EFFECTS OF BLACK OIL SUNFLOWER SEEDS IN DIETS FOR NURSERY PIGS

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TABLE OF CONTENTS

LIST OF TABLES

REVIEW OF LITERATURE

SUNFLOWER SEEDS

Sunflower seed is produced primarily for the production of oil, however, those not suitable for oil production may be available for livestock feed. Compared with soybeans, cottonseed, and peanuts, the proteins of which are partially used as food ingredients, relatively little is known about the nature and potential of sunflower seed proteins (Lusas, 1985). Two distinct types of sunflower seeds are grown: oil and confectionary (non-oil). The oil types have small achenes and black, thinner hulls. Two fatty acids, oleic (C18:1) and linoleic (C18:2), constitute approximately 85% of sunflower oil with the other 15% consisting primarily of palmitic and stearic. No major antinutritional factors are present in raw sunflower seeds.

SUNFLOWER SEEDS IN SWINE DIETS

Marchello et al. (1984) evaluated the effects of feeding sunflower seeds on carcass quality, diet digestibility and feedlot performance of swine. Barley based diets containing 0, 13, 26, and 39% sunflower seeds were fed to growing-finishing swine. Carcass characteristics of firmness, marbling, and PSE score of pigs fed diets containing 13% or more sunflower seeds were generally poorer compared to pigs fed no sunflower seeds. Daily gains of pigs fed diets containing 0, 13, and 26% sunflower seeds were similar with a numerical ($P>.05$) decrease for pigs fed the diet containing 39% sunflower seeds. Digestion coefficients for DM, GE and fat were not different among treatments. However, there was a trend for digestibility of fat to increase with each additional increment of sunflower seeds. The digestibility of CP was higher in the diets in which sunflower seeds were substituted for barley-soybean meal ($P<.05$). Apparent digestibility seemed to be

greater in the sunflower seeds than in the barley-soybean meal diet. The addition of 13, 26, and 39% sunflower seeds to diets had an adverse effect on carcass characteristics. Firmness, marbling and PSE score generally decreased from that of the control. The most dramatic effect was on firmness, as the percentage of sunflower seeds in the diet increased, the carcasses became progressively softer ($P<.05$). Because of the deleterious effects on carcass quality, the addition of 13% or more sunflower seeds in diets for growing-finishing swine was not recommended.

Hartman et al. (1985) conducted two trials to determine the effect of various levels of sunflower seeds in finishing swine diets on growth performance, carcass traits, fatty acid composition of backfat and pork quality. Pigs were fed diets containing 0, 5, 10, or 20% sunflower seeds in Trial 1 and 0, 2.5, 5, or 10% sunflower seeds in Trial 2. In Trial 1, overall gain showed a cubic effect ($P<.05$) with pigs fed the 5% sunflower seeds having the highest ADG and pigs fed 20% sunflower seeds having the lowest ADG. In Trial 2, overall gain increased linearly ($P<.01$) with increasing level of sunflower seeds. Feed conversion was not affected by level of dietary sunflower seeds. Feed intake was depressed ($P<.06$) in Trial 1 when pigs were fed diets containing 10 or 20% sunflower seeds. In Trial 2, feed intake was not affected with increasing level of dietary sunflower seeds. Therefore, the differences seen in overall gain in Trial 1 may have been mostly affected by the reduction in feed intake of pigs fed diets containing 10 and 20% sunflower seeds. Iodine number of fat as well as subjective scores were both used to evaluate carcass firmness. Both measures indicated a progressive decrease in carcass firmness with increasing level of dietary sunflower seeds. The fatty acid composition of the backfat increased markedly in linoleic acid and decreased in all other fatty acids as dietary level of sunflower seeds increased. Sunflower seeds did not have any effect on quantitative carcass characteristics, chemical

composition or taste panel scores. These results indicate that up to 10% sunflower seeds can be used in growing-finishing swine diets without adversely affecting either growth performance or pork quality.

Sunflower seeds were also evaluated as a feed ingredient for swine in a growth trial, a digestion trial, and a finishing trial by Laudert, 1973. There were 20, 40 and 60% sunflower seeds in the diets for the growth and digestion trials. The addition of sunflower seeds in the diets of growing pigs resulted in a linear ($P<.05$) decrease in feed intake. At the 20 and 60% levels, there were no effects on daily gain, but daily gain of pigs fed the diet containing 40% sunflower seeds was reduced ($P<.05$). Feed efficiency improved as the level of sunflower seeds in the diet increased. In the digestion trial there were no differences in grams of N digested and grams of N retained ($P<.05$), but the percentage N retained decreased ($P<.05$) linearly as the level of sunflower seeds in the diet increased. Ether extract digestibility increased and GE digestibility decreased ($P<.05$) as the level of sunflower seeds increased in the diet. Apparent digestibility of sunflower seed was determined to be: DM 69 ± 4%, GE 77 ± 5%, ether extract 91 ± 3%, and CP 79 ± 5%. In the finishing trial, sunflower seeds were included in the diets at levels of 0, 25, or 50%. Average daily gain was greater ($P<.05$) for pigs fed the control diet than for pigs fed diets containing either 25 or 50% sunflower seeds. Feed intake decreased numerically as the level of sunflower seeds in the diet increased to 25%. There were no differences in feed efficiency. As the level of sunflower seeds in the diet increased, there was an increase in the total unsaturated fatty acids of both the backfat and the longissimus. Most dramatic was the increase in linoleic acid from 14.7% to 34.0% to 40.5% in the backfat samples of pigs fed diets containing 0, 25, and 50% sunflower seeds, respectively. A similar increase

was observed for linoleic acid in samples of longissimus from 9.0% to 25.3% to 38.1%, respectively.

