HIGH MOISTURE, ACID TREATED WAXY, OPAQUE-2 AND YELLOW DENT CORN RATIONS FOR GROWING STEER CALVES AND GROWING-FINISHING SWINE

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ABSTRACT

HIGH MOISTURE, ACID TREATED WAXY, OPAQUE-2
AND YELLOW DENT CORN RATIONS FOR GROWING
STEER CALVES AND GROWING-FINISHING SWINE

By

Stephen Scott Sachtleben

The quality as well as quantity of available protein in the two mutant corns, opaque-2 and waxy, has been the center of debate in recent years in regards to their nutritional value, whether advantageous or disadvantageous, in the performance of beef cattle and swine. The superiority of opaque-2 in respect to swine seems to have been established although there have been conflicting reports. The value of waxy corn has not really been defined for swine or cattle. Beef cattle seem to have gained nothing from the superior amino acid balance of opaque-2 rations since there is adequate microbial synthesis of essential amino acids when adequate nitrogen is provided. It was the purpose of this study to examine the possible advantages or disadvantages of each corn type in regards to both the growing steer and growing, finishing pig.

EXPERIMENT I - Cattle Feeding Trial

A 3x3 factorial design was utilized to compare average daily gains and gain per feed ratios with different

combinations of sixty percent silage and forty percent high moisture, rolled corn rations. Seventy-two Charolais-Hereford crossbreed steer calves were randomly lotted into nine treatment groups representing each silage-corn combination of waxy, opaque-2 and yellow dent corns and silages. Silages were treated with an ammonia mineral suspension in order to raise the protein level from 8% to about 13% on a dry matter basis. All shelled corn types were acid treated with a 60% acetic - 40% propionic solution because their initial moisture levels were too high for conventional storage without appreciable losses due to spoilage.

Cattle were fed ad libitum, weighed biweekly and removed from experiment after 159 days.

Average daily gains were not significantly different across treatments although there was a tendency for waxy corn rations to increase gain and for opaque-2 corn rations to depress gain when compared to dent corn. Feed efficiencies did not differ significantly, however, opaque-2 rations required more feed per pound gained than either waxy or regular corn.

EXPERIMENT II - Swine Feeding Trial

Thirty-three swine were randomly allotted to four different treatment groups. Each group represented a diet composed of either dry dent, high moisture dent, high moisture opaque-2 or high moisture waxy corn. Each lot was fed this ration until market weight was reached. All diets were formulated on an equal dry matter corn basis and supplemented with soybean meal to comprise a 16% protein diet during the growing phase and a 13% protein diet during finishing.

Average daily gains did not differ significantly although waxy corn tended to decrease gain by as much as 8% when compared to the other rations. Carcass data were obtained upon slaughter with no dissimilarities.

EXPERIMENT III - Balance Trial

Each of the four feeds utilized in the swine feeding trial during the grower phase was employed in this trial. Eight pigs were divided randomly into two lots and a nitrogen and energy balance was conducted with each lot on each of the four rations.

There were no significant differences in energy or nitrogen absorptions or retentions across treatments. Waxy corn consumption seemed depressed possibly due to its flaky texture.

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INTRODUCTION

One of the most critical problems of those who raise animals, whether ruminant or monogastric, is the price of feed. Many things can affect feed prices such as inflation, supply and demand and labor costs in the feed industry. Therefore, it would be to the advantage of the farmer to obtain the best performance in terms of feed efficiency and average daily gain or in reality, gain per dollar expended on feed. Thus, this study was devoted to the examination of utilizing different corn types and their protein components in regards to performance both in ruminants and monogastrics.

Opaque-2 corn is a mutant which has a superior amino acid balance than regular corn. This superior amino acid balance is mainly due to increased lysine and tryptophan levels. Since lysine and tryptophan are often the dietary amino acids limiting growth performance, it is in this capacity that opaque-2 would perhaps be superior to regular corn.

The amino acid pattern of waxy corn is similar to that of regular corn, however, waxy corn is higher in the protein component zein. Zein is supposedly much less degraded in the rumen since it resists attack by proteolytic enzymes (McDonald, 1954). The insoluble protein portion which passes to the lower gut could in turn be hydrolized with subsequent absorption of amino acids.

It has been suggested that opaque-2 corn would be advantageous in swine production since swine have no rumen microbes to synthesize amino acids and the additional, better balance of essential amino acids would facilitate better performance. Cattle may perform as well on regular corn as opaque-2 since their rumen microbes may synthesize any additional amino acids needed for performance, thus the better quality of protein in opaque-2 may not be utilized.

Waxy corn may add to the amino acids available for intestinal synthesis in cattle due to rumen bypass of zein; in essence making more amino acids available for body utilization. In swine the question arises as to whether the relative difficulty in the digestion of zein would lead to poorer performance.

These questions were examined in this study in order to determine the nutritional status of each corn type in respect to cattle and swine performance.

LITERATURE REVIEW

Acid Treatment of Corn

The question as to whether one successfully stores grain is dependent upon the inhibition of mold growth and the regulation of bacterial growth. These two factors, the prevention of mold formation and strict governing of bacterial growth, are regulated by the percent moisture of the corn, oxygen supply and the pH of the stored feed (Long, 1973).

In the past, it has been the procedure to air dry the corn to an approximate 14% moisture level before ensiling. However, Beeson and Perry (1958) were the first to report that they had obtained improved feed efficiency, in cattle, by feeding ensiled, high moisture, ground ear corn. Contemporaries of Beeson and Perry have sustantiated the initial findings that feed efficiencies had indeed increased due to the ensiled high moisture corn (Heuberger *et al.*, 1959).

There is, however, an upper limit of percent moisture and if surpassed, a depression in average daily gain will occur. Tonroy *et al.* (1974) have shown that a moisture content of 33.8% depressed gains by ten percent ($P<.05$). Heuberger *et al.* (1959) also reported a marked depression in gains when cattle were fed a corn ration with 36% moisture.

A reduction in dry matter intake may also occur if moisture levels are too great (Heuberger et al., 1959; Burkhardt et al., 1969; Tonroy et al., 1974). When the corn is not fed at excessively high moisture levels, the dry matter intake will be indirectly proportional to the percent moisture. This results in improved feed efficiency.

In 1974 Tonroy et al. demonstrated that cattle fed high moisture corn had improved the feed efficiency (gain/dry matter) from between 9-25%.

The usage of high moisture corn was limited however to ensiled, sealed systems. With increased yields of newer hybrids, early harvest continued and a need for larger, less confining, cheaper, storage areas arose. In 1971, the United States' researchers were given the Environmental Protection Agency's clearance for the addition of certain volatile acids, mainly acetic and propionic, to high moisture grains in order to inhibit bacterial and fungal growth while stored in simple, uncovered bins.

Preliminary tests by Miller et al. (1969) at Cornell University, showed that shelled corn reconstituted to 30% moisture and treated with 1.5% propionic acid remained mold free for three months under laboratory conditions that far exceeded actual summer heat and humidity.

Supplemental feed-lot trials by Miller _et al_. (1969-1970) resulted in no significant differences in feed efficiency or average daily gain when high moisture corn treated with volatile fatty acids was compared to dry corn on a dry matter basis.

Work in high moisture corn improvement was carried on by Forsyth _et al_. (1970). Their research with corn treated with propionic acid led to the conclusion that, in beef cattle, corn, treated with 1.5% propionic acid, would increase feed efficiency by 10% over artificially dried corn. A significant increase in gain/feed ratio ($P<.05$) was obtained in weanling pigs if high moisture corn was treated with .67% propionic acid (Meisinger _et al_., 1974).

Acetic and propionic acid mixtures have also been studied as to their effect on the nutritional value of high moisture corns. Preliminary trials at Cornell by Miller and coworkers (1969) depict that there was no significant advantage to treating the high moisture corn with an acetic: propionic mixture although there was a tendency for the preserved corn to obtain slightly better results in gain and feed efficiencies. Tonroy _et al_.(1974) reported that their data showed a seven percent feed efficiency increase in cattle when the corn had been treated with volatile fatty acids in the following proportions: acetic 57.0%, propionic 40.0% and 3.0% water.

