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The Effect of Various Levels of Dietary Sunflower Seeds on Performance and Carcass Characteristics of Growing-Finishing Pigs

Alan D. Hartman

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BY

ALAN D. HARTMAN

A thesis submitted
in partial fulfillment of the requirements for the
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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

Sunflower seeds have become an important crop in several midwestern states. In the past, sunflower seeds have been used primarily in the production of sunflower oil and sunflower meal, with some seeds being used in the production of confectionery seeds. Not all sunflower seeds are suitable for these uses. An alternate use of these seeds would be incorporating them into livestock diets.

Sunflower seeds may contain 40% or more oil that is highly unsaturated in nature. In swine diets the addition of a fat source such as sunflower seeds would be primarily at the expense of a carbohydrate source in the diet. This would have the effect of increasing the energy content per kilogram of feed and of shifting the source of energy from carbohydrates to a mixture of carbohydrates and fat.

The addition of sunflower seeds to swine diets is a relatively new concept. Substantial work has been done in the area of increasing the fat content of swine diets either by adding fat directly or by including high fat-type seeds such as soybeans. Although there is some variation in results, most studies indicate that adding fat to a swine diet will increase the feed efficiency of the pig and usually decrease feed consumption. There is much less agreement on the effect adding a fat source to a diet has on average daily gain.

When adding a fat source to swine diets, one must also be concerned with the effects of the added fat on carcass composition and quality. Fat sources that are highly unsaturated can produce carcasses that are soft and less desirable to the meat packer. This results from a lower melting point of fat containing an increased level of unsaturated fatty acids. Pork storage also becomes a concern because intramuscular fat that has a higher level of unsaturated fatty acids is more susceptible to oxidative rancidity, thereby producing a product that is less desirable to the consumer.

All the effects described above can be moderated by the total fat content and the fatty acid composition of the dietary fat. Therefore, various fat sources in different quantities could produce slightly different carcass characteristics in the pig.

The objectives of these experiments were to determine the effects of feeding diets containing various levels of sunflower seeds to growing-finishing swine on:

1. Average daily gain, feed efficiency, and average daily feed intake.
2. Quantitative carcass characteristics such as carcass length, average backfat, tenth rib fat, loin eye area and kilograms of muscle contained in the carcass.
3. Qualitative carcass characteristics, including carcass firmness and color, firmness and marbling of the longissimus muscle.
4. Fatty acid composition of backfat.
5. Consumer acceptability of the meat product.

REVIEW OF LITERATURE

Since there are few published reports concerning the use of whole unprocessed sunflower seeds in swine diets, a review of the literature concerning the addition of other high fat seeds or the direct addition of fat to swine diets may be useful.

Fatty Acid Composition Of The Carcass As Affected By Diet

In the early 1900's, pigs raised in the southeastern United States were allowed to graze in peanut fields. The popularity of this practice coincided with an increase in the amount of "soft" pork produced. The United States Department of Agriculture organized a cooperative project involving many southeastern states to study the soft pork problem and define its cause. The studies indicated that diet was the major factor causing soft pork.

In one of these studies, Ellis and Isbell (1926) described the effect of various diets on body fat composition of hogs. The four diets fed were a very low fat diet (brewers rice and tankage), a common diet used at that time (corn plus tankage or fish meal), a diet high in fat (corn plus soybeans or peanuts) and a diet consisting solely of soybeans or peanuts.

Individual fatty acid composition was determined from backfat samples taken at the time of slaughter. The fatty acid analysis of samples from pigs fed either soybeans or peanuts resembled the fatty acid analysis of the fat contained in the seeds. Of all fatty acids, the linoleic acid content changed the most, increasing from 1.9% in the fat of pigs fed brewers rice to 30.6% in the fat of pigs consuming whole soybeans.

Since this period, research has been conducted with a wide variety of fats added to swine diets. For 8 wk following weaning, Gorton and Duncan (1954) fed pigs a diet containing a maximum of 5% cod liver oil and lard in a 1:1 ratio. Fatty acid analysis of backfat from pigs fed this diet indicated that fatty acids present in the dietary fat source were absorbed essentially unchanged and deposited along with those fatty acids synthesized by the pig.

Kropf et al. (1954) found that supplementing a corn soybean meal diet with 10 or 15% beef tallow did not affect the iodine numbers of backfat samples taken at the time of slaughter. This finding indicates that the total number of double bonds in the fatty acids of the backfat did not change with dietary treatment.

Comparisons were made (Leat et al., 1964) among carcass fatty acid compositions from swine fed a commercial barley diet, those fed a synthetic diet containing no fat, and pigs fed synthetic diets containing 10% beef fat or 10% corn oil. Fatty acid composition was determined for fat from the cervical and sacral regions of the back and for intermuscular and perinephric fat. They found that oleic, palmitic and stearic acids accounted for 90 to 95% of the total fatty acids in the depot areas of pigs fed a synthetic diet containing no fat.

Linoleic acid was present but in all cases made up less than 1% of all fatty acids. It was also determined that the fatty acid composition of depot fat in pigs fed the synthetic diet plus 10% beef tallow remained nearly the same as the fatty acid composition of the depot fat in those pigs fed the synthetic diet alone. The authors suggested that this could be due to the poor digestibility of beef tallow as determined by Howard et al. (1965). When 10% corn oil was added to the synthetic diet, linoleic acid accounted for 25 to 30% of the total amount of fatty acids present in the depot areas compared to 5 to 7% linoleic acid present in the depot areas of pigs fed the barley-based control diet. These workers also found that the outer layer of backfat contained proportionately more unsaturated fatty acids than the inside layer, regardless of the type of diet. Preferential deposition of unsaturated fatty acids in the outer layer of backfat has also been reported by Sink et al. (1964) and Koch et al. (1968).

The effects of feeding a semi-synthetic diet containing 10% beef tallow or 10% corn oil were studied by Mason and Sewell (1967). Fatty acid composition was determined for liver, kidney, pancreas, spleen, heart, tongue, intestine, stomach, lung, brain, backfat, kidney fat, skin, longissimus muscle and semimembranosus samples. Adding beef tallow to the diet produced no changes in the quantity of palmitoleic, stearic or oleic acids found in backfat. The percentage of linoleic acid in the backfat did show a slight but significant increase with the addition of beef tallow to the diet. Changes in the fatty acid composition of the other tissues were varied when pigs consumed diets containing beef tallow. The addition of corn oil to the diet produced a substantial increase in the proportion of linoleic acid present in each tissue examined, even though the actual percentage of linoleic acid varied among tissues.

Nordstrom et al. (1972) added 3 and 12% corn oil to a corn-soybean meal diet. Diets containing 3% corn oil produced an increase in the proportion of linoleic acid in carcass backfat. However, adding 12% corn oil to the diet produced even greater increases in the proportion of linoleic acid in carcass backfat. Increasing percentages of linoleic acid were mainly at the expense of oleic acid, which decreased in proportion as the level of corn oil in the diet increased.

Swine diets containing 10% safflower oil were also shown to cause an increase in the proportion of linoleic acid with a corresponding decrease in the proportion of oleic acid in backfat of pigs when compared to the fatty acid composition of backfat of pigs fed a control barley-soybean meal diet (Koch et al., 1968). They also determined that the fatty acid composition of backfat from pigs fed a safflower oil diet for 6 wk would return to normal if beef tallow replaced safflower oil in the diet, and the new diet was fed for 5 weeks. This indicates a fairly rapid turnover of fatty acids in fat depot areas of swine.

The effects of diet on fatty acid composition of backfat were compared by Christensen (1964) after feeding a diet high in saturated fatty acids (barley plus coconut oil), a diet high in unsaturated fatty acids (barley plus soybean oil) and a diet naturally low in fat (barley plus skim milk). Linoleic acid content was highest when the diet containing soybean oil was fed, lowest when the diet with coconut oil was fed and intermediate when the diet containing skim milk was fed. Although it was found that diets high in saturated fatty acids produced changes in carcass fatty acid composition, the author felt that unsaturated fatty acids produced a more direct effect on carcass fat. Chemical analyses of fat samples changed more drastically when compared to the control group if the diets fed to the pigs were high in unsaturated fatty acids rather than high in saturated fatty acids. A similar point was made by Brooks (1971), who determined that the proportion of linoleic acid found in pork fat was dependent on the amount of linoleic acid consumed per unit of gain by the pig.

Fat levels in swine diets have also been increased by the incorporation of high fat seeds. Castell and Mallard (1974) added 0, 4, 8 and 12% rapeseed to barley-based diets. They found that the amount of linoleic acid in the backfat of pigs fed the 4% rapeseed diet was greater than the amount in the backfat of pigs fed 0% rapeseed. As the level of rapeseed in the diet increased, the proportion of linoleic acid in the backfat further increased.

By far the most popular high fat seed chosen by researchers to add to swine diets is the soybean. Wahlstrom et al. (1971) fed isonitrogenous diets to pigs with initial weights of 29.5 kg and final weights of 93 kg. Corn diets were balanced for protein using soybean meal, a 1:1 combination of soybean meal and cooked soybeans or cooked soybeans. Linoleic and oleic acids were found to be the only fatty acids that changed significantly in the backfat, with the percentage of linoleic acid increasing and the percentage of oleic acid decreasing as cooked soybeans were added to the diet. Iodine numbers of backfat were also found to increase as soybeans were added to the diet.

In a similar trial (Villegas et al., 1973), corn-based diets were balanced for protein using soybean meal, whole roasted soybeans or a combination of both. Addition of whole soybeans to the diet produced an increase in the amount of unsaturated fatty acids in backfat and perirenal fat, with linoleic acid being the most responsive to the diet. Changes in fatty acid composition were greater as the amount of roasted soybeans in the diet increased. Seerley et al. (1974) and Skelley et al. (1975) found increases in the proportion of linoleic acid and decreases in the proportion of oleic acid of backfat samples when cooked soybeans replaced soybean meal as the protein source.

Iodine number indicates the number of double bonds in a substance, therefore giving an idea of the relative amount of unsaturated fatty acids present. Villegas et al. (1970) determined iodine numbers of backfat samples taken from pigs fed corn-based diets containing various levels of unprocessed soybeans. Iodine number increased with each addition of whole soybeans to the diet. Similar results were noted by Jimenez et al. (1963), Bergkamp and Topel (1970) and Romans et al. (1970). McConnell et al. (1975) also reported increased iodine numbers in the backfat of pigs fed roasted soybeans in corn, wheat, milo or barley-based diets.

High Oil Diets and Carcass Quality

As indicated in the previous section, pigs fed diets high in unsaturated fats had a larger proportion of unsaturated fatty acids, namely linoleic acid, present in the fat depot areas of the body. Linoleic acid, or any unsaturated fatty acid when compared to its saturated counterpart, will have a lower melting point as indicated by the Chemical and Rubber Publishing Company (CRC, 1980). It is possible that carcasses containing a large proportion of unsaturated fatty acids, especially linoleic acid, will have a decreased carcass firmness.

