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EVALUATION OF CORN DISTILLERS DRIED GRAINS WITH SOLUBLES FOR FINISHING PIGS

by

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ABSTRACT

Three experiments were performed to test 7.5 and 15.0% distillers dried grains with solubles (DDG/S) in a diet for finishing pigs. Average initial weight of pigs was 55.0 kg with a final weight of approximately 90.0 kg. The DDG/S replaced soybean meal on an isonitrogenous basis. L-lysine was supplemented to the DDG/S diets equivalent to that of the soybean meal control diet.

The 15.0% DDG/S level produced a significantly lower a.d.g. than the control and the 7.5% level was intermediate and not significantly different from the control or 15.0% diet.

Although no sex x treatment interaction could be shown for a.d.g., it appeared that the decreases in a.d.g. were corresponding to similar decreases in feed consumption. The feed consumption of boars decreased most with higher levels of DDG/S, followed by a lesser magnitude by gilts and barrows affected least. DDG/S impaired feed efficiency of boars, slightly for barrows but only at the 15.0% level for gilts.

Digestibility studies revealed that a low dry matter and lysine digestibility of DDG/S could have contributed to the impaired performance of the DDG/S diets.

There were no overall carcass differences due to treatment.

Barrows consumed more than gilts with boars consuming an intermediary amount. Boar gain was similar to barrows which gained significantly faster than gilts. Feed efficiency was best with boars, followed by gilts and then barrows.

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Gilts were significantly superior to barrows in total backfat, area of loin, % ham of side, carcass length and % yield of trimmed cuts. Carcass measurement means showed boars to be superior to gilts and barrows in total backfat but intermediate in loin eye area. Per cent yield of trimmed cuts of boars was similar to gilts.

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INTRODUCTION

It is known that feed is the largest single cost in producing a pig for market. It is also known that over one-half (150 kg out of 250 kg) of the feed charged to each weaner pig fed to market is consumed in the finishing stage (50-90 kg). Because of the high feed consumption of the finishing pig, any slight improvements in feed efficiency or feed costs yield a larger saving to hog producers than a similar percentage improvement at any other stage.

Both protein quantity and quality play an important role in the nutrition of the growing-finishing pig. Protein requirements have been traditionally established with barrows and gilts, but little data exist on boar requirements. Since boars generally gain faster, more efficiently and produce better carcass yields than barrows or gilts, in the future it may be necessary to reconsider the use of boar meat for human consumption. However, in order to do this efficiently, further studies are necessary to determine their nutrient requirements.

The meagerness of research data on the use of Distillers Dried Grains with Solubles (DDG/S) in finishing pig diets limits its use, in spite of the fact that the annual North American production of DDG/S has doubled since 1957 to 386,000 tons in 1970. The monogastric, unlike the ruminant, has not been able to capitalize on the use of DDG/S in their diets because of its bulkiness, limited production and relatively low lysine level (0.70%). However, the recent large decreases in synthetic lysine prices raise the question about the economic feasibility of utilizing DDG/S with supplemental lysine in swine rations.

Presently, several methods are used to indicate the nutritive value of proteins of different feeds for pigs. One of the most recent methods is to establish a protein's ability to supply amino acids in forms which are available for absorption from the digestive tract i.e. amino acid availability. It has been suggested further that current protein values be replaced by listing amino acid availability values as indicators of the quality of a protein supplement.

With the foregoing thoughts in mind, a research project was designed to evaluate DDG/S with lysine in a barley base diet fed to finishing boars, barrows and gilts.

LITERATURE REVIEW

Fermentation is among the oldest biological phenomena discovered and utilized by mankind. Although yeast fermentation of grain is basically designed to efficiently produce beverage spirits, an important allied activity is the recovery of high-quality animal feedstuffs from the fermented and dealcoholized mash. By utilizing highly specialized techniques and processes, the distilling industry makes it possible for cereal grains to serve a double role: (1) conversion of the grain starch to spirits and (2) recovery of the remaining nutrients plus yeast cells and yeast metabolites as distillers' feeds.

PRODUCTION OF DISTILLERY BY-PRODUCTS

A flow diagram of the fermentation and feed recovery process is shown in Figure 1. The cereal grains are ground, slurred with water, cooked either batchwise or continuously to gelatinize the starch, cooled and saccharified (conversion of the starches in grains to fermentable sugars during mashing) with malt. Microbial amylases or a mixture of these enzymes and barley malt may be used to saccharify the gelatinized starch for the production of grain spirits. After holding for a period to permit saccharification, the mash is cooled to fermentation temperature, innoculated with the yeast, *Saccharomyces cerevisiae*, and allowed to ferment from three to five days. The fermented mash then is distilled and the whole spent stillage is further processed to make distillers' feeds.

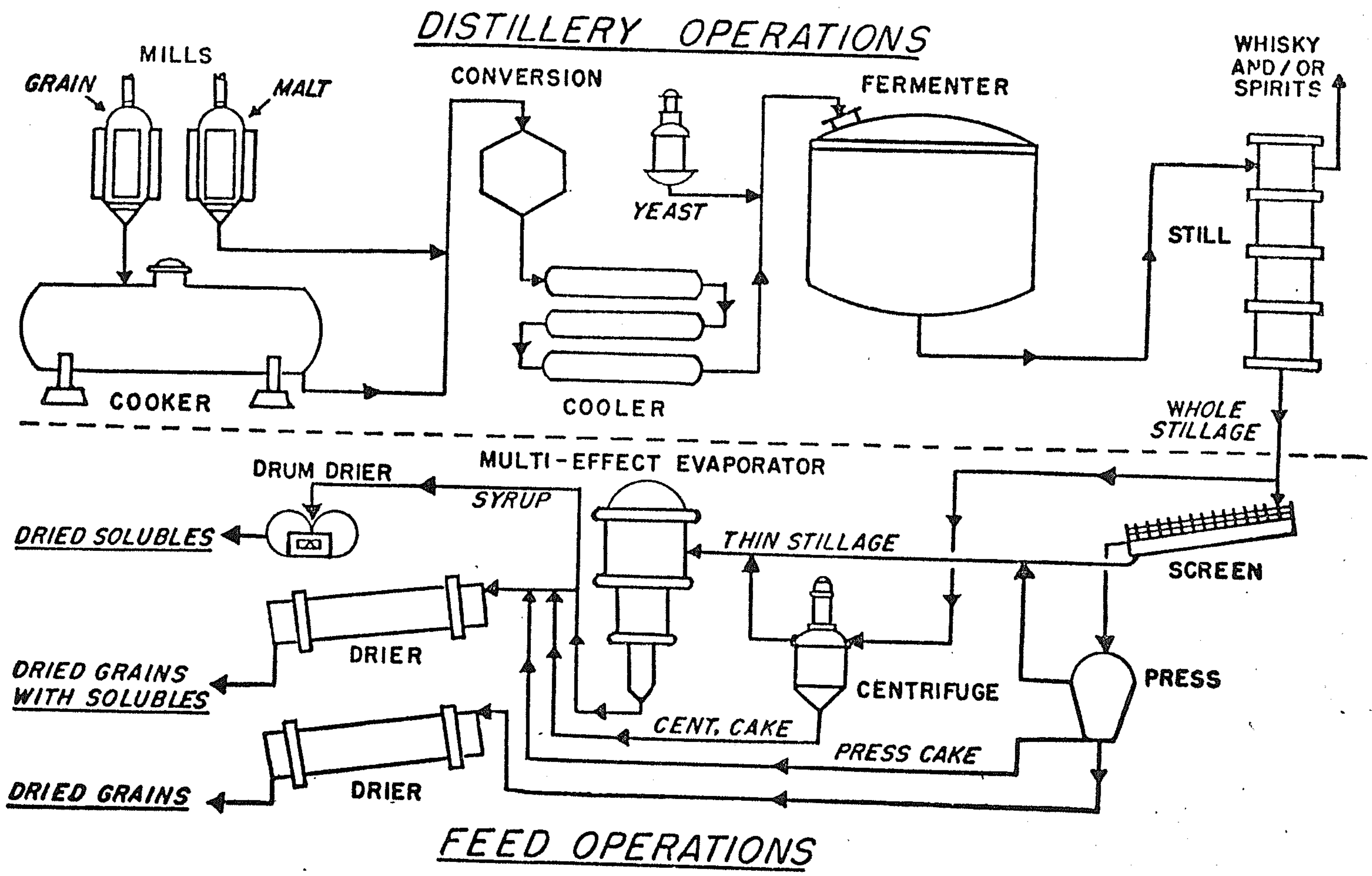

Fig. 1 – Material Process Flow, Beverage Spirits Plant

Since the whole spent stillage contains from 5 to 10% solids, the recovery of dry distillers' feed products basically involves dewatering processes. These are faciliated by separating the stillage into fractions. The choice of dewatering and fractionating equipment varies somewhat from plant to plant. In many plants, the first step consists of passing the whole spent stillage over screens with the coarser fraction being retained on the screens and the soluble and finely suspended solids passing through the screens. The coarser fraction is generally pressed for further removal of water and soluble portion containing finely suspended particles may be either centrifuged for removal of suspended solids or evaporated directly to a syrup of 30 to 40% solids.

In the production of distillers dried grains with solubles, the screened and pressed fraction and syrup are mixed and dried, generally in rotary steam-tube dryers. Drying is faciliated by mixing with previously dried material. In some plants, screens, presses and batch centrifugation have been replaced with continuous centrifuges which separate whole spent stillage into a clarified stillage of low suspended solids and a cake. The clarified stillage is evaporated to a syrup of 45 to 55% solids which is then mixed with the cake and dried either in a rotary dryer or a direct fired dryer. Distillers dried solubles are produced by drying the concentrated syrup, generally on double drum dryers. When this syrup is marketed as a semi-solid, it is called condensed distillers solubles. Distillers dried grains, when produced separately, are prepared by drying the screenable pressed material in rotary or direct fired dryers.

It is important, however, to realize that distillers' feeds are products which result from a yeast fermentation process designed primarily for the production of beverage spirits. Human tastes vary, consequently this multi-company industry uses different procedures and equipment to manufacture products to satisfy the public.

The nutrient composition of distillers' feeds can be influenced by many factors related to either the raw materials processing procedures and type of equipment used. A list of the source of potential variables is given in Table 1A, though it is acknowledged, that the composition of the cereal grains used is the principle source of nutrient variation (Carpenter 1970, deBecze 1949). The typical nutrient composition of corn distillers dried grains with solubles (DDG/S) resulting from the fermentation of corn or Bourbon mash is given in Table IIB. Although rye DDG/S and corn DDG/S appear to have a similar nutrient content, rye DDG/S has a considerably lower total digestible nutrient value and a lower digestible protein value (Morrison, 1959).

FEEDING DISTILLERY BY-PRODUCTS TO SWINE

The feeding of distillers' grains dates back in North America at least to 1900. In that era, distillers' grains were a new ingredient. Most of the spent stillage was fed in the wet state until the early 1940's. The modern distilling industry was established after the repeal of the 18th amendment to the U.S. constitution in 1933. With the rebirth of the industry came many new developments. Rapid progress was made in the recovery of fermentation residues, because the industry was aware of the nutritional and economic value represented by the primary feed

Table 1

A. Factors Influencing the Composition of Distillers Feeds

I. Raw Materials

a) kind of cereal grains
b) variety of grains
c) quality of grains
d) grain formulae or mash bill

II. Processing

a) grinding procedure
b) cooking
c) conversion
d) dilution of converted grain
e) fermentation
f) distillation
g) processing of spent or dealcoholized stillage

B. Typical Nutrient Composition[1] of Corn Distillers Dried Grains with Solubles

Dry Matter %	92.0
Protein %	27.4
Fat %	9.3
Fiber %	9.0
Ash %	2.6
Lysine %	0.70
(available)	0.60[2]
Methionine %	0.50[2]
Phenylalanine %	1.70
Tryptophan %	0.10
GE, kcal/kg	4528
DE, kcal/kg	3085
ME, kcal/kg	2790[2]
TDN %	70

[1] N.R.C., 1968

[2] Carpenter, 1970

supplement and the resultant public health and pollution problems if spent stillage were disposed of in streams and rivers.

Good and Smith (1915) carried out some of the earliest experimental work in feeding distillers' feeds to swine. Their trial involved growing-finishing swine on pasture with supplements of distillers dried grains alone and also in combination with corn. The results were not impressive for the distillers dried grains by itself; the pigs did not find it palatable and gains were poor. However, when fed in combination with corn, distillers dried grains improved growth rate and reduced feed requirements.

In this same era whole spent stillage was also being fed to swine. Following World War I, it was shown that large amounts of stillage were required to make possible appreciable gains and the large amounts of water which swine consumed posed management problems. In addition, soft pork resulted unless the stillage was supplemented properly (Wilford, 1948). There was no further research on distillers' feeds for swine until it was established that distillers dried solubles were a rich source of vitamins. Krider _et al_.(1942) reported preliminary findings on the value of distillers dried solubles in swine formulations. A year later, Bohstedt _et al_.(1943) found that distillers dried solubles could be used as a source of B-vitamins when swine were fed vegetable protein concentrates in drylot.

Many experiments were conducted with distillers'feeds in the decade from 1945 to 1955. However, all involved corn and most were fed in drylot. Catron _et al_.(1956) summarized 24 experiments with growing-finishing swine fed distillers dried solubles. In the 24 experiments involving a total of 1737 pigs, an average of 10.8% distillers dried solubles diets of various combinations, gave a 4.2% increase in average daily gain and 3.3% increase in feed efficiency.