Numerous researchers across the country have run trials with various other animals. Lambs fed corn treated with 57% acetic, 40% propionic and 3% water (Chemstore^R) apparently did not show any significant performance differences according to Polzin and fellow workers (1972). Swine (Lynch et al., 1974) significantly benefitted ($P<.05$) in average daily gain when a 1.2% propionic-acetic mixture was used on high moisture corn and compared to a dry corn ration. It should be noted that in this particular trial, the corn sprayed with the volatile fatty acids had reduced carotene and vitamin E levels after 20 weeks.

The addition of water to previously dried corn will result in lower gains and feed ratios than if one used corn with high moisture right from the field. According to Tonroy, Beeson and Perry (1974), the nature of the moisture and fermentation contribute to the final results. Artificially added moisture to corn produces a different fermentation product than natural high moisture corn during ensilement.

Although reconstituted high moisture corns were somewhat inferior in gains and efficiencies, this type of corn was digested more thoroughly on a dry matter basis (McLaren and Matsushima, 1968).

This more thorough digestion ($P<.05$) of dry matter did not however make up for the increased protein digestibility shown by Tonroy et al.(1974) in the high moisture and acid treated corns.

All high moisture corns whether reconstituted, untreated high moisture, or high moisture corn treated with volatile fatty acids, have significantly ($P<.05$) increased dry and organic matter digestion and contain more digestible energy than dry corn (McKnight et al. 1973) for beef cattle. Clark and Harshbarger (1972) showed similar results for lactating dairy cattle.

Starch digestibility tended to be higher in high moisture corn diets, but only corn that had been acid treated was significantly higher ($P<.05$) according to McKnight et al. (1973). Increased starch digestibility combined with significant increases in nitrogen digestibility may be a factor of importance concerning the superiority of high moisture corns. Polzin et al. (1972) showed no significant differences ($P<.05$) in N digestion and retention in lambs.

Upon digestion of acid treated corns, rumen fluid volatile fatty acids (acetic, butyric and propionic acids), did not seem to differ, but on measuring the total volatile fatty acid concentration, the level had risen by approximately three percent as shown by Miller and coworkers in 1972. The rumen propionic acid level increased by 12-13% as compared to regular dry corn. One can deduce from this that other fatty acids had decreased in concentration. It would stand to reason that the pH of the rumen dropped accordingly.

In reference to the rate of passage of these corns, McKnight et al.(1973) stated that high moisture corn, as a whole, had a significantly ($P<.05$) slower rate of digestion than dry corn. This could be related to the particle size and density of the corn. As a result of the high moisture corn not leaving the rumen as rapidly as dry corn, it may be hypothesized that it was therefore more thoroughly digested. The acid, from the results of spraying the corn for preservation, along with the fermentation process could aid in the breakdown of the hard endosperm of the kernel, thus aiding in the digestion. The high moisture content in itself could assist in softening the outside and keeping the kernel, as a whole, more pliable.

There are various other chemicals employed to preserve high moisture corns although their use in most cases can not be justified when compared on a cost per gain basis. Bothast and workers (1974) when comparing ammonia, ammonia isobutyrate (AIB), isobutyric acid (IBA) and propionic-acetic acid treated corn in Herefords found no differences across treatments in reference to average daily gain or average daily intake with the exception that the ammoniated corn was significantly ($P<.05$) lower in feed efficiency.

In treated high moisture corn diets for swine, Lynch et al. (1974) showed no differences when comparing .45% NH_3, .82% propionic, 1.2% PA, 1.5% IBA and .6% methylene bis propionate. A solution of .67% methylene bis propionate utilized by Meisinger, Kroening and Hodson (1974) at Southern Illinois University did show significant differences ($P<.05$) in weanling pigs. Feed to gain ratios were higher than ensiled high moisture corn and corn treated with a .67% propionic acid solution.

While there seem to be discrepancies among data as to which treatment of high moisture corn gives the best results, several conclusions can be drawn. First, treatment of high moisture corn by the aforementioned chemicals, does retard bacterial and fungal growth whereas untreated corn, high in moisture, would rot due to acetic and lactic acid formation combined with overheating. There are differences in length of storage dependent on type of chemical employed and management practices.

Secondly, ammonia treatment increases feed to gain ratios significantly. This is due to the additional blood urea formation. Thirdly, according to Florence et al.(1968) grinding of high moisture corns may enhance their solubility and as a result increase digestibility in the rumen.

The author feels that the effects of chemical treatment of high moisture corn can be summarized by the words of McKnight and his coworkers (1973): "Significant differences in beef cattle and dairy cattle performance are likely if physical and chemical characteristics of high moisture corn are altered by processing in such ways as to affect rumen fermentation patterns, extent of digestion in the rumen, and the overall digestion."

Opaque-2 Corn

Corn, without supplement, is a low protein type of ration. The protein level usually is within the range of from eight to nine percent. Many farmers formulate a specific corn variety by genetic cross-breeding that would result in a corn with higher protein levels. These higher protein contents would theoretically enable an animal to have superior growth performance provided the protein was of better quality.

Genetically, opaque-2,(O-2), is a strain of corn which differs from normal corn in that opaque-2 contains a mutant, recessive, O-2 gene which changes the protein content of the corn kernel (Mertz *et al.*, 1964). This gene reverses the major components of corn protein, mainly glutelin and zein. In opaque-2 corn glutelin levels are higher than normal varieties and zein levels are decreased. This reversal of corn protein ratios is responsible for an increase in the amino acids lysine and tryptophan by almost 100 percent and slight elevations in histidine, arginine, aspartic acid, threonine, glycine, valine, cystine and isoleucine. Mertz also points out that high lysine corn has decreased amounts of leucine.

Mertz and fellow workers (1964) have shown, through laboratory analysis, that lysine levels in opaque-2 corn were at least double that of normal corn. The zein levels had dropped from a mean of 46% in normal corn to 15.7% in high lysine corn. Zein, according to Osborne and Mendel (1914), is the major constituent of regular corn protein and is practically devoid of lysine and tryptophan. Therefore when zein decreased and glutelin increased, researchers speculated that it was the lysine-tryptophan rich glutelin that caused superior performance in rats.

The first study conducted with the opaque-2 mutant known to this author was performed by Mertz et al. (1956). In this trial rats were utilized. They showed opaque-2 corn to be superior to regular corn and equivalent in results to a soybean meal supplemented ration. The male rats on O-2, in reality, gained 3.6 times faster than the rodents on normal corn diets. Upon analysis, the O-2 corn showed higher levels of lysine and tryptophan. Because of these increased amino acid levels, it was theorized that this was the reason for apparent opaque-2 superiority in rats (Mertz et al., 1965; Gipp, 1968; Gipp and Cline, 1972 and Klein et al., 1972).

Veum, Pfander and Bellamy (1974) showed no significant differences in performance of rats when they were fed normal and opaque-2 rations supplemented with soybean meal or additional amino acids.

Further experimentation by Mertz in 1966 demonstrated that no single essential amino acid was the limiting factor for growth in rats and that opaque-2 rations were equal to a casein diet supplemented with cysteine.

In poultry, lysine seems to be the superior component of opaque-2, not a lysine and tryptophan combination. Rogler (1966) declared that on an equal nitrogen basis, opaque-2 corn was not better than normal corn without methionine supplementation. Here methionine was a limiting factor and even surplus lysine would not affect growth. However, Rogler showed that with addition of methionine to the diet, the opaque-2 corn would produce better gains and feed efficiencies than normal corn.