Christensen (1964) studied the effects of barley-skim milk based diets, which contained 30% of their caloric content in the form of coconut or soybean oil, on the carcass firmness of pigs. An addition of coconut oil, which is characterized by its high percentage of short-chain saturated fatty acids, produced very firm fat in the depot areas. However, the addition of soybean oil, characterized by an abundance of unsaturated fatty acids, especially linoleic, caused fatty tissues to become soft and pliable. Even though the two experimental diets were formulated to contain the same caloric content per kilogram of feed, pigs receiving soybean oil in the diet showed a greater tendency to deposit fat. The author explained this by pointing out that fatty acids from soybean oil can be deposited in the depot areas of the pig without change. Pigs fed coconut oil must transform many of the short-chain fatty acids into new compounds before fat can be deposited. This requires energy. Since the diets were originally balanced for energy, pigs receiving coconut oil in their diet had less energy available for the formation of fat reserves.

The addition of fat to a diet will increase the energy content of the diet. Providing feed consumption is not drastically affected, pigs receiving the high fat diet will have more energy available for laying down fat in depot areas.

In an attempt to determine the effect of diet on carcass characteristics, Greeley et al. (1964) added 0, 4, 8 and 12% tallow to a corn-soybean meal diet fed to pigs. They found a linear increase in backfat thickness and a slight increase in dressing percent as tallow in the diet increased. Other carcass characteristics measured but not affected by diet were carcass length, longissimus muscle area and percent ham and loin.

Similarily, Barrick (1953) fed a diet supplemented with 10% peanut oil, 10% beef fat or a 1:1 combination of the two sources. Backfat thickness was found to increase with the addition of either fat source to the diet.

Leat et al. (1964) fed a semi-synthetic diet containing no fat, the same diet supplemented with either 10% beef tallow or 10% maize oil or a commercial barley-based diet. The amount of subcutaneous fat was found to increase when diets containing 10% maize oil were fed. The amounts of subcutaneous fat in pigs fed the semi-synthetic diet, the beef tallow diet or the commercial barley-based diet were equal but less than the amount of subcutaneous fat in pigs receiving maize oil in the diet.

Similar results were noted by Tribble et al. (1979) when they fed a sorghum-soybean meal diet supplemented with 0, 4 and 8% tallow. There were no changes in backfat thickness with the addition of tallow to the diet. Likewise, carcass length; longissimus muscle area, color, firmness and marbling; and percentage of fat, moisture and protein of the longissimus muscle did not change with dietary treatment. Kropf et al. (1954) reported that pigs fed a corn-soybean meal diet supplemented with 0, 10 or 15% beef tallow did not differ in dressing percent, carcass backfat or carcass firmness.

Two experiments were conducted by Seerley et al. (1964) to study the relationship between energy and protein in growing-finishing swine. In the first experiment, a corn or a corn-oats based diet was supplemented with 0, 4 and 8% stabilized yellow grease. The level of added grease produced no effect on average backfat, longissimus muscle area, carcass length or percentage of lean cuts. In the second experiment, 0, 4 and 8% dextrose was replaced in a corn-oats diet by the same amount of yellow grease to produce diets of low, medium and high energy content. Backfat thickness increased in pigs receiving the medium and high energy diets, while percentage of lean cuts decreased in pigs fed the high energy diet. Energy content of the diet did not affect longissimus muscle area or carcass length.

Kennington et al. (1958) found a linear increase in backfat thickness when lard (0 to 20%) was added to "practical" swine diets, ranging from 14 to 20% in protein content. There was no fat x protein interaction reported.

Various high oil seeds or their oils have also been added to swine diets. Barley-based diets supplemented with up to 12% rapeseed were fed to pigs from average weights of 24 to 91 kg and did not affect dressing percent, longissimus muscle area, amount of lean in ham face or average backfat (Castell and Mallard, 1974). Carcass firmness decreased when 12% corn oil was added to swine diets (Nordstrom et al., 1972). There was no effect on average backfat thickness, carcass length, longissimus muscle area or percent ham and loin. The authors felt that carcasses from pigs fed 12% corn oil were so soft and oily that they would be unacceptable to the meat packer. Pigs receiving 3% corn oil in the diet had carcasses that exhibited less severe, although detectable, softening.

Much research has been conducted concerning the addition of soybeans or their oil to swine diets. In a series of five experiments, Bull et al. (1931) used either corn or barley-based diets supplemented with various levels of whole soybeans. When soybeans replaced tankage as the protein source, dressing percent and carcass firmness decreased. The authors attributed the decreased carcass firmness to the high level of dietary soybean oil which has a low melting point.

Decreased carcass firmness is the only carcass characteristic consistently produced by the addition of cooked soybeans to swine diets. The effect on other carcass characteristics varies somewhat from study to study. Wahlstrom et al. (1971) reported that pigs fed cooked soybeans had increased dressing percentages, while Seerley et al. (1974) found no such effect but noted decreased longissimus muscle area and marbling. Decreased longissimus muscle area was also observed by McConnell et al.(1975). Other treatment effects included decreased percent lean, increased longissimus muscle color and increased backfat. Romans et al. (1970) found decreased percent ham and increased percent belly when cooked soybeans were added to the diet, but in a second trial noted no such effects. Villegas et al. (1970) and Ruffin et al. (1971) observed that backfat depth increased when cooked soybeans were added to swine diets. Jimenez et al. (1963) and Skelley et al. (1972, 1975) noted no effects, other than decreased carcass firmness, of dietary cooked soybeans on the carcass characteristics they measured.

Consumer Acceptance of Soft Pork

With an increase in the amount of unsaturated fatty acids present in pork fat, oxidative rancidity may become a problem. Storage life for pork is less than for beef or lamb because pork fat normally contains more unsaturated fatty acids than does beef or lamb fat. Therefore, diets high in unsaturated fatty acids which cause an increased deposition of unsaturated fatty acids in fat depot areas may produce pork that is less acceptable to the consumer.

A detailed study performed by Palmer et al. (1952) determined the effects of feeding a corn-tankage diet, a corn diet plus 25% ground soybeans or combinations of both on taste panel acceptance of ground pork, pork chops and pork roasts. The effects of length of storage, packaging material and storage temperature were also determined. Flavor and odor rancidity, flavor and odor desirability and peroxide values were determined on the pork samples. For fresh pork, flavor and odor rancidity and flavor and odor desirability scores were found to decrease when the corn-soybean diet was fed. Although scores in these categories were reduced, no score indicated an unacceptable meat product. Peroxide values, which are a chemical means of indicating rancidity, increased in pigs fed corn-soybean diets. Storage temperature, length of storage and packaging material also affected the parameters measured.

Of greater interest were the interactions which took place between storage temperature, storage length, packaging material and iodine number of fat in the ground pork samples. While flavor rancidity scores decreased with increasing iodine number of fat regardless of packaging material, the decrease was greater when waxed paper versus laminated paper was used. Despite the effect observed on flavor rancidity, neither peroxide values nor flavor desirability showed a significant interaction between iodine number and packaging material. Fat saturation and length of storage produced interactions in flavor rancidity, flavor acceptability and peroxide values. Although flavor rancidity and flavor acceptability decreased with increasing storage length, the decrease was greater in ground pork having high iodine numbers. Peroxide values increased with increasing storage lengths, but the increase was greatest when the storage length was coupled with ground pork having a higher iodine number. There were no interactions observed between fat saturation and storage temperature.

As mentioned earlier, Palmer et al. (1952) also tested pork chops and roasts for the effect of ground soybeans on acceptability of the pork. There were no dietary treatment effects noted for flavor rancidity, odor rancidity, odor desirability or peroxide value of the pork chops. Flavor desirability was slightly decreased when pigs were fed the diet containing ground soybeans. No dietary treatment effects were observed for any of the criteria used when determining pork roast acceptability. Lower taste panel acceptance of longissimus muscle samples from pigs fed roasted soybeans has also been reported by Bergkamp and Topel (1970).

Olson et al. (1973) compared taste panel acceptance of various pork products from pigs fed a corn-swine mix diet versus a corn-roasted soybean diet. Taste panel acceptance for bacon, hams, frankfurters and fresh sausage was determined. Crispiness, flavor, saltiness and overall acceptability of bacon samples did not change with diet. Canned ham juiciness did not change when roasted soybeans were added to the diet, but flavor and overall acceptability scores did increase in hams from pigs fed diets containing roasted soybeans. The canned hams were stored for up to 180 d before testing. During this period of time, there were no adverse effects due to dietary treatment. When unprocessed pork trim from pigs fed roasted soybeans was frozen for 30 d prior to processing into frankfurters, which were then stored at 4 C for 56 d prior to evaluation, flavor and overall acceptability scores decreased. Effects of storage length were also determined on fresh sausage from pigs fed the corn-swine mix diet versus the corn-roasted soybean diet. Pork sausage was stored for 30- and 60-d periods prior to evaluation. Sausage from pigs fed the corn-swine mix diet had higher texture and overall desirability scores after 60 d storage.

Wahlstrom et al. (1971) found that dietary full-fat soybeans did not affect tenderness, flavor, juiciness or Warner-Bratzler shear values for loin chop samples. Similar effects were noted by Romans et al. (1970), Ruffin et al. (1971), Skelley et al. (1972) and McConnell et al. (1975).

Dietary sources of fat other than soybeans have not proven to be detrimental to pork quality. Heitman (1956) found no "off" flavors when a taste panel evaluated loin roasts from pigs fed barley-based diets supplemented with 10% stabilized tallow or 10% lard. Koch et al. (1968) found similar results for loin chops from pigs fed barley-soybean meal diets supplemented with 10% safflower oil or 10% safflower oil for the first 5 wk of growth and 10% beef tallow for the remaining 6 wk of the trial. There also were no effects of these diets on tenderness, juiciness, flavor, overall desirability or Warner-Bratzler shear values.

As indicated in the literature cited, some research has shown decreased taste panel acceptability of pork containing high levels of unsaturated fatty acids when compared to pork containing normal fatty acid composition. Other studies have found no differences. It is important to understand that many factors such as storage temperature, storage length and packaging material can affect the development of oxidative rancidity and, therefore, consumer acceptability.

High Fat Diets and Pig Performance

Addition of fat to swine diets will increase the energy content of those diets. It also shifts the pig's energy source from one of carbohydrates to a mixture of carbohydrates and fat. Therefore, it becomes important to determine if high fat diets will be palatable to pigs and how they will affect growth rate and feed efficiency.

Clawson et al. (1962) used a corn-soybean meal diet balanced for various protein levels and supplemented with 0, 5 and 10% yellow grease to determine the effects of added fat and the calorie to protein ratio on performance of pigs. Supplementary dietary fat improved rate and efficiency of gain but decreased feed consumption. Similar results were obtained by Kennington et al. (1958). Although feed consumption decreased when fat was added to the diet, the actual amount of energy received per day was not affected. Cole et al. (1967) also determined that pigs eat to meet their energy requirements regardless of the energy content of the diet. Similar results have been found when diets with reduced caloric density were fed. Owen and Ridgman (1967) added sawdust to swine diets and found that, although energy intake was decreased in pigs weighing 27 to 50 kg, energy intake of pigs from 50 to 118 kg did not vary.