In a digestion trial, Kepler (1981) evaluated diets containing 0, 25, and 50% sunflower seeds. The coefficients of apparent digestibility for GE decreased linearly ($P<.01$) from 81.6 to 79.1 and 72.7 for diets containing 0, 25, and 50%, respectively. Digestible energy increased linearly ($P<.05$) as the percentage of sunflower seeds increased from 0 to 50%. However, in examining the values for DE of 3,192, 3,499, and 3,486 kcal/kg for diets containing 0, 25, and 50%, respectively, a plateau was apparently reached at the 25% level. Coefficients of apparent digestibility for ether extract increased (linear and quadratic $P<.01$) with values of 20.6, 64.9, and 68.1% for 0, 25, and 50% sunflower seeds diets, respectively. Apparent digestibility of CP was reduced, numerically in pigs fed the 50% sunflower seeds diet. A decrease (linear and quadratic $P<.05$) in the coefficients of apparent digestibility for DM from the 0 to the 50% level of sunflower seed diets is a reflection of the decrease in apparent digestibility of all components except ether extract.

In evaluating the use of sunflower seeds in diets of late gestating and early lactating sows, Kepler et al. (1982) found no advantage of added sunflower seeds in sow diets with the exception of an increase in the fat content of milk. Diets containing 25 or 50% sunflower seeds were fed from day 100 of gestation through d 14 of lactation. Replacing part of the energy and protein in sow diets with 25% sunflower seeds had no adverse affect on sow or piglet performance. However, because of decreased intake of diets containing 50% sunflower seeds, this level of sunflower seeds is not recommended in sow diets.

The effect of dietary protein and fat levels on: (1) the utilization of the fat in sunflower seeds by the young pig and (2) whole body composition of pigs fed diets containing sunflower seeds was evaluated by Adams and Jensen (1985a). In a balance trial,

weanling pigs were fed two levels of fat and three levels of CP. Sunflower seeds containing 36% fat and 21% CP were added at 28 and 56% to formulate diets containing 10 and 25% dietary fat, respectively. Estimates of fat and N digestibility were corrected for endogenous fecal fat and N. As dietary CP increased, the values for corrected fat, DM, and GE digestibility decreased ($P<.01$) while N digestibility was not different. With an increase in dietary fat, the digestibility of DM, GE and ME decreased ($P<.01$) as well as the digestibility of N ($P<.05$). Fat digestibility was not affected by level of fat in the diet and N retention was not affected by either dietary CP or fat concentrations. The DE and ME values were calculated to be 4,207 and 3,984 kcal/kg for sunflower seeds. Following the balance trial, pigs continued to receive their respective diets for a total of 30 d. At the beginning of this trial, a subcutaneous fat sample was taken from the mid-shoulder region. On d 30, the pigs were sacrificed and a second fat sample was taken from the same region. Contents of the gastro-intestinal tract were removed and the carcasses were ground, sampled, and analyzed. Whole body concentrations of DM, fat, and energy decreased linearly ($P<.01$), while CP content increased linearly ($P<.01$) as dietary CP level increased. As dietary fat level increased, whole body concentration of DM, fat, and GE increased ($P<.05$) but CP concentration decreased($P<.05$). Average daily gain increased linearly ($P<.025$) as dietary CP level increased but tended to decrease as dietary fat level increased. Neither dietary fat or CP level affected the final whole body weights of DM, fat, energy, or ash, but increasing dietary CP level increased ($P<.01$) total body CP weight. Fatty acid profiles of the subcutaneous fat samples taken at the beginning and at the end of the trial were different. There were decreases ($P<.01$) in the proportions of 14:0, 16:0, and 16:1 as well as a decrease ($P<.05$) in 18:1. There were increases ($P<.01$) in the proportions of 18:2 and 18:3, indicating a direct incorporation of these fatty acids from sunflower

seed fat into body fat. Dietary fat level increased ($P<.05$) only the proportion of 18:2 in the fat samples while dietary protein had no effect on the composition of subcutaneous fat. These results indicate that the fat in sunflower seeds is highly digestible and the fatty acids in sunflower seed fat are directly incorporated into body fat. Therefore, sunflower seeds can be considered a good source of dietary fat for young pigs.

Adams and Jensen (1985b) evaluated the effect of processing (roasting and dehulling) on the utilization by young pigs of the fat in sunflower seeds. In a balance trial, weanling pigs were fed diets containing regular or roasted sunflower seeds or dehulled sunflower seeds that were formulated to be equal in fat, N, and lysine. The diets contained 56.0, 52.6, and 44.6% sunflower seeds, roasted sunflower seeds, and dehulled sunflower seeds, respectively. Fat excreted in the feces was corrected for endogenous fecal fat. The corrected values for fat, DM, GE, and N digestibility and the ME values were not different between regular and roasted sunflower seeds but roasting tended to decrease digestibility of fat in sunflower seeds. The fat in the dehulled sunflower seeds was less digestible ($P<.05$) than in the regular and roasted sunflower seed diets, while the DM and N were more digestible ($P<.05$). The decrease in fat digestibility was not expected but perhaps was a result of the fat level in the diet (27.5%) exceeding the absorptive capacity of the small intestine. Also, the particle size of the ground dehulled sunflower seeds, which was larger than that of the other diets, could have increased separation of the dietary ingredients in the stomach resulting in a lower digestibility in the small intestine.

Lin and Jensen (1983) fed diets containing 0, 5, and 10% dehulled sunflower seeds to young pigs to evaluate the utilization of dehulled sunflower seeds by growing pigs. In Experiment 1, a 28-d weanling pig performance evaluation, average daily gain was greater ($P<.01$) in pigs fed diets containing dehulled sunflower seeds. There were no differences

in feed intake, but there was a tendency toward improved ($P<.08$) feed efficiency for pigs fed diets containing dehulled sunflower seeds. In Experiment 2, performance of growing pigs was evaluated for 14 d. Average daily gain was greater ($P<.05$) for pigs fed diets containing 10% dehulled sunflower seeds. There were no differences in feed intake between dietary treatments, but there was an improvement ($P<.01$) in feed efficiency of pigs fed diets containing dehulled sunflower seeds compared to pigs fed the control diet.