Cromwell _et al_. (1966) at Purdue demonstrated improved overall gains ($P<.01$) in chicks fed normal corn over opaque-2 corn on crude protein rations of 21, 19, 17 and 15%. There was no amino acid supplementation in this trial. Dependent on the protein percentage, feed efficiency differed from level to level. Chicks on a 15% ration were more efficient ($P<.01$) when fed opaque-2 , but on a 17% diet, normal corn was superior ($P<.01$). Additional analysis by Cromwell _et al_. uncovered a methionine deficiency in respect to National Research Council (1960) guidelines. In response to this finding and the work of others (Rogler, 1966 and Featherston _et al_. 1960) methionine was added to the diet, thus alleviating the limiting factor. As a result, chicks fed O-2 over a given weigh period were significantly heavier (P<.01) at the 15% protein level and tended to be heavier at other levels although not significantly. Feed efficiency for chicks fed O-2 was significantly better than those fed normal corn at 18% and 15% levels and relatively identical at 21% protein. This would lead one to believe that, in poultry, opaque-2 corn is superior to normal corn predominantly at suboptimal protein levels on methionine supplementation.

Cromwell (1966), to further substantiate the theory that lysine was the "superior factor" in opaque-2 corn, conducted a trial using chicks fed opaque-2 and normal corn without lysine supplementation. The O-2 chicks gained 13% faster (P<.01) and 16% (P<.01) more efficient than chicks on normal corn diets. However, if the levels of lysine in the normal corn were supplemented until they were equal to the lysine levels found in the O-2 corn, the results of daily gain and efficiencies would be statistically identical. When soybean protein was added to the opaque-2 and normal corn rations in order to balance them isonitrogenously, the normal corn diet received more soybean and less corn than the opaque-2 diet. The normal corn rations caused significantly (P<.05) higher final weights than the opaque-2 rations over all protein levels; feed conversions were similar. This data may be explained as the result of equal lysine levels in both diets and thus the reason why the opaque-2 corn was no longer superior. The superiority of the normal corn ration can be explained by suggesting that the soybean protein was superior to opaque-2 corn's protein.

With the possibility of increased lysine levels in rations resulting in better gains and feed efficiencies in chicks, the question arose as to lysine's effect on other larger animals both monogastrics and ruminants.

Beeson et al. (1966) and Pickett (1966) in their work showed that weanling pigs fed an opaque-2 corn diet, fortified only with vitamins and minerals, gained 3.6 times faster than those swine on a normal hybrid ration. When the protein level of the normal hybrid diet was elevated to that of the opaque-2 the gains were similar. Beeson, Pickett and coworkers concluded that opaque-2 corn was equivalent to an isonitrogenous diet of normal corn fortified with soybean meal. Additional work by Cromwell (1967) revealed significant increases in average daily gains and gain/feed ratios when opaque-2 was compared to normal corn in swine rations. Excess nonessential N addition to normal diets had no effect on results. Cromwell (1967) stated that superiority shown by opaque-2 may have been the reflection from varying levels of essential amino acids between the two corns. Based on National Research Council (1964) standards, the normal corn was deficient in tryptophan, valine and phenylalanine whereas the opaque-2 corn had sufficient levels. Sihombing et al. (1969), Maner et al. (1971) and Gipp and Cline (1972) supported Cromwell's work as their research revealed significant increases in average daily gain and feed efficiency with opaque rations. Wahlstrom and fellow workers' (1973) data showed improved feed efficiency when swine were fed opaque-2 varieties.

The average daily gains and feed efficiencies of swine fed either opaque-2 or normal corn will vary depending on the amino acid levels of the corns and actual protein level of the diet. In chicks, opaque-2 corn's superiority was dependent on the availability of lysine and particularly methionine (Rogler, 1966 and Cromwell, 1967). This is not the case with swine. Cromwell et al. (1966), Cromwell, Beeson and Pickett (1967) and Drews et al. (1969) showed that levels of tryptophan affected the performance of opaque-2 and normal corns. Lysine addition to swine rations did not result in performance data equal to that of lysine and tryptophan supplementation. This evidence suggests that the amino acid tryptophan may have a more limiting effect on swine corn rations than lysine.

Welch et al. (1966) discovered that N retention was significantly increased in swine fed lysine and tryptophan supplements together, but not singly. Cromwell and coworkers (1967) found that normal corn supplemented with lysine and tryptophan gave poorer gains and feed conversions than non-supplemented opaque-2. Klein et al. (1972), Cromwell et al. (1969) and Marroquin and coworkers (1974) have shown pigs fed O-2 corn varieties to have increased N retention and greater apparent digestible protein. This may be due to a decline in zein fractions in the high lysine corn varieties. Cromwell stated that pigs fed O-2 retained ($P < .01$) greater amounts of nitrogen on an absolute and percent basis than did normal corn when fed to pigs isonitrogenously. He also indicated that when fed on an equivalent corn protein basis, the swine tended to retain more protein in opaque rations, thus suggesting that opaque corn would have a superior biological value when compared to normal corn varieties. This greater retention of the absorbed opaque-2 N is most probably due to a superior balance of amino acids in the opaque-2 mutant.

Urinary urea excretion is reduced upon tryptophan addition to either opaque-2 or normal corn rations although the extent of the excretion depression is dependent on the levels of the limiting amino acid. Brown and Cline (1974) found that as the dietary amino acid balance was improved by supplementing the diet with the first limiting amino acid, the protein synthesized would increase and free plasma amino acid levels would decline. As a result, less nonlimiting amino acids would be catabolized to urea and excreted. The increase in protein synthesis is the basis for the decline in urinary urea output. Brown's work supports the theory of Almquist (1954) that an amino acid deficiency causes a slow down of protein synthesis and an increase in free amino acids in the plasma. This evidence would substantiate the theory that opaque-2, due to its increased tryptophan and lysine levels, would hasten protein synthesis and decrease free amino acid plasma levels thus increasing N retention and protein utilization in swine.

In regard to acceptability, swine tend to consume more opaque-2 than normal corn when fed free choice (Wahlstrom and Libal, 1973). Wahlstrom et al. (1973) and Cromwell and coworkers (1969) also reported that swine fed opaque and normal corn rations both supplemented with soybean meal and fed free choice consumed less supplement and more opaque when compared to the normal corn ration. Increased consumption of the opaque corn may be the result of better palatibility due to the softer texture of the kernel and the better over-all balance of available amino acids. Abernathy et al. (1958) suggest that decreased consumption of feed may be due to the build-up of plasma amino acids caused by a limiting amino acid deficiency, thus declining the need for protein and resultant feed intake depression.

Opaque-2 corn with its higher glutelin and lower zein contents may not be of any real advantage to the ruminant since their rumen microbes synthesize the essential amino acids. It is rather the rate at which the dietary protein constituent is proteolyzed and the N released thus available for microbial utilization that lends its advantages to the ruminant.

However, McDonald (1954) and Ely et al. (1967) have concluded that 40 to 60% of the zein consumed is digested postruminally since it is not readily susceptible to proteolytic breakdown.

Research by Beeson, Thomas, Perry and Mohler at Purdue University during 1971, 1972 and 1973 has shown that opaque-2 is not superior to normal corn in regards to feeding power in beef cattle. Heifers, on their feeding trials, had equivalent daily gains when opaque-2 was tested against a normal corn hybrid. The feed efficiency of those heifers fed opaque-2 was improved by 8%. Beeson et al. (1973) showed data from steers fed opaque-2 that consumed less feed, gained more slowly and had poorer feed efficiencies when contrasted to a normal hybrid corn ration.

Nelson et al. (1971) found that in their trial with steer calves comparing opaque-2 shelled corn with regular shelled corn, the steers on opaque-2 produced significantly ($P<.01$) more efficient gains. However, there was no apparent differences in rate of gain.

Crossbred steer calves utilized by Goodrich and coworkers (1970) tested the performance of both high lysine and regular corn silages. The feedlot data showed that the rate of gain was similar for both silages although opaque-2 tended to depress gain. Feed/100 kg gain was slightly less for steers fed opaque-2. Goodrich et al. (1970) also pointed out that cattle fed the normal silage ration tended to eat slightly more feed per day.

Two recent studies by Beeson et al. (1974) and Goodrich and Meiske (1974) found no difference in the nutritional values of opaque-2 and normal corn for beef cattle. In both trials cattle tended to eat less opaque-2, most likely because of the powdery consistency obtained when rolled.

As noted earlier, in ruminants, the value of a ration, in regards to protein value, can be measured by the availability of N to the microbes for microbial protein synthesis.