Clawson et al. (1962) studied the effects of calorie to protein ratio on pig performance. They observed that, while growth and feed consumption were depressed, efficiency of gain was unaffected when fat was added to a low protein diet. Pigs receiving the diet containing the intermediate calorie to protein ratio (31 gross calories per gram of protein) consistently consumed more feed per day than pigs fed diets containing 26 or 38 calories per gram of protein. The authors thought that the depressed growth rate could be the result of decreased consumption of a diet that, when consumed at the normal level, would just meet the protein requirement of the pig.

Seerley et al. (1978) supplemented a corn-soybean meal diet with 0, 2.5 and 5% poultry or animal fat. Fat source had no effect on rate or efficiency of gain. With the addition of either fat source, feed to gain ratio was found to improve approximately 7%. Similar results have been reported by Kropf et al. (1954), Greeley et al. (1964) and Seerley et al. (1964) when animal fat was added to pig diets. Thrasher et al. (1959), Hale et al. (1968) and Tribble et al. (1979) reported improved feed efficiency and decreased feed intake with the addition of dietary animal fat. Addition of fat has not always been shown to affect pig performance. Heitman (1956) and McDonald and Hamilton (1976) found no significant differences in pig performance when animal fat was added to pig diets, although the latter study indicated a trend toward decreased feed consumption and improved feed efficiency.

Various high oil seeds or their oils have also been added to swine diets. Barrick et al. (1953) found improved gain and efficiency when 10% beef fat, 10% peanut oil or a 1:1 combination of the two was added to swine diets. Nordstrom et al. (1972) did not observe improved gains but found feed efficiency improved when 3 or 12% corn oil was added to a corn-soybean meal diet. Friend et al. (1975) added 10 and 20% rapeseed oil or soybean oil and found decreased feed consumption and improved feed efficiency. Castell and Mallard (1974) reported small but nonsignificant differences in pig performance when up to 12% rapeseed was added to barley-based diets.

There are conflicting reports concerning the performance of pigs fed cooked soybeans as a replacement for soybean meal in swine diets. Hanson et al. (1970), Hanke et al. (1972) and Seerley et al. (1974) found performance to be unaffected when cooked soybeans were used as the protein source. Jimenez et al. (1963) reported increased gains in the first of two experiments. In the second, cooked soybeans were not found to affect pig performance. Improved feed efficiency has been reported by Ruffin et al. (1971), Thrasher et al. (1973) and McConnell et al. (1975) when cooked soybeans were used as the protein source. Wahlstrom et al. (1971) found no effect on growth rate or feed conversion but did find decreased feed intake when cooked soybeans were used as the protein source.

Sunflower Seeds in Swine Diets

Research concerning the addition of sunflower seeds to swine diets is very limited. Kepler (1981) fed diets containing 25 and 50% sunflower seeds to gestating and lactating sows and gilts. Although three sows refused to eat the 50% sunflower seed diet, feed consumptions for the remaining animals were not affected. The author noted no differences in feed consumption when diets containing 25 and 50% sunflower seeds were fed to a limited number of barrows in a digestion trial.

Laudert and Allee (1975) included 0, 20, 40 and 60% sunflower seeds in corn-soybean meal diets. Ten parts sunflower seeds replaced eight parts corn and two parts soybean meal to produce the three sunflower seed diets. In the growth trial, the addition of sunflower seeds resulted in a linear decrease in feed consumption and a linear increase in feed efficiency. In the finishing trial, pigs fed the control corn-soybean meal diet gained the fastest. The authors also reported an increase in the total unsaturation of the fatty acid content of backfat and longissimus muscle of pigs fed sunflower seed diets. Linoleic acid showed the most drastic increase. Backfat thickness did not vary among treatments. However, there was a trend toward increasing amounts of intramuscular fat as the level of sunflower seeds in the diet increased.

Researchers at North Dakota State University (Dinusson et al., 1980b) added 0, 2.5, 5 or 10% sunflower seeds to barley-soybean meal diets in an attempt to determine diet acceptability and performance of pigs. Results of the experiment were not conclusive. As indicated by feed intake, diets containing up to 10% sunflower seeds were acceptable to the pigs. No significant treatment effects on growth rate or feed efficiency were observed. Although there were numerical differences in rate of gain for the four treatments, these differences were not related to the level of sunflower seeds in the diet.

In another study, Dinusson et al. (1980a) fed diets containing 0, 13, 26 or 39% sunflower seeds. Although rate of gain decreased when 39% sunflower seeds were added to the diet, feed efficiency and feed intake were unaffected by sunflower seed additions. The authors thought that this was unusual since the high level of sunflower seeds in the diet would increase the energy content of the diet. Therefore, they felt that either the sunflower oil was not digested or it interfered with the digestibility of other nutrients. It is also possible that the high fiber levels associated with high levels of sunflower seeds could affect nutrient digestibility.

Cook et al. (1980) determined the effects of dietary sunflower seeds on carcass quality of swine. The pigs used in this study were the same animals that were used in Dinusson's experiment. Addition of sunflower seeds to the diet was found to decrease carcass quality, carcass firmness and longissimus muscle marbling.

Fatty acid analysis was determined on fat samples from pigs in the second Dinusson project by Marchello et al. (1981). Samples were taken from leaf fat, flank fat, inner and outer layers of backfat and intramuscular fat of the longissimus muscle. The relative amounts of myristic, palmitic, stearic, palmitoleic, oleic and linolenic acids decreased and linoleic, eicosadienoic and arachidonic acids increased. The proportion of linoleic acid changed the most, with mean values ranging from 13.6 to 48.5% of all fatty acids present. Comparison of the linoleic acid content of sunflower seed oil and backfat indicated that linoleic acid content of backfat was directly related to linoleic acid content of sunflower seeds.

MATERIALS AND METHODS

Two experiments involving 176 crossbred pigs were conducted. In each trial, pigs were randomly assigned on the basis of ancestry, sex and weight to a randomized, complete block design. Pigs were housed in a completely enclosed confinement barn at the South Dakota State University swine research unit. Pens measured 1.2 m by 2.4 m and were totally slatted. Pens were equipped with self-feeders and nipple waterers to provide feed and water ad libitum throughout the experimental period. Pig weights were determined every other week, and feed intake was measured every 4 weeks. Average daily gain was based on individual weight measurements, while feed consumption used for calculation of feed per gain ratio and average daily feed intake were pen averages. The experiments were divided into two periods (initial weight to 59 kg and 59 to 100 kg) so that the diet could reflect the lower lysine requirement of heavier pigs.

At average pen weights of 100 plus or minus 2.3 kg, the barrows, which comprised half the total number of pigs in the experiment, were slaughtered at the South Dakota State University meat laboratory where various carcass measurements and samples were taken.

Statistical analyses were performed by least squares analysis of variance as outlined by Steel and Torrie (1980). When significant differences were detected among treatment means, linear, quadratic and cubic components of variance were tested. For purposes of analyses, an additional treatment level was added so that the level of sunflower seeds in the diet increased linearly from treatment to treatment.

Experiment 1

Ninety-six pigs were allotted to six blocks of four dietary treatments. There were four pigs per pen for a total of 16 pigs in each block. Average initial weights were 36.5, 32.9, 30.5, 28.3, 26.8 and 23.8 kg for blocks one through six, respectively.

Sunflower seeds were added to a corn-soybean meal diet at levels of 0, 5, 10 and 20% to produce the four dietary treatments shown in table 1. Corn was the major ingredient which sunflower seeds replaced, but the corn-soybean meal ratio was varied to produce diets calculated to contain .79% lysine when fed to pigs with average pen weights up to 59 kg and .64% lysine in diets fed for the remainder of the trial. Diets were formulated to contain lysine in excess of the minimum requirements set forth by the National Research Council (NRC, 1979) to insure that all pigs would have an adequate lysine intake. Nutrient composition of the diets, as determined by chemical analyses, is shown in table 2 and nutrient composition of sunflower seeds is shown in table 3.

During the course of the trial, it became necessary to remove six pigs from the experiment because of very poor growth. Two of these pigs were submitted to the South Dakota State Diagnostic Laboratory for autopsy. Examination revealed moderately severe pneumonia and

TABLE 1. PERCENTAGE COMPOSITION OF DIETS FOR EXPERIMENT 1

	Dietary periods							
	To 59 kg				59 to 100 kg			
	Sunflower seeds, %							
Ingredients	0	5	10	20	0	5	10	20
Corn	76.6	71.9	67.2	57.6	82.5	77.8	73.0	63.6
Soybean meal	20.7	20.5	20.3	19.9	15.0	14.8	14.6	14.2
Sunflower seeds	0	5.0	10.0	20.0	0	5.0	10.0	20.0
Dicalcium phosphate	1.2	1.1	1.0	.9	1.0	.9	.9	.7
Limestone	.8	.8	.8	.9	.8	.8	.8	.8
Trace mineralized salt	.3	.3	.3	.3	.3	.3	.3	.3
Vitamin premix[a]	.4	.4	.4	.4	.4	.4	.4	.4

[a] Supplied per kg of diet: vitamin A, 3306 IU; vitamin D, 331 IU; vitamin E, 6.6 IU; vitamin K, 2.6 mg; riboflavin, 3.3 mg; pantothenic acid, 13.2 mg; niacin, 21.2 mg; choline, 66.1 mg; vitamin B_{12}, 13.2 mcg; selenium, 119 mcg and aureomycin, 27.6 mg.

TABLE 2. CHEMICAL COMPOSITION OF DIETS, EXPERIMENT 1 (%)

	Dietary periods							
	To 59 kg				59 to 100 kg			
	Sunflower seeds, %							
Source	0	5	10	20	0	5	10	20
Moisture	7.9	7.6	7.2	6.5	12.2	12.2	11.6	10.8
Crude protein	18.0	18.4	18.9	19.4	15.2	15.5	15.9	16.7
Crude fiber	2.6	3.7	4.3	5.2	2.8	3.9	4.3	5.2
Ether extract	3.6	5.0	6.9	10.3	3.6	5.3	6.7	10.3
Ash	4.5	4.6	4.7	4.5	3.7	4.0	4.0	4.3
Nitrogen-free extract	63.5	60.7	58.0	54.1	62.5	59.1	57.5	52.7
Lysine	.90	.93	.96	.94	.72	.68	.73	.76

TABLE 3. CHEMICAL COMPOSITION OF SUNFLOWER SEEDS USED IN EXPERIMENT 1 (%)

Source	Percent
Moisture	7.5
Crude protein	17.4
Crude fiber	16.2
Ether extract	39.2
Ash	3.0
Nitrogen-free extract	16.7
Lysine	.51

hyperkeratosis of the skin on the legs and perineum. Several strains of bacteria were isolated from the lungs of the pigs and determined to be the cause of the pneumonia.

Data for pigs removed from the trial were omitted for the entire trial. Adjustments to feed consumption were made based on total digestible nutrient (TDN) requirements for maintenance and growth as indicated by Brody (1945) and TDN content of the diets fed. An alternate method was used to check the results of the first method. In the second method, individual feed consumption was assumed to be a product of the pig's weight as compared to the total weight of all pigs in the pen. Estimates produced by one method were similar to those produced by the other method.