Catron (1956) showed a weight decrease in young pigs as distillers dried solubles was increased and claimed this was due to a decrease in digestible carbohydrates and proteins. Greater controversy and variability of the results exist with gestation-lactation because of the length of the research period required.

In 1964 a five year study of distillers' feeds was initiated at Florida by Wallace and Combs. They first compared corn dried distillers solubles and dried distillers' grains with solubles as sources of unidentified growth factors for the pig (Wallace and Combs, 1965). Both feed products, when added at a level of 5% to the diet, reduced rate of gain during the early growth period from 8-11 weeks of age. There were no consistent patterns evident in the gain data for the finishing phase. Pigs fed the basal diet or the diet supplemented with distillers dried grains and solubles gained slightly better, than the group supplemented with solubles only. The overall averages for feed conversion showed that differences due to treatment were not significant nor was the difference due to pig source significant.

From the previous report, another study was initiated to determine if a lower digestibility of certain nutrients accompanied the growth depression of pigs fed diets containing DDG/S (Combs and Wallace, 1969). Thirty-six pigs having an initial weight of 7.5 kg were housed in individual concrete floored pens and fed corn-based diets containing 0, 10 or 20% DDG/S for a 42-day period. Neither daily gain, daily feed consumption nor feed efficiency was significantly (P 0.05) influenced by the addition of DDG/S to pig starter diets. Dry matter digestibility was significantly ($P<0.05$) lower in pigs fed the 20% DDG/S diet than in those fed the 0 and 10% DDG/S diet. The pigs fed the 20% level of DDG/S also had a significantly ($P<0.05$) lower digestion coefficient for protein and ether extract than that found with pigs given the 0 level of DDG/S with the 10% level being intermediate to the other two and not significantly different from either.

Since DDG/S did not significantly influence rate or efficiency of gain when included in the diet at levels of 10% or 20%, another study was initiated by Wallace and Combs (1970) to study the effects of DDG/S upon growth performance and nutrient digestibility when added to the diets of growing-finishing swine. Growing-finishing pigs (initial weight 22.3 kg) were fed diets containing 0, 10 or 20% DDG/S. Daily gain, feed consumption and feed efficiency were not significantly ($P>0.05$) influenced by dietary level of distillers' grains. In general, the degree of depression in digestibility was correlated with the dietary level of DDG/S. In an additional long term study, Wallace and Combs (1969) concluded that feeding 5% corn distillers dried solubles in a corn-soybean diet to gestation-lactation sows, had no adverse or advantageous influence on reproductive performance.

Wahlstrom et al. (1970) conducted three experiments on growing-finishing swine to determine the effect of 5, 10 and 20% DDG/S on gain, feed consumption, feed conversion and nutrient digestibility as well as the effect of lysine and fat supplementation to corn-based diets. The data indicated that levels of 5 or 10% DDG/S can be fed in corn-soybean meal rations without adversely affecting rate of gain or feed efficiency. A level of 20% DDG/S reduced digestibility of protein, N.F.E. and dry matter as well as gain and feed efficiency, probably due in part to a lower lysine level. In the second experiment, energy (lard) was added to the 5, 10 or 20% DDG/S diets so they were isocaloric, and resulted in similar average daily gain, feed intake or feed conversion for all treatments. However, an improvement in feed efficiency from 3.28 to 2.89 was achieved when 0.25% synthetic lysine was supplemented to the 20% DDG/S diet. In the same experiment supplementing all of these diets with lysine to an equivalent level of 0.75%, did not affect performance significantly. Average daily gain was improved by 8% and required 12% less feed per unit gain with lysine supplementation of the 20% DDG/S diet versus the same diet without lysine. Supplementing with lysine to obtain a total dietary level of 0.65% in the third experiment appeared to be adequate for all diets. Without lysine supplementation average daily gain and feed conversion was significantly poorer for only the 20% DDG/S diet.

Livingstone and Livingstone (1966) tested the suitability of 'distillers grains plus solubles' in a barley base diet for pigs from 20 to 90 kg liveweight. There were no differences between diets with 0 and 14.7% DDG/S in growth rate or feed efficiency but both these measures were significantly poorer when DDG/S was included at the 25% level. The only significant improvement in carcass measurement was the increased carcass length of the intermediate treatment (14.7% DDG/S) but no reason was given to account for this.

PROTEIN AND AMINO ACID REQUIREMENTS OF THE FINISHING PIG

In nutritional experiments one frequently studies if an animal's requirements for specific nutrient(s) are met by the diet's supply of these nutrients. The review will be restricted to finishing pigs fed a barley base diet, ad libitum. It is known that within physiological limits, swine consume a balanced ration at a rate adequate to fulfil their need for calories. However, poor protein quality or a lack of certain nutrients are some of the factors that can inhibit feed intake. A protein's quality is determined by its ability to supply the essential amino acids assuming sufficient nitrogen is available for non-essential amino acid synthesis.

Mertz et al. (1949) was one of the first to show that lysine was one of the essential amino acids required by swine. Subsequently, several amino acid studies have been conducted to indicate that lysine is the first limiting amino acid (Dinusson et al. 1962, Soldevila and Meade, 1964) with tryptophan (Gallo and Pond, 1968, Allee and Baker, 1970), methionine (Evans, 1961) and threonine (Kroening et al. 1965), each suspected to be the second limiting amino acid depending upon the diet. The minimal nutrient levels for normal growth and performance of finishing pigs as recommended by N.A.S.-N.R.C. (1968), are shown in Table 2. However, the nutrient requirements, especially for amino acids, of the finishing pig remain inconclusive because much of the data are extrapolated from more numerous studies on the very young pig. Therefore, calculations and interpolations may be required with varying feed mixtures to account for variations in protein level and in caloric density. Caution also has to be employed in not producing any amino acid imbalances, toxicities or antagonisms, but yet producing an optimum amino acid level.

Table 2 Nutrient Requirements of Swine[1]

	%	g/day
Protein	14	462
Digestible energy kcal/g	3,100	10,230
Isoleucine	0.35	11.55
Tryptophan	0.09	2.97
Lysine	0.50	16.50

[1]60 - 100 kg finishing pigs, full-fed on wheat, barley, oats, N.A.S.-N.R.C., 1968.

Bowland (1962) reported that the addition of lysine (0.2%) to a 13% protein barley, wheat and soybean meal ration containing 0.55% lysine for individually fed pigs (16.4 - 50.5 kg) increased average daily gain and feed efficiency such that the ration was essentially equal to a 16% protein ration containing 0.75% lysine. However, the advantage from lysine supplementation was lost in the finishing stage producing a significantly poorer feed efficiency but a similar average daily gain as compared to the unsupplemented 13% protein diet. Bell (1965), essentially repeating Bowland's work, found that an addition of 0.12% lysine to a 13% protein ration having 0.55% lysine but maintaining the same protein level, significantly increased average daily gain and feed efficiency of finishing pigs so that they were equal to those obtained with a 16% protein diet containing 0.67% lysine. However, better carcass quality was obtained with the 16% protein ration giving a higher lean:fat ratio.

Reimer et al. (1964) indicated that the addition of lysine to a 13.3% protein pelleted barley ration did not improve rate of gain or feed efficiency. No measure of carcass leanness was significantly improved with lysine additions. The lysine content of the basal rations ranged from 0.60 to 0.66%. These workers also indicated that source of protein (soybean meal, tankage, bloodmeal or fishmeal) had no effect on average daily gain or feed efficiency. It was concluded that rations containing 0.48% lysine and 13% protein for pigs heavier than 45.5 kg supported satisfactory performance.

Soldevila and Meade (1964) showed that the addition of L-lysine and DL-methionine to a barley-soybean meal diet (based on barley) containing 11.7% protein were without significant effect upon nitrogen retention of the growing pig. When the rate of intake was changed from 5.5 to 6.5% of the $W^{0.9}$ kg daily, an increase in lysine caused a subsequent increase in nitrogen retention of pigs fed a 14% protein diet based on barley containing 13.3% protein. However, methionine supplementation produced no effect and no lysine-methionine interaction existed. From the nitrogen retention studies, it was concluded that lysine is the first limiting amino acid in barley protein or barley soybean diets when fed in meal form.

Since publication of the Nutrient Requirements of Swine, (N.A.S.-N.R.C., 1968) as previously indicated, several other evaluations of an optimum lysine level with varying parameters were performed on finishing swine. Sauer and Stothers (1969) suggested that improved average daily gain can be achieved in finishing pigs by supplementing lysine to an 11.3% protein, all barley ration to a level of 0.66% lysine. Average daily gain was significantly improved from 0.77 to 0.89 kg/day but not significantly different from a 14.3% protein diet (0.85 kg/day).

One of the most extensive studies was performed by Blair et al. (1969) where a total of 512 pigs were given, from 22.7 kg liveweight, one of sixteen diets containing 4 lysine levels at each of 12, 14, 16 and 18% protein, at one of four levels of intake. Liveweight gain was not improved significantly by increasing the lysine level above 1.04, 0.74, 0.70 and 0.59% respectively for the 22.7 - 45.5, 45.5 - 68.2, 68.2 - 90.9 and 90.9 - 113.6 kg stages of growth. However, conversion of feed per unit gain was improved significantly during the 22.7 - 45.5 kg stage by increasing the lysine level to 1.22%. Raising the lysine level at each level of protein had no significant effects on rate and efficiency of lean meat gain. Live weight gain was significantly improved by increasing the level of feed intake almost to ad libitum for the 22.7 - 45.5, 45.5 - 68.2 and 68.2 - 90.9 kg stages.

Braude and Lerman (1970) carried out a co-ordianted trial at 21 centres to compare a diet containing 15.0% crude protein and 0.64% total lysine with a diet containing 14.0% crude protein and 0.57% lysine. The effect of synthetic lysine supplementation of the second diet to a level of 0.64% and the replacement of fish meal with soybean meal, also to a lysine level of 0.64%, was also studied. A small, but significant, improvement in performance was achieved by feeding the higher levels of lysine and protein. The ration with the lower protein but supplemented with synthetic lysine to an equivalent level gave similar performance data to the higher protein diet. It was also shown that synthetic lysine supplementation was equally as effective with white fish meal or soybean meal. Carcass data could not be properly assessed due to the varying energy content of the diets. The break-even cost of synthetic lysine was estimated to be $2.72/kg. Dent et al. (1970) gave a further review of the regression analysis and economic aspects of crude protein, dietary lysine and energy intake effects on pig growth. The liveweight and lean gains response to increased crude protein and lysine intake was almost linear in young growing pigs, however, little response was noted in the finishing stage. The live-weight gain and lean gains response to dietary lysine, particularly with young pigs, depended on the level of energy intake and level of crude protein. At low dietary crude protein levels the response to increased dietary lysine improved with increasing energy intake, but with high crude protein the response to lysine decreased or is unaffected by the level of energy intake. These interactions are not evident in pigs over 68.2 kg live weight.

Brown et al. (1972) reported that a level of 0.48% dietary lysine, which was similar to the N.A.S.-N.R.C. (1968), was required for maximum average daily gain but 0.60% dietary lysine was required for maximum feed efficiency and carcass leanness. These levels were determined by feeding 146 finishing pigs a 13.3% protein corn-sesame meal basal diet supplemented with graded levels of L-lysine (0.35 - 0.85%).

By reviewing seventy individual studies of lysine, Rerat and Lougnon (1968) calculated a regression equation of the requirement of lysine (per cent of the diet) on live weight to be $y = 0.869 - 0.0052x$, $r = 0.50$, taking into account that pigs adjust their feed consumption according to the energy content of the diet. However, the relationship between daily amino acid consumption (y in g/d) and live weight (x in kg) may be characterized for weights between 2 - 50 kg by a first degree equation $y = 3.21 + 0.74x$, $r = 0.72$ with a second degree equation for overall growth to 100 kg being $y = 1.85 + 0.404x - 0.0025x^2$ with the statistical significance of each term of this equation also being very high. However, the dispersion of the points between 50 and 100 kg was such that the value of the second equation is only of indicative value.

AVAILABILITY OF AMINO ACIDS

Jones et al. (1962) initiated a new concept when pigs given diets containing equal levels of available lysine[1] from four sources, had identical performances and carcass quality even when total lysine and crude protein contents differed. Therefore, available lysine appeared to offer an alternative method for assessing protein requirement.

Similarly, Lynch et al. (1971) experimented with four levels of available lysine, 0.56, 0.65, 0.74 and 0.84%, two sources of lysine, white fish meal and soybean meal and two slaughter weights, 50 and 85 kg. Again source of available lysine had no effect on performance on carcass traits. Higher available lysine levels improved growth rate and feed efficiency such that the maximum level gave maximum performance. Stage of growth x protein level interactions were significant for daily gain and feed efficiency from 50 to 85 kg liveweight.

Ostrowski et al. (1971) studied the nitrogen metabolism of the pig utilizing protein from different sources but with equivalent 'available lysine content'. Results of this experiment showed that when diets contain different protein concentrates, the equating of the diets on an available lysine basis will give very similar daily live weight gains and feed conversion efficiencies. There were no differences in digestibility of nitrogen between diets and since growth rates were similar, the most important parameter of nitrogen metabolism can be taken as the rate of nitrogen retention (g/d). Diets with the lowest concentration of crude

[1]Determined by the method of Carpenter, Biochem. J. 61:XL 1955 (FDNB procedure)

protein had the highest efficiency of nitrogen utilization. When crude protein concentration was high (18%), interactions were found between protein concentration and lysine concentration in their effects on the nitrogen retention of pigs, so that at high lysine concentrations, crude protein concentrations per se again were important.

