted diets. Though significantly better, improvements in efficiency were very small. Gorrill et al. (1960) compared pelleted to meal diets in which the effects of other variables; wheat bran, antibiotics and protein supplement were also evaluated. Results showed pigs fed pelleted diets gained faster and were more efficient than those fed meal diets. The authors reported that "on the whole there was no advantage due to pelleting." Luce (1973) fed a 16% protein milo diet to growing pigs and compared various pellet diameters with the meal diet. Pelleting improved feed efficiency and rate of gain, though size of pellets had little or no effect on pig performance with milo diets. Hintz and Garrett (1967) used barley containing diets to compare pellet and steam-pressure processed meal. Results showed pelleted diets produced greater rates of gain and apparently increased feed efficiency over the steam-pressure processed meal. Gamble et al. (1967) compared meal and pelleted diets during both creep and grower-finisher periods and the incidence of ulcers. Three experiments failed to show consistent results of improved feed efficiency due to pelleting.

A non-nutritional disadvantage of high crude fiber or high oat rations is the bulky nature of the mixture. This physical characteristic can prevent an even flow in self-feeders. Pigs fed meal form diets may be able to separate out some of the fiber, while palatability may also be a factor. Feed wastage is also a problem when feeding meal diets with high fiber. Complete pelleting largely alleviates these problems since pelleting reduces bulkiness and associated feeder difficulties to an appreciable extent. Seerley et al. (1962) compared corn-soybean, 20% oats in place of corn and 40% oats replacing corn in pelleted and meal forms. Pelleting the high-corn diet significantly improved rate of gain and feed efficiency when feed intake was equalized between meal and pellet diets. Trends were the same for the 20% and 40% oat diets, but the differences between meal and pellets were not significant on an equalized feed intake basis. However, pelleting significantly improved daily gains and feed efficiency when the three test diets (pooled data) were equally and ad libitum fed.

Larsen and Oldfield (1960) fed barley diets and compared meal and pelleted forms. Pelleting the barley diets apparently improved growth rate of the pigs, though not significantly. Pelleting did significantly improve efficiency of feed conversion of the barley ration ($P<.05$). Results from experiments by Dinusson et al. (1955, 1956b, 1958) show pelleting of barley diets resulted in a 10% to 12% increase in gain and a saving of 12% to 14% in feed. Dinusson et al. (1960) used oat hulls added at two levels (15% and 30%) to increase the fiber content and simulate "sample grade" barleys. The oat hulls replaced barley in the basal diet with soybean oil meal added to equate the protein of the

basal diet. The pigs on the pelleted diets gained faster and had better feed efficiency than pigs fed meal diets. These authors summarized that "data reported for the meal diet were more variable, reflecting the incapacity of the pigs to eat enough more to gain as efficiently." Also, the data reflected the wastage usually found when high fiber diets are fed in meal form. Troelsen and Bell (1962) studied the effects of pelleting on five different fiber sources at three levels each. They concluded that the pelleting of the diets resulted in improved rates of gain without a significant increase in daily feed consumption. Cameron (1960) reported that pelleting high fiber diets resulted in increased rates of gain due to increased feed intake. Meade et al. (1966) fed growing swine diets in which oats replaced 0, 10, 20, 30, and 40% of the corn. Pelleting did not increase rate of gain over the meal diets. However, it did improve feed efficiency. Inclusion of rye into a swine diet usually depresses feed intake; however, Friend (1969) reported that pelleting a diet with 30% rye significantly improved the feeding value of rye for swine.

Poor performance and diarrhea in early weaned pigs have hampered the swine industry for years. Combined with high death losses, reduced performance of scouring pigs result in large economic losses to the swine industry. The poor performance period immediately following weaning lasts 7 to 14 days, depending on management and environmental conditions (Smith and Lucas, 1956, 1957a,b; Lucas et al., 1959; Calder et al., 1959; Leibbrandt et al., 1975). Changes in diet, environment, mixing of litters and other stress conditions have been postulated by workers (Jennings, 1959; Richards and Fraser, 1961, Stevens, 1963;

Palmer and Hulland, 1965; Smith and Halls, 1967; Thomlinson, 1969) to result in poor performance immediately post-weaning.

Diets of higher fiber content have been suggested to result in firmer stools in young pigs immediately post-weaning. The incorporation of either rolled or ground oats has been used in pig diets with varying conclusions as to their effectiveness. Richards and Fraser (1961) suggested that feedstuffs such as middlings, shorts or oats should be added to post-weaning pig diets followed by gradual introduction of a more concentrated ration. Moser (1977) reported the greatest pig survival resulted when the diets contained 15% to 20% oats and a broad spectrum antibiotic for pigs weaned at 3 to 4 weeks of age. Smith and Halls (1967) found that when pigs were fed barley fiber ad libitum they did not develop diarrhea after a challenge dose of a pathogenic strain of Escherichia coli as compared to control pigs. Armstrong and Cline (1976) reported that when known enteropathogenic strains of Escherichia coli were inoculated into ligated intestinal loops of pigs, results showed there was a significantly greater fluid accumulation than in control segments. When 20% ground oats were included in the diets of these pigs, there was reduced fluid accumulation in ligated intestinal loops as compared to similar loop treatments in pigs fed the control diet. Armstrong and Cline (1977) also found that following an oral Escherichia coli challenge, the addition of 20% oats to a 22% protein corn-soy diet reduced fluid accumulation in the digestive tract of pigs as compared to pigs fed the control diet.

Other workers have shown that increased dietary fiber in the diet had no beneficial effect on reducing the incidence of post-weaning

diarrhea in 4 to 5 week old pigs (Katz et al., 1977; Mahan and Newland, 1976; Wahlstrom et al., 1977; Real et al., 1977; Rivera et al., 1978). However, in these studies the incidence of diarrhea was low and when it did occur dietary effects were not evident.

INTRODUCTION

Poor performance and diarrhea in early weaned pigs have hindered the swine industry for years. Large economic losses result each year in the swine industry as a result of high death losses and reduced performance of scouring pigs. Several workers have reported that young pigs, upon weaning, generally go through a poor performance period during which they consume small quantities of feed, often suffer from diarrhea, and gain little weight (Smith and Lucas, 1956, 1957a,b; Lucas et al., 1959; Calder et al., 1959; Leibbrandt et al., 1975; Mahan and Newland, 1976). This poor performance period usually lasts from 7 to 14 days, depending on environmental conditions and management. Changes in diet, environment, the mixing of litters and other stress conditions have been suggested by several workers to result in poor performance immediately post-weaning (Jennings, 1959; Richards and Fraser, 1961; Stevens, 1963; Palmer and Hulland, 1965; Smith and Halls, 1967; Thomlinson, 1969; Mahan and Newland, 1976).

Diets of higher fiber and lower protein content have been suggested to result in firmer stools with young pigs. The incorporation of either rolled or ground oats has been used in pig diets with varying conclusions as to their effectiveness. Richards and Fraser (1961) suggested that following weaning, pigs should be provided with diets containing middlings, shorts, or oats and gradually introduced

to improved rations. Moser (1977) reported that greatest pig survival resulted when the starter diets contained 20% oats. He suggested a starter diet containing 15 to 20% oats and a broad spectrum antibiotic be fed to pigs weaned at 3 to 4 weeks of age.

Armstrong and Cline (1976) reported that when known enteropathogenic strains of Escherichia coli were inoculated into ligated intestinal loops of pigs, results showed there was a significantly greater fluid accumulation than in control segments. When 20% ground oats were included in the diets of these pigs, there was reduced fluid accumulation in ligated intestinal loops as compared to similar loop treatments in pigs fed the control diet. Armstrong and Cline (1977) also found that following an oral Escherichia coli challenge, the addition of 20% oats to a 22% protein corn-soy diet reduced fluid accumulation in the digestive tract of pigs as compared to pigs fed the control diet.

Other workers have shown that increased dietary fiber in the diet had no beneficial effect on reducing the incidence of post-weaning diarrhea in 4 to 5 week old pigs (Katz et al., 1973; Mahan and Newland, 1976; Wahlstrom et al., 1977; Real et al., 1977; Rivera et al., 1978). Katz et al. (1973) suggested that rolled oats was of questionable value in the diets of young pigs. However, Wahlstrom et al. (1977) suggested that good quality oats can replace up to one-half of the corn and that dehulled high protein oats supplemented with lysine could replace all of the corn and soybean meal in starter diets.

The trials reported herein were designed to evaluate the effect of various levels of dietary oats and oat hulls in practical swine

starter rations on pig performance, ration digestibility and on the incidence of diarrhea in pigs weaned at 4 to 5 weeks of age in conventional weaning systems.

EXPERIMENTAL PROCEDURE

General

In all trials, pigs were weaned at 4 to 5 weeks of age. In the post-weaning growth trials, pigs were housed in an environmentally controlled slatted-floor nursery, in 1.5 x 3.3 meter pens. Diets were offered ad libitum in self feeders and water was supplied by nipple waterers. Temperature was maintained at approximately 26.7°C for the trials. Initial and weekly weights were recorded and daily gain, feed efficiency and daily feed intake were determined at the conclusion of the trial. Subjective diarrhea scores were taken daily and were based on the following: 1 = firm feces; 2 = soft feces; 3 = loose feces; 4 = watery feces; 5 = bloody feces. Scores were recorded on a pen basis following observations of individual pigs and signs of stool consistency in the pen. The scores are reported as average cumulative pen scores over a 14-day period. In all trials, pigs were randomly assigned to treatments from outcome groups based on body weight and sex. A randomized complete block design was used for growth and digestion trials with the data being treated statistically using analysis of variance and Duncan's New Multiple Range Test (Snedecor and Cochran, 1976).

In the digestion studies, the pigs were housed individually in metabolism cages allowing for separate collection of feces and urine.