Noland et al. (1980) compared the digestibility of dehulled sunflower seeds, a high energy, low fiber product from sunflower seeds, with soybean meal. In two metabolism trials, pigs were fed diets containing dehulled sunflower seeds at levels of 0, 8.0, 15.5, and 30.7%. Diets were balanced on a lysine basis with the use of synthetic lysine. The total replacement of soybean meal with dehulled sunflower seeds in the diet had no effect on the DE and apparent N retention of the experimental diets. However, pigs fed diets formulated by replacing only 25% of the soybean meal with dehulled sunflower seeds had the greatest coefficients ($P<.05$) of energy and protein digestibility and the greatest ($P<.05$) N retention. In comparing those diets containing dehulled sunflower seeds with the diet containing only soybean meal, the diets containing dehulled sunflower seeds were higher ($P<.05$) in protein digestibility. These results indicate that the GE and protein in diets with dehulled sunflower seeds were more digestible than the diet containing corn and soybean meal. The apparent N retention of the diets decreased as the amount of sunflower seeds in the diet increased.

The amount of heat required when processing sunflower seeds into sunflower meal was evaluated by feeding diets containing sunflower meal heated or unheated to growing rats (Amos et al., 1975). Rats fed sunflower meal processed at 100°C gained faster ($P<.005$) than rats fed unheated sunflower meal. However, sunflower meal heated to

127°C resulted in reduced daily gain ($P<.05$) than from the 100°C heated sunflower meal. Gains of rats fed unheated sunflower meal and sunflower meal heated to 127°C were the same. These data show that the nutritional value of sunflower meal is dependent on the temperature employed during processing of the seed for oil removal. Also, any benefit obtained from heating the seed at 100°C for one hr was lost in seed heated to 127°C for one hr due either to increased amino acid destruction or the degree of availability.

Gargallo and Zimmerman (1981) evaluated the nutritional value of sunflower hulls for finishing pigs. Sunflower hulls were fed at 2, 10 and 20% of the basal corn-soybean meal diet which was fed at 3% of body weight. The effect of dietary sunflower hulls on VFA concentration and production rate in the cecum and colon were estimated and the amount of VFA energy as a percent of maintenance energy was evaluated. They concluded that dietary sunflower hulls are not well utilized by finishing pigs.

UTILIZATION OF DIFFERENT FAT SOURCES BY THE YOUNG PIG

Cera et al. (1988a) evaluated the apparent digestibilities of fat from diets supplemented with 8% corn oil, lard, or tallow, fed to pigs weaned at 21 d for a four wk digestion trial. The corn oil supplemented diet had a relatively low level of saturated fatty acids (15%) and a high proportion of unsaturated fatty acids (85%). The diets supplemented with lard and tallow had a higher level of saturated fatty acids (35%) and lower levels of unsaturated fatty acids (65%). A larger quantity of fat was apparently absorbed ($P<.01$) during wk 1 postweaning from diets containing corn oil than from diets with lard or tallow, but all diets were similar from wk 2 to 4. Apparent digestibilities of fat were higher ($P<.05$ wk 1 and 2, $P<.01$ wk 3 and 4) each wk postweaning for the corn

oil than for the lard or tallow diets. Pigs fed the corn oil diet tended ($P<.10$) to have a higher DM digestibility than pigs fed the lard or tallow diets during wk 1 and 2 postweaning. These results indicate that diet utilization by the weanling pig, particularly dietary fat absorption, N retention, fat digestibility, and DM digestibility, were influenced by supplemental fat source.

In evaluating the effects and interactions of supplemental dietary corn oil and dried whey on growth rate, feed intake, efficiency of feed utilization, apparent fat digestibility, and apparent N retention of weanling pigs, Cera et al. (1988b) fed diets containing levels of either 0 or 6% corn oil in a factorial arrangement with either 0 or 25% dried whey. The results of these experiments indicated that incorporation of dried whey in the diet of weanling pigs enhanced growth rate, which was associated with greater feed intakes and improved feed efficiency. Added corn oil in the diets did not influence the growth rate or feed efficiency of young swine.

The utilization of dietary fat by weanling pigs was also evaluated by Cline et al. (1977). Pigs were fed diets with a constant protein:calorie ratio which were formulated to contain 43, 58, and 74% of the non-protein calories from fat. They found that the young pig is capable of utilizing fat calories efficiently.

Allee et al. (1971) investigated the effects of dietary fat on performance of young pigs fed diets in which each nutrient was kept in a constant ratio to metabloizable energy. In three experiments, it was demonstrated that the young pig is capable of utilizing fat calories as effectively as carbohydrate calories.

Ohh et al. (1983) examined the effect of particle size of corn and sorghum grain on performance and nutrient digestibility of weanling pigs. Corn and sorghum grain were both ground through a hammermill equipped with either a 3.2 mm or 6.4 mm screen or dry rolled to a fine or coarse particle size. Particle size did not affect either ADG or average daily feed intake. However, reducing particle size of the grain improved ($P<.05$) efficiency of feed utilization. Gross energy digestibility and CP digestibility both increased ($P<.05$) as particle size of the grain in the diets decreased.

Goodband and Hines (1988) conducted experiments with weanling pigs fed barley based diets to determine the effects of particle size on performance characteristics. Barley in the diets processed using a hammermill equipped with a 3.2 mm resulted in a smaller mean particle size and greater surface area for both the ground grain and complete diets than those processed through a 4.8 mm screen. Reducing particle size of barley based diets fed to starter pigs improved both ADG and feed efficiency. This suggested that perhaps fine grinding had a greater potential for improving feed efficiency with a high-fiber cereal grain such as barley than with either corn or grain sorghum.

Wu (1985) evaluated the effects of particle size and surface area of corn, sorghum grain, and wheat on pig performance and nutrient digestibility. Two growth and two digestion trials were conducted using weanling pigs fed corn diets ground through a hammermill equipped with a 3.2 mm, 6.4 mm, or 12.8 mm screen or sorghum grain diets ground through a hammermill equipped with a 3.2 mm or 6.4 mm screen or through a roller mill. Average particle diameter of the corn based diets increased from 524 to 864 to 1,117 microns with respective increases in hammermill screen diameter. There were no

differences in ADG or feed intake between dietary treatments. However, there was an improvement ($P<.06$) in feed efficiency as dietary particle size decreased from 1,117 to 524 microns. The apparent digestion coefficients for DM, N and GE all increased ($P<.05$) between pigs fed diets ground through a hammermill equipped with a 3.2 mm screen and pigs fed diets ground through a 6.4 mm screen, but there were no differences between pigs fed diets ground through a hammermill equipped with a 6.4 mm screen and pigs fed diets ground through a 12.8 mm screen. Average particle size of the grain sorghum diets were 704, 1,125 and 994 microns from diets ground using a hammermill equipped with a 3.2 mm and a 6.4 mm screen and through a roller mill, respectively. There were no differences found between dietary treatments in either performance characteristics or digestion coefficients for grain sorghum based diets.