Waxy Corn

This hybrid, because of its resemblance to a hard wax both in texture and physical appearance, was suggested by Collins (1909) to be designated cereous or waxy endosperm. It was initially developed by the Chinese and brought to the United States to replace imported tapioca starch when tapioca supplies were reduced due to Japanese invasion of Pacific countries at the outbreak of World War II. These starches mobilized from the waxy corn were utilized not for livestock feed but rather for adhesives, gum, paper and puddings. It was not until an excess of waxy cereals became prevalent did researchers theorize its possibilities for livestock consumption.

Genetically, the waxy trait is the consequence of a recessive gene which controls the percentage and type of starch, either amylose or amylopectin, in the endosperm.

Differences in the percent and type of starch found in waxy corn gives it a unique distinction over the conventional yellow dent type. Amylose accounts for 25% of yellow dent endosperm and the remaining 75% is amylopectin. Waxy corn is comprised of approximately 100% amylopectin. Amylose is a straight chained molecule that is smaller than amylopectin which is branched and wavy (McDonald, 1973). Amylopectin has 40 times as many glucose units. On chemical analysis, waxy corn was similar in protein and amino acids present, but slightly higher in oil, sugar and weight per volume.

Although McDonald (1973) stated that the corns were similar in protein, he also implied that further research need be undertaken concerning protein differences. Higher crude protein values for waxy corn were obtained by Braman et al. (1973) and Hanson (1946).

Boundy et al. (1967) showed waxy corn to have almost two percent less protein. Braman and coworkers (1973) declared that their data portrayed increased protein due to the alcohol soluble protein zein. The higher zein content was also reflected in the amino acid composition of waxy corn. There is an elevation of leucine, glutamic acid, proline and alanine and a decline in lysine as compared to regular dent corn. Boundy et al. (1967) indicated lower zein contents and thus lower glutamic acid, proline, alanine and leucine levels. However, in the literature reviewed, Boundy and workers are the only indicators of a decreased zein level in waxy corn. The evidence seems to point toward increased zein levels in waxy corn even though the protein is not very high in quality.

More research to determine actual protein composition, i.e. amino acids, is required before any deductions can be made as to whether protein content or starch type affects average daily gain and feed to gain ratios.

In a feeding trial with rats, Robinson et al. (1974) compared waxy and regular corn in respect to average daily gain and feed to gain ratio. The waxy diet boosted ADG by 8% and gain/feed by approximately 13%. This ration contained 15% protein. If the percent protein were raised to 25%, the dent corn was superior in ADG by almost 20% and a mere 2% in feed efficiency. This would suggest that there was a protein threshold where upon once reached, waxy corn metabolism becomes inferior to that of dent in rats.

Data from research by Braman et al. (1973) indicate that feeding lambs waxy corn increases ADG ($P<.01$), gain/feed ($P<.01$) and plasma urea-nitrogen concentration ($P<.01$) when compared to dent corn. Coupled with these increases were decreases in fecal N ($P<.01$) and retention of absorbed N ($P<.01$) although corn type had no effect on nitrogen intake retained. Apparent N digestibilities in waxy corn were higher ($P<.10$) even though dry matter digestibilities were not significantly different between the two corns. This elevated nitrogen digestibility was reflected in the decreased fecal nitrogen losses ($P<.10$). However, the apparent N digestibilities were also associated with significant ($P<.01$) increases of urinary nitrogen excretion. Consequently, retention of absorbed nitrogen was higher ($P<.10$) with a yellow dent corn diet.

In a similar experiment also conducted by Braman, Hatfield, Owens and Rincker (1973), lambs were fed waxy or dent corn supplemented with soybean meal or urea. Of these two diets, regular corn supplemented with urea caused urinary nitrogen excretion to increase markedly ($P<.01$). McDonald (1954), as a result of experimentation, proposed that waxy corn, with a higher zein level, would be somewhat more resistant to proteolytic enzyme attack in the rumen. Consequently, less ruminal ammonia would be produced. Braman, in his Ph.D. thesis, stated that lambs on a waxy corn diet had a more active rumen fermentation. This fact would increase nitrogen requirements of the microflora and a supplement such as urea should be added to the ration. This addition of NPN would intensify microbial protein synthesis and as a final result increase body tissue growth and maintenance. An improved quantity of amino acids from microbial sources would enhance retention of nitrogen and thus amino acid breakdown and excretion of urea-nitrogen would decline (Braman, 1973). Braman theorizes that the significant differences in average daily gain and feed efficiency ($P<.05$) in those lambs fed waxy corn were due to increased microbial end products, i.e. amino acids, protein, cells and the resulting energy retenion.

A nitrogen balance trial with 20 lambs by Robinson et al. (1974) failed to depict any significant differences when the animals were on a 16% protein diet.

Mussehl et al. (1944) discovered that waxy corn was equivalent to yellow dent or slightly superior, although not significant, in its usage in poultry diets. Work done by Kent Feeds Research Farms in 1973 with laying hens showed a 5% decline in egg production when fed a 16% soybean meal, waxy corn ration.

Hanson _et_ _al_. in 1946 conducted the first swine trials comparing regular corn to waxy known to this author. A cereal named Nebraska waxy was utilized in the experiment which was comprised of 88 pigs. The corn was a hybrid, a cross of the original strain brought from Asia with two standard varieties of regular corn. Hanson's research showed no significant differences in gain or feed efficiencies. In one trial however, the pigs were given a choice of feed; either waxy or regular corn. They consumed 2.6 times as much non-waxy corn than waxy. Nevertheless, the trial deductions were not altered. The reason for the differences in type of corn consumed was not known.

Trials conducted at the University of Nebraska (1973) and the University of Kentucky (1973) showed no significant divergencies in swine trials when fed waxy corn.

According to McDonald (1973), Kent Feeds of Iowa did show an improvement in average daily gain and feed efficiency. Pigs fed waxy corn gained 2.1% faster and their efficiency was 4.0% better than their regular corn counterparts. The feed efficiency difference occurred during the last 77 days which could infer that the growing and finishing phases had dissimilar effects.

The earliest published beef cattle trials with waxy corn were conducted by Braman _et_ _al_. in 1973. Waxy corn supplemented with soybean meal was superior ($P<.05$) to other non-waxy corn diets. There was no difference in feed efficiencies, although feed consumption tended to be higher with a waxy diet supplemented with soybean meal. Carcass data were similar among treatments.

Robinson, Hatfield and Hixon (1974) conducted a feedlot trial with 180 yearling Holstein steers. They found no significant dissimilarities either in corn type effects or level of protein. Similar trials with 124 heifer calves were performed without differences.

Braman et al. in 1973, conducted a trial with steers supplementing the corns with soybean meal or a soybean meal-urea mixture. Reports contrary to his trials with sheep were obtained. Steers fed soybean meal had greater gains and a little improvement in feed efficiencies. Urea-soybean supplements seemed to have a detrimental effect on gain and feed ratios. Braman gives two reasons for the reverse data between lambs and steers. First, feed intake was restricted in the sheep trials but the steers were fed ad libitum. There could possibly be a palatability problem concerning the urea with the steer trial, thus accounting for the depressed results. Secondly, the degree of nitrogen digested and recycled to the rumen may differ from animal to animal.

Other beef cattle trials were performed by Kent Feeds of Iowa, under the auspices of McDonald et al. (1973). His results depicted a 10% increase in average daily gain and a 9.5% positive response in feed efficiency when the beef cattle were on a waxy corn diet. These responses were highly significant ($P<.025$). In this experiment, NPN was added and the ration fed <u>ad libitum</u>. However, the above results should not be termed conclusive, since another trial utilizing a different corn crop showed only a .4% increase in average daily gain and a 4.7% increase in feed efficiency. Both increases were not significant. McDonald offers no reason for this turn about in statistical data, regardless of the fact that both formulated rations were identical as to percent protein, type of protein supplement employed and the ratio of corn to supplement fed. This author can only theorize that the waxy corn itself differed from trial to trial in protein and starch content.

Both of McDonald's trials (1973) showed a slight decline in the daily feed intake of the waxy diet compared to the dent. No differences were observed in carcass characteristics.