By supplementing barley containing 0.45% lysine to 0.57%, Braude et al. (1972) significantly improved daily gain of growing pigs from 0.39 to 0.53 kg/d and feed efficiency from 4.09 to 3.01. Whether performance obtained in this study would have been further improved by the addition of a protein concentrate is not known. Braude et al. (1972) in comparing barley and wheat offal, with and without supplemental lysine, showed that the diet with the highest amount of lysine produced carcasses with the greatest amount of lean while the diet with the lowest amount of lysine produced the smallest amount of lean (energy varied from 2.8 to 3.0 M cal/kg). This shows the dietary treatment's effect (lysine) on tissue protein synthesis as shown by lean content of the carcass. However, the importance of the biological availabilities, total nitrogen and other essential amino acids were not tested for in this case.

Hughes and Hauge (1945) were among the first to suggest the limitations of dried solubles as a protein supplement because of a deficiency in certain essential amino acids. By means of biological assays, they ascertained that lysine and tryptophan were the limiting amino acids for growth when this product was fed at a 15% level to rats. In the same study it was found that biological values for dried solubles, corn and the combination of dried solubles and corn were relatively low in comparison to the values for yeast, casein and the combination of yeast and dried solubles. The requirements of the animal for lysine and tryptophan could not be satisfied by increasing the protein level to 20% and other amino acid deficiencies became apparent when the protein content was lowered to a 10% level. Chemical studies with pancreatic digestion (proteolytic enzymes) revealed that 56% as much lysine and 71% as much tryptophan were liberated from dried solubles as from yeast protein, therefore, amino acids are liberated from dried solubles to a lesser extent. Although, the dried solubles product used in these experiments was deficient in lysine and tryptophan, it was possible for the dried solubles to be used as a source of protein in rations of farm animals providing these deficiencies were corrected by other constituents of the ration.

Combs and Bossard (1969), using chick bioassays, indicated that 81% of the total lysine in corn distillers dried grains was available to the chick. Therefore, there would be 0.57% available lysine out of a total of 0.70% analysed in DDG/S. Using the same method, there appeared to be 0.61% methionine available to the chick out of a total of 0.60% methionine! However, cystine might have been influencing the methionine value and lysine could have been destroyed during hydrolysis of the sample in the chemical analysis or there was incomplete hydrolysis in the microbial assay.

Since a high proportion of the total protein of a conventional diet is produced by a cereal component, it is unfortunate that the methods for the determination of the available amino acid content of a cereal protein have not proved easy to develop. It is well known that one of the roles of protein concentrates is to counteract amino acid deficiencies (usually of lysine in pigs) in cereal components of a diet and this almost inevitably means adding an excess of other amino acids which are not needed for protein synthesis. In order to reduce this excess as much as possible, it is necessary to have a thorough knowledge of dietary amino acid content, their availabilities and of the amino acid requirements of the pig. The shortage and high cost of supplemental protein for inclusion in feeding stuffs is likely to increase, so that further studies on the problems of supplementation of cereal proteins with synthetic amino acids, provided they can be made at a suitable price, are urgently required.

EXPERIMENTAL PROCEDURE

A. OBJECTIVE

From the literature review, the meagerness of information on the use of DDG/S in pig rations becomes obvious. Only one earlier study showed that DDG/S with a barley base could be used effectively in pig rations (Livingstone and Livingstone, 1966). Some of the factors to be considered when DDG/S are included in swine diets are low dry matter digestibility (82.7%), low lysine level and the medium protein level of DDG/S. Lysine alone supplemented to barley has proven somewhat effective in increasing performance of finishing pigs (Sauer and Stothers, 1969). Finishing pigs are known to have lower nutrient requirements and a more efficient utilization of fiber than growing pigs. Therefore, the objective of this study was to effectively counter the shortcomings of DDG/S with the lower requirements of finishing pigs but provide a potentially low cost diet giving optimum performance.

B. MATERIALS

All performance and carcass data were obtained from Managra[1] and Managra crossbred pigs, bred and grown in the minimum disease barn at the Glenlea Research Station. Since boar performance and carcass data are comparatively scarce, boars were included in this experiment in spite of the difficulty in obtaining the carcass data.

Herta barley was the prime dietary ingredient supplemented with DDG/S and/or soybean meal and additionally fortified with microingredients.

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[1] The breed composition of Managra consists of 45% Swedish Landrace, 20% Wessex Saddleback, 15% Welsh and 20% Minnesota #1--Berkshire--Yorkshire--Tamworth.

L-lysine[1] was supplemented to the DDG/S diets to maintain the lysine level at or above the N.A.S.-N.R.C. (1968) requirements. All diets were fed in pellet form (0.48 cm) with feed and water available ad libitum. Liveweight gains and feed consumption data were recorded biweekly for all pigs and then weekly as the first pig in a pen reached market weight.

The federal R.O.P. measurements consisted of average daily gain on test, adjusted age to slaughter[2], adjusted total fat[2], length of side, area of loin, % ham of side, lean area per ham weight and % yield trimmed feed consumption or replication was impossible, feed consumption and feed efficiency could not be statistically analyzed.

Data analyzed were subjected to a two-way statistical analysis of variance followed by a Duncan's test for final analysis. Pens and treatments were randomized across one side of the barn to minimize any environmental effects.

C. METHOD

The three experimental diets (0, 7.5 and 15.0%) were calculated to contain similar nutrient levels with DDG/S replacing soybean meal on an isonitrogenous basis. Because of the low lysine level in DDG/S (0.70%), it was necessary to supplement L-lysine to the 7.5 and 15.0% DDG/S diets equivalent to that of the barley-soybean meal diet (Table 3).

A summary listing the number of pigs of each sex and breed in each experiment is shown in Appendix Table 6.

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[1]L-lysine mono HCl (98%)

[2]Adjusted to an equivalent live market weight of 91.0 kg

Table 3. Composition of Experimental Diets -- Experiment 1

Ingredients (%)	Control	7.5%	15.0%
Barley	88.50	84.85	81.25
Soybean Meal	10.00	6.00	2.00
Distillers DG/S	--	7.50	15.00
Limestone	1.00	1.00	0.90
Calcium Phosphate	0.30	0.40	0.50
Trace Mineral Salt	0.25	0.25	0.25
L-lysine	--	0.07	0.14
Vit.-Antibiotic Premix[1]	+	+	+
CHEMICAL COMPOSITION (%)			
Dry Matter	90.08	90.89	90.99
Protein	14.66	14.31	14.16
Lysine	0.576	0.530	0.523
Ether Extract	1.77	2.28	2.78
Fiber	3.97	4.91	4.29
Ash	3.83	3.98	3.79
Energy (Cal/gm)	3985	4029	4086

[1]Vit.-Antibiotic Premix contained levels of Vit. A, Vit. D, Vit. B_{12}, Zinc to meet or exceed N.R.C. requirements (1968). Aureomycin was supplied at a level of 490 mg/kg

1. Experiment 1

Seventy-six finishing swine were available for allotment. All the boars were of the Managra breed while the barrows and gilts consisted of twenty Managra crossbreds and thirty-four Managra purebreds. From the twenty-two available boars, eight were randomly assigned to the 0% diet, seven to the 7.5% diet and seven to the 15% diet. Also, nine barrows and nine gilts, uniformly distributed within breed, were randomly allotted to each of the 0, 7.5 and 15.0% DDG/S treatments.

The boars, barrows and gilts were randomly assigned to their diets at an average initial weight of 59.6, 62.2 and 56.8 kg on February 23, 1971. Average slaughter weights for boars, barrows and gilts were 94.8, 90.1 and 90.3 kg, respectively. Hot carcass weights and backfat measurements were recorded at slaughter. After overnight cooling, regular federal R.O.P. carcass data were measured. Special permission was required to permit the boar carcasses for measurement in the Canada Packer's cooler, whereafter they were condemned according to federal regulations.

2. Experiment 2

Except that no boars were tested, Experiment 2 was a replication of Experiment 1 with eighty-one Managra pigs used, with nine pigs per pen randomly selected so as to have one pen of barrows and two pens of gilts each on 0, 7.5 and 15.0% DDG/S diets, (Table 4). Due to the difference in protein analysis of the barley used for Experiment 2, it was necessary to change the diet compared to Experiment 1, so as to maintain consistency between experiments (Table 4). Wheat middlings and soybean oil were mixed with the L-lysine to insure more uniform distribution of the supplemental L-lysine throughout the diets.

Table 4. Composition of Experimental Diets -- Experiment 2

Ingredients (%)	Control	7.5%	15.0%
Barley	90.50	86.85	83.25
Soybean Meal	8.00	4.00	--
Distillers DG/S	--	7.50	15.00
Limestone	1.00	1.00	0.90
Calcium Phosphate	0.30	0.40	0.50
Trace Mineral Salt	0.25	0.25	0.25
L-lysine	--	0.07	0.14
Vit.-Antibiotic Premix[1]	+	+	+
CHEMICAL COMPOSITION (%)			
Dry Matter	89.27	90.05	90.16
Protein	13.76	13.84	13.45
Lysine	0.587	0.576	0.560
Ether Extract	1.65	2.31	3.09
Fiber	4.29	4.02	4.51
Ash	3.89	3.84	3.96
Energy (Cal/gm)	3871	4044	4056

[1]Vit.-Antibiotic Premix contained levels of Vit. A, Vit. D, Vit. B_{12}, Zinc to meet or exceed N.R.C. requirements (1968). Aureomycin was supplied at a level of 490 mg/kg

Average initial weights of the barrows and gilts on June 17, 1971 were 56.5 kg and 53.0 kg. Corresponding slaughter weights were 90.3 and 90.4 kg, respectively. Standard federal R.O.P. carcass data were obtained on all pigs in Experiment 2.

3. Experiment 3

One hundred and thirty-five finishing pigs were available for allotment to the same diets used in Experiment 2 except that L-lysine supplementation was increased to 0.078 and 0.156% for the 7.5 and 15.0% diets so as to maintain an equivalent available lysine level of 0.456%.[1] The pigs were blocked according to sex and breed giving five blocks which were Managra gilts, Managra x Yorkshire gilts, Managra barrows, Managra x Yorkshire barrows and Managra boars. Two Yorkshire pigs of the same sex were included in every Managra pen, but for statistical analysis they were considered as Managra. From each block of twenty-seven pigs, nine were randomly assigned according to weight to one of the three diets (0, 7.5 and 15.0%). One Managra barrow on 7.5% DDG/S had to be removed after three days on test due to loss in weight and general poor condition and was eliminated from any calculations.

Average initial weights of all pigs, per pen, were 50.5 $\pm$1 kg and average slaughter weight of 89.5, 89.7 and 88.3 kg for boars, barrows and gilts, respectively. The pigs were started on test on January 13, 1972 with the last slaughter date on April 10, 1972. Standard procedures were used for obtaining R.O.P. data for the gilts and barrows. The boars were killed at a provincially licensed slaughter plant at Carman, Manitoba

[1]Based on an available lysine of 58.0% for DDG/S, 72.6% for Barley and 90.0% for Soybean meal. (Smelski, 1971, unpublished data)

Table 5. Chemical Composition of Experimental Diet -- Experiment 3

Composition	Control	7.5%	15.0%
Dry Matter	90.10	90.90	90.81
Protein	12.15	12.12	11.90
Lysine	0.529	0.511	0.500
Ether Extract	1.81	2.48	3.01
Fiber	4.16	4.35	4.79
Energy (Cal/gm)	3908	3933	3966

Table 6. Composition of Digestibility Diets

Ingredients (%)	Barley (B)	½ - ½	DDG/S/½
Barley (Herta)	100.0	50.0	----
DDG/S	--	25.0	50.0
Sucrose	--	18.7	37.5
Alpha-floc	--	5.0	10.0
Corn Oil	--	1.3	2.5
Chemical Composition (%)			
Dry Matter	93.03	95.70	94.92
Protein	8.97	11.63	14.04
Lysine	0.319	0.325	0.320
Ether Extract	2.31	4.79	7.30
Fiber	5.32	6.94	9.55

and carcass data were obtained to simulate the standard R.O.P. procedure.

4. Digestibility Studies

Four 20-21 kg Managra barrows were assigned to metabolic cages as described by Bell (1948) to determine the biological digestibilities of barley and DDG/S. A pelleted 16% grower diet with 1% ferric oxide was fed for three days before and after each two-day test period as both an adjustment and marker diet. During the test period the two pelleted test diets contained either Herta barley (B) or DDG/S diluted one-half with a protein-free diet (DDG/S/½). The pigs were fed these diets for 30-40 minutes at 8:30 A.M., 12:30 P.M. and 5 P.M. for two consecutive days during the test period. Analytical methods to determine the apparent amino acid availability involved the same procedure as described by Sauer (1972).

Three finishing Managra barrows averaging 83.8 kg were assigned to metabolic stalls as described by Milne (1965). As well as diets B and DDG/S/½, a third diet was included consisting of an equal mixture of B and DDG/S/½ labelled as ½-½ (Table 6). Diets and pigs were randomized according to a 3 x 3 latin square design. Feeding included 1250 grams of each diet being fed at 9:00 A.M. and again at 4:30 P.M. for two consecutive days. The same analytical procedure was used as in the first study.