The effect of reducing particle size by rolling and grinding on nutrient digestibilities measured at the terminal ileum and over the total digestive tract of growing-finishing pigs was investigated by Owsley et al. (1981). Sorghum grain was processed into three distributions of particle sizes by dry rolling (coarse), grinding through a 6.4 mm hammermill screen (medium), and grinding through a 3.2 mm hammermill screen (fine). Six 30-kg barrows were each surgically fitted with a simple T-cannula approximately 15 cm cranial to the ileocecal junction. Average daily gain (grams) and gain to feed of the cannulated animals for test periods 1 through 3 were 479 and .40, 601 and .39 and 606 and .33, respectively. The finely ground sorghum diet had higher ($P<.05$) apparent digestibilities of N, DM, starch and GE over the total digestive tract and higher ($P<.05$) DE and ME contents than did the diets formulated using the medium and coarsely ground sorghum. Total tract digestibilities for the diets prepared using the medium and coarsely ground sorghum were nearly identical. However, the apparent ileal digestibility of DM, starch, GE

and N improved ($P<.05$) with each successive reduction in particle size. The disappearance of these dietary components in the large intestine increased ($P<.01$) the mean total tract digestibility values. The amounts of starch, DM, and GE disappearing in the large intestine were affected by sorghum particle size, with the greatest ($P<.05$) losses occurring with the coarsely ground sorghum diet. This clearly indicates that digestion in the large intestine, a less efficient utilization of energy than absorption in the small intestine, can greatly affect total tract digestibilities of dietary components. The higher digestibility of N in the finely ground diet resulted in greater ($P<.05$) N absorption per day, but this was offset by increased ($P<.05$) urinary N losses. As a result, N retention per day was similar ($P<.10$) for pigs fed all three diets. There were no differences between the diets in lysine digestibility measured at the terminal ileum. The finding of similar ileal lysine digestibility for the treatments has a special significance, since lysine is the first limiting amino acid for sorghum-soybean meal diets. These data suggest that improved feed efficiency resulting from fine grinding of sorghum in swine diets would indicate an increased utilization of dietary energy rather than dietary protein.

PELLETING SWINE DIETS

Jensen and Becker (1965) investigated the effects of pelleting diets and dietary components for pigs weaned between 2 and 3 weeks of age. No advantage was seen in gain when diets, whole or in part, were subjected to the pelleting process. However, diets fed in the pelleted form produced a 13.8% improvement in feed efficiency. Diets utilizing grain that had been pelleted and then reground prior to mixing resulting in a 10.3% improvement in feed efficiency. It was noted that the chemical characteristics of the diet

or its components were chemically altered as a result of pelleting. Proximate analysis of corn samples taken prior to and after pelleting showed that pelleting resulted in less crude fiber and more total N ($P<.05$). Enzymatic digestion of the same corn samples indicated that pelleting had rendered the starch fraction of corn more susceptible to enzyme action.

The NCR-42 Committee on Swine Nutrition (1969) conducted a cooperative experiment to compare the performance of pigs fed diets as a meal or pelleted. Pigs initially weighing 20 to 22 kg were fed the experimental diets. Thirty pens per treatment were included in the analysis. There were no differences found in daily gain but there was an improvement ($P<.01$) in gain to feed ratio when pigs were fed diets in the pelleted form compared to diets fed in the meal form.

Seerley et al. (1962a) evaluated the effect of pelleting swine rations on rate of gain, feed efficiency, apparent DE, and apparent digestible N when paired pigs were equally fed meal or pelleted diets to between 82 and 91 kg and then ad libitum fed to a heavier weight. Three experimental diets were formulated; the first was corn-soybean meal based, the second and third were formulated by replacing 20 and 40% of the corn with oats respectively on an equal weight basis. One half of each diet was made into 4.8 mm pellets. Pelleting the corn-based diet improved ($P<.05$) rate of gain and feed efficiency when feed intake was equal. There were similar trends in the 20 and 40% oat diets but the differences were not significant. Pigs fed pelleted diets containing 20 and 40% oats ad libitum gained faster ($P<.05$) than their meal-fed counterparts. Pigs fed corn-based diets followed a similar trend but the differences were not significant. In both the equal and ad libitum feeding, the apparent digestibility of the corn-based diet was greater ($P<.05$) when fed in the pelleted form compared to the meal form. When feed intake was equal, the apparent energy digestibility of the 40% oat diet was not different for the meal form

compared to the pelleted form but when fed ad libitum, energy digestibility of the meal form was improved ($P<.05$) compared to the pelleted form. Apparent N digestibility was the same for the corn-based and 40% oats diets when fed in either the meal or pellet form.

In order to understand differences found between diets fed to pigs in pelleted or meal forms, Seerley et al. (1962b) compared the rates of passage through the alimentary tract of pigs. Comparisons were made of food passage in pigs fed meal to those fed an equal amount of pelleted feed. Later the same pigs were used to evaluate ad libitum feeding of meal and pelleted diets. Two experimental diets were evaluated. The first was corn-soybean meal based and the second was a diet with 40% of the corn replaced by oats on an equal weight basis. It was postulated that particle passage was an indication of the rate of food passage through the alimentary tract. By thoroughly mixing colored particles with each day's diet, the time the feed remained in the alimentary tract was estimated by recording the time fed and the average particle excretion time. Because the initial and final excretion of particles varied greatly, the 5% excretion time, the 95% excretion time and the average retention time were used to evaluate the data. The 5% excretion time of the 40% oat diet was faster ($P<.05$) when fed on an equal basis in the pelleted form compared to the meal form. The 95% excretion time for the corn-based diet was faster ($P<.05$) when fed in the pellet form. The mean retention time was less ($P<.05$) with the pelleted diets than with the meal fed diets. When the data from both diets were combined into equal-fed or ad libitum-fed, the 5% excretion time, the 95% excretion time, and the mean retention time all indicated that particle passage was faster with pelleted diets ($P<.05$). The effect of feed intake as related to rate of passage was not consistent between pigs fed meal and pelleted diets. The pellet-fed pigs consumed more feed during the ad libitum

phase of the passage study than during the equal feeding phase, causing a decrease in mean retention time. The meal-fed pigs also increased their feed intake when fed ad libitum compared with equal feeding but mean retention time was slightly increased. Higher feed intake increased the rate of passage with pelleted diets, but slightly reduced rate of passage with meal-fed diets.