Barrows were slaughtered and backfat samples were taken from the midline between the second and fifth lumbar vertebrae immediately after slaughter. Special care was taken to insure all layers of backfat were removed in their entirety. Skin was removed from the samples prior to storage in airtight containers at -20 C. Hot carcass weights were taken prior to moving the carcasses into a blast cooler kept at a temperature between 0 and 1.1 C. Carcasses were allowed to hang in the cooler a minimum of 24 h before carcass measurements were made. Carcass characteristics measured included carcass length, average backfat, tenth rib fat, and area, color, firmness and marbling of the longissimus muscle. Carcass length and average backfat were averages of values from both sides of the carcass, while the other measurements were taken from the right side only. Procedures from the National Pork Producers Council (NPPC, 1976) were followed when measuring carcass characteristics. Longissimus muscle areas were traced and later measured using a polar planimeter. Kilograms of muscle were calculated based on tenth rib fat, carcass weight and longissimus muscle area by formula as provided by NPPC (1983).

Four loin chops 1.9 cm thick were removed distally from the tenth rib and stored at -20 C. In all cases, the first and second loin chops removed were used for taste panel determination, the third loin chop for Warner-Bratzler shear tests and the fourth loin chop for chemical analyses of a raw meat sample.

Loin chops were stored at -20 C four to five months before taste panel evaluation. Upon removal from the freezer, chops were thawed at 2 C for 24 h prior to cooking. The chops were then cooked to a final internal temperature of 75 C and served to panelists as soon as possible in accordance with the standards described by the American Meat Science Association (AMSA, 1978).

The taste panel consisted of eight experienced members who judged the samples for flavor, juiciness, tenderness and overall desirability through the use of an eight-point descriptive scale. Panelists were encouraged to write specific comments on the evaluation form regarding any "off" flavors they may have encountered.

Warner-Bratzler shear tests were performed on loin chops prepared under the same conditions used for the taste panel. Cooked loin chops were allowed to cool before two 2.54-cm cores were removed. Each core was sheared twice so that the final value was an average of four separate shears.

The remaining loin chops were used for chemical determination of protein, fat and moisture content. Modified Association of Official Analytical Chemists (AOAC, 1980) procedures were followed for the chemical analyses. The loin chops were allowed to thaw just enough to permit cutting. At this point, the longissimus muscle was removed from the loin chop, cubed, and quick frozen in liquid nitrogen. The frozen cubes were then powdered using a Waring blender, labeled and stored at -20 C until the actual chemical analyses could be performed. The above procedure was performed to insure that the sample used in the chemical analyses would be representative.

Duplicate samples of approximately 1 g of the powdered sample were placed in dried and weighed paper thimbles and dried at a temperature of 98 C for 12 h. The samples were then placed in a desiccator until they were cool, at which point they were weighed and percent moisture determined. The dried samples contained in the paper thimbles were placed in a reflux tube. Ether was heated in a flask connected to the reflux tube so that ether condensed in the reflux tube would rinse over the samples. This process was allowed to continue for 12 h, at which point the samples were removed from the reflux tube and air-dried in the vent. Samples were then dried at 97 C for 12 h, cooled in a desiccator and weighed. Percent ether extract was calculated indirectly, based on the weight loss of the samples. Kjeldahl nitrogen was determined on the dried and extracted samples according to AOAC (1980). All analyses were performed in duplicate. For the results to be accepted, the two values had to be within one percentage unit of each other. If they were not, all three analyses were completed a second time. If the difference was still more than 1%, all four values were averaged.

Backfat samples used for determination of iodine number and individual fatty acid composition were cubed, quick frozen in liquid nitrogen and blended in a Waring blender to assure a representative sample was used. The Hanus method for determination of iodine number as described by AOAC (1980) was used.

A 5-g sample of the powdered fat was purified according to the procedures outlined by Folch et al. (1957) and later used for determination of fatty acid composition. The procedures as stated were for a total collection of all lipids. For the purposes of this experiment, it was important to obtain a representative sample rather than a total collection of the lipids. Therefore, only a portion of the lipid solution was saved. Two ml of the lipid solution were evaporated to dryness under nitrogen, and methyl esters were prepared using boron triflouride according to the procedures outlined by Van Wijngaarden (1967).

Percentages of methylated fatty acids were determined using a Varian Aerograph, Series 2400. A 10% ethylenesuccinate-methylsilicon co-polymer (EGSS-X) with a 100/120 mesh size was used as the liquid phase and packed in a stainless steel column having a diameter of 3.2 mm and a length of 2.9 m. A Sargent-Welch strip chart recorder, Model SRG, was used to record the results. Relative percentages of myristic, palmitic, palmitoleic, stearic, oleic and linoleic acids were determined. Linolenic acid was present in quantities too small to measure accurately and therefore was omitted when calculating the relative proportion of the fatty acid esters.

Experiment 2

Eighty crossbred pigs were allotted, four pigs per pen, to four dietary treatments. Average initial weights were 30.1 kg for blocks one, two, three and four and 29.3 kg for blocks five and six.

The four dietary treatments contained 0, 2.5, 5 and 10% sunflower seeds in a corn-soybean meal fortified diet. The percentage composition of experimental diets is presented in table 4. Diets were balanced for lysine in the same manner used in experiment 1. Chemical analyses of the diets and the sunflower seeds are shown in tables 5 and 6, respectively.

During the course of the experiment, it became necessary to remove four pigs. One pig was removed because of a rectal prolapse, while the other three removed exhibited the same symptoms as those pigs removed from the previous experiment. Feed consumption was adjusted based on the weight of the pig removed compared to the total weight of the entire pen. Data for pigs removed from the trial were omitted for the entire trial.

Barrows were slaughtered when average pen weights of 100 plus or minus 2.3 kg were reached. Carcass length and longissimus muscle area, color, firmness and marbling measurements were taken in a manner similar to that used in the first experiment. Average backfat and tenth rib fat measurements were also taken. Since barrows in experiment 2 were skinned after slaughter, .25 cm was added to all backfat measurements and the carcass weights divided by a factor of .94 to

TABLE 4. PERCENTAGE COMPOSITION OF DIETS FOR EXPERIMENT 2

	Dietary periods							
	To 59 kg				59 to 100 kg			
	Sunflower seeds, %							
Ingredients	0	2.5	5	10	0	2.5	5	10
Corn	76.6	74.3	71.9	67.2	82.5	80.2	77.8	73.0
Soybean meal	20.1	20.6	20.5	20.3	15.0	14.7	14.8	14.6
Sunflower seeds	0	2.5	5.0	10.0	0	2.5	5.0	10.0
Dicalcium phosphate	1.2	1.2	1.1	1.0	1.0	1.0	.9	.9
Limestone	.8	.8	.8	.8	.8	.8	.8	.8
Trace mineralized salt	.3	.3	.3	.3	.3	.3	.3	.3
Vitamin premix[a]	.4	.4	.4	.4	.4	.4	.4	.4

[a] Supplied per kg of diet: vitamin A, 3306 IU; vitamin D, 331 IU; vitamin E, 6.6 IU; vitamin K, 2.6 mg; riboflavin, 3.3 mg; pantothenic acid, 13.2 mg; niacin, 21.2 mg; choline, 66.1 mg; vitamin B_{12}, 13.2 mcg; selenium, 119 mcg and aureomycin, 27.6 mg.

TABLE 5. CHEMICAL COMPOSITION OF DIETS, EXPERIMENT 2 (%)

	Dietary periods							
	To 59 kg				59 to 100 kg			
	Sunflower seeds, %							
Source	0	2.5	5	10	0	2.5	5	10
Moisture	10.4	10.7	10.1	9.6	10.3	10.2	10.0	10.6
Crude protein	16.7	17.8	17.0	17.5	14.2	15.6	14.8	14.8
Crude fiber	3.0	3.3	3.6	4.3	3.0	3.3	4.2	3.7
Ether extract	3.1	4.4	4.7	6.9	3.2	3.8	4.4	5.5
Ash	4.5	5.0	4.4	4.4	3.8	4.1	3.8	3.9
Nitrogen-free extract	62.3	58.8	60.2	57.3	65.5	63.0	62.8	61.5
Lysine	.94	.91	.86	.82	.69	.75	.72	.69

TABLE 6. CHEMICAL COMPOSITION OF SUNFLOWER SEEDS USED IN EXPERIMENT 2 (%)

Source	Percent
Moisture	7.3
Crude protein	17.4
Crude fiber	12.2
Ether extract	39.3
Ash	4.3
Nitrogen-free extract	19.5
Lysine	.58

produce adjusted values (NPPC, 1983). Carcass firmness was determined by subjective measurement. Scores of 1 to 5 were given, with a score of 1 indicating a very firm carcass and a score of 5 indicating a very soft carcass. Backfat samples were removed for iodine number determination as described for trial 1.

The effect of dietary sunflower seeds on bacon sliceability was also determined. Bacon sides were dry-cured for 10 d prior to being cooked in a smokehouse at 52 C for 2.5 h and 74 C for 4 h to produce a final internal temperature of 61 C. Bacon was sliced 3.6-mm thick using a Hobart Automatic Slicer, Model 1712. Based on visual appraisal of the slicing operation, sliceability scores were given, with individual scores indicating bacon sliceability as follows:

1. Normal slicing.
2. Slight fat build-up on slicing blade.

3. Moderate fat build-up on slicing blade causing some product wastage.
4. More severe slicing problems, with clogging becoming a slight problem.
5. Normal slicing using automatic slicer no longer possible.

RESULTS AND DISCUSSION

Experiment 1

Experiment 1 was conducted to determine the effects of up to 20% dietary sunflower seeds on performance, carcass characteristics, carcass quality, consumer acceptability of the meat product and fatty acid composition of backfat of growing-finishing swine.

A significant treatment-block interaction was found in the dietary period up to 59 kg. The cause of the interaction is somewhat hard to explain, but it did not appear to be the result of the different starting weights of the pigs in the six replications.

The effects of sunflower seeds on pig performance for the three dietary periods are shown in table 7. Average daily gain improved cubically ($P<.05$) during the early growth period (initial to 59 kg). Results indicated that 5% dietary sunflower seeds maximized rate of gain, while pigs receiving 20% dietary sunflower seeds gained at the lowest rate. Pigs receiving 10% sunflower seeds in the diet gained similarly to those receiving the diets without sunflower seeds.

In the dietary period of 59 to 100 kg, daily gain decreased linearly ($P<.01$) with the addition of sunflower seeds to the diet. Even so, pigs receiving 5% sunflower seeds gained as well as those receiving no sunflower seeds in the diet. A cubic response ($P<.05$) was again noted for the overall period. Average daily gain for pigs receiving 5% sunflower seeds in the diet was higher than gains for pigs on any of the

TABLE 7. PERFORMANCE CHARACTERISTICS OF PIGS IN EXPERIMENT 1[a]

Source	Sunflower seeds, % 0	5	10	20
To 59 kg				
Avg daily gain, kg[b]	.78	.86	.79	.74
Avg daily feed, kg	2.26	2.23	2.05	2.12
Feed/gain	2.90	2.66	2.58	2.73
59 to 100 kg				
Avg daily gain, kg[c]	.78	.78	.71	.69
Avg daily feed, kg	2.53	2.57	2.32	2.32
Feed/gain	3.20	3.28	3.19	3.43
Overall				
Avg daily gain, kg[b]	.78	.82	.74	.71
Avg daily feed, kg[d]	2.41	2.41	2.20	2.20
Feed/gain	3.06	3.00	2.93	3.08

[a] Six blocks of four pigs each (initial weight 36.5, 32.9, 30.5, 28.3, 26.8 and 23.8 kg for blocks 1 through 6, respectively).
[b] Cubic response (P<.05).
[c] Linear response (P<.01).
[d] Cubic response (P<.06).

other treatments. Mean values for average daily gain were slightly depressed when pigs were fed the 10% sunflower seed diet and were depressed further when 20% sunflower seeds were added to the diet.