Statistical analysis included a 3 x 3 latin square analysis on the three finishing pigs and a two-way analysis of variance of the entire digestibility study (Snedecor and Cochran, 1969). Most consideration was given to the amino acid availability figure $\pm$ standard error for barley and DDG/S of both studies.

RESULTS AND DISCUSSION

As noted in the literature review, most studies with DDG/S were performed in the period from 1945-1955. This has left comparison with present conditions difficult because of the tremendous changes in such areas as breed improvement due to selection and crossbreeding, feeding and management improvements and past indifference in the U.S.A. to carcass data. In spite of these changes, some implications can be made on the comparative nutritive value of DDG/S.

Experiment 1

Treatment

Treatment effects of DDG/S on pig performance and carcass data in Experiment 1 are shown in Table 7. No significant differences due to treatment were observed in average daily gain (a.d.g.) and there were no significant sex x treatment interactions. However, it is interesting to note the response of each sex to increasing levels of DDG/S. Barrows performed slightly better with respect to a.d.g. and feed efficiency with increasing levels of DDG/S while boars exhibited a more marked opposite trend. Boars, also decreased their feed consumption with the inclusion of DDG/S in the diet while barrows consumed a fairly uniform amount with both diets. DDG/S did not cause any large variation in feed consumption of gilts with the largest difference of 0.11 kg/day occurring between the control and the 7.5% diet. Only the a.d.g. of

Table 7. Means[1] for Performance and Carcass Traits -- Experiment 1

	Boars	Barrows	Gilts	Mean
Average Daily Feed Consumption (kg/d)				
Control	2.83	2.92	2.49	2.75
7.5%	2.65	2.84	2.60	2.69
15.0%	2.67	2.88	2.55	2.66
Mean	2.70	2.88	2.56	
Average Daily Gain (kg/d)				
Control	0.81	0.75	0.68	0.72
7.5%	0.75	0.75	0.71	0.74
15.0%	0.69	0.77	0.64	0.70
Mean	0.75[a]	0.75[a]	0.70[b]	
Feed Efficiency				
Control	3.50	3.94	3.69	3.71
7.5%	3.53	3.79	3.65	3.65
15.0%	3.86	3.73	3.99	3.78
Mean	3.64	3.81	3.78	
Carcass Means for Treatments	Control	7.5%	15.0%	
Length of Side (cm)	79.25	79.76	77.98	
Total backfat (cm)	9.47	9.78	9.96	
Area of Loin (cm^2)	30.96	28.38	29.03	
% ham of side	26.7	26.2	26.7	
Lean area/ham wt.	1.14[b]	1.21[Aa]	1.11[Bb]	
% yield trimmed cuts	70.93	71.20	69.86	
Carcass Means for Boars, Barrows and Gilts	Boars	Barrows	Gilts	
Length of Side (cm)	81.79[A]	77.22[B]	77.98[B]	
Total backfat (cm)	9.50	10.03	9.63	
Area of Loin (cm^2)	29.87[ab]	27.94[b]	30.52[a]	
% ham of side	26.2 [B]	25.8 [B]	27.5 [A]	
Lean area/ham wt.	1.15[ab]	1.18[a]	1.12[b]	
% yield trimmed cuts	70.26[ab]	70.07[b]	71.57[a]	

[1]Means followed by a different lower case letter differ significantly P<0.05 and upper case letter differ significantly at P<0.01 (Comparisons made among treatments and among sexes.)

gilts fed 15.0% DDG/S appeared to be slightly impaired by DDG/S. Similarly, feed efficiency for gilts on the 15.0% diet was much poorer (3.99) than gilts on the control or 7.5% DDG/S diet (3.69 and 3.65 respectively). In summary DDG/S essentially had no effect on the feed consumption and feed efficiency of barrows while the feed consumption and feed efficiency of boars and gilts were slightly affected, primarily by the 15% DDG/S level.

The carcass data revealed lean area/ham weight to be the only carcass measurement significantly affected by treatment. Lean area/ham weight was larger for the 7.5% diet than the control or 15.0% diet even though % ham of carcass, ham weight or lean area of ham were not affected by the treatment

Sex

The comparison of boars to barrows and gilts is biased with the average daily gain of boars underestimated because of the hybrid vigor involved with the crossbred barrows and gilts. Teague (1964), Wismer-Pedersen (1968) and Bayley and Summers (1968) reported that boars and barrows showed a comparable gain, but which was significantly greater than for gilts. Blair and English (1965), Wong et al. (1968) and Newell and Bowland (1972) have shown boars gain significantly faster than barrows which gain significantly faster than gilts. Therefore, a greater a.d.g. could be anticipated with boars as compared to barrows of the same breed. However, in this study with the breed effect and lower feed consumption, the a.d.g. for boars was similar to barrows, but boars had the usual better feed efficiency.

Young et al. (1968) showed that barrows consume significantly more than gilts and a similar trend was apparent in Experiment 1, where barrows consumed more than gilts (2.88 kg/day and 2.51 kg/day, respectively). Boars consumed an intermediary level of 2.70 kg/day. Wong et al. (1968) and Newell and Bowland (1972) could not establish any significant patterns in feed consumption between 'sexes' even though boar consumption was less than or similar to gilts. In a review, Field (1971) concluded that it takes approximately 0.2 kg less feed to produce 1 kg liveweight on boars than barrows. A similar difference of 0.15 kg in feed efficiency was observed in this study. These data are also in agreement with Wong et al. (1968) who stated that boars and gilts had significantly superior feed efficiency when compared to barrows.

The usual differences attributable to sex were observed for most carcass traits. The problem of slaughtering boars in a federal inspected slaughter house caused a delay in the marketing of boars. These boars were slaughtered weighing 4.6 kg heavier than the barrows or gilts, and consequently heavier carcass weights were produced for boars than for barrows and gilts (74.0, 69.6 and 69.5 kg, respectively). In general, the boar data compared favorably with the literature.

Significant differences in total backfat, loin eye area, % ham of side (% ham), % lean in ham and length of side are well documented with characteristics related to leanness in favor of gilts over barrows. Fewer comparisons of barrows and gilts with boars exist.

The length of side (carcass length) was significantly greater in boars than in barrows or gilts. Charette (1961) found that carcass length of boars and gilts exceeded that of barrows. Wong et al. (1968) and Newell and Bowland (1972) could determine no significant sex differences in carcass length. The difference in this study was probably due to the delay in slaughter.

The total backfat measurements in Experiment 1, appeared to favor the boars and gilts over barrows (9.50, 9.63 and 10.03 cm, respectively). Fifteen different references cited by Martin (1969) and Wismer-Pedersen (1968) showed boars averaging 0.6 cm less in mean backfat measurements than barrows. Young and Ingram (1969) analyzing 61,138 carcasses, showed gilts to measure 0.66 cm less than barrows.

The % ham of carcass was significantly larger ($P<0.01$) in gilts than in boars or barrows. A similar pattern was noted by Wong et al. (1968). Bowland and Berg (1959) and Pierce and Bowland (1972) showed % ham of carcass weight to be significantly larger in gilts than in barrows.

The loin eye area of the gilts was significantly larger than barrows while that of boars was intermediate. Charette (1961) showed loin eye area was greater in boars and gilts than those of barrows, while Wong et al. (1968) showed gilts exceeded both boars and barrows in the size of the loin eye area. A possible breed difference may be important when determining loin eye area as Charette (1961) experimented with the Yorkshire pigs whereas Wong et al. (1968) used Managra.

Lean area/ham weight was larger for barrows than for gilts, while boars were intermediate and not significantly different from either. This is a recent R.O.P. measurement and only one earlier study showed lean area/ham weight to be similar in barrows and gilts (Pierce and Bowland, 1972). Previous literature stated per cent lean in ham face to be in favor of gilts and barrows versus boars (Wong et al. 1968, Newell and Bowland, 1972). The lean area/ham weight was higher for barrows in the present study, probably due to the significantly lower ham weights of the barrows versus gilts or boars.

The cumulative effect of total backfat, area of loin, percentage lean in ham face and % ham of carcass, unadjusted for male or female effect, appear in the % yield of trimmed cuts (% yield). Gilts had a % yield (71.57) which was significantly better than barrows (70.07). Boars (70.26) were not significantly different from gilts or barrows. Newell and Bowland (1972) showed boars had a significantly higher % yield (68.4) than gilts (67.1) which in turn were superior to barrows (64.5). Similarly, Pierce and Bowland (1972) showed that % yield was significantly superior in gilts than in barrows (68.9 versus 67.0).

Table 8. Average Daily Gain and Carcass Traits[1] of the Managra Purebred and Managra Crossbred -- Experiment 1

	Average daily gain (kg/d)	Carcass length (cm)	Total back-fat (cm)	% ham of side (%)	Lean area/ ham wt	Area of loin (cm^2)	% yield trimmed cuts
Managra Purebred	0.70	77.95	9.75	26.94	1.16	29.94	71.18
Managra Crossbred[2]	0.75	77.55	9.96	26.51	1.14	29.68	70.20

[1]as defined by Canada Department of Agriculture, 1968.

[2]consisting basically of Managra x Yorkshire

Breed

Since the Managra crossbreds and Managra pigs were uniformly distributed among treatment and sex (barrows and gilts), it was possible to statistically analyze the a.d.g. and carcass trait differences between breeds. The Managra crossbred outgained the Managra by 5.9%. However, as indicated in Table 8, there were no significant differences in a.d.g. or carcass data between breeds.

Experiment 2

Treatment

As designated in Table 9, the control diet produced a significantly higher a.d.g. ($P<0.05$) than either the 7.5 or 15.0% DDG/S diet. The 7.5% and 15.0% diets were not different from each other. There were no significant sex x treatment interactions in spite of the tendency of gilts to be affected more by higher levels of DDG/S than barrows.

Except for feed efficiency, barrows were relatively unaffected with DDG/S. The feed consumption of the barrows remained fairly uniform on all diets, whereas gilts consumed less with the inclusion of DDG/S, especially 7.5%, and consequently they had a significantly lower a.d.g. ($P<0.05$) on the DDG/S diets. The different response of the barrows and gilts to different levels of DDG/S (6-12% *Saccharomyces cerevisiae*) was supported by a significant sex x treatment interaction to brewers dried yeast (*Saccharomyces cerevisiae*) shown by Bell and Voldeng (1968). However, unlike Bell and Voldeng (1968), an inferior feed efficiency was found with both sexes as the DDG/S level increased.

Table 9. Means for Performance and Carcass Traits -- Experiment 2

	Barrows	Gilts	Mean
Average Daily Feed Consumption (kg/d)			
Control	2.84	2.70	2.77
7.5%	2.90	2.36	2.63
15.0%	2.80	2.53	2.66
Mean	2.84	2.53	
Average Daily Gain (kg/d)			
Control	0.64	0.63	0.63[a]
7.5%	0.63	0.55	0.58[b]
15.0%	0.60	0.56	0.57[b]
Mean	0.64[a]	0.58[b]	
Feed Efficiency			
Control	4.44	4.28	4.36
7.5%	4.58	4.30	4.44
15.0%	4.69	4.51	4.60
Mean	4.57	4.36	
Carcass Means for Treatments	Control	7.5%	15.0%
Length of Side (cm)	76.40	76.63	76.96
Total backfat (cm)	10.13	10.04	10.39
Area of Loin (cm^2)	28.64	29.03	28.90
% ham of side	25.50	25.77	25.39
Lean area/ham wt.	1.22	1.23	1.20
% yield trimmed cuts	70.26	70.46	70.21
Carcass Means for Barrows and Gilts	Barrows	Gilts	
Length of Side (cm)	75.41[B]	77.32[A]	
Total backfat (cm)	11.10[B]	9.75[A]	
Area of Loin (cm^2)	26.90[B]	29.81[A]	
% ham of side	25.09[b]	25.79[a]	
Lean area/ham wt.	1.19[b]	1.23[a]	
% yield trimmed cuts	68.83[B]	71.05[A]	

[1] Means followed by a different lower case letter differ significantly at P<0.05 and upper case letter differ significantly at P<0.01 (Comparisons made among treatments and between sexes.)

The performance of all pigs in Experiment 2 was especially low with respect to feed efficiency (4.46 versus 3.75 in Experiment 1). A partial explanation for the difference is that Experiment 1 included crossbred pigs whereas all pigs in Experiment 2 were purebred. Fahmy and Bernard (1971) have shown that crossbreds are consistently superior to purebreds in rate and efficiency of gain. Other suspected parameters that could not be controlled but have been found to cause significant variation are: temperature and humidity (Smith et al. 1967), barley from a specific year (McBeath, 1960) and selection pressure (Fahmy and Bernard, 1971).

Treatment had no effect on any R.O.P. carcass measurements.

Sex

As in Experiment 1, the usual differences between sex were noted for a.d.g. and carcass data. Barrows outgained the gilts by 0.07 kg/day in Experiment 1 and significantly ($P<0.01$) outgained the gilts in Experiment 2 by 0.06 kg/day. In Experiments 1 and 2 respectively, gilts consumed less (2.51 and 2.53 kg/day) than barrows (2.88 and 2.84 kg/day). Again, gilts had a more efficient feed to liveweight conversion than barrows.

As denoted by the subscripts in Table 8, the gilts were significantly superior in length of side, total backfat, % ham of carcass, lean area/ham weight, and loin eye area. The % yield was poorer for barrows versus gilts. It should be noted that the gilts, and especially the barrows, had more total backfat in Experiment 2 than in Experiment 1. This could account for some of the differences in feed efficiency between experiments, as it is known that it requires more feed for gain in body fat than body lean. A similar concept differentiates the better feed efficiency of the gilts versus barrows, however, this is due to a natural physiological or metabolic occurrence.