Daily feed intake was constant and fed in two equal portions. At the time of feeding, water was added to the diet and it was fed in the form of a gruel. Upon completion of the feeding, sufficient fresh water was placed in the trough so that a small amount was left at the next feeding. A five-day adjustment period preceded each five-day collection period. Chromic oxide marker was fed at the beginning and end of each five-day period. Feces were collected daily and stored in a freezer. The entire five-day fecal collection was dried in a forced air oven at 50°C for 7 days, allowed to come to air-dry weight, and ground in a Wiley mill equipped with a 40-mesh screen. Urine was collected in an 8-liter container to which 20 ml of concentrated HCl had been added. Each daily collection was diluted to a constant volume (2 liters) and a 100 ml aliquot taken. Accumulated aliquots were stored in a refrigerator at 1°C until analyzed in triplicate for energy and nitrogen as outlined by A.O.A.C. (1975). Crude fiber determination was also analyzed according to A.O.A.C. (1975). Acid detergent fiber, neutral detergent fiber, cell content, cellulose, hemicellulose, and lignin were analyzed according to procedures outlined by Van Soest (1963, 1967), Van Soest and Wine (1967, 1968), and a modified NDF procedure (Appendix A) of Goering and Van Soest (1970).

Composition of the basal diets is shown in Table 1. The oats used in the trials were 38 lb. test weight. The oats and oat hulls analyses, given on a dry matter basis, are shown in Table 2. Additions of oats or oat hulls were added by replacing corn on an equal weight basis. Calculated analyses of crude fiber, energy, and protein for experimental diets are shown in Table 3.

TABLE 1. COMPOSITION OF BASAL DIETS

Ingredient, %	International Reference Number	(Trials 1,2,3,5)	(Trial 4)
Ground yellow corn	4-02-931	62.10	52.10
Ground oats	4-03-315	0.00	10.00
Soybean meal (50%)	5-04-612	33.80	33.80
Dicalcium phosphate	6-01-080	1.50	1.50
Ground limestone	6-02-632	1.10	1.10
Salt		.50	.50
Vitamin premix[a]		.50	.50
Trace mineral premix[b]		.10	.10
M and B premix[c]		.35	.35
Calculated Analysis, %			
Metabolizable energy (kcal/kg)		3305.00	3220.00
Crude protein		22.18	22.53
Lysine		1.00	1.10
Crude fiber		2.20	3.00
Calcium		.79	.79
Phosphorus		.69	.69

[a]Each kilogram of mix contained the following: Vitamin A palmitate, 880,000 IU; Vitamin D_3, 66,000 IU; Vitamin E, 4,400 IU; Riboflavin, 990 mg; d-pantothenic acid, 2,640 mg; Niacin, 5,500 mg; Choline chloride, 101,420 mg; Vitamin B_{12}, 4.84 mg; Menadione sodium bisulfite, 699.6 mg.

[b]Containing 0.1% Cobalt, 1.0% Copper, 0.3% Iodine, 10% Iron, 10% Manganese and 10% Zinc.

[c]Containing 0.25% Mecadox and 0.10% Banminth.

TABLE 2. ENERGY, PROXIMATE AND VAN SOEST ANALYSIS OF OATS AND OAT HULLS[a]

Parameter, %	Oats[b]	Oat Hulls
Gross energy (kcal/g)	4113	3981
Crude protein	13.92	3.12
Ash	3.16	5.93
Crude fiber	10.47	33.15
Ether extract	3.93	0.51
Cell walls	42.25	90.72
Cell content	57.75	9.28
ADF	15.08	45.75
Cellulose	1.65	36.18
Hemicellulose	27.17	44.97
Lignin	1.03	2.90

[a]Analysis on a dry matter basis; mean of three samples.

[b]38 lb. test weight oats.

TABLE 3. CALCULATED ANALYSES OF CRUDE FIBER, ENERGY, AND PROTEIN OF EXPERIMENTAL DIETS

Diets	Crude Fiber, %	Energy, kcal/kg	Protein, %
Basal			
Corn-soybean meal	2.2	3305	22.18
Basal + Oats			
Basal + 10% oats	3.0	3228	22.75
Basal + 20% oats	3.9	3146	23.30
Basal + 30% oats	4.7	3064	23.85
Basal + 40% oats	5.6	2983	24.40
Basal + 60% oats	7.3	2819	25.50
Basal + Oat Hulls			
Basal + 2.8% oat hulls	3.0	3242	22.06
Basal + 5.5% oat hulls	3.9	3176	21.94
Basal + 8.2% oat hulls	4.7	3110	21.81
Basal + 10.9% oat hulls	5.6	3045	21.68
Basal + 16.4% oat hulls	7.3	2912	21.43
Basal + Oats + 5% Fat			
Basal + 20% oats + 5% fat	3.8	3371	22.87
Basal + 40% oats + 5% fat	5.5	3208	23.97

Trial 1. A growth trial was conducted using 228 Yorkshire pigs averaging 8.4 kg. Pigs were allotted according to weight and sex to 36 pens representing three replications of twelve dietary treatments. In two of the three replications, pigs were housed seven to a pen in an environmentally controlled slatted floor nursery. In the third replication, five pigs per pen were fed in elevated decks in the same nursery. Tallow was the fat source; ground oats and oat hulls were the fiber sources. The experiment, lasting 35 days, included the following dietary treatments:

A. Corn-soy fortified basal diet (CF 2.2%);

B. Basal + 10% oats (CF 3.0%);

C. Basal + 20% oats (CF 3.9%);

D. Basal + 30% oats (CF 4.7%);

E. Basal + 40% oats (CF 5.6%);

F. Basal + 2.8% ground oat hulls (CF 3.0%);

G. Basal + 5.5% ground oat hulls (CF 3.9%);

H. Basal + 8.2% ground oat hulls (CF 4.7%);

I. Basal + 10.9% ground oat hulls (CF 5.6%);

J. Basal + 16.4% ground oat hulls (CF 7.3%);

K. Basal + 20% oats with 5% fat (CF 3.8%);

L. Basal + 40% oats with 5% fat (CF 5.5%).

Trial 2. A second growth trial was conducted to determine what effect pelleting would have on performance of pigs fed oats or oat hulls. The trial consisted of 98 crossbred pigs (Duroc-Yorkshire x Hampshire) averaging 13 kg. Pigs were allotted according to weight and sex to 14 pens representing two replicates of seven diets. Ground

oats and oat hulls were the fiber sources with tallow as the fat source. All diets were pelleted. The experiment, lasting 28 days, included the following treatments:

A. Corn-soy fortified basal diet (CF 2.2%);

B. Basal + 20% oats (CF 3.9%);

C. Basal + 2.8% oat hulls (CF 3.9%);

D. Basal + 40% oats (CF 5.6%);

E. Basal + 5.5% oat hulls (CF 5.6%);

F. Basal + 60% oats (CF 7.3%);

G. Basal + 40% oats + 5% fat (CF 5.5%).

Trial 3. A third growth trial was conducted using a 2 x 4 factorial experiment with four diets and comparing meal versus pellet diet form. The trial consisted of 160 Yorkshire pigs averaging 11.0 kg. Pigs were allotted according to weight and sex to 16 pens representing two replications of the eight dietary treatments. The experiment, lasting 35 days, included these dietary treatments:

A. Basal, corn-soy fortified diet, meal (CF 2.2%);

B. Basal, corn-soy fortified diet, pelleted (CF 2.2%);

C. Basal + 20% oats, meal (CF 3.9%);

D. Basal + 20% oats, pelleted (CF 3.9%);

E. Basal + 40% oats, meal (CF 5.6%);

F. Basal + 40% oats, pelleted (CF 5.6%);

G. Basal + 60% oats, meal (CF 7.3%);

H. Basal + 60% oats, pelleted (CF 7.3%).

Trial 4. A digestion trial was conducted using 12 crossbred barrows (Duroc-Yorkshire x Hampshire) weighing an average of 10.2 kg.

Three groups of four littermates were used in a randomized complete block design and allotted to four treatments. Treatments within groups were randomly assigned and fed for one period (10 days), after which treatments were reallotted for another period so as to provide a second replicate. Daily intake was 380g for the first period and 700g for the second period. The treatments consisted of:

A. Corn-soy + 10% oats (CF 3.0%);

B. Corn-soy + 2.8% oat hulls (CF 3.0%);

C. Corn-soy + 5.5% oat hulls (CF 3.9%);

D. Corn-soy + 8.2% oat hulls (CF 4.7%).

Trial 5. A digestion trial was conducted using 12 Yorkshire barrows weighing an average of 8.8 kg. Three groups of four littermates were used in a randomized complete block design and allotted randomly to four treatments. Similar procedures were used as discussed in Trial 4. Daily intake was 600g for the first period and 800g for the second period. The four dietary treatments consisted of:

A. Basal corn-soy fortified diet (CF 2.2%);

B. Basal + 20% oats (CF 3.9%);

C. Basal + 40% oats (CF 5.6%);

D. Basal + 10.9% oat hulls (CF 5.6%).

Trial 6. A digestion trial was conducted using 12 Yorkshire barrows weighing an average of 8.0 kg. Three groups of four littermates were used in a randomized complete block design and allotted randomly to four treatments. Similar procedures were used as discussed in Trial 4. Daily intake was 750g for the first period and 870g for the second period. The treatments, all fed in meal form, were as follows:

A. Basal corn-soy fortified diet (CF 2.2%);

B. Basal + 20% oats (CF 3.9%);

C. Basal + 40% oats (CF 5.6%);

D. Basal + 60% oats (CF 7.3%).

RESULTS

Trial 1. Influences of fiber source and fiber level on performance of pigs weaned at 4 to 5 weeks of age are shown in Table 4. There were no significant differences in average daily gain or daily feed consumption between pigs fed the basal diets and those fed diets with added crude fiber levels. However, pigs fed diets containing oat hulls tended to consume more feed daily than pigs fed the basal diets or diets containing ground oats.

The addition of ground oats to the diets tended to give slightly better feed efficiency than pigs fed the basal corn-soy diet. Diets containing oats plus 5% fat provided the best feed/gain ratios of the trial; however, none of these differences were significant. Pigs fed the diets containing oat hulls required slightly more feed/gain than did those fed diets containing oats or the basal diet. There was a significant ($P<.05$) increase in feed/gain ratio when oat hulls were added to 16.4% of the diet (7.3% crude fiber).