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EFFECTS OF BLACK OIL SUNFLOWER SEEDS IN DIETS FOR NURSERY PIGS

ABSTRACT

Three experiments, utilizing 624 crossbred pigs weaned at 21 to 28 d of age, were conducted to evaluate the effects of level of dietary inclusion and processing (roasting, pelleting, fine grinding) sunflower seeds (SFS) on performance characteristics and apparent digestibility. Diets were formulated containing 0, 10, 15, 20 and 25% SFS. The inclusion of SFS in nursery pig diets resulted in a linear ($P<.01$) decrease in ADG and average daily feed intake (ADFI), but a linear ($P<.01$) improvement in feed efficiency (G/F). The apparent dry matter digestibility (DMD) was not affected by SFS, but apparent nitrogen digestibility (ND) ($P<.01$) and total fat digestibility (TFD) ($P<.02$) improved linearly due to dietary SFS level. Pigs fed diets containing 15% SFS performed as well as pigs fed the control diet. Reduced particle size diameter of nursery diets containing SFS resulted in improved DMD, ND and TFD ($P<.01$). Average daily gain of pigs fed diets containing 25% SFS ground through a hammermill equipped with a 3.2 mm screen was similar to pigs fed 15% SFS. Pigs fed diets containing 25% SFS roasted to an exit temperature of 125°C had improved overall G/F ($P<.02$), but no significant differences in ADG, ADFI, DMD, ND or TFD. Pelleting diets containing 25% SFS resulted in a 10% improvement ($P<.01$) in G/F, with no differences in ADG, ADFI, DMD, ND or TFD. These data indicate that SFS can be included in nursery pig diets up to 15% with no impairment in performance. Fine grinding or pelleting diets and roasting SFS improved performance of pigs fed diets containing 25% SFS resulting in similar performance to those pigs fed the control or 15% SFS diets.

(Key Words: Nursery Pigs, Sunflower Seeds, Particle Size, Roasting, Pelleting.)

Introduction

The number of acres devoted to the production of sunflower seeds (SFS) in Kansas increased from 64,000 in 1982 to over 195,000 in 1988. Although SFS are used primarily for the production of oil, all SFS are not suitable for oil production and, therefore, may be available for use in swine diets.

The effects of dietary SFS on both performance and carcass characteristics of growing and finishing pigs have been evaluated (Hartman, et al., 1985; Laudert, 1973; Marchello, et al. 1984). Although ADG of pigs fed 60% SFS diets was not significantly affected, the incorporation of the highly unsaturated fat of SFS into swine carcasses caused a reduction in the quality of pork produced. Therefore, inclusion of more than 10% SFS in swine finishing diets is not recommended. Kepler, et al.,(1982) concluded that SFS could be included in diets of late gestating and early lactating sows at 25% with no reduction in feed intake but diets containing 50% SFS caused initial feed intake problems and are therefore, not recommended. The fat in SFS has been found highly digestible by the young pig, suggesting that SFS can be a good source of dietary fat for young pigs (Adams and Jensen, 1985a). Processing high fiber barley diets to a smaller particle diameter was found to improve performance of weaned pigs (Goodband and Hines, 1988). Also, pelleting nursery pig diets has been observed to improve feed efficiency (Jensen and Becker, 1965; NCR Committee on Swine Nutrition, 1969; Seerley et al., 1962). Adams and Jensen (1985b) observed that roasting SFS tended to decrease fat digestibility in young pigs, but Amos et al. (1975), found that rats fed sunflower meal processed at 100°C gained faster than rats fed sunflower meal either unheated or processed at 127°C.

Therefore, this series of experiments was designed to evaluate the effects of level of dietary inclusion and processing (roasting, pelleting, fine grinding) SFS on performance characteristics and apparent digestibility of weaned pigs.

Experimental Procedure

Three experiments utilizing 624 crossbred pigs weaned at 21 to 28 d of age were conducted in an environmentally controlled nursery facility. Experiment 1 and 3 were arranged in a randomized complete block design, Experiment 2 was arranged in a randomized incomplete block design. Pigs were allotted randomly to dietary treatment on the basis of weight, ancestry and sex and were housed in 1.2-m by 1.5-m pens with woven wire flooring. Pigs were given feed and water ad libitum during each 35 d trial. All diets were formulated to contain 1.25% lysine and to meet or exceed all other nutrient estimates of the 5 to 10 kg pig (NRC 1988). Pigs and feeders were weighed weekly and feed additions were recorded. ADG, average daily feed intake (ADFI) and feed efficiency (G/F) were determined. Digestibility of DM (DMD), nitrogen (ND) and total fat (TFD) were determined by the indirect method using chromic-sesquaoxide at .3% of the diet. Diets containing the marker were fed to pigs four days beginning on d 14. Feces samples were then collected from four pigs/pen and frozen at −20°C. Samples were dried, ground and pooled by pen for analysis of DM and N (AOAC 1984) and TFD (Sukhija and Palmquist, 1988). Chromic sesquaoxide content of feed and feces was determined using the method of Williams et al. (1962).

The SFS used in each experiment were the black-oil type. Chemical analysis and amino acid content (AOAC, 1984) of raw (R), low-roast (LR) and high-roast (HR) SFS used in Experiment 3 are presented in Table 1.

Experiment 1. Corn, soybean meal, 20% dried whey diets containing 0, 10, 15, 20 or 25% SFS (Table 2), were evaluated using 240 weaned pigs. Each of the five treatments was replicated six times with eight pigs per pen averaging 5.9 kg initial weight. The corn and SFS in all diets were ground through a hammermill equipped with a 3.2 mm screen. Diets contained a minimum of 20.1 CP (analyzed).