These results agree quite closely with the work reported by Dinusson et al. (1980b) who found no effect on gain when up to 10% sunflower seeds were added to a barley based diet. Decreased gains were also noted by Laudert and Allee (1975) when 20% sunflower seeds were added to swine diets. However, Dinusson et al. (1980a) noted no effect on gain when diets containing 13 and 26% sunflower seeds were fed, although they found decreased gains when feeding a diet containing 39% sunflower seeds.

The results reported herein are in agreement with those of Friend et al. (1975) who reported decreased gains when 20% rapeseed oil or 20% soybean oil was added to swine diets but disagree with Kennington et al. (1958) who found that daily gain decreased linearly when diets conainint up to 20% stabilized lard was consumed by swine. The majority of diets containing added fats (Greeley et al., 1964; McDonald et al., 1976; Seerley et al., 1978; and Tribble et al., 1979) or diets containing full-fat soybeans (Hanson et al., 1970; Hanke et al., 1972; Thrasher et al., 1973; and McConnell et al, 1975) have produced no effect on gain.

Average daily feed intakes for the period up to 59 kg and from 59 to 100 kg average pen weights were unaffected by the level of sunflower seeds in the diet. However, for the overall period, a cubic response ($P<.06$) was noted for feed intake. Pigs receiving diets containing 10 and 20% sunflower seeds consumed less feed per day than pigs receiving 0 and 5% sunflower seeds in their diets. It appeared that growth rate may be a response to feed intake, with depressed growth occurring when pigs consume less feed daily. Feed efficiency was not affected by dietary treatment during any of the three growth periods.

In contrast to these results, reports by Dinusson et al. (1980a,b) indicated that dietary sunflower seeds had no effect on average daily feed intake. It is difficult to explain why there was no effect on feed consumption in the second publication since a maximum of 39% sunflower seeds was added to the diet. Laudert and Allee (1975) found a linear decrease in daily feed intake and a linear increase in feed per gain ratio when 0, 20, 40 and 60% sunflower seeds were added to swine diets. The much higher levels of sunflower seed supplementation could account for some of the differences between their results and those reported herein.

The diets supplemented with 20% sunflower seeds contained 10.3% ether extract (table 2). Corn-based diets balanced for protein with full-fat soybeans contain approximately 6 to 8% ether extract depending on the protein level of the diet and the fat content of the beans. Jimenez et al. (1963), Hanson et al. (1970), Wahlstrom et al. (1971), Hanke et al. (1972), Seerley et al. (1974) and McDonald et al. (1976) found no effects of dietary full-fat soybeans on feed efficiency or average daily feed intake of pigs. However, Ruffin et al. (1971) and McConnell et al. (1975) reported improved feed efficiencies when full-fat soybeans were used in swine diets.

In comparison, it is common for the direct addition of fat to swine diets to produce changes in feed per gain ratio or average daily feed intake. Kennington et al. (1958), Thrasher et al. (1959), Seerley et al. (1964), Hale et al. (1968) and Tribble et al. (1979) found improved feed efficiency or decreased daily feed intake when fat was added to swine diets. Heitman et al. (1956) and Greeley et al. (1964)

reported that added fat did not affect feed efficiency or feed intake. All the diets used in the above experiments contained at least 8% added fat, producing diets containing approximately 10% ether extract. Although the results of the experiments were not in complete agreement, there seemed to be a minimum amount of fat required in a diet before effects on feed efficiency and feed intake could consistently be observed. Diets containing 8% ether extract may or may not affect feed intake or efficiency, but diets containing 10% ether extract usually reduced feed consumption and improved feed efficiency.

Dietary sunflower seeds produced no effects on quantitative or qualitative carcass characteristics (table 8). Carcasses from pigs fed the diets high in sunflower seeds were visibly softer than carcasses from pigs fed the sunflower seed-free diet. Figures 1, 2 and 3 show the effects of dietary sunflower seeds on hams, loins and bellies with the ribs still intact, respectively. In each case, pigs consuming the 20% sunflower seed diet produced wholesale cuts that were obviously softer and less able to maintain their shape. The literature has consistently indicated that diets high in unsaturated fatty acids produce soft carcasses. Cook et al. (1980) found that carcass firmness decreased when diets containing 13, 26 or 39% sunflower seeds were fed to pigs. Bull et al. (1931), Romans et al. (1970), Ruffin et al. (1970) and Thrasher et al. (1973) observed decreased carcass firmness when cooked soybeans replaced soybean meal in pig diets.

TABLE 8. EFFECT OF DIETARY SUNFLOWER SEEDS ON QUANTITATIVE AND QUALITATIVE CARCASS CHARACTERISTICS (EXPERIMENT 1)

Source	Sunflower seeds, %			
	0	5	10	20
Carcass weight, kg	70.44	71.58	71.26	73.30
Carcass length, cm	80.00	80.05	80.00	80.03
Avg backfat, cm	2.64	2.82	2.69	2.92
Tenth rib fat, cm	2.29	2.49	2.16	2.11
Kilograms of muscle[a]	38.9	38.0	38.9	38.4
Longissimus muscle				
Area, cm^2	30.65	29.67	31.16	30.65
Color[b]	2.75	2.83	2.67	2.50
Firmness[c]	2.58	2.75	2.42	2.33
Marbling[c]	2.83	2.66	2.42	2.17

[a] Kilograms of muscle in a standardized 72.6-kg carcass.
[b] Range of 1 to 5 with 1 being the lightest and 5 the darkest.
[c] Range of 1 to 5 with 1 being the least and 5 the most.

Comparisons between the effects of diet on carcass characteristics other than firmness for the experiment reported herein and in other studies were difficult to make. Various carcass characteristics have been shown to be affected by high fat diets, but results have not been consistent from experiment to experiment. When full-fat soybeans were used in place of soybean meal, Romans et al. (1970) found decreased percent ham and increased percent belly; Wahlstrom et al. (1971) reported increased dressing percentages and Seerley et al. (1974) noted decreased longissimus muscle area, increased longissimus muscle color and decreased percent lean.

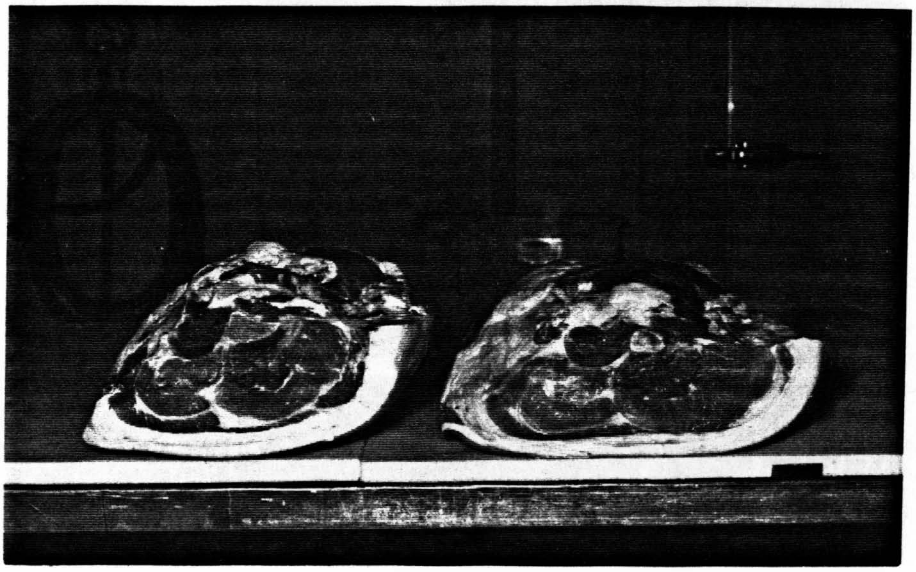

Figure 1. Hams from pigs fed diets without sunflower seeds (left) and 20% sunflower seeds (right).

Addition of sunflower seeds to the diet produced many changes in the chemical analyses of adipose tissue, as shown in table 9. Iodine numbers of backfat increased linearly with the addition of sunflower seeds to the diet. Although iodine number is a measure of the proportion of unsaturated linkages present in a fatty acid (CRC, 1980), increased iodine numbers have also been associated with decreased carcass firmness (Blumer et al., 1957). Bergkamp et al. (1970), Romans et al. (1970) and Wahlstrom et al. (1971) have reported that decreased carcass firmness, along with increased iodine numbers, was produced when pigs were fed diets containing full-fat soybeans, demonstrating that iodine number is a good indicator of carcass firmness.

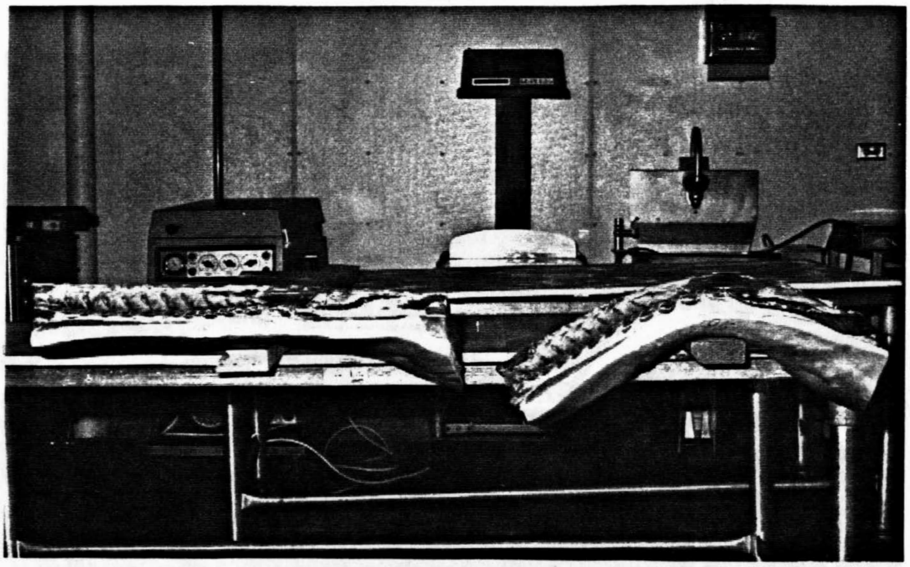

Figure 2. Loins from pigs fed diets without sunflower seeds (left) and 20% sunflower seeds (right).