All pigs performed poorly immediately after weaning due to the stresses involved in weaning. This period lasted approximately seven days. Diarrhea was not a problem on this trial and average daily fecal scores were similar for all treatments.

Trial 2. Performance of pigs fed pelleted diets containing oats or oat hulls is shown in Table 5. There were no significant differences

TABLE 4. EFFECT OF FIBER SOURCE AND FIBER LEVEL IN DIETS ON PIG PERFORMANCE (Trial 1)

	Oats					Oat Hulls					Oats + 5% Fat	
Criteria, %	0	10	20	30	40	2.8	5.5	8.2	10.9	16.4	20	40
Crude fiber, %	2.2	3.0	3.9	4.7	5.6	3.0	3.9	4.7	5.6	7.3	3.8	5.5
No. pigs[1]	18	18	19	19	19	19	18	19	19	19	19	19
Period I[2]												
ADG, kg	.16^{ab}	.12^{ab}	.12^{ab}	.22^{a}	.11^{ab}	.15^{ab}	.17^{ab}	.17^{ab}	.10^{b}	.13^{ab}	.11^{ab}	.13^{ab}
ADFI, kg	.33	.35	.32	.42	.31	.34	.41	.37	.35	.35	.29	.35
F/G	2.06	2.92	2.67	1.91	2.82	2.27	2.41	2.18	3.50	2.69	2.64	2.69
Period II[3]												
ADG, kg	.41^{ab}	.43^{ab}	.41^{ab}	.47^{a}	.42^{ab}	.45^{ab}	.47^{a}	.43^{ab}	.39^{b}	.39^{b}	.42^{ab}	.46^{a}
ADFI, kg	.64^{ab}	.63^{ab}	.61^{b}	.69^{ab}	.59^{b}	.68^{ab}	.74^{b}	.67^{ab}	.66^{ab}	.76^{b}	.58^{a}	.63^{ab}
F/G	1.55^{ab}	1.48^{a}	1.49^{a}	1.51^{a}	1.46^{a}	1.53^{ab}	1.58^{ab}	1.59^{ab}	1.71^{b}	1.97^{c}	1.39^{a}	1.39^{a}
Dia. scores[4]	1.71	1.57	1.79	1.50	1.50	1.71	1.36	1.86	1.79	1.79	1.50	1.36

[1]Pig average initial weight 8.4 kg; final weight 24.1 kg; 3 replicates; 35 day trial.

[2]Days 0 to 7 post-weaning.

[3]Days 0 to 35 post-weaning.

[4]Average pen diarrhea scores based on a subjective score of 1 for firm feces, 2 for soft feces, 3 for loose feces, 4 for watery feces and 5 for bloody feces.

[abc]Means with different superscripts differ significantly (P<.05).

TABLE 5. PERFORMANCE OF PIGS FED PELLETED DIETS CONTAINING OATS OR OAT HULLS (Trial 2)

	Oats				Oat Hulls		Oats + 5% Fat
Criteria, %	0	20	40	60	2.8	5.5	40
Crude fiber, %	2.2	3.9	5.6	7.3	3.9	5.6	5.5
No. pigs[1]	14	14	14	14	14	14	14
Period I[2]							
ADG, kg	.61^{bc}	.55^{c}	.66^{ab}	.68^{a}	.63^{ab}	.64^{ab}	.62^{ab}
ADFI, kg	.85^{ab}	.78^{a}	.84^{ab}	.90^{b}	.87^{b}	.89^{b}	.86^{b}
F/G	1.39^{bc}	1.42^{c}	1.27^{a}	1.32^{ab}	1.38^{bc}	1.39^{bc}	1.39^{bc}
Period II[3]							
ADG, kg	.61	.56	.59	.63	.58	.60	.59
ADFI, kg	.98^{ab}	.92^{a}	.99^{b}	1.07^{c}	.99^{b}	1.02^{bc}	.95^{ab}
F/G	1.62	1.62	1.66	1.70	1.71	1.71	1.62
Dia. scores[4]	1.57	1.36	1.64	1.43	1.57	1.79	1.50

[1]Pig average initial weight 12.9 kg; final weight 29.6 kg; 2 replicates; 28 day trial.

[2]Days 0 to 7 post-weaning.

[3]Days 0 to 28 post-weaning.

[4]Average daily pen diarrhea scores based on a subjective score of 1 for firm feces, 2 for soft feces, 3 for loose feces, 4 for watery feces and 5 for bloody feces.

^{abc}Means with different superscripts differ significantly (P<.05).

in average daily gain. Pigs fed the 60% oat diet (7.3% crude fiber) consumed more feed ($P<.05$) than pigs fed the basal diet or diets containing 20 or 40% oats. Pigs fed the 20% oat diet consumed significantly ($P<.05$) less feed/day than those pigs fed the 40% oat diet. Pigs fed the diets containing 2.8 or 5.5% oat hulls (3.9% and 5.6% crude fiber, respectively) tended to have greater daily feed consumption than those fed diets containing 20 or 40% oats (3.9% and 5.6% crude fiber, respectively) with similar crude fiber levels. There was no significant difference in feed/gain; however, as the crude fiber level of the diets increased, there tended to be an increase in feed/gain, except on diets containing 20% oats and 40% oats with 5% fat. Also, the diets containing oat hulls required the largest amount of feed for gain of all the diets, though they were not significantly different. The addition of 5% fat to a 40% oat diet had no significant effect on pig performance. As in the previous trial, there were no differences in daily diarrhea scores, as there was not a diarrhea problem in this trial.

Trial 3. Results of performance of growing pigs fed meal or pelleted diets containing ground oats are shown in Table 6. There were no significant differences in pig growth rate and daily feed consumption when pigs were fed meal diets. Pigs fed pelleted diets also were not significantly different for average daily gain or daily feed consumption when compared to those fed the basal diet. However, pigs fed the pelleted 40% oat diet had significantly faster growth rates than pigs fed the 20% pelleted oat diet, as well as pigs fed the 40 or 60% oat meal diets. Also, pigs fed the pelleted 20% oat

TABLE 6. PERFORMANCE OF PIGS FED MEAL OR PELLETED DIETS CONTAINING OATS (Trial 3)

Criteria, %	Basal	20% Oats	40% Oats	60% Oats
Crude fiber, %	2.2	3.9	5.6	7.3
No. pigs[1]				
meal	20	19	20	20
pellet	20	19	20	20
Period I[2]				
ADG, kg				
meal	.44	.46	.43	.33
pellet	.48	.50	.53	.45
ADFI, kg				
meal	.55	.56	.50	.43
pellet	.56	.50	.57	.54
F/G				
meal	1.25	1.22	1.16	1.30
pellet	1.17	1.00	1.08	1.20
Period II[3]				
ADG, kg				
meal	$.55^{ab}$	$.57^{ab}$	$.54^{b}$	$.53^{b}$
pellet	$.55^{ab}$	$.54^{b}$	$.60^{a}$	$.55^{ab}$
ADFI, kg				
meal	$.89^{ab}$	$.95^{ab}$	$.92^{ab}$	$.97^{b}$
pellet	$.87^{ab}$	$.84^{a}$	$.92^{ab}$	$.92^{ab}$
F/G				
meal	1.62^{ab}	1.66^{a}	1.70^{a}	1.84^{c}
pellet	1.58^{ab}	1.54^{b}	1.54^{b}	1.66^{a}
Dia. scores[4]				
meal	1.57	1.64	1.71	1.43
pellet	1.64	1.43	1.50	1.57

[1]Pig average initial weight 11.0 kg; final weight 30.4 kg; 2 replicates; 35 day trial.

[2]Days 0 to 7 post-weaning.

[3]Days 0 to 35 post-weaning.

[4]Average pen diarrhea scores based on a subjective score of 1 for firm feces, 2 for soft feces, 3 for loose feces, 4 for watery feces, and 5 for bloody feces.

[abc]Means with different superscripts differ significantly ($P<.05$).

diet consumed significantly less feed/day than pigs fed the 60% oat meal diet. Although not significant, there was a trend for pigs fed pelleted diets to consume less feed/day than pigs fed comparable diets in meal form.

Feed/gain ratios tended to increase for pigs fed meal diets with the increase of oat content in the diets. The addition of 60% oats (7.3% crude fiber) to the meal diet resulted in the poorest feed efficiency ($P<.05$) of all diets, whether in meal or pellet form. Pelleted diets containing 20 or 40% oats tended to result in better feed efficiency than the basal diets, and had significantly ($P<.05$) better feed efficiency than the 60% pelleted oat diet. Pelleting the diets containing 20, 40 or 60% oats improved ($P<.05$) feed efficiency.

As in the previous growth trials, there was no problem with scouring. Diarrhea scores were similar for all pigs, whether fed pellets or meal, basal or 20, 40 or 60% oats.

Trial 4. Results of the digestion trial for diets containing 10% oats and increasing levels of oat hulls are shown in Table 7. As the level of crude fiber in the diet increased by the addition of oat hulls, there was a trend toward depressed apparent digestibility coefficients for digestible energy and cell content. Digestibility coefficients were similar for all diets for crude protein, crude fiber and lignin. Nitrogen retention as a percent of intake tended to be highest for diets containing 10% oats and 5.5% oat hulls, with 8.2% oat hulls in the diet being significantly ($P<.05$) lower than diets containing 10% oats or 5.5% oat hulls. Nitrogen retention, as a percent of digested and apparent digestibilities for cell wall digestion

TABLE 7. APPARENT ENERGY, PROTEIN, CRUDE FIBER, AND VAN SOEST DIGESTIBILITIES OF DIETS CONTAINING OATS AND OAT HULLS (Trial 1)[1]

	Oats	Oat Hulls		
Criteria, %	10%	2.8%	5.5%	8.2%
Crude fiber, %	3.0	3.0	3.9	4.7
Digestible energy	84.9[a]	83.3[ab]	81.8[bc]	80.2[c]
Crude protein (N x 6.25)	85.5	85.2	85.6	85.0
Nitrogen retention[2]	60.4[ab]	56.0[bc]	61.0[a]	54.4[c]
Nitrogen retention[3]	70.7[a]	65.7[b]	71.3[a]	63.9[b]
Crude fiber	40.9	43.3	37.8	39.0
Cell content	92.8[a]	90.8[a]	89.0[a]	86.5[b]
Cell wall	66.2[a]	80.9[b]	66.3[a]	79.9[b]
Acid detergent fiber	41.3[a]	59.5[b]	40.5[a]	37.7[a]
Hemicellulose	69.7[a]	84.9[b]	93.3[b]	87.3[b]
Cellulose	44.5[ab]	52.3[a]	33.7[b]	39.9[ab]
Lignin	44.2	42.3	30.6	44.5

[1]Values are averages of 6 observations; initial weight 10.2 kg.