Kent Feeds also reported that waxy corn increased nitrogen balance and nitrogen retention by 18 and 17% respectively. These figures may be disputed however since the waxy corn used was a mixture of genetic and environmental backgrounds. McDonald did not go into any further detail concerning these data.

MATERIALS AND METHODS

In this study, three experiments were performed: a feeding trial with steers, a feeding trial with swine and a metabolic trial concerning nitrogen retention and energy utilization in swine.

EXPERIMENT I - Steer Feeding Trial

A - Design

A 3x3 factorial design was employed to compare average daily gains and feed per pound gain ratios with different combinations of sixty percent silage and forty percent high moisture, rolled corn rations on a dry matter basis. The experimental design is portrayed by Table 1.

B - Silage Harvest

All corns utilized for silage were planted between May 18, 1973 and May 21, 1973. The three corns, sowed from three lots of six, fifty pound bags, had the following pedigrees: opaque, A61902 x A63202; yellow dent, A619 x A632 and waxy, WX 43619 x A632. Each lot was well isolated from any other lot to prevent contamination by cross-pollination.

TABLE 1

EXPERIMENTAL DESIGN

40% SHELLED CORN	60% CORN SILAGE					
	YELLOW DENT		OPAQUE-2		WAXY	
Yellow Dent	1	A.D.G.[a] ______ A.W.[b] ______ D.M.[c] ______	4	A.D.G. ______ A.W. ______ D.M. ______	7	A.D.G. ______ A.W. ______ D.M. ______
Opaque-2	2	A.D.G. ______ A.W. ______ D.M. ______	5	A.D.G. ______ A.W. ______ D.M. ______	8	A.D.G. ______ A.W. ______ D.M. ______
Waxy	3	A.D.G. ______ A.W. ______ D.M. ______	6	A.D.G. ______ A.W. ______ D.M. ______	9	A.D.G. ______ A.W. ______ D.M. ______

a) average daily gain for that lot
b) average weight after period ends
c) dry matter consumed per day for period

All silage corn was harvested between September 6, 1973 and September 10, 1973. Dry matter percentages, acres harvested and yields are reported in Table 2.

In this trial the silage was treated with ammonia mineral suspension (Pro-Sil[R]) thus alleviating the necessity of a protein supplement. The ammonia mineral suspension (AMS) was applied at the rate of approximately 1.0 kilogram of AMS to 49.0 kilograms silage. This treatment resulted in the elevation of the silage protein level from 8% to about 13% on a dry matter basis. After treatment, the silages were stored in three metal roofed, concrete silos which were approximately twelve feet in diameter and fifty feet tall.

C - Shelled Corn Harvest

All shelled corn utilized was planted between May 18, 1973 and May 21, 1973. Identical pedigrees, as those used for silage, were employed and obtained from Moews Feed Company, Illinois. Isolation procedures were again enforced to alleviate contamination.

The shelled corn was harvested between November 2, 1973 and November 16, 1973. Dry matter was measured and the percent moisture was found too high for storage. (Dry matter figures, acres corn planted and yields are in Table 3). In order to store the high moisture shelled corn, a volatile fatty acid compound was applied. This commercial product called "ChemStor[R]" (Celanese Corporation) was applied

TABLE 2

DRY MATTER % AND YIELDS
OF CORN SILAGES

Type	Hectares	% Dry Matter	Yield @ 30% DM [1]
Yellow Dent	2.833	38.48	17.22
Opaque-2	2.525	38.78	16.39
Waxy	2.538	34.05	16.59

[1] metric tons per hectare

TABLE 3

DRY MATTER % AND YIELDS
OF SHELLED CORNS

Type	Hectares	% Dry Matter	Yield @ 85% DM[1]
Yellow Dent	6.730	72.0[2]	2.638
Opaque-2	6.961	72.0[2]	2.476
Waxy	6.212	72.0[2]	2.484

[1] metric tons per hectare

[2] dry matter figures are an average of all corns

at the rate of 1.5% of the corn weight. As a simplified example, 1000 kg of corn would require 15.0 kg of Chem-Stor^{R}. The Chem-Stor^{R} was a mixture of acetic and propionic acids in a ratio of 60:40, respectively. The acid treated corn was stored in three plywood alley bins, each 6'x64'x4' and lined with plastic to prevent contamination and moisture seepage from outside sources.

D - Feeding Trial

Seventy-two Charolais-Hereford crossbred steers averaging 235 kg (518 lbs) were used in this feeding trial. They were weighed on two consecutive days and the average used for the initial weight. Final weights were determined in the same manner. They were blocked for this experiment from a larger herd based on their first day weight and randomly assigned to treatments after their second day weight. The result of the lotting was nine lots, each with eight steers. The cattle were placed on experiment on November 9, 1973. During the course of the trial all cattle were fed *ad libitum* once daily and water was always available (see Table A - 1, Appendix, for actual feeding values).

Since this experiment measured only the growing phase of the cattle, this trial was terminated after 159 days. The cattle were fed regular corn and silage supplemented with urea daily until slaughter weight was reached. Carcass data were not obtained.

E - Collection of Feed Samples for Analysis

All silages and acid-treated corns were randomly collected at several depths from each corn type storage facility and a composite made for each corn type. Corn samples were ground through a mesh screen with 2 mm diameter openings in a Wiley Mill[1] prior to all chemical analysis with the exception of obtaining percent dry matter.

F - Dry Matter Percent

All corn types were tested biweekly for percent dry matter by recording initial wet weight and then the samples were placed in an oven at 100°C for 24 hours. Upon complete drying, weights were recorded as percent of wet sample.

G - Crude Protein and N Levels

All treatments were tested biweekly for percent protein and N levels by the semi-micro Kjeldahl method using the Aminco system with a Sargent Spectro-Electro titrator. A 10% copper sulfate solution was used as catalyst.

H - pH Determination of Feeds

About 25 grams of each feed treatment was placed in a homogenizer flask and 100 ml of distilled water were added. The mixture was then homogenized for two minutes on a

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[1]Thomas-Wiley Mill, Arthur Thomas Co., Philadelphia, Pa.

Sorvall onimixer and the pH was then taken upon cessation of homogenization. The pH was recorded every other week.

I - Volatile Fatty Acid Determination of Silages

The homogenized mixture obtained when the pH was recorded was then centrifuged at 15,000 RPMs for 15 minutes and the supernatant saved. Each sample was injected into a Packard gas chromatograph and VFA contents recorded from the resulting graph.

J - Lactic Acid Analysis

Lactic acid levels were determined by the methods of Barker and Summerson (1941).

K - Amino Acid Analysis of Shelled Corn

From the protein levels determined by the Kjeldahl method, a sample of each corn variety containing about 10 mg protein was utilized for amino acid determinations. The 10 mg protein sample was placed in a hydrolysis tube with norleucine and 5-B-4-pyridylethyl-L-cysteine which acts as an internal standard. After having been placed on vacuum, the samples were autoclaved at 121°C for 16 hours to hydrolyze the protein. The sample was then filtered through No. 2 Whatman paper and HCl removed by evaporation. The residue was then washed twice with about 10.0 ml distilled water and resuspended in a citrate buffer of pH2 to 4.0 ml. The amino acids in the buffer solution were then applied to a TSM-1 amino acid analyzer[1] as described by Bergen *et al.* (1971).

L - Statistical Analyses

All data from the feeding trial was subject to the least squares analysis on the CDC 6500 computer at the Michigan State University Computer Center.

EXPERIMENT II - Swine Feeding Trial

A - Design

Thirty-six pigs were used in this portion of the trial. The purpose was to compare average daily gain and feed/gain ratios. It should be noted, however, that three pigs were removed from the trial shortly after the start due to illness not connected with the experiment.

B - Corn Harvest: Rations

The corns used were from the alley bins described in Experiment I. However, since all three corn varieties previously used were high moisture in nature, a fourth corn, artifically dried yellow dent, was added as a control. This was done in order to test for a significant difference due to the acid treatment of the corn in respect to average

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[1] Technicon Corp., Tarrytown, N.Y.

daily gain and feed efficiency. All feeds were ground shelled corn, fortified with soybean meal and adequate vitamins and minerals. Since both growing and finishing phases were studied, two diets with different protein levels were formulated; one for each phase (shown in Tables 4 and 5). The grower diet was about 16% protein and the finisher about 13% protein. All rations were formulated on a corn, dry matter basis.