Experiment 2. One hundred ninety-two pigs, averaging 5.9 kg initial weight, were used, in a 2 by 2 factorial arrangement with a control treatment, to evaluate corn, soybean meal, dried whey diets containing 0, 15 or 25% SFS (Table 2). The SFS diets were ground through a hammermill equipped with either a 3.2 mm or 4.8 mm screen and the control diet was ground through a hammermill equipped with a 4.8 mm screen. The four SFS treatments were replicated five times with eight pigs per pen and the control diet was replicated four times with eight pigs per pen. Data from two samples of each diet obtained for determination of mean particle diameter, SD of particle size, surface area and number of particles/gram (ASAE, 1973), are presented in Table 3.

Experiment 3. One hundred twelve pigs were utilized to evaluate diets containing 0 or 25% R or LR or HR SFS fed either as meal or pellets in a 3 by 2 factorial arrangement with a control treatment. The roasting was accomplished using a gas-fired roaster (Roast-A-Tron, manufactured by Mix-Mill, Inc., Bluffton, Indiana). Average roaster exit temperatures were 125°C and 160°C for the LR and HR SFS, respectively. Rice hulls (9.86%) and soybean oil (10%) were added to the control diet to approximate the crude

TABLE 1. CHEMICAL ANALYSIS OF BLACK OIL SUNFLOWER SEEDS

Item	Percentage[a]		
	Raw	Low-roast	High-roast
DM	93.36	97.59	98.74
Ether extract	43.74	45.60	44.90
CP	17.88	19.14	18.36
Crude fiber	25.80	23.80	30.16
Ash	3.48	3.67	4.01
Ca	.43	.18	.20
P	.58	.61	.59
Amino acids			
Alanine	.89	.75	.76
Arginine	1.25	1.08	1.16
Aspartic acid	1.68	1.72	1.67
Cystine	.27	.25	.20
Glutamic acid	3.00	3.13	3.14
Glycine	.87	.96	.98
Histidine	.38	.46	.43
Isoleucine	.64	.67	.67
Leucine	.92	.94	1.01
Lysine	.55	.56	.41
Methionine	.31	.31	.27
Phenylalanine	.64	.67	.64
Proline	.59	.73	.70
Serine	.67	.70	.52
Threonine	.58	.63	.61
Tryptophan	.23	.20	.22
Tyrosine	.23	.29	.28
Valine	.74	.79	.83

[a]As-fed basis.

TABLE 2. COMPOSITION OF EXPERIMENTAL DIETS[a]

Item	Sunflower seed, %					
	0	0	10	15	20	25
Ingredient, %						
Corn	44.62	28.76	41.04	37.07	33.10	29.13
Soybean meal (48% CP)	27.28	27.28	24.91	23.89	22.87	21.85
Sunflower seeds	——	——	10.00	15.00	20.00	25.00
Dried whey[b]	20.00	20.00	20.00	20.00	20.00	20.00
Soy oil	4.00	10.00	——	——	——	——
Rice hulls	——	9.86	——	——	——	——
L-lysine HCl	.10	.10	.10	.10	.10	.10
Monocalcium phosphate	1.68	1.68	1.68	1.69	1.71	1.73
Limestone	.72	.72	.68	.65	.62	.59
Salt	.10	.10	.10	.10	.10	.10
Trace mineral premix[c]	.10	.10	.10	.10	.10	.10
Vitamin premix[d]	.25	.25	.25	.25	.25	.25
Copper sulfate[e]	.10	.10	.10	.10	.10	.10
Se premix[f]	.05	.05	.05	.05	.05	.05
Antibiotic[g]	1.00	1.00	1.00	1.00	1.00	1.00
Chemical analysis[h]						
CP, %	20.67	20.72	20.32	20.12	20.62	20.44
Crude fiber, %	2.20	6.20	3.70	4.60	5.10	6.10
Calculated analysis						
Lysine, %	1.25	1.25	1.25	1.25	1.25	1.25
Ca, %	.90	.90	.90	.90	.90	.90
P, %	.80	.80	.80	.80	.80	.80
ME, kcal/kg	3,440	3,309	3,329	3,359	3,386	3,417

[a]Diets were formulated for Exp. 1 contained 0, 10, 15, 20, and 25% SFS; for Exp. 2 contained 0, 15 and 25% SFS; for Exp. 3 contained 0% SFS with 9.86% rice hulls and 10% soy oil and 25% R or LR or HR SFS.

[b]Extra grade, edible dried whey.

[c]Contained 10% Mn, 10% Fe, 10% Zn, 4% Ca, 1% Cu, .4% K, .3% I, .2% Na, and .1% Co.

[d]Each kg of premix contained: vitamin A, 4,840,000 IU; vitamin D_3, 484,000 IU, vitamin E, 19,360 IU; menadione, 1,936 mg; riboflavin, 4,840 mg, pantothenic acid, 12,100 mg; niacin, 26,620 mg; choline, 484,000 mg; and vitamin B_{12}, 24 mg.

[e]Provided 250 ppm Cu.

[f]Contained 600 mg Se/kg premix.

[g]Contained 5.5 g carbadox/kg premix.

TABLE 3. PARTICLE SIZE ANALYSIS OF SUNFLOWER SEED DIETS (EXP. 2)

Item	Sunflower seed, %/screen size, mm				
	0/4.8	15/3.2	15/4.8	25/3.2	25/4.8
Mean particle diameter, μm	667.16	610.40	662.47	570.38	615.78
SD of particle size	1.87	1.79	1.87	1.75	1.80
Surface area, cm^2/g	82.88	88.26	83.41	93.34	87.85
Number of particles/g	14,883	15,375	15,112	16,943	15,547

fiber and oil content of the SFS diets (Table 2). Corn and SFS in all dietary treatments were ground using a hammermill equipped with a 4.8 mm screen. The control diet was fed in the meal form. All treatments were replicated four times with four pigs per pen averaging 7.3 kg initial weight.