[2]Percent of intake.

[3]Percent of digested.

[abc]Means with different superscripts differ significantly ($P<.05$).

were significantly ($P<.05$) higher for the diets containing 10% oats and 5.5% oat hulls than for diets containing 2.8 and 8.2% oat hulls. Acid detergent fiber digestibility was significantly ($P<.05$) higher for the 2.8% oat hull diet than the other diets. Hemicellulose digestibilities were significantly ($P<.05$) higher for the oat hull diets than the diet containing oats, while cellulose digestibility was significantly ($P<.05$) higher for the 2.8% oat hull diet than the 5.5% oat hull diet.

Pigs fed the control 10% oat diet and those fed the 2.8% oat hull diet (both with 3.0% crude fiber) had similar digestibilities for digestible energy, crude protein, crude fiber, cell content, cellulose, lignin and nitrogen retention (as a percent of intake). However, nitrogen retention (as a percent of digested) was significantly ($P<.05$) higher for the 10% oat diet than the similar oat hull diet, while the 2.8% oat hull diet resulted in significantly ($P<.05$) higher digestibility coefficients for cell wall, ADF and hemicellulose.

Trial 5. Results of the digestion trial for diets containing 0, 20 and 40% oats and 10.9% oat hulls are shown in Table 8. As the crude fiber level of the diets increased, there was a trend toward depressed digestibilities for digestible energy, crude protein and crude fiber. As crude fiber level in the diet increased to 5.6%, there was a linear ($P<.05$) depression of apparent digestibilities for energy. Crude protein digestibility coefficients were not significantly different between diets. Nitrogen retention (as a percent of intake and as a percent of digested) was similar for the control, 40% oat and the 10.9% oat hull diets; however, the 20% oat diet was significantly

TABLE 8. APPARENT ENERGY, PROTEIN AND CRUDE FIBER DIGESTIBILITIES OF DIETS CONTAINING OATS AND OAT HULLS (Trial 5)[1]

	Oats			Oat Hulls
Criteria, %	0	20	40	10.9
Crude fiber, %	2.2	3.9	5.6	5.6
Digestible energy	85.8[a]	80.2[b]	75.9[c]	75.1[c]
Crude protein (N x 6.25)	85.8	85.3	85.1	84.0
Nitrogen retention[2]	62.9[a]	57.6[b]	58.9[ab]	60.7[ab]
Nitrogen retention[3]	73.3[a]	67.7[b]	69.0[ab]	72.3[ab]
Crude fiber	53.8[a]	26.9[b]	17.3[b]	22.9[b]

[1]Values are averages of 6 observations; initial weight 8.8 kg.

[2]Percent of intake.

[3]Percent of digested.

[abc]Means with different superscripts differ significantly ($P<.05$).

($P<.05$) lower than the control diet. Crude fiber digestibility was significantly ($P<.05$) higher for the control diet than the 20 or 40% oat and the 10.9% oat hull diets.

Digestibility coefficients were not significantly different for the 40% oat diet or the 10.9% oat hull diet (both with 5.6% crude fiber), for digestible energy, crude protein, crude fiber or nitrogen retention.

Trial 6. Results of the digestion trial for diets containing 0, 20, 40 and 60% oats are shown in Table 9. As the level of crude fiber increased in the diets from 2.2% for the basal diet to 7.3% crude fiber for the 60% oat diet, there was a linear depression ($P<.05$) for the apparent digestibility of digestible energy. Crude protein digestibility tended to decrease; however, only the 20% oat diet (crude fiber at 3.9%) was significantly ($P<.05$) different from the basal diet. There tended to be a linear decrease in crude fiber and cell wall digestibilities; however, the 40 and 60% oat diets were not significantly different for these components.

There was also a tendency for depressed digestibilities of cell content and cellulose; however, only the 60% oat diet was significantly ($P<.05$) different from the other diets. As crude fiber level of the diets increased, there tended to be a depression of the digestibility for acid detergent fiber, although only the 40 and 60% oat diets were significantly ($P<.05$) different than the basal diet. Hemicellulose digestibilities of the oat diets were significantly ($P<.05$) lower than the basal diet, with 40% oats being significantly ($P<.05$) lower than the diets containing 20 or 60% oats. Apparent digestibility of the

TABLE 9. APPARENT ENERGY, PROTEIN, CRUDE FIBER, AND VAN SOEST DIGESTIBILITIES OF DIETS CONTAINING OATS[a] (Trial 6)[1]

	Oats			
Criteria, %	0	20	40	60
Crude fiber, %	2.2	3.9	5.6	7.3
Digestible energy	86.6[a]	82.4[b]	79.2[c]	74.7[d]
Crude protein (N x 6.25)	86.0[a]	84.1[b]	85.1[ab]	84.6[ab]
Crude fiber	53.6[a]	34.9[b]	21.1[c]	12.4[c]
Cell content	89.7[a]	89.1[a]	88.6[a]	85.3[b]
Cell wall	80.4[a]	65.3[b]	55.5[c]	55.6[c]
Acid detergent fiber	47.5[a]	40.8[ab]	33.6[b]	12.4[c]
Hemicellulose	87.1[a]	75.2[b]	68.2[c]	73.6[b]
Cellulose	52.9[a]	36.4[a]	34.2[a]	17.8[b]
Lignin	71.7[ab]	80.6[a]	50.6[b]	30.3[bc]

[1]Values are averages of 6 observations; initial weight 8.0 kg.

[abcd]Means with different superscripts differ significantly ($P<.05$).

20% oat diet was significantly ($P<.05$) higher than the digestibilities of the basal, 40% oat or 60% oat diets for lignin, though there was a tendency for depressed digestibility coefficients with the higher levels of oats in the diet.

DISCUSSION

Growth Trials

The addition of ground oats or ground oat hulls to a basal corn-soy diet, up to a crude fiber level of 7.3%, had no effect on growth rate of pigs weaned at four to five weeks of age. The crude fiber content of 60% oats (7.3%) and 16.4% oat hulls (7.3%) both exceeded the 6.57% optimum level for growth as reported by Axelsson and Ericksson (1953). The present study is in agreement with Hochstetler et al. (1959) who reported no significant differences in gain or efficiency with diets containing 20 or 40% oats. Also, Wahlstrom and Libal (1975) reported that levels of 0, 20, 40 and 60% oats in the diets did not affect rate of gain. Mahan and Newland (1976) observed beneficial effects on pig performance from 15% oats with 25% oats being undesirable, while Rivera et al. (1978) reported similar results in that pigs fed 10% oats had beneficial effects on pig performance but 30% oats in the diet tended to cause higher feed/gain ratios. Jensen et al. (1959a) reported crude fiber levels (on dry-matter basis) above the approximate 3.0% in the basal rations did not improve gain or efficiency. While the results presented from the present study did not improve gain or efficiency, there was no significant difference in growth rates of pigs fed diets containing oats or oat hulls and those fed the basal corn-soy diet, and only on

the diets containing 7.3% crude fiber was there significantly ($P<.05$) poorer feed efficiency.

There was a trend toward slightly increased feed consumption and feed/gain as the level of oats or oat hulls was increased in the diet, increasing the crude fiber content of the diet. Diets containing oats or oat hulls with a crude fiber level of 7.3% did show a significant ($P<.05$) increase in feed required for gain, when the diet was fed in meal form. Wahlstrom and Libal (1975) reported that 60% oats in the diet did not affect gain but feed efficiency at this level was reduced by about 3%. In the present study the addition of 60% oats (in meal form) reduced feed efficiency by about 12%. Several reports support the suggestion that the pig tends to eat until it satisfies its energy requirement unless prevented by bulk or possibly palatability (Teague and Hanson, 1954; Cole et al., 1967b; Henry, 1969; Baird et al., 1970; and Baird et al., 1975).

Increased daily feed consumption associated with reduced energy has been reported by Merkel et al. (1958), Haugse et al. (1962), Troelsen and Bell (1962), Cole et al. (1967a,b), Dinusson et al. (1956), and Dinusson et al. (1969). Kornegay (1978), using soybean hulls as a fiber source, reported that pigs fed 24% hulls were not able to maintain a growth rate similar to pigs fed diets containing 0, 6 or 12% soybean hulls, although feed intake was increased.

Pigs fed the diets containing oat hulls had similar growth rates as pigs fed oat diets with similar crude fiber levels. However, pigs fed the diets with oat hull additions tended to be less efficient than pigs on the basal or oat diets. In contrast, Jensen et al. (1959b)

added 7 and 13% oat hulls to corn-soybean meal diets and fed the diets to 22.7 kg pigs. They reported both levels of hulls added to the basal diet markedly depressed performance. These authors suggested that the growth inhibitory effect of oat hulls was mediated through the dilution of energy in the ration and lowered feed intake.

The results of this study are in general agreement with the above reports. Calculated metabolizable energy values were reduced as the crude fiber level of the diets was increased by the addition of oats or oat hulls. The pigs on the oat or oat hull diets were able to consume a great enough quantity of diet to make up for the reduced energy value and not have a deleterious effect on growth rate.