Experiment 3

Treatment

Experiment 3 showed a similar response to the average performance results of Experiments 1 and 2. As indicated in Table 10, the control diet produced a significantly higher a.d.g. than the 15.0% DDG/S diet, with the 7.5% level being intermediate and not significantly different from either treatment. No sex x treatment interactions occurred for any observations.

Other than a slight decrease in feed consumption of the 15.0% diet, as compared to the 7.5% diet, no specific trend in feed consumption could be established. Feed efficiency appeared to be only slightly hindered with either level of DDG/S. A similar non-significant impairment of feed efficiency was noted by Combs and Wallace (1970). It remains suggestive that lysine was the hindering factor in the 15.0% DDG/S diet, especially since no safety margin above the N.A.S.-N.R.C. (1968) recommendation for lysine was used to compensate for the low dry matter digestibility of DDG/S (Combs and Wallace, 1970, Wahlstrom et al. 1970).

The responses of the Managra and the Managra crossbreds at different levels of DDG/S, within the same sex, show the greatest variation. The a.d.g. of the Managra and Managra crossbred gilts on the 15.0% DDG/S were both low when compared to the control and 7.5% diets. The decrease in a.d.g. appeared to be a result of the decrease in feed consumption of the 15.0% diet. The increase in a.d.g. of the Managra crossbred gilts (0.72 kg) versus the Managra gilts (0.65 kg) on the control diet is likely due to crossbreeding (Lasely, 1963, Fahmy and Bernard, 1971). On the contrary, the Managra gilts fed 7.5% DDG/S outgained the Managra crossbreds fed

Table 10. Means for Performance and Carcass Traits -- Experiment 3

	Boars	Barrows		Gilts		
	Managra	Managra	MxY[1]	Managra	MxY	Mean
Average Daily Feed Consumption (kg/d)						
Control	2.62	3.05	2.70	2.68	2.61	2.73
7.5%	2.81	2.83	2.82	2.71	2.62	2.76
15.0%	2.47	2.88	2.84	2.56	2.54	2.66
Mean	2.64	2.91	2.78	2.65	2.59	
Average Daily Gain (kg/d)						
Control	0.71	0.77	0.72	0.65	0.72	0.72^{a}
7.5%	0.69	0.66	0.75	0.71	0.67	0.70^{ab}
15.0%	0.65	0.70	0.71	0.64	0.64	0.67^{b}
Mean	0.68	0.71	0.73	0.66	0.68	0.68
Feed Efficiency						
Control	3.74	3.99	3.86	4.27	3.64	3.90
7.5%	4.12	4.35	3.83	3.93	3.93	4.03
15.0%	3.75	4.14	4.03	4.09	3.96	3.99
Mean	3.88	4.15	3.90	4.09	3.84	
Carcass Means						
Length of Side (cm)	75.69^{b}	77.72^{a}	77.98^{a}	78.23^{a}	78.74^{a}	
Total backfat (cm)	9.04^{c}	10.29^{a}	10.39^{a}	9.78^{b}	10.26^{a}	
Area Loin (cm^2)	30.32^{a}	28.06^{b}	28.26^{b}	30.84^{a}	30.84^{a}	
% ham side	25.58^{c}	26.85^{b}	26.98^{b}	27.90^{a}	27.38^{ab}	
Lean area/ham wt.	1.21^{a}	1.11^{b}	1.10^{b}	1.07^{b}	1.09^{b}	
% yield trimmed cuts	71.10^{a}	69.30^{b}	69.14^{b}	70.66^{ac}	69.85^{bc}	

[1]Managra x Yorkshire

Means followed by a different lower case letter differ significantly P<0.05 and upper case letter differ significantly at P<0.01 (Comparisons made among treatments and among sexes.)

7.5% DDG/S. The Managra gilts also had an a.d.g. which was higher than would be expected between the linear perspective of the control to 15.0% DDG/S. Therefore, the relatively large variation implies that a genetic x treatment interaction existed.

The Managra and Managra crossbred barrows fed the 15.0% diet had a similar a.d.g. However, contrary to the gilts, Managra barrows outgained Managra crossbreds fed the control diet while Managra crossbreds outgained Managra fed the 7.5% DDG/S, suggesting that not only does a genetic x treatment interaction exist, but a genetic x treatment x sex interaction could also be possible. The only notable difference in feed consumption between breeds, within sex, appeared with the barrows fed the control diet but again, with the data available it was not possible to establish a definite relationship. Similarly, the only notable differences in feed efficiency between breeds appeared either in the gilts fed the control diet or in barrows fed the 7.5% diet, however, feed efficiency of both barrows and gilts, regardless of the extent of difference, was consistently better for the crossbred.

There were no significant carcass differences due to treatment or sex x treatment interactions.

The boars in Experiment 3 reacted in a similar pattern to the boars of Experiment 1, with a.d.g. decreasing as DDG/S increased in the diet. The low level of lysine accompanied with a low dry matter and protein digestibility of DDG/S (Wallace and Combs, 1970, Wahlstrom et al. 1970) could have been a limiting factor for performance especially since boars are notably leaner and consequently may require higher amounts of essential amino acids for protein synthesis (Braude et al. 1972, Newell and Bowland, 1972, Brown et al. 1972). The feed consumption of boars increased with the 7.5% diet and decreased with the 15.0% diet as compared to the control. The feed efficiencies of the boars fed the control diet and 15.0% diet were similar (3.74 and 3.75, respectively) but both were better than the feed efficiency of boars fed 7.5% DDG/S (4.12).

Sex

In Experiment 3, the usual sex differences were noted with regard to a.d.g. and carcass measurements as indicated in Table 11. As in Experiments 1 and 2 and previous literature mentioned, barrows gained significantly better than gilts. The a.d.g. of the boars were intermediate and not significantly different from either the barrows or gilts. However, the performance differences were possibly confounded by breed differences. Again boars and gilts had a better feed efficiency and lower feed consumption when compared to barrows.

Boars had significantly superior total backfat, lean area/ham weight and % yield but a smaller carcass length and % ham of side than barrows or gilts. The shorter carcass length in Experiment 3 is contrary to the observations made by Charette (1961), Prescott and Lamming (1969) and observations in Experiment 1. A determining factor could be slaughter weight because as the slaughter weight increased in each study, there was a proportional increase in carcass length. Boars and gilts had a significantly larger % ham of carcass than barrows. Percent yield ranged in the usual order with boars, greater than gilts, greater than barrows.

Table 11. Means[1] for Performance and Carcass Traits -- Experiment 3

	Boars	Barrows	Gilts	Mean
Average Daily Feed Consumption (kg/d)				
Control	2.62	2.88	2.65	2.73
7.5%	2.81	2.83	2.67	2.76
15.0%	2.47	2.86	2.55	2.66
Mean	2.64	2.85	2.62	
Average Daily Gain (kg/d)				
Control	0.71	0.75	0.69	0.72[a]
7.5%	0.69	0.71	0.69	0.70[ab]
15.0%	0.65	0.70	0.64	0.67[b]
Mean	0.68[AB]	0.72[A]	0.67[B]	
Feed Efficiency				
Control	3.74	3.93	3.96	3.90
7.5%	4.12	4.14	3.93	4.03
15.0%	3.75	4.09	4.02	3.99
Mean	3.88	4.03	3.97	
Carcass Means for Treatments	**Control**	**7.5%**	**15.0%**	
Length of Side (cm)	77.86	77.62	77.56	
Total backfat (cm)	10.07	9.84	9.96	
Area of Loin (cm^2)	29.49	29.50	30.03	
% ham of side	26.96	26.68	27.11	
Lean area/ham wt.	1.11	1.13	1.10	
% yield trimmed cuts	69.82	70.28	70.02	
Carcass Means for Boars, Barrows and Gilts	**Boars**	**Barrows**	**Gilts**	
Length of Side (cm)	75.69[B]	77.80[A]	78.44[A]	
Total backfat (cm)	9.04[a]	10.34[b]	9.93[b]	
Area of Loin (cm^2)	30.32[A]	28.13[B]	30.84[A]	
% ham of side	25.58[C]	26.92[B]	27.65[A]	
Lean area/ham wt.	1.21[A]	1.10[B]	1.08[B]	
% yield trimmed cuts	71.10[a]	69.23[b]	70.24[a]	

[1] Means followed by a different lower case letter differ significantly $P<0.05$ and upper case letter differ significantly at $P<0.01$ (Comparisons made among treatments and among sexes.)

Table 12. Average Daily Gain and Carcass Traits[1] of the Managra Purebred and Managra Crossbred -- Experiment 3

	Average daily gain (kg/d)	Carcass length (cm)	Total back-fat (cm)	% ham of side (%)	Lean area/ ham wt	Area of loin (cm^2)	% yield trimmed cuts
Managra Purebred	0.69	78.00	9.93[a]	27.40	1.09	29.48	69.96
Managra Crossbred[2]	0.70	78.26	10.31[b]	27.18	1.10	29.55	69.49

[1]as defined by Canada Department of Agriculture, 1968

[2]consisting basically of Managra x Yorkshire

Breed

An additional comparison in Experiment 3 involved comparison of the Managra and Managra crossbred barrows and gilts (Table 12). Differences in a.d.g. were not significant, however, the Managra crossbred out-performed the purebred with regard to rate and efficiency of gain by 2 and 6%, respectively. This also substantiates some of the differences between Experiment 1 and Experiment 2 with respect to breed.

Except for total backfat, no significant carcass differences appeared between crossbred and purebred.

Digestibility Studies

The 3 x 3 latin square statistical analysis of the digestibility study on the finishing pigs revealed significant differences between treatment means for dry matter, phenylalanine, methionine, isoleucine, leucine, threonine and valine as shown in Table 13. Most amino acids,

Table 13. Digestion Coefficients[1] for Finishing Pigs in the 3 x 3 Latin Square Design

	Coefficients of Digestion for Treatments			Significance		
	DDG/S/½	½ -½	Barley	Treatment	Animal	Period
Dry Matter	83.53	87.61	87.55	*	--	--
Protein	83.67	88.14	83.76	--	--	--
Lysine	62.45	74.83	76.69	--	--	--
Histidine	87.66	91.20	88.70	--	--	--
Phenylalanine	80.81	90.42	87.10	*	*	--
Methionine	80.84	85.58	74.51	**	**	**
Isoleucine	79.51	83.88	74.42	**	*	*
Arginine	85.49	90.67	86.81	--	--	--
Leucine	90.61	91.45	85.87	**	*	*
Threonine	83.56	86.45	83.52	*	**	--
Valine	84.31	87.68	84.67	*	**	--

[1] $\frac{\text{Total amino acid intake} - \text{Total amino acid in feces}}{\text{Total amino acid intake}}$

*means differ significantly, $P < 0.05$

**means differ significantly, $P < 0.01$

i.e. lysine, histidine, phenylalanine, isoleucine and arginine, had the lowest availabilities from the DDG/S/½ diet. With the exception of lysine, the ½-½ diet had the highest amino acid availabilities possibly reflecting the higher protein digestibility. Neither lower dry matter nor protein digestibility was found with the ½-½ diet (25% DDG/S), contrary to Combs and Wallace (1970) and Wahlstrom et al. (1970), who had shown a decreased dry matter, protein and N.F.E. digestibility when 20% DDG/S was included in the diet. However, similar to previous findings (Sauer, 1972), lysine had one of the lowest availabilities relative to other amino acids in the three diets used in the digestibility study.

Period or row significance showed digestibility of methionine, isoleucine and leucine increased with time (R_1, R_2, R_3) suggesting that a longer adjustment period may have been required. Also pig #274 consistently had the lowest digestibility (for significant column differences) and pig #273 consistently maintained the highest digestibility suggesting either errors in the "colour appraisal" method of separating feces or innate differences in digestibility between individuals. Clawson et al. (1955) supported the latter theory by showing a highly significant difference among digestion coefficients with individual pigs, self fed the same ration in one lot.

No significant differences appeared between the two weight groups (20 and 80 kg). Therefore, the digestibility coefficients were combined as shown in Table 14. Significant differences ($P \leq 0.05$) appeared between barley and DDG/S/½ treatments for dry matter, lysine and leucine digestibilities. Dry matter digestibility has previously been shown to decrease significantly with the inclusion of 20% DDG/S in a corn base diet for swine (Combs and Wallace, 1970, Wahlstrom et al. 1970).

Leucine was significantly more available ($P < 0.01$) from DDG/S/½ (89.37%) than from barley (84.47%). Although leucine is essential for growth (N.A.S.-N.R.C., 1968); Baker et al. (1966) stated that leucine appeared to be a partially dispensable amino acid for swine and suggested that swine can possibly synthesize a considerable quantity of this amino acid making it non-essential for maintenance. Considering the availability factor, leucine in DDG/S appears to be well in excess of the requirement (0.40%) for finishing swine as reported by Becker et al. (1966).

Protein digestibility was not significantly affected in this study in spite of the increased fiber content of DDG/S/½. This may be as a result of the higher crude protein level of 14.04% in DDG/S as compared to 8.97% in barley. Whiting and Bezeau (1957) showed a significant increase in apparent digestible protein from 78 to 85% by increasing dietary protein from 5 to 14%, and a significant decrease in apparent digestible protein from 86 to 83% by increasing fiber from 5 to 10%. Therefore, it appeared that the difference in fiber content was neutralized by the difference in dietary protein with respect to apparent digestible protein coefficients.