C - Feeding Trial

Weanling pigs, averaging 17.8 kilograms in initial weight, were lotted into four pens. The first lot had seven pigs; the second and fourth lots had nine and the third lot eight. The pens were totally isolated from any outside environment factors and had aluminum slotted floors.

The pigs were allowed to adjust to the feed for several days before initial weights were taken and then the swine were placed on trial. The experiment commenced March 22, 1974. Feed and water were available *ad libitum*.

Each pig was individually weighed, biweekly, until slaughter weight was reached. At approximately 55 kilograms the ration was switched from the grower to finisher ration (see Tables 4 and 5). There was a shift from a 16% protein diet to a 13% diet and an increase in carbohydrate content.

On July 8, 1974 the pigs were sent to slaughter and carcass data collected.

TABLE 4

GROWER PHASE: 16% PROTEIN RATION

Ingredient	Corn DM%	Lot 1	Lot 2	Lot 3	Lot 4
Dry Dent Corn	87.0	788[2]	---	---	---
Dent H.M.[1] Corn	79.0	---	868[2]	---	---
Opaque H.M. Corn	79.0	---	---	868[2]	---
Waxy H.M. Corn	76.0	---	---	---	900[2]
Soybean Meal 49		180	180	180	180
Defluorinated P		10	10	10	10
Ground Limestone		7.5	7.5	7.5	7.5
Salt		5.0	5.0	5.0	5.0
M.S.U. Vit. Premix		5.0	5.0	5.0	5.0
Vit. E Premix		2.5	2.5	2.5	2.5
Antibiotic (aureomycin-10)		2.0	2.0	2.0	2.0

[1] denotes high moisture corns
[2] figures in kilograms

TABLE 5

FINISHER PHASE: 13% PROTEIN RATION

Ingredient	Corn DM%	Lot 1	Lot 2	Lot 3	Lot 4
Dry Dent Corn	87.0	854[2]	---	---	---
Dent H.M.[1] Corn	79.0	---	942	---	---
Opaque H.M. Corn	79.0	---	---	942	---
Waxy H.M. Corn	76.0	---	---	---	980
Soybean Meal 49		115	115	115	115
Defluorinated P		10	10	10	10
Ground Limestone		7.5	7.5	7.5	7.5
Salt		5.0	5.0	5.0	5.0
M.S.U. Vit. Premix		5.0	5.0	5.0	5.0
Vit. E Premix		2.5	2.5	2.5	2.5
Antibiotic (aureomycin)		1.0	1.0	1.0	1.0

[1] denotes high moisture corns
[2] figures in kilograms

D - Collection of Feed Samples for Analysis

Samples were taken randomly from each lot feeder and analyzed for crude protein, N content and gross energy values.

E - Protein and N Determination

Crude protein and percent N were determined by the semi-micro Kjeldahl method using the Aminco system with a Sargent Spectro-Electro titrator.

F - Gross Energy of Feed

Gross energy values for each ration were obtained by utilizing the Parr[1] Adiabatic Oxygen Bomb Calorimeter method.

G - Slaughter Procedure

Upon reaching a market weight of about 90 kg, the swine were slaughtered and dressing percentages and percent ham and loin obtained.

H - Statistical Analyses

Data from this trial were subject to one-way analysis of variance with missing data. All computer analyses were performed at the Michigan State University Computer Center on a CDC 6500 series computer.

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[1]Parr Instrument Co., Moline, Illinois

EXPERIMENT III - Swine Metabolic Trial

A - Design

Eight pigs averaging 24.7 kg were randomly divided into two lots and placed in metabolic cages. Each cage was seven feet long and five feet wide and elevated about four feet. All cages had wire mesh floors suitable for excretion collection. The purpose of the trial was to determine the nitrogen and energy balances in respect to each feed.

B - Rations

All feed utilized was from the grower phase of Experiment II (Table 4).

C - Feeding

All feed treatments were *ad libitum* fed to both lots on an individual trial basis, thus attempting to alleviate any unnecessary error due to pig type. Before going onto experiment, each lot was adjusted to each particular feed for about three days. By doing this all feed from previous feedings of different sources had been excreted and would not confound feed effects. Each feed was on trial in each pen for three days or a total of six days in both pens. Feed was available *ad lib*. and water was always present when desired.

D - Collection of Samples

Urine samples were collected daily from each lot on three consecutive days. All urine weights were recorded. Each day a subsample was removed and securely sealed and stored until analyses were performed.

Daily fecal samples were collected, weighed and subsamples obtained for analysis. The daily fecal samples for each pen trial were composited after the three day trial in order to have a complete overall sample for analysis for each feed. This composite was weighed and then oven dried at 100°C for 24 hours and dry matters obtained. The dried feces were then ground twice through a 2 mm diameter screen in a Wiley Mill.

E - Percent Protein and N Determinations

All urine and fecal samples were tested for N and protein contents by the standard semimicro Aminco Kjeldahl method using a Sargeant Spectro-Electro titrator.

F - Gross Energy Determinations

Urine and fecal energies were determined by the Parr Adiabatic Oxygen Bomb Calorimetric method.

G - Statistical Analyses

Upon obtaining the data from the N balance study and gross energy determinations of the feed, urine and feces, treatment differences in regards to percent digestible energy, percent metabolizable energy, percent absorbed N and percent N retention were determined by the multiple range test of Duncan (1955). These analyses were performed on a Hewlett-Packard[1], model 9100A calculator.

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[1] Hewlett-Packard, Loveland, Colorado

RESULTS AND DISCUSSION

EXPERIMENT I - Steer Feeding Trial

The cattle performance data are presented in Tables 6 - 8. The three corn silages, yellow dent, opaque-2 and waxy, had been treated with an ammonia mineral suspension mixture so that all rations were based on the yellow dent corn's treated 13% protein level on a dry matter basis. Any superiority of the opaque-2 or waxy corn would be evident quantitatively in any protein percent over the 13 percent level of the dent corn.

All lots of cattle were fed a mixture of 40% rolled shelled corn and 60% corn silage on a dry matter basis. As shown previously (Table 1), the experimental design provided that each type of shelled corn was fed with each variety of corn silage.

Average daily gain (Table 6) differences were not significant. The opaque-2 silage did depress average daily gains by as much as 20% in the first 28 days of the experiment to an overall average of 4.3% depression when compared to the dent corn. Conversely, the waxy corn silage consistently increased average daily gain by 1.3% when compared to dent corn. Similar results held true for the shelled corn types.

TABLE 6

AVERAGE DAILY GAIN, KG

Type of Shelled corn	Type of corn silage Dent	Opaque-2	Waxy	Mean
Dent	1.08	.98	1.08	1.05
Opaque-2	1.04	.99	1.02	1.02
Waxy	1.03	1.04	1.09	1.06
Mean	1.05	1.01	1.07	1.03

a) each lot had 8 steer calves
b) initial and final weights were 235 and 400 kg respectively
c) no significant differences or interactions

Opaque-2 depressed ADG by 2.6% and waxy shelled corn increased average daily gain by about .9% when compared to the dent shelled corn.

In a comparison of cattle fed opaque-2 silage - opaque-2 shelled corn, yellow dent silage - yellow dent shelled corn or waxy corn silage - waxy shelled corn, the contrasts were more pronounced. The opaque-2 - opaque-2 ration reduced ADG by 8% when compared to the dent - dent ration while the waxy - waxy group increased ADG by 1.3% over the dent - dent cattle group and a 9.2% improvement when compared to the opaque-2 silage and corn mixture.