Pigs fed diets containing additions of 20% oats and 5% fat or 40% oats and 5% fat had similar growth rates as pigs fed the other experimental diets. However, the addition of 5% fat to diets containing 20% or 40% oats tended to result in lower daily feed consumption for pigs fed these diets. Likewise, pigs fed these diets tended to have better feed/gain ratios than pigs fed the other experimental diets, demonstrating that increasing the caloric density of swine diets generally results in reduced daily feed consumption and improved efficiency of gain. Numerous experiments have demonstrated similar results (Pond et al., 1960; Noland and Scott, 1960; Clawson et al., 1962; Kuryvial et al., 1962; Lowrey et al., 1962; Wagner et al., 1963; Greeley et al., 1964a; Greeley et al., 1964b; Hale et al., 1968; Allee et al., 1971c; Allee and Hines, 1972; Allee et al., 1972).

Pelleting the diets had no significant affect on pig growth rate but it significantly ($P<.05$) increased efficiency of gain from 2.5%

for the basal diet to 10.8% for the 60% oat diet, over comparable diets fed in meal form. The NCR-42 Committee on Swine Nutrition (1969) carried out a cooperative evaluation of meal versus pellet fortified corn-soybean meal rations for growing-finishing pigs. They concluded that rate of gain was similar on both rations but gain per unit of feed consumed was significantly higher for pelleted rations.

A non-nutritional disadvantage of the high crude fiber diet was the bulky nature of the mixture. Jensen et al. (1959a) reported the bulky characteristic of high oat diets prevented an even flow of feed in the self-feeders and necessitated daily attention to ensure feed being available to the pigs. In the present study a similar problem was noted with meal diets containing 7.3% crude fiber. Pigs fed meal form diets may be able to separate out some of the fiber, while palatability may also be a factor. Feed wastage was a problem as well, when feeding the meal diets containing high levels of crude fiber. However, pelleting in this study largely alleviated these problems, since pelleting reduced bulkiness and associated feeder difficulties to an appreciable extent.

Several workers have reported that young pigs, upon weaning, generally go through a poor performance period during which they consume small quantities of feed, often suffer from diarrhea, and gain little weight (Smith and Lucas, 1956, 1957a,b; Lucas et al., 1959; Calder et al., 1959; Leibbrandt et al., 1975; Mahan and Newland, 1976). In the present study, pigs in trial 1 (average initial weight 8.4 kg) had low average daily gains and poor feed efficiency immediately after weaning; however, pigs in trials 2 and 3 (average initial weight

12.9 and 19.0 kg, respectively) did not exhibit reduced daily gains or poor feed efficiency. These results are in general agreement with those observed by Rivera et al. (1978) that the level of performance was more depressed in lighter weight pigs than with heavier pigs when comparing post-weaning performance.

Diets of higher fiber content have been suggested to result in firmer stools with pigs (Richards and Fraser, 1961; Smith and Halls, 1967). Armstrong and Cline (1976, 1977), using gut loop and titration methods, showed that 20% dietary oats was beneficial in reducing fluid accumulation following an oral E. coli challenge. The present study showed no beneficial effects of increased fiber from oats or oat hulls in the diet on reducing the incidence of post-weaning diarrhea of pigs weaned at 4 to 5 weeks of age. Daily fecal scores were similar for all diets. These results are in agreement with recent reports by other workers in that the addition of 10 to 20% oats to the diets of weaned pigs did not reduce the incidence of diarrhea (Mahan and Newland, 1976; Real et al., 1977; Rivera et al., 1978). However, in these studies as well as the present study, the incidence of diarrhea was low and when it did occur dietary effects were not evident.

Moser (1977) reported that the addition of 20% oats to a corn-soy diet gave similar or better pig performance when fed in combination with antibiotics than did a control corn-soy diet for 3 to 4 week old pigs. This same worker observed a higher feed consumption during the first 3 weeks post-weaning and a significant increase in survival of pigs fed the higher fiber diet. Mortality was low in the present study and the 8 pigs that died (486 total pigs involved) could not be

correlated to any of the dietary treatments. Rivera et al. (1978), feeding oats and kaolin to pigs weaned at 4 to 5 weeks, also reported low mortality and that mortalities could not be correlated to dietary treatments.

Digestion Trials

In general, digestion coefficients for digestible energy, crude fiber, and the Van Soest components tended to be depressed as the level of crude fiber, from oats, was increased in the diet. Digestion coefficients for these components followed a similar trend when oat hulls were added to the diets; however, cell wall and hemicellulose components tended to be more digestible for the oat hulls than the same components from oats. Also, crude fiber digestibility for oat hulls was similar to the 10% oat control diet in contrast to published data indicating that increasing crude fiber tends to depress crude fiber digestibility. It has been well established that increasing crude fiber level depresses the digestibility of nutrients in a diet for swine (Lloyd and Crampton, 1955; Pond et al., 1962; Troelson and Bell, 1963; Henry, 1968; Boenker, Tribble and Pfander, 1969; Bowland et al., 1970).

In trial 4, cell wall and hemicellulose digestibilities tended to be higher for diets containing the oat hulls than for the control 10% oat diet, indicating that these fibrous components of oat hulls were more digestible than those of the basal diet which consisted of corn, soybean meal and 10% oats. Also, the digestibilities of ADF and cellulose were higher for the 2.8% oat hull diet than the basal 10%

oat diet (both with similar levels of 3.0% crude fiber) although the digestibility coefficients for cellulose were not significantly higher. Kornegay (1978) added 15 and 30% soybean hulls to a basal diet containing corn, 20% oats, 5% dehydrated alfalfa meal and soybean meal. He concluded that digestion coefficients for ADF, cellulose and lignin were increased as soybean hulls were substituted for the basal diet, while the digestion of cell walls and hemicellulose was unaffected.

Bowland et al. (1970) used finely ground oat hulls as the crude fiber source for diets containing 3.1, 6.1, 9.1 and 12.1% crude fiber. They found for pigs weighing approximately 50 kg the digestion coefficients for crude fiber were 43.2, 35.0, 28.4 and 20.2%, respectively. In the present study, finely ground oat hulls were used for diets containing 3.0, 3.9, 4.7 and 5.6% crude fiber. Digestion coefficients for these diets were 43.3, 37.8, 39.0 and 22.9%, respectively, and were in general agreement with their results.

In trial 5 there was also a tendency for digestion coefficients to be reduced for digestible energy and crude fiber when the crude fiber level of the diet increased to 5.6% from the addition of oats or oat hulls. As in the previously discussed trial, oat hulls were slightly more digestible, though not significant, than the oat diet at similar crude fiber levels, indicating that crude fiber from oat hulls may be more digestible than from oats.

There was a tendency for digestion coefficients to be depressed for digestible energy, crude fiber and Van Soest components in trial 6, as the crude fiber level of the diet increased to 7.3% from the addition of oats. This again is in agreement with reports that increasing

the crude fiber level depresses the digestibility of a diet for swine (Lloyd and Crampton, 1955; Pond et al., 1962; Troelsen and Bell, 1963; Henry, 1968; Boenker, Tribble and Pfander, 1969; Bowland et al., 1970).

An inverse relationship between level of crude fiber and apparent digestibility of crude protein has been well documented (Teague and Hanson, 1954; Whiting and Bezeau, 1957a; Pond et al., 1962; Glover and Duthie, 1958; Likuski et al., 1961; Boenker et al., 1969; Bowland et al., 1970; Keys et al., 1970). Kornegay (1978) reported about a 1% decrease in crude protein digestion for each 1% increase in crude fiber content of the diet when using soybean hulls as the crude fiber source. In the present study, crude protein digestibility coefficients were similar in trials 4 and 5, while in trial 6 only the 20% oat diet was significantly ($P<.05$) different than the basal corn-soy diet. Thus, the crude protein digestibility coefficients were similar regardless of the increased level of crude fiber in the diet from the additions of oats or oat hulls. This may be explained by the high level of crude protein in these diets. Pond et al. (1962), using ground corn cobs as the crude fiber source, compared diets of low fiber-high protein (5.3 and 18.0%, respectively) and high fiber-high protein (9.5 and 18.9%, respectively) and found apparent crude protein digestibilities of 70.7% for the low fiber-high protein diet and 71.7% for the high fiber-high protein diet. Also, Lloyd and Crampton (1955) observed that increasing the percentage of protein or decreasing the percentage of crude fiber in the ration had a tendency to increase the apparent digestibility of protein.

Horszezaruk (1962) suggested, based on his work and other literature which he reviewed, that the differences in the digestibility of crude fiber obtained for the various fiber sources was related to their lignin content and the content of other incrusting substances. The lignin ($kMnO_4$ method) component is typically considered to be undigestible. Kornegay (1978), using soybean hulls at levels of 0, 15 and 30%, reported apparent digestibility coefficients of 44.1, 47.1 and 51.2%, respectively. In the present study, trial 4 digestibility coefficients for lignin were 44.2, 42.3, 30.6 and 44.5% for diets containing 10% oats and 2.8, 5.5 and 8.2% oat hulls, respectively. However, in trial 5, apparent digestibility coefficients for lignin were 71.7, 80.6, 50.6 and 30.3% for diets containing 0, 20, 40 and 60% oats, respectively. There may be problems associated with the chemical analysis of this component. Lignin is intimately associated with the polysaccharides of the cell walls and is apparently linked to the hemicellulose component by covalent bonds; therefore, it is difficult to separate it from these polysaccharides (Hartley, 1978). The presence of artifact lignin can give high lignin values. Also, particle size of the fiber, as finer grinding increases the likelihood that fiber particles will flow with liquid, whereas coarser fiber will tend to mat and become occluded through filtration effects.

SUMMARY

Three growth trials and three digestion trials utilizing 522 pigs were conducted to evaluate the effects of various levels of dietary oats and oat hulls in swine diets on pig performance, ration digestibility and incidence of diarrhea in pigs weaned at approximately 5 weeks of age (8 to 13 kg).