Table 14. Average Digestion Coefficients for all Pigs[1]

	DDG/S/½	Barley
Dry Matter	82.65 ± 1.13[b,2]	87.15 ± 1.01[a]
Protein	81.21 ± 1.57	82.81 ± 1.23
Lysine	65.36 ± 3.21[b]	77.28 ± 1.60[a]
Isoleucine	79.52 ± 1.49	76.28 ± 1.86
Phenylalanine	87.79 ± 0.86	86.55 ± 0.91
Histidine	87.90 ± 0.69	87.39 ± 1.33
Methionine	80.37 ± 1.54	78.00 ± 1.90
Arginine	86.08 ± 2.01	89.63 ± 1.19
Leucine	89.73 ± 0.83[A]	84.74 ± 1.06[B]
Threonine	82.70 ± 1.03	82.01 ± 1.51
Valine	82.35 ± 1.43	82.48 ± 1.42

[1]All pigs includes both weight groups (20 and 80 kg) pigs

[2]Mean ± standard error. Means followed by a different lower case letter differ significantly $P<0.05$ and upper case letter differ significantly at $P<0.01$.

The only other significant difference in availability appeared with lysine which had an availability of 77.28% from barley and 65.36% from DDG/S/½. This becomes a very important factor because, as previously discussed, lysine is the first limiting amino acid for swine on a barley base diet. In addition, lysine becomes the least available amino acid accentuating the incapability of DDG/S to act as a nutritional supplement with respect to lysine. Hughes and Hauge (1945) had previously stated that the limitations of dried solubles were as a result of a deficiency in lysine and tryptophan. Similarly, Spanyer and Thomas (1956) could only find trace levels of tryptophan in distillers solubles. Tryptophan is probably destroyed in the distillery process because of the low pH in the still effluent. Unfortunately, tryptophan quantity or availability was not determined in this study, because it is destroyed during acid hydrolysis. Hughes and Hauge (1945) further showed that distillers solubles had a protein digestibility coefficient of 88%, a biological value of 50% and using proteolytic enzymes, lysine and tryptophan were only partially released from the distillers solubles as compared to yeast. These observations support other studies which indicate lysine to be one of the least available essential amino acids in various feeds (De Muelenaere et al. 1967, Ostrowski et al. 1970, Sauer, 1972). In contrast, Combs and Bossard, (1969) using the Maryland chick bioassay method, determined 81% of the total lysine to be available (i.e. 0.57% available lysine) from DDG/S. The lysine availability was determined from a blended mixture of corn-gluten meal as the low-lysine basal diet combined with various levels of L-lysine or DDG/S.

GENERAL DISCUSSION

Treatment

The combined treatment means of Experiments 1, 2 and 3 for feed consumption, average daily gain (a.d.g.) and feed efficiency, are shown in Table 15. Overall statistical comparisons of boar data with that of barrows and gilts were impractical because boars were omitted from Experiment 2 and only purebred boars were tested in Experiments 1 and 3.

According to previous chemical analysis of DDG/S (Morrison, 1961, N.A.S.-N.R.C., 1968, Carpenter, 1970) and further analysis at the University of Manitoba all experimental diets met or exceeded the N.A.S.-N.R.C. (1968) requirements (Table 16). In spite of this, relatively uniform chemical composition of the three experimental diets, the 15.0% DDG/S level produced a significantly lower a.d.g. ($P<0.05$) than the control diet. The 7.5% level was intermediate and not significantly different from the other treatments. Though no sex x treatment interaction could be statistically analyzed, the feed consumption, a.d.g. and feed efficiency response to increasing levels of DDG/S appeared to follow a trend which depended upon the sex of the pig.

Barrows were least affected by DDG/S with respect to feed consumption, a.d.g. or feed efficiency. Gilts had a slightly decreased feed consumption corresponding with an impaired a.d.g. on the 7.5% DDG/S diet and a further decrease in feed consumption and a.d.g. was found with the 15.0% DDG/S. Gilt feed efficiency was impaired only at the 15.0% level. As previously noted, the boars were variable in the

Table 15. Mean[1] Performance Results of Experiments 1, 2 and 3

	Control	7.5%	15.0%	Mean
Average Daily Feed Consumption (kg/d)				
Boars	2.73	2.73	2.57	2.67
Barrows	2.88	2.85	2.85	2.86[a]
Gilts	2.62	2.57	2.55	2.58[b]
Barrow-Gilt Mean[1]	2.75	2.71	2.70	
Mean	2.74	2.71	2.65	2.70
Average Daily Gain (kg/d)				
Boars	0.76	0.72	0.67	0.72
Barrows	0.72	0.70	0.70	0.71[A]
Gilts	0.67[a]	0.65[ab]	0.61[b]	0.64[B]
Barrow-Gilt Mean	0.69[A]	0.67[AB]	0.65[B]	
Mean	0.72	0.69	0.66	0.69
Feed Efficiency				
Boars	3.62	3.83	3.81	3.76
Barrows	4.06	4.13	4.15	4.11
Gilts	3.97	3.95	4.14	4.02
Barrow-Gilt Mean	4.03	4.05	4.13	
Mean	3.88	3.97	4.03	3.96

[1]Means for barrows and gilts including all experiments and all breeds. Means followed by a different lower case letter differ significantly $P<0.05$ and upper case letter differ significantly at $P<0.01$.

Table 16. Average Chemical Composition[1] of Experimental Diets

	Control	7.5%	15.0%
Protein (N x 6.25)	13.55	13.45	13.20
Fiber %	4.15	4.44	4.54
Energy kcal/gm	3929	4010	4044
Amino Acids[2] (%)			
Lysine	0.57	0.54	0.53
Methionine	0.21	0.21	0.22
Valine	0.64	0.63	0.61
Isoleucine	0.47	0.44	0.43
Leucine	0.94	0.98	1.08
Histidine	0.27	0.25	0.25
Arginine	0.66	0.68	0.54
Threonine	0.46	0.45	0.48
Phenylalanine	0.63	0.61	0.61
Tyrosine	0.39	0.39	0.40

[1]Weighted averages of Experiments 1, 2 and 3

[2]Analyzed by the Beckman 114-116 amino acid analyzer

amount of feed consumed. The 7.5% level of DDG/S produced a 6% decrease in feed consumption in Experiment 1 and a 7% increase in Experiment 3, however, a consistent decrease in feed consumption appeared with 15.0% DDG/S. Feed efficiency was impaired to the same extent at both levels of DDG/S while a.d.g. was progressively impaired with increasing levels of DDG/S. This was probably due to the decreased feed consumption with 15.0% DDG/S. Thus, the overall significant effects of DDG/S on a.d.g. was a composite of the individual sex responses to DDG/S with boars affected most, gilts affected slightly and barrows virtually unaffected.

Increases in DDG/S produced decreased feed consumption and consequently proportionate decreases in a.d.g. Therefore, palatibility of DDG/S, as reflected by consumption, appears to be a major factor influencing the performance of finishing pigs. Troelsen and Bell (1962) have shown that not all sources of bulk in swine diets caused an increase in feed consumption to achieve an equivalent energy intake but increased levels of alfalfa, wheat bran and cellulose depressed feed intake and consequently reduced a.d.g. No important interactions were determined for sex x level or sex x source of bulk.

Combs and Wallace (1970) have shown increases in feed consumption with increasing levels of DDG/S with corn based diets while Hughes and Hauge (1945) and Wilford (1951) noted the opposite trend in feed consumption. Wahlstrom et al. (1970) found no significant differences in feed consumption with 5, 10 or 20% DDG/S diets but pigs fed the 20% DDG/S diet tended to consume more than those fed other diets. None of the earlier work on DDG/S studied feed consumption of finishing barrows, gilts or boars separately, at different levels of DDG/S.

Decreased nutrient digestibilities as shown by the lower dry matter digestibility (Combs and Wallace, 1970, Wahlstrom et al. 1970) and in the present study may have contributed to the lower a.d.g. on the 15.0% diet. Peter et al. (1971) have shown that the constituents in corn DDG/S had no effect on metabolizable energy of finishing pigs when DDG/S was substituted to 10 or 20% in a corn-soybean diet. However, two conditions differed in the present study. Barley, a lower energy base grain, was used instead of corn,and rye and barley contributed to the "mash bill",therefore, lowering the T.D.N. value of DDG/S (Morrison, 1961). The constituents of the indigestible dietary fraction in DDG/S and its relationship to dietary fiber require further investigation. It is possible that the addition of DDG/S may decrease performance because of palatability problems and/or the effect on digestibility due to its fiber (bulk) content.

Feed efficiency was impaired by DDG/S additions, slightly in barrows only at the 15.0% level in gilts and at both levels in boars. Livingstone and Livingstone (1966) found no effect of 14.7% distillery by-products on feed efficiency of growing-finishing pigs, but a significant impairment in feed efficiency occurred when the distillery by-products were increased to 25.0% of a barley base diet. In their study, total lysine was maintained at 0.76, 0.76 and 0.73% and fiber at 4.9, 4.9 and 6.1% for the control, 14.7% and 25.0% diets, respectively. Wahlstrom et al. (1970) found a significant impairment in a.d.g. and feed efficiency when 20% DDG/S was included in a corn base diet fed to growing pigs, but when the 20% DDG/S diet was supplemented with 0.15% lysine (total lysine to 0.65%), the a.d.g. and feed efficiency were similar to the corn-soybean control diet. Although the nature of the diets differed between these studies, bulk could have been one of the limiting factors to cause the impaired feed efficiency, but there was a partial improvement when higher lysine levels were incorporated into the diets (Livingstone and Livingstone, 1969, Wahlstrom et al. 1970). Again none of the earlier studies differentiated sex responses of feed efficiency to increasing levels of DDG/S.

Quality of protein (level and balance of amino acids) is as important as quantity of protein in a swine ration (Kropf et al. 1959, Dinussion et al. 1967, Smith et al. 1967). Morrison (1961) stated that the protein in distillers' solubles is not of high quality for poultry and swine and it does not effectively supplement the protein in cereal grains. However, from the analysis of the (essential) amino acids of the experimental diets (Table 16), lysine and tryptophan are the only amino acids that may be in limited amounts. Tryptophan as reported by Hughes and Hauge (1945) and Spanyer and Thomas (1956) appears to be very limiting in distillers' solubles. However, the low requirement of finishing swine for tryptophan (0.09%) should be easily supplied by the 0.18% tryptophan in barley (N.A.S.-N.R.C., 1968). Similarly, Bell (1964) showed increasing the tryptophan level from 0.20% to 0.23% had no effect on the performance of growing pigs but lysine rather than tryptophan or protein accounted for the superiority of the ration.

As explained in the experimental procedure, L-lysine was supplemented to compensate for its low level in DDG/S so as to meet or exceed N.A.S.-N.R.C. (1968) requirements. Whether the supplemented lysine was sufficient, especially in Experiment 3, to account for the digestibility of DDG/S may be questioned. Lysine requirements for pigs may be variable with higher levels recommended for maximum leanness and feed efficiency as compared to a maximum rate of gain (Brown et al. 1972, Jensen, 1972).

Studies have shown that equating diets on an available lysine basis yields similar performance results, thus giving an alternative method for assessing protein requirements (Jones et al. 1962, Ostrowski et al 1971). The possible lower digestibility of lysine in DDG/S rather than crude protein or total lysine could contribute to the differences between the experimental diets and the different sex responses to DDG/S. This is further verified by Anderson and Bowland (1967) who have shown a significant sex x lysine digestibility interaction with young pigs and Hughes and Hauge (1945) who have shown the relatively slow release of lysine from distillers' solubles using proteolytic enzyme digestion.

Treatment produced no significant differences in length of side, total backfat, area of loin, % ham of side, ham weight, carcass weight or % yield in any of the three experiments. Similarly, no carcass differences due to treatment were observed for barrows or gilts in the overall average lean area/ham weight, total backfat, area of loin, or % yield (Table 17).

Sex

Barrows consumed more than gilts with boars consuming an intermediate amount. Boar[1] gain was similar to barrows which gained significantly faster than gilts. Feed efficiency was best with boars, followed by gilts and then barrows. These performance traits are consistent with literature previously discussed.

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[1]Boars were not included in the statistical analysis because of breed and experimental differences.

Table 17. Mean[1] Carcass Results of Experiments 1, 2 and 3

	Control	7.5%	15.0%	Mean
Total Fat (cm)				
Boars	9.04	9.47	9.19	9.23
Barrows	10.57	10.24	10.52	10.44[A]
Gilts	9.68	8.59	10.01	9.80[B]
Barrow-Gilts Mean[2]	10.06	9.96	10.24	
Mean	9.75	9.42	9.91	
Loin Area (cm^2)				
Boars	30.71	29.49	29.81	30.01
Barrows	27.87	27.74	27.94	27.74[A]
Gilts	30.65	30.52	30.52	30.58[B]
Barrow-Gilt Mean	29.36	29.29	29.36	
Mean	29.74	29.25	29.43	
% Yield trimmed cuts				
Boars	70.33	71.58	70.26	70.68
Barrows	69.17	69.75	69.07	69.33[B]
Gilts	70.95	70.87	70.69	70.84[A]
Barrow-Gilt Mean	60.16	70.38	69.98	
Mean	70.15	70.73	70.01	

[1]Means followed by a different lower case letter differ significantly P 0.05 and upper case letter differ significantly at $P<0.01$

[2]Means for barrows and gilts including all experiments and all breeds

Gilts were significantly superior to barrows in total backfat, area of loin, % ham of side and carcass length and % yield. These observations were in agreement with Wong et al. (1968), Young et al. (1968), Owusu-Domfeh and Bell,(1971)and Newell and Bowland (1972). A similar % yield was observed between the boars and gilts. The % yield of gilts could have been affected by crossbreeding as indicated in Table 19, and further comparison would require adjustment for breed and experiment. Regardless of breed, boars appeared to be superior to gilts and barrows in total backfat but intermediate in loin eye area. The same observations were reported by Martin (1969) and Newell and Bowland (1972). The data for lean area/ham weight was quite variable for all 'sexes', therefore, no differences could be statistically differentiated. This is a recent measurement, yet one study showed no differences between barrows and gilts (Pierce and Bowland, 1972).