Feed efficiency differences were evident, but not significantly different. The values are shown in Table 7. Again, the pattern established in the ADG performance data for straight corn type rations was similar in feed efficiency results. Opaque-2 silage - opaque-2 corn increased the feed needed per pound gained by 4.2% when compared to the straight dent type feed mixture and 5.3% when contrasted to the waxy - waxy ration. However, when shelled corn type was contrasted, opaque-2 improved feed efficiency over dent corn by 1.3% although still decreased by .4% when compared to waxy shelled corn rations. When rations of corn silage type comparisons were made opaque-2 decreased feed efficiency by 4.5% and 6.3% when contrasted to dent silage and waxy silage, respectively.

Average daily dry matter consumption data show that all the types of rations were similar except that the opaque

TABLE 7

DRY MATTER (KG) CONSUMED PER KG GAIN

Type of Shelled corn	Type of corn silage Dent	Opaque-2	Waxy	Mean
Dent	6.15	6.76	5.93	6.28
Opaque-2	6.04	6.42	6.13	6.20
Waxy	6.28	6.18	6.08	6.18
Mean	6.16	6.45	6.05	6.22

a) each lot had 8 steer calves
b) initial and final weights were 235 and 400 kg respectively

shelled corn tended to depress intake by about 4.0 percent (see Table 8).

The three shelled corn and silage types were analyzed biweekly for dry matter, nitrogen contents, lactic acid, percent protein and pH. (These results are shown in Table A - 2, Appendix). The results for the volatile fatty acid contents of the silages are also shown in the Appendix (Table A - 2).

In regards to the protein content of the silages, the dent corn was about 1% less than the desired 13% level. However, since all the silages were treated with the same ammonia mineral suspension flow, this should not be of any concern.

The shelled corn differed by only .6% protein across all three types on a dry matter basis. The actual amino acid content of each shelled corn type on a dry matter basis is presented in Table 9.

The data from this trial is in agreement with the work of Beeson *et al*. (1971-1974), Nelson *et al*. (1971), Goodrich and co-workers (1970) and Goodrich and Meiske (1974). They showed no differences in the rate of gain between opaque-2 corn and regular corn and all the aforementioned authors except Nelson (1971) reported no differences in efficiency data. Nelson *et al*. (1971) showed opaque-2 corn to improve feed efficiency ($P<.01$) when compared to yellow dent. Waxy corn in comparison to dent corn showed no significant improvement in ADG or feed efficiency according to Robinson *et al*.

TABLE 8

AVERAGE DAILY D.M. CONSUMPTION (KG)

Type of Shelled corn	Type of corn silage Dent	Opaque-2	Waxy	Mean
Dent	6.63	6.62	6.44	6.57
Opaque-2	6.30	6.38	6.25	6.31
Waxy	6.47	6.45	6.64	6.52
Mean	6.47	6.49	6.44	6.47

a) each lot had 8 steer calves
b) initial and final weights were 235 and 400 kg respectively

(1974), McDonald (1973) and Perry _et al_. (1974). The only report known to this author comparing all three corn types was that of Beeson and coworkers (1974). This trial showed "no significant or practical difference in the nutritional value of regular hybrid corn, opaque-2 corn or waxy corn for finishing steers." The data from this trial are in accordance with this statement.

Upon analysis of the percent of amino acids in the crude protein of each shelled corn (Table 9), the values coincide with those obtained by Mertz _et al_. (1964), Klein and coworkers (1972) and Cromwell, Pickett and Beeson (1967). There is a definite increase in lysine in the 0-2 as compared to the regular corn variety with slight increases in histidine, arginine, aspartic acid, threonine, glycine, valine and cystine. This is in accordance with Mertz (1964). Higher levels of serine and proline were also obtained in the 0-2 corn in this trial. Decreased levels of glutamic acid, alanine, methionine, leucine, isoleucine, tyrosine and phenylalanine were also found in the 0-2 corn.

Waxy corn was quite similar to regular corn in amino acid percent patterns. This supports data from McDonald (1973). Although not greatly different, elevations in leucine, glutamic acid, proline and alanine were observed probably due to increased zein as compared to regular corn varieties (Bramen _et al_., 1973).

In a comparison of opaque-2 corn with waxy corn, lysine, histidine, arginine, aspartic acid, threonine, serine and

TABLE 9

AMINO ACID PERCENT OF PROTEIN IN H.M. SHELLED CORN

Amino Acids[1,2]	Dent	Opaque-2	Waxy
Lysine	2.762	3.917	2.661
Histidine	2.910	3.171	2.871
Arginine	4.941	6.397	4.950
Aspartic	7.058	8.277	5.977
Threonine	3.459	4.239	3.555
Serine	4.754	5.021	4.833
Glutamic	18.780	17.180	19.439
Proline	9.163	9.337	9.447
Glycine	3.403	4.899	3.843
Alanine	7.992	5.771	8.037
Cystine	.911	.946	.895
Valine	5.399	5.467	5.429
Methionine	2.092	1.680	1.733
Isoleucine	4.200	3.877	4.038
Leucine	13.478	10.517	13.762
Tyrosine	2.936	2.887	3.031
Phenylalanine	5.712	4.993	5.492
Crude Protein[3]	10.360	11.000	10.950

[1] All amino acids based on a standard of .025 μmoles except cystine which was .0125 μmoles

[2] Tryptophan was not determined

[3] Dry matter basis

glycine were higher. Observed decreases were glutamic acid, alanine, isoleucine, leucine and phenylalanine.

EXPERIMENT II - Swine Feeding Trial

The superiority of opaque-2 corn over dent corn in swine performance has been established (Beeson et al., 1966; Pickett, 1966; Cromwell, 1967; Wahlstrom et al., 1973 and Gipp and Cline, 1972). The swine performance, however, is dependent on the increased availability of amino acids.

Waxy corn also has higher protein levels than normal corn probably as a result of higher zein levels (Hanson, 1946 and Braman, 1973). Zein, however, is mostly bypassed to the lower gut where some hydrolysis and absorption takes place (McDonald, 1954). It is then the extent of the zein proteolysis that would decide as to whether waxy corn would have any nutritional superiority over normal or opaque-2 corns.

In this trial, the results (Table 10) are different than that of Beeson et al. (1966), Pickett (1966), Cromwell (1967), Wahlstrom et al. (1973) and Gipp and Cline (1972). Opaque-2 corn did not show any significant advantages in ADG or feed efficiencies when compared to either dent or waxy corn. However, the data representing the waxy corn trial did substantiate earlier reports by Hanson (1946) and McDonald (1973) that waxy corn did not significantly increase average daily gains or improve feed efficiencies.

TABLE 10

PERFORMANCE DATA OF PIGS ON DRY DENT, H.M. DENT, H.M. O-2 OR H.M. WAXY CORNS[1]

Item	Dry Dent	H.M. Dent	H.M. O-2	H.M. Waxy	± SE[2]
Initial wt.	17.2	18.4	17.4	18.0	1.03
56 day wt.	53.3	56.8	57.1	54.7	2.80
Final wt.	93.5	95.6	95.4	92.3	3.98
0 - 56 day ADG	.63	.72	.83[a]	.67	.06
0 - 105 day ADG	.72	.73	.74	.71	.03
Daily feed[3]	1.98	2.29	2.18	2.38	---
Feed/gain	2.75	3.09	2.95	3.35	---

[a] significantly greater than the least value in that row (P<.025)
[1] all weights in kilograms
[2] standard error of the mean
[3] feed values on a dry corn basis

The 0-2 corn tended to increase average daily gain during the separate weigh periods, and in the overall feeding trial increased ADG by 1.2%, 2.2% and 4.8% when compared to high moisture dent, artificially dried dent corn and H.M. waxy corn, respectively. Feed efficiency of the H.M. opaque-2 ration was superior to either H.M. dent corn or H.M. waxy by 4.6% and 11.9%, respectively. However, the artificially dried dent corn was superior to 0-2 in feed efficiency by 6.8%. This would suggest that acid-treated H.M. corn could depress feed efficiency when compared to a ration of artificially dried origin in swine, however, these differences could not be designated significant.

In regards to the daily feed consumed on a dry matter basis, the swine on the dry dent corn ate at least 9% less feed than swine on the other corns. There may be two reasons for this result. Abernathy _et al_. (1958) suggested that swine may eat less feed due to a build-up of plasma amino acids as a result of a deficiency in the limiting amino acid or acids. A second reason could be attributed to the physical texture of the dry dent corn as compared to the high moisture corns. This would be the more likely reason as the dry corn had better feed/gain ratios.