Pigs fed experimental diets containing oats or oat hulls with crude fiber levels of 3.0, 3.9, 4.7, 5.6 or 7.3% had similar growth rates as pigs fed the basal corn-soybean meal diet. Pigs fed up to 40% ground oats in the diet had similar feed efficiency compared to pigs fed the basal diets. Pigs fed diets containing 16.4% oat hulls and 60% ground oats (both 7.3% CF) did have significantly ($P<.05$) higher feed to gain ratios when comparing the diets in meal form; but, when these diets were pelleted, there were no differences. Although not significant, feed to gain ratios for pigs fed the different levels of oat hulls tended to be slightly higher than for pigs fed ground oat diets with similar crude fiber levels.

Adding 5% fat to diets containing 20 and 40% oats resulted in similar growth rates to pigs fed the control ration; however, these diets did show a slight improvement in feed efficiency. Pelleting the diets containing oats or oat hulls had no effect on pig growth rates, but pelleting did increase feed efficiency from 2.5% for the

basal diet to 10.8% for the 60% oat diet over comparable diets fed in meal form.

Lighter weight pigs in trial 1 (average initial weight 8.4 kg) performed poorly the first seven days post-weaning regardless of diet as compared to trials 2 and 3 (average initial weights 12.9 and 11.0 kg, respectively) in which heavier weight pigs were used. Diarrhea was not a problem in the trials and daily diarrhea scores were similar for all treatments. Mortality was low in all three growth trials and no deaths could be attributed to dietary treatment.

In the digestion trials, as the level of crude fiber was increased in diets containing 0, 20, 40 and 60% oats, the apparent digestibility coefficients tended to be depressed for digestible energy, crude fiber and the Van Soest components. For diets containing 10% oats and 2.8, 5.5, 8.2 and 10.9% oat hulls, digestion coefficients tended to be depressed for digestible energy, cell content, acid detergent fiber and cellulose. Digestion coefficients for cell wall and hemicellulose increased with the addition of oat hulls. Crude fiber digestibilities were similar for diets containing 10% oats and 2.8, 5.5 and 8.2% oat hulls. Crude protein digestion coefficients were similar in each trial. Apparent digestibility coefficients for lignin were similar for diets containing 10% oats and 2.8, 5.5 and 8.2% oat hulls, while they tended to be depressed as the crude fiber level in the diet increased with the addition of 0, 20, 40 and 60% oats.

LITERATURE CITED

Allee, G.L., D.H. Baker and G.A. Leveille. 1971a. Fat utilization and lipogenesis in the young pig. J. Nutr. 101:1415.

Allee, G.L., E.K. O'Hea, G.A. Leveille and D.H. Baker. 1971b. Influence of dietary protein and fat on lipogenesis and enzymatic activity in pig adipose tissue. J. Nutr. 101:869.

Allee, G.L., D.R. Romsos, G.A. Leveille and D.H. Baker. 1972. Lipogenesis and enzymatic activity in pig adipose tissue as influenced by source of dietary fat. J. Anim. Sci. 35:42.

Allee, G.L. and R.H. Hines. 1972. Influence of fat level and calorie:protein ratio on performance and carcass composition of young pigs. KSU Swine Day Rep. 193:29.

Allee, G.L. 1977. Performance of young pigs as affected by energy density of and method of adding fat to rations. Kansas Swine Day Rep. 312:13.

A.O.A.C. 1975. Official Methods of Analysis (12th ed.) Association of Official Agricultural Chemists. Washington, D.C.

Armstrong, W.D. and T.R. Cline. 1976. The effects of various dietary nutrient levels on the incidence of colibacillary diarrhea in pigs: Intestinal ligation studies. J. Anim. Sci. 42:592.

Armstrong, W.D. and T.R. Cline. 1977. The effect of various nutrient levels and environmental temperatures on the incidence of colibacillary diarrhea in pigs: Intestinal fistulation and titration studies. J. Anim. Sci. 45:1042.

Axelsson, J. 1947. The ability of cattle, sheep, horses, and swine to digest the nutrients of the feeding stuffs. Ann. Roy. Agr. College of Sweden. 16:84.

Axelsson, J. and S. Eriksson. 1953. The optimum crude fiber level in rations of growing pigs. J. Anim. Sci. 12:881.

Baird, D.M., H.C. McCampbell and J.R. Allison. 1970. Levels of crude fiber with constant energy levels of growing-finishing swine using computerized rations. J. Anim. Sci. 31:518.

Baird, D.M., J.R. Allison and E.K. Heaton. 1974. The energy value for and influence of citrus pulp in finishing diets for swine. J. Anim. Sci. 38:545.

Baird, D.M., H.C. McCampbell and J.R. Allison. 1975. Effects of levels of crude fiber, protein and bulk in diets for finishing hogs. J. Anim. Sci. 41:1039.

Becker, D.E., A.H. Jensen and B.G. Harmon. 1963. Fineness of grinding corn for growing-finishing pigs. Ill. Agr. Exp. Sta., Mimeo AS-586.

Bell, J.M., J.P. Bowland, C.D.T. Cameron, E.W. Crampton, L.E. Lloyd, M.E. Seale and F. Whiting. 1958. Nutrient requirements for Canadian Yorkshire swine. II. The effects of barley and oat finishing rations on rate of gain, feed utilization and carcass quality of pigs marketed at 185 and 200 pounds liveweight. Can. J. Anim. Sci. 38:73.

Boenker, D.E., L.F. Tribble and W.H. Pfander. 1969. Energy and nitrogen evaluation of swine diets containing added fat or corn cobs. J. Anim. Sci. 28:615.

Bohman, V.R., J.F. Kidwell and J.A. McCormick. 1953. High levels of alfalfa in the rations of growing-fattening swine. J. Anim. Sci. 12:876.

Bohman, V.R., J.E. Hunter and J.A. McCormick. 1955. The effect of graded levels of alfalfa and aureomycin upon growing-fattening swine. J. Anim. Sci. 14:499.

Bohstedt, G. and J.M. Fargo. 1933. The effect of varying amounts and kinds of fiber in rations for swine. Wis. Exp. Sta. Bul. 425.

Bowland, J.P., H. Bickel, H.P. Pfirter, C.P. Wenk and A. Schurch. 1970. Respiration calorimetry studies with growing pigs fed diets containing from three to twelve percent crude fiber. J. Anim. Sci. 31:494.

Breirem, K., M. Husby, K. Presthegge and T. Homb. 1958. Cellulose as a feed for pigs. Zeitschr. Tierphysiol., Tierenshrung, Futtermittel. 13:129. (Cited in Biol. Abstr. 35:1876. 1960).

Brooks, C.C. 1972. Molasses, sugar (sucrose), corn, tallow, soybean oil and mixed fats as sources of energy for growing swine. J. Anim. Sci. 34:217.

Calder, A.F.C., G.A. Lodge and R. Blair. 1959. The early weaning of pigs. V. The inclusion of digestive enzymes and antibiotics in diets for pigs weaned at 6-7 lbs. live weight. J. Agr. Sci. 53:130.

Cameron, C.D.T. 1960. Effects of high fiber and pelleted and non-pelleted high fiber-high fat rations on performance and carcass characteristics of bacon pigs. Can. J. Anim. Sci. 40:126.

Carroll, W.E., W.P. Gorrigus, G.E. Hunt and R.A. Smith. 1937. Value and use of oats in rations of growing-fattening swine. Ill. Agr. Exp. Sta. Bul. 436.

Clausen, H. and J. Ludvigsen. 5th Intern. Congress on Nutrition, Panel VI, p 31. Washington, D.C. 1960.

Clawson, A.J., T.N. Blumer, W.W.G. Smart, Jr. and E.R. Barrick. 1962. Influence of energy-protein ratio on performance and carcass characteristics of swine. J. Anim. Sci. 21:62.

Coey, W.E. and K.L. Robinson. 1954. Some effects of dietary crude fiber on liveweight gains and carcass conformation of pigs. J. Agr. Sci. 45:41.

Cole, D.J.A., J.E. Duckworth and W. Holmes. 1967a. Factors affecting voluntary feed intake in pigs. I. The effect of digestible energy content of the diet on the intake of castrated male pigs housed in holding pens and in metabolism crates. Anim. Prod. 9:141.

Cole, D.J.A., J.E. Duckworth and W. Holmes. 1967b. Factors affecting voluntary feed intake in pigs. II. The effect of two levels of crude fiber in the diet on the intake and performance of fattening pigs. Anim. Prod. 9:149.

Crampton, E.W. and J.M. Bell. 1946. The effect of fineness of grinding on the utilization of oats by market hogs. J. Anim. Sci. 5:200.

Crampton, E.W., G.C. Ashton and L.E. Lloyd. 1954. Improvement of bacon carcass quality by the addition of fibrous feeds into the hog finishing ration. J. Anim. Sci. 13:327.

Cunningham, H.M., D.W. Friend and J.W.G. Nicholson. 1961. The effect of a purified source of cellulose on the growth and body composition of growing pigs. Can. J. Anim. Sci. 41:120.

Cunningham, H.M., D.W. Friend and J.W.G. Nicholson. 1962. The effect of age, body weight, feed intake and adaptability of pigs on the digestibility and nutritive value of cellulose. Can. J. Anim. Sci. 42:167.

DeGoey, L.W. and R.C. Ewan. 1975. Effect of level of intake and diet dilution on energy metabolism in the young pig. J. Anim. Sci. 40:1045.

Dinusson, W.E., D.W. Bolin and M.L. Buchanan. 1955. Pelleted barley for hogs - II. Bimonthly Bul. 18:56.

Dinusson, W.E., D.W. Bolin and M.L. Buchanan. 1956(b). Plump-vs- thin barley. Bimonthly Bul. 19:66.

Dinusson, W.E. and D.W. Bolin. 1958. Feeds for swine. Bimonthly Bul. 20:16.

Dinusson, W.E., P.A. Nystuen, D.W. Bolin and C.N. Haugse. 1960. Pelleted feeds: Effect of hull and fiber on gain and efficiency of swine. N. Dak. Agr. Exp. Sta. Res. Rep. 2.

Dinusson, W.E., C.N. Haugse, D.L. McIlroy and R.L. Harrold. 1969. Fiber-protein-energy relationships in rations for growing-finishing swine. N. Dak. Agr. Exp. Sta. Res. Rep. 21.