Experiments

The overall statistical analysis showed Experiment 2 to have a poorer a.d.g. and feed efficiency than either Experiments 1 or 3 (Table 18). Season (temperature and humidity) and breeding probably contributed to the poorer performance in Experiment 2. However, further comparisons would be required to quantitate these differences.

In the carcass data analyzed, there were no carcass differences due to experiments, other than % yield (adjusted for sex) being higher in Experiment 1.

Breed

The means for the performance and carcass data for Managra versus Managra crossbred (barrows and gilts only) are shown in Table 19. The Managra crossbred outgained the Managra by 4.3% ($P>0.05$). Feed consump-

Table 18. Performance and Carcass means[1] for Experiments 1, 2 and 3

	Avg. daily feed (kg/d)	Avg. daily gain (kg/d)	Feed efficiency	Total backfat (cm)	Area of loin (cm^2)	% yield trimmed cuts
Experiment 1	2.70	0.72^A	3.79^a	9.83	28.84	70.82^A
Experiment 2	2.69	0.60^B	4.47^b	10.19	29.81	69.97^B
Experiment 3	2.79	0.70^A	4.00^a	10.13	29.55	69.72^B

[1]Comparisons made among treatments and between barrows and gilts.

Table 19. Means for Average Daily Gain and Carcass Traits of Managra and Managra Crossbreds

	Average daily gain (kg/d)	Carcass length (cm)	Total back-fat (cm)	% ham of side (%)	Lean area/ ham wt	Area of loin (cm^2)	% yield trimmed cuts
Managra Purebred	0.69	77.95	9.86^a	27.18	1.12	29.74	70.44^a
Managra Crossbred	0.72	78.05	10.24^b	27.00	1.11	29.55	69.88^b

Means followed by a different lower case letter differ significantly $P<0.05$ and upper case letter differ significantly at $P<0.01$.

tion and feed efficiency could only be compared in Experiment 3 and as previously noted feed efficiency appeared to be improved with the crossbreds.

The carcass data revealed that the crossbred is significantly inferior in total backfat and % yield but similar in carcass length, % ham, lean/ham and area of loin.

Future Areas of Research

The lack of recent research with DDG/S poses many questions about the nutritional capabilities of DDG/S for maximum swine performance. From this study, several major areas in the use of DDG/S appear to require further investigation. It seems necessary to determine the true amino acid availabilities and metabolizable energy values for various dietary levels of DDG/S. This should include boars, barrows and gilts. The lysine availability should then be compared to values obtained for available lysine from a growth assay. This could involve various levels of supplemental lysine with various levels of DDG/S and equating these diets to swine growth. It may be necessary to study methods of increasing lysine availability from the feed (i.e. regrinding, pelleting, etc.) since it appears that supplemental lysine may be the limiting cost factor in feed containing DDG/S. From these studies, changes in gut flora and rates of passage could be determined and related to the digestion and metabolism of bulky feeds.

It would also be of interest to determine the diet preferences of each sex to various levels of DDG/S in combination with various protein supplements. The "co-operative effect" which is claimed to exist by the Distillers Feed Research Council when DDG/S is combined with other protein supplements should also be further examined. Since there appears to be a palatability problem of DDG/S with boars and to a lesser extent gilts, studies could be extended to maximize feed consumption through feed flavoring.

SUMMARY

Three experiments were performed with finishing boars, barrows and gilts to evaluate the isonitrogenous replacement of soybean meal with distillers dried grains with solubes (DDG/S). L-lysine was supplemented to the 7.5 and 15.0% DDG/S diets to ensure equivalent lysine levels to that of the barley-soybean meal control diet.

In spite of the relatively uniform chemical composition of the three experimental diets, the 15.0% diet produced a significantly lower average daily gain (a.d.g.) than the control. The 7.5% level was intermediate and not significantly different from the control or 15.0% diet. Feed consumption and feed efficiency could not be statistically analyzed because of pen feeding.

Even though no sex x treatment interaction for a.d.g. could be shown, the decreases in a.d.g. appeared to be a reflection of the varying decreases in feed consumption of each sex to increases in DDG/S. The palatability and/or fiber (bulk) of DDG/S reduced feed consumption of boars most, to a lesser magnitude gilts and barrows affected least. DDG/S impaired feed efficiency for boars, slightly for barrows but only at the 15.0% level for gilts.

Digestibility studies revealed that a low dry matter and lysine digestibility of DDG/S could have contributed to the impaired performance of the DDG/S diets.

There were no overall carcass differences due to treatment.

The usual sex differences between boars, barrows and gilts were noted for feed consumption, a.d.g., feed efficiency and carcass measurements consisting of length of side, total backfat, area of loin, % ham of side and lean area/ham weight. Gilts had the usual larger % yield of trimmed cuts than barrows. Boars had a similar % yield to that of gilts.

Average daily gain was significantly better in Experiment 2 compared to Experiments 1 and 3. Feed efficiency was also poorer in Experiment 2. Carcass measurements showed only % yield of be superior in Experiment 1. These effects were believed to be due to seasonal and breed differences between experiments.

The crossbred Managra pigs had a 3% better a.d.g. ($P>0.05$) than Managra purebreds. However, purebreds were superior in total backfat and % yield possibly due to the breed selection in the crossbreeding.

BIBLIOGRAPHY

Allee, G. L. and D. H. Baker. 1970. Limiting nitrogenous factors in corn protein for adult swine. J. Animal Sci. 30:748

Anderson, G. H. and J. P. Bowland. 1966. Lysine and fat supplementation of weanling pig diets. Can. J. Animal Sci. 46:47 - 55

Bayley, H. S. and J. D. Summers. 1968. Effect of protein level and lysine and methionine supplementation on the performance of growing pigs: Response of different sexes and strains of pigs. Can. J. Animal Sci. 48:181

Bell, J. M. 1948. An adjustable cylindrical cage for use in metabolism studies with young pigs. J. Nutr. 35:365

Bell, J. M. 1964. Nutrient requirements for Canadian Yorkshire swine. A study of the lysine, tryptophan, riboflavin and pantothenic IV. acid requirements of pigs weighing 50 to 100 pounds. Can. J. Animal Sci. 44:106

Bell, J. M. 1965. Nutrient requirements for Canadian Yorkshire Swine. V. A study of the lysine and protein requirements of finishing pigs weighting from 100 to 200 pounds. Can. J. Animal Sci. 45:105

Bell, J. M. and L. O. Voldeng. 1968. Further observations on lysine and protein requirements of 23 to 89 kilogram pigs. Can. J. Animal Sci. 48:251

Blair, R. and P. R. English. 1965. The effect of sex on growth and carcass quality in the bacon pig. J. Agr. Sci. 64:169

Blair, R., J. B. Dent, R. R. English and J. R. Raeburn. 1969. Protein, lysine and feed intake level effects on pig growth. J. Agric. Sci. Camb. 72:379

Bohstedt, G., R. H. Grummer and O. R. Ross. 1943. Cattle manure and other carriers of B-complex vitamins in rations for pigs. J. Animal Sci. 2:373

Bowland, J. P. 1962. Addition of lysine and/or a tranquilizer to low protein, soybean meal supplemented rations for growing bacon pigs. J. Animal Sci. 21:852

Bowland, J. P. and R. T. Berg. 1959. Influence of strain and sex on the relationship of protein to energy in the rations of growing and finishing bacon pigs. Can. J. Animal Sci. 39:102

Braude, R. and P. Lerman. 1970. Protein and lysine levels in practical rations. J. Agric. Sci., Camb. 74:575

Braude, R., K. G. Mitchell, A. W. Myres, M. J. Newport and A. Cuthbertson. 1972. The replacement of protein concentrates by synthetic lysine in the diet of growing pigs. Br. J. Nutr. 27:169

Brown, H. W., B. G. Harmon and A. H. Jensen, 1972. Re-evaluation of the lysine requirement of finishing swine. J. Animal Sci. 35:211 abs. 180

Canada Department of Agriculture. 1968. Canada's new hog carcass valuation system. Livestock Division, Production and Marketing Branch, Ottawa, Ontario.

Carpenter, L. E. 1970. Nutrient composition of distillers feeds. Proc. Twenty-fifth Distillers Feed Conference, 54.

Catron, D. V. 1956. New developments in baby pig nutrition. Proc. Eleventh Distillers Feed Conference, 27.

Catron, D. V., F. Diaz, V. C. Speer, G. C. Ashton and C. H. Liu. 1955. Distillers dried solubles in starter and growing-finishing rations for swine. Proc. Tenth Distillers Feed Conference, 58.

Charette, L. A. 1961. The effects of sex and age of male at castration on growth and carcass quality of Yorkshire swine. Can. J. Animal Sci. 41:30

Combs, G. F. and E. H. Bossard. 1969. Further studies on available amino acid content of corn distillers dried grains with solubles Proc. Twenty-fourth Distillers Feed Conference, 53.

Combs, G. E. and H. D. Wallace. 1969. Dried distillers grains with solubles in pig starter diets. Fla. Agri Exp. Sta., 14th Ann. Swine Field Day, Mimeo AN69 - 14

Combs, G. E. and H. D. Wallace. 1970. Dried distillers grains with solubles for growing-finishing swine. Fla. Agric. Exp. Stat. AN70 - 13

de Becze, G. I. 1949. Factors affecting the composition of distillers feeds. Proc. Fourth Conference on Feeds of the Grain Distillers, 64.

De Muelenaere, H. F. H., M. L. Chen and A. E. Harper. 1967. Assessment of factors influencing estimation of lysine availability in cereal products. J. Agri. Food Chem. 15:310

Dent, J. B., R. Blair, P. R. English and J. R. Raeburn. 1970. Protein lysine and feed intake level effects on pig growth III. Regression analysis and economic aspects. J. Agric. Sci., Camb. 75:189

Dinusson, W. E., D. O. Erickson, C. N. Hauge and B. W. Boling. 1962. Barley rations for swine: protein and lysine as supplements. N. Dak. Research Report No. 5.

Evans, R. E. 1961. The protein-saving action of synthetic lysine and methionine. J. Agric. Sci., Camb. 57:111

Fahmy, M. H. and C. S. Bernard. 1971. Crossbreeding swine: evaluation of twenty-eight crosses of market pigs. Can. J. Animal Sci. 51:645

Field, R. A. 1971. Effect of castration on meat quality and quantity. J. Animal Sci. 32:849

Gallo, J. T. and W. G. Pond. 1968. Amino acid supplementation to all-corn diets for pigs. J. Animal Sci. 27:73

Good, E. S. and W. V. Smith. 1915. The value of distillers dried grains in swine feeding operations. Ky. Agr. Exp. Sta., Bul. 190.

Hughes, C. W. and S. M. Hauge. 1945. Nutritive value of distillers' dried solubles as a source of protein. J. Nutr. 30:245

Jensen, A. H. 1972. Nutrient requirements of swine. Feedstuffs Volume 44, Number 38:33

Jones, A. S., R. M. Livingstone and A. Cadenhead. 1962. A comparison of the performance of pigs given different protein concentrates in diets providing the same 'available' lysine concentration. J. Animal Sci. 21:852

Krider, J. L., B. W. Fairbanks and W. E. Carroll. 1942. Distillers' by-products in swine rations. J. Animal Sci. 1:359

Kroening, G. H., W. G. Pond and J. K. Loosli. 1965. Dietary methionine-cystine requirements of the pigs as affected by threonine and protein levels. J. Animal Sci., 24:519

Kropf, D. H., R. W. Bray, P. H. Phillips and R. H. Grummer. 1959. Effects of protein level and quality in swine rations upon growth and carcass development. J. Animal Sci. 18:755

Lasley, J. F. 1963. Genetic of Livestock Improvement. Prentice-Hall, Inc., New Jersey.

Livingstone, R. M. and D. M. S. Livingstone. 1969. Use of distillers by-products in diets for growing pigs. Animal Prod. 11:259

Lynch, P. B. and J. F. O'Grady. 1971. Effect of level and source of lysine and protein level sequence on performance of growing-finishing pigs. Ir J. Agric. Res. 10:245

Martin, A. H. 1969. The problem of sex taint in pork and relation to the growth and carcass characteristics of boars and barrows: A review. Can. J. Animal Sci. 49:1

McBeath, D. K., C. F. Bentley, D. L. Lynch and J. P. Bowland. 1960. The nutritional value of increased levels of protein resulting from nitrogen fertilization of barley. Can. J. Animal Sci. 40:57

Mertz, E. T., D. C. Shelton and W. M. Buson, 1949. The amino acid requirements of swine, lysine. J. Animal Sci. 8:524.