Statistical Analysis. Data were analyzed using the GLM procedure of SAS (1982). Linear and quadratic contrasts of SFS level were tested in Experiments 1 and 2. In Experiment 3, treatment and block were included in the model to determine treatment effects. Then the control treatment was deleted and main effects of roasting and pelleting were analyzed in a 2 by 3 factorial to determine the probability values. No interactions were observed between block and treatment, roasting or pelleting. Pen was the experimental unit in all three experiments.

Results and Discussion

Experiment 1. At d 14, increasing the percentage SFS in nursery pig diets did not affect ADG, ADFI or G/F (Table 4). Increasing percentage SFS in diets decreased ADG, ADFI and improved G/F at d 35 linearly ($P<.02$). Percentage SFS in diets increased DMD, ND and TFD ($P<.02$) linearly. Pigs fed diets containing 15% SFS performed similar in ADG and G/F to pigs fed the control diet. These results are consistent with reports that diets containing up to 10% SFS had no deletrious effects on growing pig performance, but ADG and ADFI of growing-finishing pigs fed diets containing more than 20% SFS were decreased (Marchello et al., 1984; Laudert, 1973; Hartman et al., 1985). Laudert (1973) found pigs fed SFS diets had an improved feed efficiency. Kepler (1981), found ether extract digestibility of diets containing SFS was increased, but DMD was reduced. Laudert (1973) also observed an increase in ether extract digestibility with increasing levels of SFS

TABLE 4. EFFECTS OF SUNFLOWER SEED ON GROWTH PERFORMANCE AND APPARENT DIGESTIBILITIES (EXP. 1)[a]

Item	Sunflower seed, %					CV
	0	10	15	20	25	
ADG, g						
0 to 14 d	173	159	181	156	146	18.29
0 to 35 d[b]	386	376	378	350	348	5.90
Average daily feed intake, g						
0 to 14 d	296	281	313	262	274	11.95
0 to 35 d[b]	690	676	673	594	593	6.48
Gain/feed						
0 to 14 d	.579	.569	.576	.592	.536	12.36
0 to 35 d[b]	.560	.559	.562	.589	.587	3.28
DM digestibility, %[b]	73.17	75.49	75.82	79.02	79.66	5.98
N digestibility, %[b]	68.96	75.62	75.29	79.07	80.68	6.04
Total fat digestibility, %[b]	77.55	82.74	84.34	86.51	86.73	4.57

[a]Two hundred forty weaned pigs with avg initial and final wt of 5.8 and 18.7 kg, respectively, were used in the 35-d trial. Each treatment was assigned to six pens (eight pigs/pen). Fecal samples were obtained from four pigs/pen and pooled for determination of apparent digestibilities.

[b]Linear effect of SFS level ($P<.02$).

in the diet but DMD was not affected. Increased CP digestibility was observed by Marchello et al. (1984) in SFS diets with no differences in DMD or fat digestibility. In contrast, Adams and Jensen (1985a) observed decreased DMD and ND with no effect on fat digestibility as fat was added to diets (10 and 25%) in the form of SFS (28 and 56%). The decreased DMD and ND were probably a reflection of the high crude fiber content (16.4%) of diets containing 56% SFS, since dietary sunflower hulls are not well utilized by pigs (Gargallo and Zimmerman, 1981).

Experiment 2. Diets containing 15 and 25% SFS processed through a hammermill equipped with a 3.2 mm compared with 4.8 mm screen resulted in a mean particle diameter of 610 and 570 μm compared with 667 and 662 μm, respectively, with a corresponding larger surface area for those diets ground through a hammermill equipped with a 3.2 mm screen (Table 3).

At d 14, there were no differences in ADG, but increasing dietary percentage SFS resulted in a linear ($P<.05$) reduction in ADFI (Table 5). Decreased particle size of diets resulted in an improvement ($P<.02$) in G/F at d 14. Increasing the percentage SFS in diets resulted in a linear reduction in ADG and ADFI ($P<.05$) at d 35. Pigs fed a 25% SFS diet ground through a hammermill equipped with a 3.2 mm screen had a 6.5% increase in ADFI and 5.8% improvement in ADG compared with those fed the 25% SFS diet ground through a hammermill equipped with a 4.8 mm screen, which compared favorably with the performance of pigs fed 15% SFS diets. The increase ($P<.02$) in DMD, ND and TFD due to a reduction in particle size of diets indicates an improved utilization of those diets ground through a hammermill equipped with a 3.2 mm screen. The improvement in ND ($P<.02$) and TFD ($P<.05$) are similar to the results of Exp. 1. A reduction in DMD of 25% SFS diets was expected due to increased crude fiber, as observed when the diet was

TABLE 5. EFFECTS OF PARTICLE SIZE OF SUNFLOWER SEED DIETS ON GROWTH PERFORMANCE AND APPARENT NUTRIENT DIGESTIBILITIES (EXP. 2)[a]

Item	Sunflower seed level %/screen size, mm				Control	CV
	15/3.2	15/4.8	25/3.2	25/4.8		
ADG, g						
0 to 14 d	239	234	221	198	248	18.07
0 to 35 d[b]	377	382	366	346	391	11.08
Average daily feed intake, g						
0 to 14 d[b]	350	356	311	318	375	13.20
0 to 35 d[b]	669	656	616	578	679	10.67
Gain/feed						
0 to 14 d[d]	.681	.652	.708	.616	.660	8.47
0 to 35 d	.566	.582	.593	.597	.576	4.48
DM digestibility, %[c]	85.41	81.56	86.92	79.42	85.17	1.76
N digestibility, %[c]	83.33	81.50	86.20	81.18	79.91	1.56
Total fat digestibility, %[bc]	89.19	85.52	93.00	87.85	87.68	1.87

[a]One hundred ninety-two weaned pigs with avg intial and final wt of 5.9 and 19.0 kg, respectively, were used in the 35-d trial. Each treatment was assigned to five pens (eight pigs/pen). Fecal samples were obtained from four pigs/pen and pooled for determination of apparent digestibilities.

[b]Linear effect of SFS level ($P < .05$).