Eusebio, J.A., V.W. Hays, V.C. Speer and J.T. McCall. 1965. Utilization of fat by young pigs. J. Anim. Sci. 24:1001.

Ewan, R.C. 1970. Effect of protein quality on fat utilization by baby pigs. J. Anim. Sci. 31:1020 (Abstr.).

Friend, D.W. 1969. Digestibility of rye and its value in pelleted rations for pigs. Can. J. Anim. Sci. 49:375.

Forbes, R.M. and T.S. Hamilton. 1952. The utilization of certain cellulose materials by swine. J. Anim. Sci. 11:480.

Frobish, L.T., V.W. Hays, V.C. Speer and R.C. Ewan. 1969. Effect of diet form and emulsifying agents on fat utilization by young pigs. J. Anim. Sci. 29:320.

Gamble, C.T., C.C. Chamberlain, G.M. Merriman and E.R. Lidvall. 1967. Effects of pelleting, pasture and selected diet ingredients on the incidence of esophagogastric ulcers in swine. J. Anim. Sci. 26:1054.

Glover, J. and D.W. Duthie. 1958. The apparent digestibility of crude protein by non-ruminants and ruminants. J. Agr. Sci. 51:289.

Goering, H.K. and P.J. Van Soest. 1970. Forage Fiber Analysis. Ag. Handbook 379. USDA.

Gorrill, A.D.L., J.M. Bell and C.M. Williams. 1960. Ingredient and processing interrelationships in swine feeds: I. Effects of antibiotics, protein source and wheat bran on the responses to pelleted feed. Can. J. Anim. Sci. 40:83.

Greeley, M.G., R.J. Meade and L.E. Hanson. 1964a. Energy and protein intakes by growing swine. I. Effects on rate and efficiency of gain and on nutrient digestibility. J. Anim. Sci. 23:808.

Greeley, M.G., R.J. Meade, L.E. Hanson and J. Nordstrom. 1964b. Energy and protein intakes by growing swine. II. Effects on rate and efficiency of gain and on carcass characteristics. J. Anim. Sci. 23:816.

Hale, O.M., J.C. Johnson, Jr. and E.P. Warren. 1968. Influence of season, sex and dietary energy concentration on performance and carcass characteristics of swine. J. Anim. Sci. 27:1577.

Hartley, R.D. 1978. The lignin fraction of plant cell walls. Am. J. Clin. Nutr. 31:S90.

Haugse, C.N., W.E. Dinusson, D.O. Erickson and M.L. Buchanan. 1962. Oats and barley in pelleted growing-fattening rations for swine. N. Dak. Agr. Exp. Sta. Res. Rep. 9.

Henry, Y. 1969. Effects nutritionnels de lin-corporation de cellulose purifiee dan le regimedu pore em croissance-finition. II. Influence sur les performances de croissance et la composition corporelle. Ann. Zootech. 18:371.

Hines, R.H., B.A. Koch and G.L. Allee. 1975. Isocaloric swine finishing diets with various percentages of alfalfa meal and tallow. Kansas Swine Day Rep. 252:7.

Hines, R.H. 1977. Use of oats and fat in swine grower rations. Kansas Swine Day Rep. 312:15.

Hintz, H.F. and W.N. Garrett. 1967. Steam pressure processing and pelleting of barley for growing-finishing swine. J. Anim. Sci. 26:746.

Hochstetler, L.M., J.A. Hoefer, A.M. Pearson and R.W. Luecke. 1959. Effect of varying levels of fiber of different sources upon growth and carcass characteristics of swine. J. Anim. Sci. 18:1397.

Horszezoruk, F. 1962. Wplyw zroznicowanego poziomu wlokna surowego w dawkach na processy trawienne w swin. 3. Rozklad wlokna surowego w jelicie splepym. Roczniki Nauk Rolniczyck Tom. 80-B-3:333.

Jennings, A.R. 1959. Gastro-enteritis in the pig. Vet. Rec. 71:766.

Jensen, A.H., D.E. Becker and S.W. Terrill. 1959a. Oats as replacement for corn in complete mixed rations for growing-finishing swine. J. Anim. Sci. 18:701.

Jensen, A.H., D.E. Becker and S.W. Terrill. 1959b. Growth inhibitory effect of oat hulls in rations for growing-finishing swine. J. Anim. Sci. 18:1356.

Katz, R.S., D.H. Baker, C.E. Sasse, A.H. Jensen and B.G. Harmon. 1973. Efficacy of supplemental lysine, methionine and rolled oats for weanling pigs fed a low protein corn-soybean meal diet. J. Anim. Sci. 37(5):1165.

Keys, J.E., Jr., P.J. Van Soest and E.P. Young. 1970. Effect of increasing dietary cell wall content on the digestibility of hemicellulose and cellulose in swine and rats. J. Anim. Sci. 31:1172.

Kornegay, E.T. 1978. Feeding value and digestibility of soybean hulls for swine. J. Anim. Sci. 47:1272.

Kuryvial, M.S., J.P. Bowland and R.T. Berg. 1962. Supplemental fat as an energy source in the diets of swine and rats. I. Food and energy utilization. Can. J. Anim. Sci. 42:23.

Larsen, L.M. and J.E. Oldfield. 1960. Improvement of barley rations for swine. II. Effects of pelleting and supplementation with barlet malt. J. Anim. Sci. 19:601.

Leibbrandt, V.D., R.C. Ewan, V.C. Speer and D.R. Zimmerman. 1975. Effect of weaning and age at weaning on baby pig performance. J. Anim. Sci. 40:1077.

Leibbrandt, V.D., V.W. Hays, R.C. Ewan and V.C. Speer. 1975. Effect of fat on performance of baby and growing pigs. J. Anim. Sci. 40:1081.

Likuski, H.J.A., J.P. Bowland and R.T. Berg. 1961. Energy digestibility and nitrogen retention by pigs and rats fed diets containing non-nutritive diluents and varying in protein level. Can. J. Anim. Sci. 41:89.

Lloyd, L.E. and E.W. Crampton. 1955. The apparent digestibility of the crude protein of the pig ration as a function of its crude protein and crude fiber content. J. Anim. Sci. 14:693.

Lowrey, R.W., W.G. Pond, J.K. Loosli and J.H. Maner. 1962. Effect of dietary fat level on apparent nutrient digestibility by growing swine. J. Anim. Sci. 21:746.

Lucas, I.A.M., A.F.C. Calder and H. Smith. 1959. The early weaning of pigs. VI. The effect of early weaning and of various growth curves before 50 lbs live weight upon subsequent performance and carcass quality. J. Agr. Sci. 53:136.

Luce, W.G., I.T. Omtevedt and C.V. Maxwell. 1973. Effect of pellet size on pig performance. J. Anim. Sci. 36:204 (Abstr.).

Mahan, D.C. and H.W. Newland. 1976. Short term effects of the addition of oats, bacterial culture (probiotic) and antibiotics to the diets of weaned pigs. Ohio Swine Day Rep.

Mangold, E. 1934. The digestion and utilization of crude fiber. Nutr. Abstr. and Rev. 3:647.

Meade, R.J. 1965. How much feed processing. Hog Farm Management 3:14.

Meade, R.J., W.R. Dukelow and R.S. Grant. 1966. Influence of percent oats in the diet, lysine and methionine supplementation and of pelleting on rate and efficiency of gain of growing pigs, and on carcass characteristics. J. Anim. Sci. 25:58.

Merkel, R.A., R.W. Bray, R.H. Grummer, P.H. Phillips and G. Bohnstedt. 1958a. The influence of limited feeding, using high fiber rations, upon growth and carcass characteristics in swine. I. Effects upon feedlot performance. J. Anim. Sci. 17:3.

Merkel, R.A., R.W. Bray, R.H. Grummer, P.H. Phillips and G. Bohstedt. 1958b. The influence of limited feeding, using high fiber rations, upon growth and carcass characteristics of swine. II. Effects upon carcass characteristics. J. Anim. Sci. 17:13.

Miller, E.R. 1975. Use of oats and animal fat in swine rations. Michigan Agr. Exp. Sta. Res. Rep. 289:62.

Mitchell, H.H. and T.S. Hamilton. 1933. True and apparent digestibility of oat hulls and alfalfa meal by swine, with special reference to the ability of swine to digest cellulose and crude fiber. J. Anim. Sci. 47:425.

Moser, B.D. 1977. Survival at weaning--oats can make a difference. Nebraska Swine Rep. E. C. 77-219.

National Research Council. 1973. Nutrient Requirements of Swine. National Academy of Sciences. Washington, D.C.

NCR-42 Committee on Swine Nutrition. 1969. Cooperative regional studies with growing swine: Effects of source of ingredients, form of diet and location on rate and efficiency of gain of growing swine. J. Anim. Sci. 29:927.

Noland, P.R. and K.W. Scott. 1960. Effect of varying protein and energy intakes on growth and carcass quality of swine. J. Anim. Sci. 19:67.

Palmer, N.C. and T.J. Hulland. 1965. Factors predisposing to the development of coliform gastroenteritis in weaned pigs. Can. Vet. J. 6:310.

Poijarvi, I. 1944. Digestion and utilization of wood cellulose by pigs. Acta. agral. fenn. 57:1-53. (Cited in Nutr. Abstr. and Rev. 24:232. 1954).

Pond, W.G., E. Kwong and J.K. Loosli. 1960. Effect of level of dietary fat, pantothenic acid and protein on performance of growing-fattening swine. J. Anim. Sci. 19:1115.

Pond, W.G., R.S. Lowrey and J.H. Maner. 1962. Effect of crude fiber level on ration digestibility and performance in growing-finishing swine. J. Anim. Sci. 21:692.

Quicke, G.V., O.G. Bentley, H.W. Scott, R.R. Johnson and A.L. Moxon. 1959. Digestibility of soybean hulls and flakes and the in vitro digestibility of the cellulose in various milling by-products. J. Dairy Sci. 42:185.

Real, C.E., T.D. Tanksley, Jr. and K.W. Purser. 1977. Effect of grain source, protein level and percentage of oats in starter diets for pigs weaned at four weeks of age. American Society of Animal Science 69th Annu. Meet. (Abstr.) p. 105.