Dietary sunflower seeds also produced changes in the proportion of individual fatty acids found in swine backfat. Of those fatty acids determined to be present, the relative proportions of myristic, palmitic, palmitoleic, stearic and oleic acids were found to decrease linearly ($P<.01$), while the proportion of linoleic acid increased linearly ($P<.01$) in the backfat of pigs as the sunflower seed content of their diet increased. Linoleic acid content of backfat changed most drastically and was solely responsible for a linear increase ($P<.01$) in the sum of the proportions of all unsaturated fatty acids present in pork backfat and a linear decrease ($P<.01$) in the sum

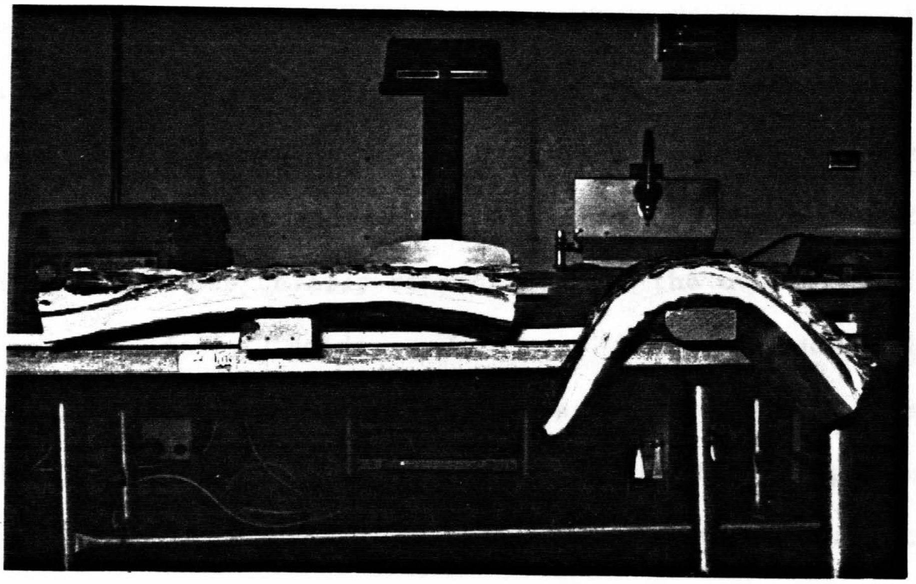

Figure 3. Bellies from pigs fed diets without sunflower seeds (left) and 20% sunflower seeds (right).

TABLE 9. EFFECT OF DIETARY SUNFLOWER SEEDS ON CHEMICAL ANALYSES OF BACKFAT (EXPERIMENT 1)

Source	Sunflower seeds, %			
	0	5	10	20
Iodine number[a]	56.91	62.36	66.28	71.55
Individual fatty acids, %				
Myristic (14:0)[a]	1.54	1.51	1.33	1.35
Palmitic (16:0)[a]	26.01	24.17	21.83	19.39
Palmitoleic (16:1)[a]	2.26	1.94	2.00	1.68
Stearic (18:0)[a]	11.89	11.03	9.96	9.43
Oleic (18:1)[a]	42.75	39.23	37.29	34.99
Linoleic (18:2)[a]	15.83	22.11	27.57	33.28
Sum of 14:0, 16:0 and 18:0[a]	39.44	36.70	33.13	30.17
Sum of 16:1, 18:1 and 18:2[a]	61.36	63.30	67.12	69.87

[a] Linear response ($P<.01$).

of all the saturated fatty acids present in pork backfat when sunflower seeds were added to the diets. Laudert and Allee (1975) and Marchello (1981) also reported a decreased proportion of saturated fatty acids and an increased proportion of unsaturated fatty acids present in the backfat as sunflower seeds in the diet increased. They also determined that linoleic acid was chiefly responsible for the overall shifts in the proportion of fatty acids. In the latter study, linolenic, eicosadienoic and arachidonic acids were also present (usually at levels less than 1.0%). Linolenic acid was found to be present in the experiment reported herein but at levels too low to measure accurately. It was not determined if eicosadienoic or arachidonic acid was present.

Brooks et al. (1971) determined that the level of linoleic acid present in pork backfat is dependent on the level of linoleic acid consumed per unit of gain. CRC (1980) reported that sunflower oil and soybean oil, two highly unsaturated oils, contained 66.7 and 50.7% respectively, of all fatty acids in the form of linoleic acid. Based on these results, diets containing sunflower oil or any other unsaturated oil should produce pigs whose backfat contains high levels of linoleic acid. In support of this proposal Wahlstrom et al. (1971), Villegas et al. (1973), Seerley et al. (1974) and Skelley et al. (1975) found large increases in the proportion of linoleic acid in pigs when full-fat soybeans replaced soybean meal as the protein source in swine diets. In comparison, diets containing beef tallow, which contains a low level of linoleic acid (CRC 1980), have not been shown to affect the linoleic acid content or the overall degree of unsaturation of backfat (Kropf et al., 1954; Leat et al., 1964).

The results of the taste panel evaluation are shown in table 10. Panelists determined that flavor, juiciness, tenderness and overall desirability were not affected by the addition of sunflower seeds to the diet. Full-fat soybeans have also been reported to have no adverse effect on taste panel acceptance of pork (Wahlstrom et al., 1971; Skelley et al., 1972; McConnell et al., 1975). Heitman et al. (1956) reported that no "off flavors" were produced when diets were supplemented with 10% beef tallow or 10% lard. Koch et al. (1968) found that diets supplemented with 10% safflower oil or 10% safflower oil and lard in a 1:1 combination had no adverse effects on taste panel acceptance of loin chops.

In contrast to these results, Palmer et al. (1952) did find that desirability of ground pork was less when pigs were fed diets containing ground soybeans. However, there were no differences in taste panel acceptance of chops or pork roasts from these same pigs. This may indicate that ground pork deteriorates faster than pork products having less surface area. Olson et al. (1973) noted only minor effects of feeding full-fat soybeans to pigs on taste panel acceptance of sausage and frankfurters and no effect on taste panel acceptance of bacon and canned hams. The differences noted may have been due to a combination of the unsaturated fatty acids present in the pork products and storage length and temperature.

TABLE 10. EFFECT OF DIETARY SUNFLOWER SEEDS ON TASTE PANEL ACCEPTANCE AND CHEMICAL ANALYSES OF PORK (EXPERIMENT 1)

	Sunflower seeds, %			
Source	0	5	10	20
Taste panel				
Flavor[a]	5.66	5.74	5.73	5.58
Juiciness[b]	5.07	5.43	5.18	5.08
Tenderness[b]	5.35	5.41	5.41	5.21
Overall desirability[a]	5.40	5.57	5.44	5.37
Shear test, kg[c]	10.50	11.12	11.13	11.00
Chemical analyses				
Moisture	73.64	73.36	73.36	72.90
Protein	22.30	22.38	22.06	21.95
Fat (fresh basis)	2.96	3.38	2.96	4.10
Fat (dry matter basis)	11.20	12.60	11.18	14.89

[a] Range of 1 to 8 with 1 being the least desirable and 8 the most desirable.
[b] Range of 1 to 8 with 1 being the least and 8 the most.
[c] Kilograms of force required to shear a 2.54-cm core.

Percentage of moisture, protein or fat of fresh meat samples taken from the longissimus muscle were not affected by level of dietary sunflower seeds (table 10). This finding was in agreement with the report of Wahlstrom et al. (1971) who found that dietary full-fat soybeans had no affect on longissimus muscle moisture, protein or fat. No differences in chemical composition of longissimus muscle were observed by Tribble et al. (1979)when swine diets were supplemented with beef tallow.

Experiment 2

Experiment 2 was conducted to more clearly identify the level at which sunflower seeds begin to produce detrimental effects on performance of growing-finishing pigs. The effects of dietary sunflower seeds on selected carcass characteristics, including two new criteria not specifically examined in experiment 1 (carcass firmness and bacon sliceability), were also determined.

Performance characteristics as affected by diet are shown in table 11. Average daily gain for pigs with up to 59 kg average pen weights was unaffected by diet. In the dietary period from 59 to 100 kg and the overall period, average daily gain increased linearly ($P<.01$) as level of sunflower seeds increased in the diet. Although mean values for average daily feed intake increased with increasing dietary sunflower seed level, these increases were not significant. Feed efficiencies were unaffected by diet, and all feed conversion ratios were acceptable.

In the overall period, average daily gain increased in experiment 2 but decreased slightly in experiment 1 when the sunflower seed content of the diets increased to 10%. It was also found that feed intake decreased in experiment 1 when 10 or 20% sunflower seeds were added to the diet and appeared to increase in experiment 2 with each addition, up to the maximum of 10%, of sunflower seeds to the diet. Therefore, it appears that gain is a function of feed intake rather than of the level of sunflower seeds in the diet.

TABLE 11. PERFORMANCE CHARACTERISTICS OF PIGS IN EXPERIMENT 2[a]

Source	Sunflower seeds, %			
	0	2.5	5	10
To 59 kg				
Avg daily gain, kg	.70	.78	.75	.75
Avg daily feed, kg	1.96	2.05	1.96	2.05
Feed/gain	2.82	2.63	2.64	2.74
59 to 100 kg				
Avg daily gain, kg[b]	.72	.72	.75	.82
Avg daily feed, kg	2.69	2.72	2.90	2.97
Feed/gain	3.77	3.84	3.73	3.69
Overall				
Avg daily gain, kg[b]	.71	.74	.76	.80
Avg daily feed, kg	2.36	2.46	2.53	2.61
Feed/gain	3.32	3.34	3.28	3.30

[a] Five blocks of four pigs each (initial weights of 30.1 kg for blocks 1 through 3 and 29.3 kg for blocks 4 and 5).

[b] Linear response ($P<.01$).

It is difficult to explain why pigs in experiment 2 consumed more feed per day as the level of sunflower seeds in the diet increased, while pigs in experiment 1 consumed less feed per day. Since feed wastage could not be measured, it was possible that differences in wastage may have been responsible, at least in part, for the differences between experiments.

Kennington et al. (1958) and Cole et al. (1967) have determined that pigs will generally eat to meet their energy requirements. There is no doubt that the replacement of corn with sunflower seeds at the levels used in this experiment would increase the energy density of the diet. Diets containing 2.5, 5 or 10% sunflower seeds fed during the period from 59 to 100 kg in experiment 2 had increased calculated energy levels of .5, 1 and 2.2 %, respectively. In comparison, diets containing 5, 10 and 20% sunflower seeds fed during the same weight period of experiment 1 had increased energy levels of .9, 3.1 and 8%, respectively. Therefore, on the basis of energy level of the diets, it would be expected that feed consumption would decrease as dietary sunflower seeds increased.

Dinusson et al. (1980a) observed no effect of dietary sunflower seeds on feed intake and suggested that the oil in sunflower seeds may not be totally digested, or perhaps the sunflower seeds in some way interfered with the digestion of other nutrients. However, there has been no direct evidence indicating this to be true.

As in the first experiment, there were no treatment effects found for most carcass characteristics (table 12). Specifically, carcass weight, carcass length, average backfat, tenth rib fat, kilograms of muscle and area, color, firmness and marbling of longissimus muscle of pork carcasses did not change with the addition of sunflower seeds to the diet.