[c]Particle size effect ($P < .02$).

ground through a 4.8 mm screen. Grinding the 25% SFS diet through a 3.2 mm screen improved DMD, reducing the effect of the increased crude fiber. The improved utilization of SFS diets ground finely through a hammermill equipped with a 3.2 mm screen is consistent with reports that particle size reduction improved nutrient digestibility of feed ingredients by increasing particle surface area, allowing for greater interaction with digestive enzymes (Owsley et al., 1981; Ohh et al., 1983; Wu, 1985). The improvement in G/F at d 14 of the high fiber, 25% SFS diet is consistent with the conclusion of Goodband and Hines (1988) that fine grinding high fiber dietary components improved feed efficiency of young pigs.

Experiment 3. The control diet was formulated using 9.86% rice hulls to approximate the fiber content of the SFS diets, since sunflower hulls are not well utilized by pigs (Gargallo and Zimmerman, 1981). At d 35, pigs fed the diet containing LR SFS had improved ($P<.02$) G/F compared to those fed R SFS (Table 6). However, there were no differences observed in ADG and ADFI due to roasting SFS. Pelleting nursery pig diets containing SFS also improved G/F at d 35 as well as G/F and ADG at d 14. The 10% improvement ($P<.01$) in G/F at d 35 with no difference in either ADG or ADFI observed when pigs were fed pelleted diets compared to pigs fed meal diets is consistent with results of other research (Jensen and Becker, 1965; NCR Committee on Swine Nutrition, 1969). There were, however, no differences observed in DMD, ND or TFD due to pelleting, indicating the improvement in G/F was not due to improved digestibility.

The 7% improvement in G/F of pigs fed the LR compared to the R SFS diet at d 35 is similar to the report of Amos et al. (1975), that rats fed sunflower meal heated to 100°C gained faster than those fed either unheated sunflower meal or sunflower meal heated to 127°C. In contrast, Adams and Jensen (1985b) reported a tendency towards

TABLE 6. MAIN EFFECTS OF ROASTING SUNFLOWER SEEDS AND PELLETING DIETS ON GROWTH PERFORMANCE AND APPARENT DIGESTIBILITIES (EXP. 3)[a]

Item	Roast			Form of diet		Control	CV
	Raw	Low	High	Meal	Pellet		
ADG, g							
0 to 14 d	236	233	252	235	245	220	16.66
0 to 35 d	436	436	448	430	450	406	7.89
Average daily feed intake, g							
0 to 14 d[b]	356	342	363	383	324	382	9.46
0 to 35 d	719	667	719	721	683	719	7.51
Gain/feed							
0 to 14 d[b]	.672	.678	.702	.609	.760	.564	11.03
0 to 35 d[bc]	.610	.653	.623	.599	.659	.561	4.55
DM digestibility, %	83.29	83.99	81.58	82.69	83.22	75.59[d]	3.40
N digestibility, %	83.35	83.48	81.57	83.57	82.03	78.02	5.66
Total fat digestibility, %	88.32	90.08	89.50	87.95	90.65	84.33	4.93

[a]One hundred twelve pigs with avg initial and final wt of 7.2 and 22.5 kg, respectively, were used for the 35-d trial. Each treatment was assigned to four pens (four pigs/pen). Fecal samples were obtained from all pigs and pooled by pen for determination of apparent digestibilities. The number of observations for the main effects of roasting and pelleting were each 24.

[b]Pellet effect ($P < .01$).

[c]Roasting effect ($P < .02$).

[d]Control different from all treatments ($P < .02$).

reduced fat and energy digestibility of roasted SFS diets and concluded that roasting decreased the availability of the fat. These results could be due to the relatively high levels (22%) of dietary fat in their experiment. Proximate analysis of R, LR and HR SFS (Table 1) used in Exp. 3, indicated increased rather than decreased ether extract of roasted compared to R SFS. Roasting resulted in no differences in TFD, indicating no effect on the availability of fat.

Implications

Nursery pigs can effectively utilize 15% raw SFS in diets with no detrimental effects on performance. Roasting SFS to an exit temperature of 125°C or fine grinding or pelleting nursery pig diets containing SFS allows inclusion of 25% SFS with no reduction in performance. Fine grinding improved digestibility of dry matter, total fat and nitrogen, therefore resulted in improved performance. No differences in digestibility of dietary components were observed due to pelleting or roasting.

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EFFECTS OF BLACK OIL SUNFLOWER SEEDS IN DIETS FOR NURSERY PIGS

by

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ABSTRACT

Three experiments, utilizing 624 crossbred pigs weaned at 21 to 28 d of age, were conducted to evaluate the effects of level of dietary inclusion and processing (roasting, pelleting, fine grinding) sunflower seeds (SFS) on performance characteristics and apparent digestibility. Diets were formulated containing 0, 10, 15, 20 and 25% SFS. The inclusion of SFS in nursery pig diets resulted in a linear ($P<.01$) decrease in ADG and average daily feed intake (ADFI), but a linear ($P<.01$) improvement in feed efficiency (G/F). The apparent dry matter digestibility (DMD) was not affected by SFS, but apparent nitrogen digestibility (ND) ($P<.01$) and total fat digestibility (TFD) ($P<.02$) improved linearly due to dietary SFS level. Pigs fed diets containing 15% SFS performed as well as pigs fed the control diet. Reduced particle size diameter of nursery diets containing SFS resulted in improved DMD, ND and TFD ($P<.01$). Average daily gain of pigs fed diets containing 25% SFS ground through a hammermill equipped with a 3.2 mm screen was similar to pigs fed 15% SFS. Pigs fed diets containing 25% SFS roasted to an exit temperature of 125°C had improved overall G/F ($P<.02$), but no significant differences in ADG, ADFI, DMD, ND or TFD. Pelleting diets containing 25% SFS resulted in a 10% improvement ($P<.01$) in G/F, with no differences in ADG, ADFI, DMD, ND or TFD. These data indicate that SFS can be included in nursery pig diets up to 15% with no impairment in performance. Fine grinding or pelleting diets and roasting SFS improved performance of pigs fed diets containing 25% SFS resulting in similar performance to those pigs fed the control or 15% SFS diets.

(Key Words: Nursery Pigs, Sunflower Seeds, Particle Size, Roasting, Pelleting.)