Milne, B. E. 1965. Studies of body fluids, nitrogen balance, some nutrient digestibilities and reproductive performance of sows fed varying levels of protein. M. Sc. Thesis, University of Manitoba, Winnipeg, Manitoba

Morrison, F. B. 1961. Feeds and Feeding, Abridged. Ninth edition. The Morrison Publishing Company, Clinton, Iowa.

National Academy of Science-- National Research Council. 1968. Nutrient Requirements of Swine. Sixth revised edition.

Newell, J. A. and J. P. Bowland. 1972. Performance, carcass composition, and fat composition of boars, gilts, and barrows fed two levels of protein. Can. J. Animal Sci. 52:543 - 551

Ostrowski, H., A. S. Jones and A. Cadenhead. 1970. Availability of lysine in protein concentrates and diets using Carpenter's method and a modified Silcock method. J. Sci. Fd. Agric. 21:103

Ostrowski, H., A. S. Jones and A. Cadenhead. 1971. Nitrogen metabolism of the pig III. Utilization of protein from different sources. J. Sci. Fd. Agric. 22:34

Owusu-Domfeh, K. and J. M. Bell. 1971. Nutrient requirements for growing and finishing pigs. Can. J. Animal Sci. 51:601

Peter, R. A., J. L. Pettigrew, B. G. Harman, A. H. Jensen and D. H. Baker. 1971. Metabolizable energy of distillers dried solubles with grains for swine. J. Animal Sci. 33:1153 abs 68

Pierce, A. B. and J. P. Bowland. 1972. Protein and amino acid levels and sequence in swine diets: Effects on gain, feed conversion and carcass characteristics. Can. J. Animal Sci. 52:531

Reimer, D. R., R. J. Meade and R. S. Grant. 1964. Barley rations for swine III. Lysine and methionine supplementation: Effects on rate and efficiency of gain and on carcass characteristics. J. Animal Sci. 23:404

Rerat A. and J. Lougnon. 1968. Amino acid requirements of growing swine. World Rev. Animal Prod. IV:65

Sauer, W. C. and S. C. Stothers. 1969. Lysine supplementation in finishing swine rations. (Unpublished data).

Sauer, W. C. 1972. Availability of amino acids from barley, wheat, triticale and soybean meal for growing pig. M. Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

Smith, J., A. J. Clawson and E. R. Barrick. 1967. Effect of ratio of protein from corn and soybean meal in diets of varying total protein on performance carcass desirability and diet digestibility in swine. J. Animal Sci. 26:752

Snedecor, W. G. and W. G. Cochran. 1967. Statistical Methods. Sixth edition. The Iowa State University Press, Ames, Iowa.

Soldevila, M. and R. J. Meade. 1964. Barley rations for swine III. The influence of L-lysine and D. L. Methionine supplementation of barley-soybean meal diets upon rate and efficiency of gain and upon nitrogen retention of growing swine. J. Animal Sci. 23:397

Spanyer, J. W. and A. T. Thomas. 1956. Determination and comparison of amino acid composition of yeast and distillers solubles. J. Agric. Food Chem. 4:631

Teague, H. S., R. F. Plimpton, Jr., V. R. Cahill, V. R. Grifo and L. E. Kunkle. 1964. Influence of diethylstilbestrol implantation on growth and carcass characteristics of boars. J. Animal Sci. 23:332

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

Wahlstrom, R. C., C. S. German and G. W. Libal. 1970. Corn distillers dried grains with solubles in growing-finishing swine rations. J. Animal Sci. 30:532

Walstra, P. and D. Kroeske. 1968. The effects of castration on meat production in male pigs. World Rev. Anim. Prod. 4:59

Wilford, E. J. 1948. Stillage as a feed for growing and fattening hogs in dry lot. Proc. Third Conference on Feeds of the Beverage Distilleries, 68

Wilford, E. J., W. P. Garrigus and C. E. Barnhart. 1951. Distillers dried solubles as a protein supplement for growing and fattening hogs in drylot. Kentucky Agric. Exp. Sta. Bulletin 577

Wismer-Pedersen, J. 1968. Boars as meat producers. World Rev. Animal Prod. 4:100

Wong, W. C., W. J. Boylan and S. C. Stothers. 1968. Effects of dietary protein level and sex on swine performance and carcass traits. Can. J. Animal Sci. 48:383

Young, L. G. and R. H. Ingram. 1968. Dried brewers grains in rations for market hogs. Can. J. Animal Sci. 48:83

Young, L. G., G. C. Ashton, R. P. Forshaw and R. H. Ingram. 1968. Relationships of dietary protein levels to performance and carcass merit of market swine. Can. J. Animal Sci. 48:71

APPENDIX

Appendix Table 1. Mean Squares for Average Daily Gain and Carcass Traits

	Experiment 1		Experiment 2		Experiment 3		Experiment 3	
Average Daily Gain								
	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Treatment	2	0.053	2	0.140	2	0.128*	2	0.128*
Sex	2	0.213*	1	0.258*	4[1]	0.084	2	0.157*
T x S	4	0.072	2	0.034	8	0.048	4	0.015
Error	67	0.056	75	0.035	119[2]	0.039	125	0.039
Length of Side								
	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Treatment	2	3.042	2	0.363	2	0.173	2	0.166
Sex	2	20.190**	1	9.582**	4	4.803**	2	9.397**
T x S	4	4.568	2	0.421	8	0.292	4	0.184
Error	66[3]	2.900	75	0.645	115[4]	0.720	121	0.701
Total Fat								
	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Treatment	2	0.224	2	0.145	2	0.090	2	0.035
Sex	2	0.316	1	4.583**	4	1.223**	2	2.208**
T x S	4	-0.001	2	0.274	8	0.102	4	0.118
Error	66	0.150	75	0.163	116	0.130	122	0.136

Appendix Table 1. Continued

	Experiment 1		Experiment 2		Experiment 3		Experiment 3	
Area Loin								
	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Treatment	2	0.548	2	0.028	2	0.100	2	0.999
Sex	2	1.789**	1	3.705**	4	1.227**	2	2.446**
T x S	4	0.043	2	0.064	8	0.106	4	0.046
Error	66	0.202	75	0.168	116	0.211	122	0.206
% ham of Side								
	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Treatment	2	2.117	2	0.964	2	2.000	2	2.012
Sex	2	16.329**	1	8.726*	4	24.060**	2	46.223**
T x S	4	1.634	2	0.455	8	0.860	4	1.315
Error	66	1.438	75	1.267	115	1.853	121	1.813
Lean area/ham Weight								
	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Treatment	2	0.070**	2	0.007	2	0.008	2	0.009
Sex	2	0.029*	1	0.200**	4	0.073*	2	0.144**
T x S	4	0.003	2	0.006	8	0.002	4	0.005
Error	66	0.010	75	0.010	115	0.023	121	0.013

Appendix Table 1. Continued

	Experiment 1		Experiment 2		Experiment 3		Experiment 3	
% yield trimmed cuts[5]								
	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Treatment	2	12.380	2	0.494	2	4.049	2	3.943
Sex	2	17.540*	1	89.343**	4	18.448**	2	31.774**
T x S	4	2.501	2	2.717	8	0.496	4	0.723
Error	66	5.628	75	3.145	115	3.795	121	3.671

*means differ significantly, $P<0.05$

**means differ significantly, $P<0.01$

[1]includes Managra boars, Managra barrows, Managra x Yorkshire barrows, Managra gilts and Managra x Yorkshire gilts

[2]pig #132 eliminated from all data due to immediate unthriftiness

[3]one pig removed due to tail infection

[4]two boars were slaughtered, one carcass lost and one carcass partially destroyed (maximum loss of one pig per pen)

[5]prediction equation = $51.68 - 3.234x_1 + 1.038x_2 + 0.485x_3 + 11.766x_4$

x_1 = total fat, 3 measurements x_2 = loin area x_3 = % ham of carcass
x_4 = area lean of ham face (ham weight)

Appendix Table 2. Mean Squares and Digestibility for Treatments[1] and Weight Groups[2]

Character	Source of Variation			
	Treatment	Weight	Treat x Wt.	Error
d.f.	1	1	1	10
Dry Matter	70.067*	4.515	0.694	9.103
Protein	8.960	30.686	5.958	13.019
Lysine	476.427*	27.726	17.467	49.453
Isoleucine	36.709	39.295	38.870	16.090
Phenylalanine	5.369	6.494	0.591	5.874
Histidine	0.890	13.401	8.401	7.261
Methionine	19.754	24.039	41.114	18.719
Arginine	44.037	31.046	12.673	18.651
Leucine	86.500**	10.796	0.154	6.559
Threonine	1.625	14.708	1.080	12.445
Valine	0.084	54.014	0.057	12.525

[1]including Barley and DDG/S/½

[2]including both weight groups 20-21 kg and 80kg

*means differ significantly, $P<0.05$

**means differ significantly, $P<0.01$

Appendix Table 3. Means Squares for Average Daily Gain and Carcass Traits for the Managra Purebred and Managra Crossbred

Character	d.f.	Average daily gain (kg/d)	Carcass length (cm)	Total back-fat (cm)	% ham of side (%)	Lean area/ ham wt	Area of loin (cm^2)	% yield trimmed cuts
Experiment 1								
Treatment	2	0.025	0.017	0.170	1.125	0.040**	0.435	6.124
Breed	1	0.104	0.339	0.089	2.311	0.004	0.018	12.186
T x B	2	0.087	0.094	0.013	0.968	0.006	0.037	3.305
Error	48	0.050	0.849	0.128	2.049	0.010	0.247	3.716
Experiment 3								
Treatment	2	0.097	0.264	0.150	1.859	0.031	0.122	1.845
Breed	1	0.025	0.036	0.621*	1.201	0.000	0.001	5.826
T x B	2	0.002	0.056	0.011	0.554	0.002	0.185	0.076
Error	101[1]	0.043	0.680	0.074	1.318	0.011	0.239	3.676

Appendix Table 3. Continued

Character	d.f.	Average daily gain (kg/d)	Carcass length (cm)	Total back-fat (cm)	% ham of side (%)	Lean area/ ham wt	Area of loin (cm^2)	% yield trimmed cuts[2]
Overall(Experiment 1 and Experiment 3)								
Treatment	2	0.084	0.094	0.111	3.109	0.025	0.123	3.139
Breed	1	0.092	0.069	0.818*	1.251	0.003	0.025	22.572*
T x B	2	0.021	0.196	0.000	0.103	0.000	0.304	1.127
Error	155[3]	0.045	0.720	0.134	1.573	0.008	0.241	3.866

*means differ significantly, $P<0.05$

**means differ significantly, $P<0.01$

[1]d.f. for carcass data reduced to 100 because of missing data

[2]final predicted yield was adjusted by adding 1.1% to the prediction for barrows and subtracting 1.1% for gilts

[3]d.f. for carcass data reduced to 154 because of missing data

Appendix Table 4. Means square for Overall Analysis

Character	Avg. daily feed		Avg. daily gain		Feed Efficiency	
	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Treatment	2	0.006	2	0.174 *	2	0.037
Sex	1	0.468 *	1	1.355 **	1	0.051
Experiment	2	0.006	2	1.410 **	2	0.727 **
S x E	2	0.002	2	0.246	2	0.015
T x E	4	0.004	4	0.038	4	0.009
S x T	2	0.006	2	0.042	2	0.014
Error	13	0.098	228	0.0397	13	0.032

Appendix Table 4. Continued

Character	d.f.	Total backfat	Area of loin	% yield trimmed cuts	% yield trimmed cuts[1]
Treatment	2	0.24	0.004	3.239	3.43
Sex	1	3.83**	11.064**	134.589**	28.82**
Experiment	2	0.35	0.448	22.171**	21.66**
S x E	2	0.92**	0.645*	7.216	6.65
T x E	4	0.11	0.291	2.661	2.49
S x T	2	0.15	0.235	2.291	2.00
Error	227	0.14	0.178	3.300	3.31

*means differ significantly, $P<0.05$

**means differ significantly, $P<0.01$

[1]final predicted yield was adjusted by adding 1.1% to the prediction for barrows and subtracting 1.1% for gilts

Appendix Table 5. Overall Treatment[1] and Sex[2] Comparison of % Ham of Side and Lean Area/Ham Weight

		% ham of side	lean/ ham wt.
	d.f.	M.S.	M.S.
Treatment	2	0.908	0.031
Sex	1	24.908**	0.000
T x S	2	0.249	0.021
Error	235	1.954	0.011

[1]control, 7.5 and 15.0% diets

[2]barrows and gilts only

**means differ significantly, $P<0.01$

Appendix Table 6. Number of Managra Crossbred and Managra Pigs Assigned from each Breed[1] to each Treatment

	Control	7.5%	15.0%	Total
Experiment 1				
Boars				
M	8	7	7	22
M x Y	--	--	--	--
Barrows				
M	6	6	5	17
M x Y	3	3	4	10
Gilts				
M	5	6	6	17
M x Y	4	3	3	10
Total	26	25	25	76
Experiment 2				
Boars				
M	--	--	--	--
M x Y	--	--	--	--
Barrows				
M	9	9	9	27
M x Y	--	--	--	--
Gilts				
M	18	18	18	54
M x Y	--	--	--	--
Total	27	27	27	81
Experiment 3				
Boars				
M	9	9	9	27
M x Y	--	--	--	--
Barrows				
M	9	9	9	27
M x Y	9	9	9	27
Gilts				
M	9	9	9	27
M x Y	9	9	9	27
Total	45	45	45	135
OVERALL TOTAL	98	97	97	292

[1] M --Managra M x Y --Managra crossbred