Richards, W.P.C. and C.M. Fraser. 1961. Coliform enteritis of weaned pigs. A description of the disease and its association with hemolytic Escherichia coli. Cornell Vet. 51:245.

Rivera, E.R., W.D. Armstrong, A.J. Clawson and A.C. Linnerud. 1978. Effect of dietary oats and Kaolin on performance and incidence of diarrhea of weanling pigs. J. Anim. Sci. 46:1685.

Robison, W.L. 1939. Substitutes for corn for growing and fattening pigs. Ohio Agr. Exp. Sta. Bul. 607.

Schneider, B.H. and W.P. Flatt. 1975. The Evaluation of Feeds Through Digestibility Experiments. (1st ed.) University of Georgia Press, Athens.

Seerley, R.W., E.R. Miller and J.A. Hoefer. 1962. Growth, energy and nitrogen studies on pigs fed meal and pellets. J. Anim. Sci. 21:829.

Seerley, R.W., G.E. Poley and R.C. Wahlstrom. 1964. Energy and protein relationship studies with growing-finishing swine. J. Anim. Sci. 23:1016.

Smith, H. and I.A.M. Lucas. 1956. The early weaning of pigs. I. The effect upon growth of variations in the protein, fat, sucrose, antibiotics, vitamins and mineral contents of diets for pigs of 8-25 lbs live weight and comparisons to wet and dry feeding. J. Anim. Sci. 48:220.

Smith, H. and I.A.M. Lucas. 1957a. The early weaning of pigs. II. The performance up to 56 days of age of pigs weaned at 8, 14 and 20 lbs live weight. J. Anim. Sci. 49:405.

Smith, H. and I.A.M. Lucas. 1957b. The early weaning of pigs. III. The influence of protein supply during two stages of growth on the performance of pigs from 9 lbs to bacon weight. J. Agr. Sci. 49:409.

Smith, H.W. and S. Halls. 1967. Observations by the ligated intestinal segment and oral inoculation method on Escherichia coli. Infection in pigs, calves, lambs and rabbits. J. Path. Bact. 93:499.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods (6th ed.) Iowa State University Press, Ames, Iowa.

Stevens, A.J. 1963. Enteritis in pigs--a working hypothesis. Brit. Vet. J. 119:520.

Teague, H.S. and L.E. Hanson. 1954. The effect of feeding different levels of cellulosic material to swine. J. Anim. Sci. 13:206.

Thomlinson, J.R. 1969. Post-weaning enteritis and dysentery. Vet. Rec. 85:298.

Troelsen, J.E. and J.M. Bell. 1962. Ingredient and processing interrelationships in swine feeds. IV. Effects of various levels and kinds of fibrous diluents in finisher rations, fed as meal or pellets, on performance and carcass quality of swine. Can. J. Anim. Sci. 42:63.

Van Soest, P.J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Official Agr. Chem. 46(5):829.

Van Soest, P.J. 1967. Development of a comprehensive system of feed analysis and its application to forages. J. Anim. Sci. 26:119.

Van Soest, P.J. and R.H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. The determination of plant cell wall constituents. J. Assoc. Official Anal. Chem. 50:50.

Van Soest, P.J. and R.H. Wine. 1968. Determination of lignin and cellulose in acid-detergent fiber with permanganate. J. Assoc. Official Anal. Chem. 51:780.

Vathana, S. 1975. Dietary caloric density and caloric utilization by pigs. Michigan Agr. Exp. Sta. Res. Rep. 289:57.

Vestal, C.M. 1922. Fiber in rations for fattening swine. Amer. Soc. An. Prod. Proc., p. 43.

Wagner, G.R., A.J. Clark, V.W. Hays and V.C. Speer. 1963. Effect of protein-energy relationships on the performance and carcass quality of growing swine. J. Anim. Sci. 22:202.

Wahlstrom, R.C. and G.W. Libal. 1975. Varying levels of high-protein oats in diets for growing-finishing swine. J. Anim. Sci. 41:809.

Wahlstrom, R.C., L.J. Reiner and G.W. Libal. 1977. Oats, dehulled oats and hulless barley as ingredients in pig starter diets. J. Anim. Sci. 45:948.

Whiting, F. and L.M. Bezeau. 1957a. The metabolic fecal nitrogen excretion of the pig as influenced by the amount of fiber in the ration and by body weight. Can. J. Anim. Sci. 37:95.

Whiting, F. and L.M. Bezeau. 1957b. The metabolic fecal nitrogen excretion of the pig as influenced by the type of fiber in the ration and by body weight. Can. J. Anim. Sci. 37:106.

Woodman, H.E. and R.E. Evans. 1947a. The nutritive value of fodder cellulose from wheat straw. I. Its digestibility and feeding value when fed to ruminants and pigs. J. Agr. Sci. 37:202.

APPENDIX

APPENDIX A

MODIFIED CELL WALL DETERMINATION (NEUTRAL DETERGENT FIBER)

-- For High Starch Samples --

I. Solutions

A. Enzyme Solution.

1) Dissolve 3g Taka-Diastase^{R} and 3g Papain in 100 ml water.

B. Neutral Detergent Fiber Solution.

1) 18 liter distilled H_2O.

2) 540g sodium lauryl sulfate UPS.

3) 335g disodium ethylene Diaminetetraacetate (EDTA).

4) 122.6g sodium borate decahydrate (RG).

5) 321g disodium hydrogen phosphate (RG).

6) 180g 2 ethoxyethanol pure.

a. Put EDTA and $NaB_4O_7H_2O$ in large beakers with distilled H_2O and heat until dissolved.

b. Make solution of Na lauryl sulfate and 2 ethoxyethanol and add (a) to this.

c. Dissolve Na_2HPO_4 in H_2O and heat until dissolved and add to (b).

d. Check pH between 6.9 - 7.1.

C. Alpha-amylase.

1) From bacillus subtilis.

2) Type IIIA with optimum activity at pH 6.9 and 80°C.

II. Procedure

A. Weigh .5g sample into a fine mesh nylon bag 4 x 2 and place in a berzelious beaker.

B. Soak at least one hour in enzyme solution (10ml).

C. Add 50ml cold NDF solution.

D. Heat to boil for 1 hour and 10 minutes.

E. Remove from heat to cool (lukewarm).

F. Add 2ml alpha-amylase.

G. Filter into tared crucible or filter paper (#41).

H. Rinse twice with boiling water and twice with acetone.

I. Dry crucible (or paper) at 100°C for 8 hours.

J. Cool and weigh.

K. Report yield of recovered NDF as % cell wall constituents.

Calculation -- 100% Dry Matter Basis

$$\frac{\text{Tare - 8 hr dried wt}}{\text{Sample wt (gm)}} \times 100 = \frac{\%\text{ cell wall}}{\text{decimal DM \%}}$$

EFFECTS OF FEEDING OATS AND OAT HULLS ON PIG PERFORMANCE AND RATION DIGESTIBILITY OF WEANLING PIGS

by

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ABSTRACT

Six experiments involving 522 weanling pigs were conducted to determine the effects of increased levels of crude fiber from the addition of oats or oat hulls to the diet on post-weaning pig performance.

All growth trials were conducted for four or five weeks. The basal corn-soybean meal diet contained 22.18% crude protein, 1.00% lysine, .79% calcium, .69% phosphorus and an antibiotic. Heavy oats (38 lb. test weight) were used. The oats and oat hulls replaced the corn in the basal diet on an equal weight basis. Oat hulls were added to equal the crude fiber levels of diets with whole ground oats. In trial 1, twelve diets (control, 10, 20, 30, and 40% ground oats; 2.8, 5.5, 8.2, 10.9 and 16.4% ground oat hulls; and 20% oats with 5% fat and 40% oats with 5% fat) were fed to 228 Yorkshire pigs weighing an average of 8.4 kg. The pigs were randomly assigned to 36 pens representing three replications of each diet. Seven diets were used in the second trial (control, 20, 40, and 60% ground oats; 5.5 and 10.9% ground oat hulls; and 40% ground oats with 5% fat) using 98 pigs averaging 13 kg. All diets were pelleted. In the third trial, a 2 x 4 factorial experiment was used with four diets (control, 20, 40, and 60% ground oats) and pelleting versus meal. One hundred sixty pigs averaging 11.0 kg were used.

No statistical differences were observed for ADG, between treatments with added oats or oat hulls and the control corn-soybean meal diet, in all three growth trials. Pigs fed meal diets containing 16.4%

oat hulls and 60% ground oats (both 7.3% CF) had higher feed to gain ratios ($P<.05$) than those fed control diets; however, pelleting the diets resulted in no differences due to treatments. Although not significant, feed to gain ratios for pigs fed the different levels of oat hulls were slightly higher than for pigs fed ground oat diets at the same crude fiber level. Adding 5% fat to diets containing 20% and 40% oats resulted in better feed efficiency but no improvement in gain. Pelleting the experimental diets improved feed efficiency by about 7%. All pigs performed poorly the first seven days post-weaning, regardless of diet. Diarrhea was not a problem in the trials and daily fecal scores were similar for all treatments. Mortality was low in all three growth trials and none could be attributed to dietary treatment.

In the digestion trials, as the level of crude fiber was increased in diets containing 0, 20, 40 and 60% oats the apparent digestibility coefficients tended to be depressed for digestible energy, crude fiber and the Van Soest components of cell walls, cell content, acid detergent fiber, cellulose, hemicellulose and lignin. For diets containing 10% oats and 2.8, 5.5, 8.2 and 10.9% oat hulls, digestibility coefficients tended to be depressed for digestible energy, cell content, ADF and cellulose. Crude fiber digestibility coefficients were similar for diets containing 10% oats and 2.8, 5.5 and 8.2% oat hulls. Crude protein digestibility coefficients were similar in each trial. Apparent digestibility coefficients for lignin were similar for diets containing 10% oats and 2.8, 5.5 and 8.2% oat hulls, while they tended to be depressed as the crude fiber level in the diet increased with the addition of 20, 40 or 60% oats.