Carcass firmness decreased (P<.01) as the level of sunflower seeds in the diet increased. Addition of sunflower seeds also produced soft carcasses in experiment 1. However, those effects were not subjectively measured. Bacon sliceability became more difficult (P<.01) as pigs consumed diets higher in sunflower seeds. The higher sliceability scores were the result of a softer bacon side which the automatic slicer could not handle as well. Although there was a decrease in the actual sliceability of bacon as sunflower seeds were added to the diet, no score indicated a severe slicing problem. There has been little work done in this area; however, Romans et al. (1970) reported no differences in sliceability of bacon slabs from pigs fed diets balanced for protein with either soybean meal or full-fat soybeans.

Also shown in table 12 is the effect of sunflower seeds on the iodine numbers of backfat samples. There was a cubic response (P<.05) among treatments, with higher iodine numbers coinciding with diets higher in sunflower seeds. Although each addition of sunflower seeds to the diet produced a higher iodine number in the backfat of pigs, the

TABLE 12. EFFECT OF DIETARY SUNFLOWER SEEDS ON CARCASS CHARACTERISTICS (EXPERIMENT 2)

Source	Sunflower seeds, %			
	0	2.5	5	10
Carcass weight, kg	66.9	65.1	64.3	66.3
Carcass length, cm	81.0	82.0	79.8	79.8
Avg backfat, cm	2.41	2.39	2.46	2.49
Tenth rib fat, cm	2.43	2.67	2.39	2.57
Longissimus muscle				
Area, cm^2	31.61	28.26	30.00	29.56
Color[a]	3.10	3.10	3.20	3.50
Firmness[b]	2.70	3.00	3.00	3.00
Marbling[b]	2.80	2.90	2.70	3.00
Kilograms of muscle[c]	39.4	38.8	39.9	39.7
Carcass firmness[d,e]	3.70	3.30	3.00	2.50
Bacon sliceability[e,f]	1.10	1.40	1.65	2.40
Iodine number[g]	55.77	58.17	64.18	71.04

[a] Range of 1 to 5 with 1 being the lightest and 5 the darkest.
[b] Range of 1 to 5 with 1 being the least and 5 the most.
[c] Kilograms of muscle in a standardized 72.6-kg carcass.
[d] Range of 1 to 5 with 1 being the softest and 5 the firmest.
[e] Linear response ($P<.01$).
[f] Range of 1 to 5 with 1 being the best and 5 the worst.
[g] Cubic response ($P<.05$).

magnitude of the change was smallest with the first addition of sunflower seeds to the diet. The increasing iodine numbers corresponded to a decrease in carcass firmness. This finding has also been noted by Blumer et al. (1957) and Bergkamp et al. (1970) and was consistent with the results previously reported for experiment 1.

SUMMARY

Two experiments with swine were conducted to determine the effects of dietary sunflower seeds on performance and carcass characteristics of growing-finishing swine.

In experiment 1, a corn-soybean diet was supplemented with 0, 5, 10 and 20% sunflower seeds to produce the four dietary treatments. In the overall period, a cubic response ($P<.05$) was observed for average daily gain. Gain increased slightly when 5% sunflower seeds were added to the diet and decreased when 10 and 20% sunflower seeds were added. The small decrease in gain of pigs fed the 10% sunflower seed diet was due to reduced gain from 59 to 100 kg average pen weights. Up to 59 kg, pigs receiving the 10% sunflower seed diet gained as well as pigs receiving the diet without sunflower seeds. The addition of 20% sunflower seeds to the diet depressed rate of gain at all stages of growth. Pigs receiving the diets containing 10 or 20% sunflower seeds had reduced ($P<.06$) daily feed intake as compared to pigs receiving diets containing 0 and 5% sunflower seeds. Feed efficiency was unaffected by any of the dietary treatments.

Carcass firmness decreased as the level of sunflower seeds in the diet increased. Carcass weight, carcass length, average backfat, tenth rib fat, kilograms of muscle and longissimus muscle area, color, firmness and marbling were unaffected by diet. Iodine number of backfat samples increased ($P<.01$) with each addition of sunflower seeds to the

diet, indicating an increase in the overall degree of unsaturation of backfat. This was verified by determination of individual fatty acid compositions. The proportion of linoleic acid in backfat greatly increased (P<.01) with each addition of sunflower seeds to the diet and was solely responsible for an increase in the overall degree of unsaturation of the fatty acids in backfat. Taste panel acceptance of loin chops and percent moisture, protein and fat of longissimus muscle samples were unaffected by dietary treatment.

In experiment 2, the four dietary treatments consisted of diets containing 0, 2.5, 5 and 10% sunflower seeds. Average daily gain increased with each addition of sunflower seeds to the diet. Feed efficiency and daily feed intake were unaffected by dietary treatment. Carcass firmness again decreased (P<.01) as sunflower seeds was added to the diet, while other carcass characteristics were unaffected. Although not severely affected, bacon sliceability decreased (P<.01) when pigs were fed increasing amounts of sunflower seeds. Iodine number of backfat samples increased (P<.01) with each addition of sunflower seeds to the diet, indicating an increase in the proportion of unsaturated fatty acids in the backfat.

These two experiments demonstrated that up to 10% sunflower seeds could be added to the diets of swine in the growing-finishing stage without adversely affecting performance. It can be expected that diets containing this level of sunflower seeds will produce changes in the fatty acid composition of fat in the depot areas and will produce carcasses that are less firm. The results indicated that these changes will not affect consumer acceptance of the pork. Meat packer acceptance of the carcass may vary depending on individual preference and degree of automation involved in the operation.

LITERATURE CITED

AMSA. 1978. Guidelines for cooking and sensory evaluation of meat. American Meat Science Association. Chicago, IL.

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

Barrick, E. R., T. N. Blumer, W. L. Brown, R. H. Smith, S. B. Tove, H. L. Lucas and H. A. Stewart. 1953. The effects of feeding several kinds of fat on feedlot performance and carcass characteristics of swine. J. Anim. Sci. 12:899 (Abstr.).

Bergkamp, J. L. and D. G. Topel. 1970. Effect of feeding swine infrared roasted soybeans on some physical and chemical characteristics of muscle and fat tissue. J. Anim. Sci. 31:1015 (Abstr.).

Blumer, T. N., E. R. Barrick, W. L. Brown, F. H. Smith and W. W. G. Smart, Jr. 1957. Influence of changing the kind of fat in the diet at various weight intervals on carcass fat characteristics of swine. J. Anim. Sci. 16:68.

Brody, S. 1945. Bioenergetics and Growth. Reinhold Publishing Co., Baltimore.

Brooks, C. C. 1971. Fatty acid composition of pork lipids as affected by ration type, fat source and fat level. J. Anim. Sci. 33:1224.

Bull, S., W. E. Carrol, F. C. Olson, G. E. Hunt and J. H. Longwell. 1931. Effect of soybeans and soybean oil meal on quality of pork. Illinois Agr. Exp. Sta. Bull. 366.

Castell, A. G. and T. M. Mallard. 1974. Utilization of ground seed or meal from low erucic acid rape (Brassica Campestiis cv. Span) in diets for growing-finishing pigs. Can. J. Anim. Sci. 54:443.

Christensen, K. D. 1964. Various fatty acids in fat tissues of Danish Landrace pigs fed with coconut fat or soybean oil. Acta Agr. Scand. 13:249.

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.

Cole, D. J. A., J. E. Duckworth and W. Holmes. 1967. 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.

Cook, N. K., M. J. Marchello, V. K. Johnson, W. D. Slanger and W. E. Dinusson. 1980. Effect of varying levels of sunflower seed rations on carcass composition of swine. North Dakota Agr. Exp. Sta. Annu. Rep., pp 99-102.

CRC. 1980. Handbook of Chemistry and Physics (60th Ed.). Chemical Rubber Co., Boca Raton, Florida.

Dinusson, W. E., R. L. Harold, J. N. Johnson and R. Zimprich. 1980b. Sunflower seeds for swine. North Dakota Agr. Exp. Sta. Annu. Rep., pp88-90.

Dinusson, W. E., J. N. Johnson, R. Zimprich and M. Hankel. 1980a. Sunflower seeds for swine. North Dakota Agr. Exp. Sta. Livestock Res. Day Rep., pp 39-41.

Ellis, N. R. and H. S. Isbell. 1926. Soft pork studies. II. The influence of the character of the ration upon the composition of the body fat of hogs. J. Biol. Chem. 69:219.

Folch, J., M. Lees and C. H. Sloan-Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497.

Friend, D. W., A. H. Corner, J. K. G. Kraner, K. M. Charlton, F. Gilka and F. D. Sauer. 1975. Growth, cardiopathology and cardiac fatty acids of swine fed diets containing soybean oil or low erucic acid rapeseed oil. Can. J. Anim. Sci. 55:49.

Gorton, G. A. and W. R. H. Duncan. 1954. Dietary fat and body fat: the composition of the backfat of pigs fed a diet rich in cod liver oil and lard. Biochem. J. 57:120.

Greeley, M. G., R. J. Meade, L. E. Hanson and J. Nordstrom. 1964. 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.

Hanke, H. E., J. W. Rust, R. J. Meade and L. E. Hanson. 1972. Influence of the source of soybean protein, and of pelleting, on rate of gain and gain/feed of growing swine. J. Anim. Sci. 35:958.

Hanson, L. E., C. E. Allen, R. J. Meade, J. W. Rust and K. P. Miller. 1970. Cooked soybeans for swine and effects on carcass characteristics. Feedstuffs 42(39):16.

Heitman, H., Jr. 1956. Use of stabilized tallow in swine rations. J. Anim. Sci. 15:1046.

Howard, A. N., W. M. Leat, G. A. Gresham, D. E. Bowyer and E. R. Dalton. 1965. Studies on pigs reared on semi-synthetic diets containing no fat, beef tallow or maize oil: husbandry and serum biochemistry. Brit. J. Nutr. 19:383.

Jimenez, A. A., T. W. Perry, R. A. Pickett and W. M. Beeson. 1963. Raw and heat-treated soybeans for growing-finishing swine and their effects on fat firmness. J. Anim. Sci. 22:471.

Kennington, M. H., T. W. Perry and W. M. Beeson. 1958. Effect of adding animal fat to swine rations. J. Anim. Sci. 17:1166 (Abstr.).

Kepler, M. A. 1981. Effects of ground sunflower seeds in diets of late gestating and early lactating swine. M. S. Thesis. South Dakota State Univ., Brookings.

Koch, D. E., A. M. Pearson, W. T. Magee, J. A. Hoefer and B. S. Schweigert. 1968. Effect of diet on the fatty acid composition of pork fat. J. Anim. Sci. 27:360.

Kropf, D. H., A. M. Pearson and H. D. Wallace. 1954. Observations on the use of waste beef fat in swine rations. J. Anim. Sci. 13:630.

Laudert, S. B. and G. L. Allee. 1975. Nutritive value of sunflower seed for swine. J. Anim. Sci. 41:318.

Leat, W. M. F., A. Cuthbertson, A. N. Howard and G. A. Gresham. 1964. Studies on pigs reared on semi-synthetic diets containing no fat, beef tallow and maize oil: composition of carcass and fatty acid composition of various depot fats. J. Agr. Sci. 63:311.

Marchello, M. J., W. J. Cook, V. K. Johnson, A. G. Fischer, W. D. Slanger and W. E. Dinusson. 1981. Fatty acid composition of swine as affected by various levels of sunflower seeds. North Dakota Agr. Exp. Sta. Annu. Rep., pp 224-228.

Mason, J. V. and R. F. Sewell. 1967. Effect of diet on fatty acid composition of swine tissues. J. Anim. Sci. 26:1342.

McConnell, J. C., G. C.Skelley, D. L. Handlin and W. E. Johnston. 1975. Corn, wheat, milo and barley with soybean meal or roasted soybeans and their effect on feedlot performance, carcass traits and pork acceptability. J. Anim. Sci. 41:1021.

McDonald, B. E. and R. M. G. Hamilton. 1976. Growth and carcass composition of pigs fed diets that contained rapeseed oil, soybean oil or tallow during the growing period. Can. J. Anim. Sci. 56:671.

Nordstrom, J. W., B. R. Behrends, R. J. Meade and E. H. Thompson. 1972. Effects of feeding high oil corns to growing-finishing swine. J. Anim. Sci. 35:357.

NPPC. 1976. Procedures to Evaluate Market Hogs. National Pork Producers Council, Des Moines, Iowa.

NPPC. 1983. Procedures to Evaluate Market Hogs. National Pork Producers Council, Des Moines, Iowa.

NRC. 1979. Nutrient Requirements of Domestic Animals, No. 2. Nutrient Requirements of Swine. (8th Ed.). National Academy of Sciences-National Research Council. Washington, DC.

Olson, D. G., F. C. Parris, Jr., R. E. Rust and B. E. Miner. 1973. Effect of feeding roasted soybeans on cured pork palatability. J. Anim. Sci. 37:49.

Owen, J. B. and W. J. Ridgman. 1967. The effect of dietary energy content on the voluntary intake of pigs. Anim. Prod. 9:107.

Palmer, A. Z., D. E. Brady, H. D. Naumann and L. N. Tucker. 1952. Deterioration in frozen pork as related to fat composition, storage temperature, length of storage period and packing treatment. Missouri Agr. Exp. Sta. Res. Bull. 492.

Romans, J. R., A. H. Jensen and F. O. VanDyne. 1970. Effect of dietary cooked soybeans on pork quality. J. Anim. Sci. 31:1017 (Abstr.).

Ruffin, B. G., W. E. Powell and V. L. Brown. 1971. Effect of roasted soybeans on pig growth and carcass quality. J. Anim. Sci. 32:391 (Abstr.).

Seerley, R. W., J. P. Briscoe and H. C. McCampbell. 1978. A comparison of poultry and animal fat on performance, body composition and tissue lipids of swine. J. Anim. Sci. 46:1018.

Seerley, R. W., J. W. Emberson, H. C. McCambell, D. Burdick and L. W. Grimes. 1974. Cooked soybeans in swine and rat diets. J. Anim. Sci. 39:1082.

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

Sink, J. D., J. L. Watkins, J. H. Ziegler and R. C. Miller. 1964. Analysis of fat deposition in swine by gas-liquid chromatography. J. Anim. Sci. 23:121.

Skelley, G. C., R. F. Borgman, D. L. Handlin, J. C. Acton, J. C. McConnell, F. B. Wardlaw and E. J. Evans. 1975. Influence of diet on quality, fatty acids and acceptability of pork. J. Anim. Sci. 41:1298.

Skelley, G. C., J. C. McConnell, D. L. Handlin and W. E. Johnston. 1972. Pork acceptability as influenced by cooked soybeans. J. Anim. Sci. 34:348 (Abstr.).

Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics. (2nd Ed.). McGraw-Hill Book Co., New York.

Thrasher, D. M., T. D. Bidner and T. L. Dumas. 1973. Roasted soybeans with corn and milo for pigs. J. Anim. Sci. 36:203 (Abstr.).

Thrasher, D. M., R. E. Brown, A. M. Mullins, S. H. Hansard and P. B. Brown. 1959. Effects of dietary animal fats on growth, feed efficiency and carcass characteristics of swine. J. Anim. Sci. 18:1494 (Abstr.).

Tribble, L. F., S. H. Ingram, C. T. Gaskins and C. B. Ramsey. 1979. Evaluation of added fat and lysine to sorghum-soybean meal diets for swine. J. Anim. Sci. 48:541.

Van Wijngaarden, D. 1967. Modified rapid preparation of fatty acid esters from lipids for gas chromatograph analysis. Anal. Chem. 39:848.

Villegas, F. J., H. B. Hedrick, T. L. Veum, K. L. McFate and M. E. Bailey. 1973. Effect of diet and breed on fatty acid composition of porcine adipose tissue. J. Anim. Sci. 36:663.

Villegas, F. J., T. L. Veum, H. B. Hedrick and K. L. McFate. 1970. Processed soybeans for swine. J. Anim. Sci. 31:213 (Abstr.).

Wahlstrom, R. C., G. W. Libal and R. J. Berns. 1971. Effect of cooked soybeans on performance, fatty acid composition and pork carcass charactersitics. J. Anim. Sci. 32:891.

APPENDIX

TABLE 1. ANALYSIS OF VARIANCE FOR AVERAGE DAILY GAIN OF PIGS IN EXPERIMENT 1

		Mean squares		
		Average daily gain		
Source	df	To 59 kg	59 to 100 kg	Overall
Treatment	3	.23**	.24	.23**
Block	5	.06	.25	.03
Treatment x block	15	.10*	.06	.04
Sex	1	.21*	.35**	.28**
Treatment x sex	3	.06	.03	.02
Block x sex	5	.01	.06	.04
Treatment x block x sex	15	.11*	.08	.06
Within	42	.05	.05	.03
Total	89			

* P<.05.
** P<.01.

TABLE 2. ANALYSIS OF VARIANCE FOR FEED INTAKE AND FEED EFFICIENCY OF PIGS IN EXPERIMENT 1

		Mean squares					
		Feed intake			Feed efficiency		
Source	df	To 59 kg	59 to 100 kg	Overall	To 59 kg	59 to 100 kg	Overall
Treatment	3	.27	.53	.37	.11	.07	.03
Block	5	.37	.32	.09	.13	.06	.05
Within	15	.26	.18	.08*	.08	.11	.03
Total	23						

* P<.01.

TABLE 3. ANALYSIS OF VARIANCE OF CARCASS CHARACTERISTICS FROM EXPERIMENT 1

		Mean squares								
						Longissimus muscle characteristics				
Source	df	Carcass weight	Carcass length	Back-fat	Tenth rib fat	Area	Color	Firm-ness	Marb-ling	Kg of muscle
Treatment	3	70.83	.05	.03	.03	.11	.21	.37	.89	26.63
Block	5	88.67	.84	.02	.03	1.28*	1.39	1.28	2.47*	14.92
Treatment x block	15	112.10	.63	.03	.06	.39	.78	.94	1.46	13.30
Within	22	121.16	1.21	.03	.04	.42	.57	.53	.89	12.32
Total	45									

* P<.05.

TABLE 4. ANALYSIS OF VARIANCE OF CHEMICAL ANALYSES OF BACKFAT SAMPLES FROM PIGS IN EXPERIMENT 1

Source	df	Mean squares								
			Percent composition							
		Iodine number	14:0	16:0	16:1	18:0	18:1	18:2	Sum of 14:0,16:0, 18:0	Sum of 16:1,18:1, 18:2
Treatment	3	403.06**	.14*	86.05**	.68**	13.14**	117.50**	610.55**	174.18**	153.39**
Block	5	9.15	.01	4.91	.14	2.49	24.32	53.10	10.33	13.34
Treatment x block	15	15.35	.09*	7.26*	.18*	2.36	10.31	31.28	13.12	13.97
Within	22	10.75	.04	2.93	.08	1.71	9.81	26.42	6.26	7.48
Total	45									

* P<.05.
** P<.01.

TABLE 5. ANALYSIS OF VARIANCE OF WARNER-BRATZLER SHEAR TEST, TASTE PANEL RESULTS AND CHEMICAL ANALYSES OF MEAT SAMPLES FROM PIGS IN EXPERIMENT 1

Source	df	Mean squares								
			Taste panel				Chemical analyses			
									Fat	
		Shear	Flavor	Juiciness	Tenderness	Overall desirability	Moisture	Protein	Dry basis	Fresh basis
Treatment	3	5.18	.06	.32	.09	.09	1.45	.44	30.40	2.89
Block	5	6.40	.16	.21	.17	.11	.87	.45	23.57	1.98
Treatment x block	15	12.10	.14	.25	.49	.12	1.16	.65	16.47	1.53
Within	22	8.63	.07	.34	.62	.19	.76	1.18	14.11	1.14
Total	45									

TABLE 6. ANALYSIS OF VARIANCE FOR AVERAGE DAILY GAIN OF PIGS IN EXPERIMENT 2

Source	df	Mean squares Average daily gain To 59 kg	 59 to 100 kg	 Overall
Treatment	3	.09	.22**	.11*
Block	4	.08	.08	.05
Treatment x block	12	.08	.10	.05
Sex	1	.00	.17*	.07
Block x sex	4	.01	.00	.01
Treatment x sex	3	.01	.00	.00
Treatment x block x sex	12	.03	.02	.01
Within	38	.04	.04	.03
Total	77			

* P<.05.
** P<.01.

TABLE 7. ANALYSIS OF VARIANCE FOR FEED INTAKE AND FEED EFFICIENCY OF PIGS IN EXPERIMENT 2

		Mean squares					
		Feed intake			Feed efficiency		
Source	df	To 59 kg	59 to 100 kg	Overall	To 59 kg	59 to 100 kg	Overall
Treatment	3	.06	.45	.27	.04	.02	.00
Block	4	.42	.50	.32	.08	.27	.20
Within	12	.16	.36	.22	.09	.1	.07
Total	19						

TABLE 8. ANALYSIS OF VARIANCE OF CARCASS CHARACTERISTICS FROM EXPERIMENT 2

		Mean squares							
						Longissimus muscle characteristics			
Source	df	Carcass weight	Carcass length	Avg backfat	Tenth rib fat	Area	Color	Firm-ness	Marb-ling
Treatment	3	56.58	1.98	.00	.03	.41	.35	.19	.15
Block	4	74.52	.33	.07*	.10	.35	.72	.91	2.40*
Treatment x block	12	33.75	.31	.02	.07	.10	.40	.37	.43
Within	18	142.03	1.18	.02	.08	.21	.31	.53	.61
Total	37								

* P<.05.

TABLE 8 CONTINUED

Source	df	Mean squares			
		Kg of muscle	Carcass firmness	Bacon slicea-bility	Iodine number of backfat
Treatment	3	25.22	2.36*	292.20**	439.37**
Block	4	9.05	.25	22.10	.94
Treatment x block	12	8.77	.91	14.10	3.94
Within	18	16.19	.53	36.81	3.26
Total	37				

* P<.05.
** P<.01.