It should be noted that feed efficiency data could not be statistically analyzed since each lot was group fed and feed consumed could only be averaged in regards to each individual pig.

The percentage of each amino acid in both the grower and finisher rations are shown in Tables 11 and 12. These amino acid percentages may be compared to the National Research Council's (1973) recommended amino acid levels. In the grower ration, all essential amino acid levels designated with a minimum requirement by the N.R.C. for swine, are met by all rations with the exception of the combined percentages of methionine and cystine. The methionine-cystine level is not met by any of the four rations, but all four rations, dry dent, H.M. waxy, H.M. dent and H.M. opaque-2, are similar in methionine and cystine content. Baker (1973) has shown that the total sulfur amino acid requirement of the growing pig is only 0.40% and thus all rations meet this requirement. The lysine level in the H.M. opaque-2 grower ration is at least 10% higher than in the other rations. This could account for the significant ($P<.025$) increase in average daily gain during the early weeks of this trial when compared to the dry dent corn and the tendency for H.M. 0-2 to have higher ADG when compared to H.M. waxy and H.M. dent diets.

In the finisher rations (Table 12), lysine levels for the dry dent corn fall below the recommended requirements. This could possibly explain the performance of these pigs on the opaque-2 ration and lower average daily gains in the finisher phase when compared to the opaque-2 ADG in the grower phase. The lysine level of the opaque-2 ration is

TABLE 11

COMPARISON OF GROWER RATION AMINO ACID PERCENTAGES TO RECOMMENDED PERCENTAGES[1]

Amino Acids	D.D.[2]	H.M.D.[3]	H.M.O-2[4]	H.M.W.[5]	N.R.C.[6]
Arginine	1.04	1.04	1.17	1.05	.20
Histidine	.36	.42	.45	.43	.18
Isoleucine	.82	.77	.76	.77	.50
Leucine	1.46	1.64	1.48	1.71	.60
Lysine	.72	.77	.87	.78	.70
Met.& Cys.	.42	.49	.48	.47	.50
Phe.& Tyr.	1.20	1.46	1.44	1.49	.50
Threonine	.64	.60	.68	.62	.45
Valine	.77	.86	.90	.89	.50

[1] Percent of diet on a dry corn basis
[2] Dry dent
[3] High moisture dent
[4] High moisture opaque-2
[5] High moisture waxy
[6] National Research Council, Nutrient Requirements of Swine, National Academy of Sciences

TABLE 12

COMPARISON OF FINISHER RATION AMINO ACID PERCENTAGES TO RECOMMENDED PERCENTAGES [1]

Amino Acids	D.D.[2]	H.M.D.[3]	H.M.O-2[4]	H.M.W.[5]	N.R.C.[6]
Arginine	.82	.82	.96	.84	.16
Histidine	.29	.32	.33	.34	.15
Isoleucine	.64	.62	.62	.63	.41
Leucine	1.28	1.48	1.29	1.57	.48
Lysine	.52	.58	.69	.59	.57
Met.& Cys.	.33	.40	.39	.39	.41
Phe. & Tyr.	.93	1.21	1.19	1.24	.41
Threonine	.54	.50	.58	.52	.37
Valine	.62	.73	.76	.75	.41

[1] Percent of diet on a dry corn basis
[2] Dry dent
[3] High moisture dent
[4] High moisture opaque-2
[5] High moisture waxy
[6] National Research Council, Nutrient Requirements of Swine, National Academy of Sciences

TABLE 13

CARCASS DATA

Item	Dry Dent	H.M. Dent	H.M. O-2	H.M. Waxy	± SE[1]
% Dress	73.2	71.8	74.5	73.1	1.15
% Ham & Loin	42.1	40.8	40.9	39.6	1.14

[1] standard error of the mean

still above the recommended minimum, but perhaps the decline in average daily gain could convey that the recommended levels stated by the N.R.C. (1973) were too low for maximum performance in the finisher phase.

No significant carcass data differences were obtained upon slaughter (Table 13). This was the general case with all research reports reviewed.

EXPERIMENT III - Balance Trial

Feeds used for the balance trial were from the grower phase of Experiment II and therefore had identical amino acid levels and protein percentages. No significant differences were obtained concerning the nitrogen balance, dry matter balance or energy balance studies (see Table 14).

In the dry matter study there seems to be a similarity among the dry dent, H.M. 0-2 and H.M. dent corns. The waxy corn consumption seems depressed possibly as a result of its flaky texture. Apparent dry matter digestibilities are not dissimilar.

In the energy trial, digestible energy percents do not differ significantly nor do the metabolizable energy percentages.

This trial would seem to portray that of the corns used, no one corn ration was significantly superior to any other in the nitrogen, dry matter or energy balance studies.

TABLE 14

SUMMARY OF BALANCE STUDY

Item	Dry Dent	H.M. Dent	H.M. Opaque-2	H.M. Waxy	±SE[1]
N balance[2,3]					
N intake, g	42.70	35.76	37.67	39.43	5.43
Fecal N, g	7.29	5.84	6.44	5.90	1.10
Absorbed N, %	82.78	83.67	82.90	85.04	1.59
Urinary N, g	8.31	5.54	8.84	6.67	1.46
N retention, g	27.10	24.38	22.39	26.86	3.58
N retention, %	64.46	68.24	59.11	68.52	3.26
Biological Value App.	76.50	81.60	71.70	80.10	----
Dry matter balance[2,4]					
D.M. intake, g	1566	1072	1237	997	----
Fecal D.M., g	299	168	201	166	----
Fecal D.M., %	32	27	28	30	----
D.M. app. dig., %	68.0	73.0	72.0	70.0	----
Energy balance[2,4]					
Energy intake, kcal[5]	6097	4219	4945	3817	564
Fecal energy, kcal	1250	761	909	758	179
Urinary energy, kcal	56	44	65	56	9.9
Digestible energy, kcal[6]	4847	3458	4036	3059	404
Energy digested, %	79.5	81.9	81.6	80.1	2.3
Metabolizable energy, kcal[7]	4791	3414	3971	3003	400
Energy metabolized,%	78.6	80.9	80.3	78.7	2.2
N-corrected ME, kcal	4608	3249	3853	2821	385
N-corrected ME, % [8]	75.6	77.0	77.9	73.9	2.1

[1] standard error of the mean
[2] based on per pig/day mean values
[3] as fed basis means
[4] D.M. basis means
[5] Gross energy, kcal/kg= 3895,3936,3997,3828, respectively
[6] DE, kcal/kg= 3097,3226,3262,3068, respectively
[7] ME, kcal/kg= 3061,3210,3185 3011, respectively
[8] N-corr. ME, kcal/kg= 2878,3020,3092,2829, respectively

GENERAL CONCLUSIONS

The results of the three experiments have led the author to make the following conclusions:

1. In beef cattle, opaque-2, waxy and yellow dent corns support similar performance.
2. Increased lysine may have no nutritional value to the ruminant since amino acid synthesis occurs in the rumen by microbial processes.
3. The only way in which opaque-2 corn is advantageous to beef cattlemen is through yields per acre which are equal to or superior to that of dent corn. In this case the yield was lower.
4. Opaque-2 corn could possibly be of some value to swine producers as long as the protein level does not fall below that of regular corn.
5. Waxy corn did not significantly improve cattle performance although there was a tendency to do so. Its yields were equal to that of O-2 corn and less than dent corn in this trial.
6. Waxy corn rations tended to depress swine performance probably due to its decreased lysine and increased zein. Tryptophan levels should have been analyzed.
7. There was no real difference among corns concerning nitrogen retention, dry matter digestion and energy retention by swine.

BIBLIOGRAPHY

BIBLIOGRAPHY

Abernathy, R. P., R. F. Sewell and R. L. Tarpley. 1958. Interrelationships of protein, lysine and energy in diets for growing swine. J. Anim. Sci. 17:635.

Almquist, H. J. 1954. Utilization of amino acids by chicks. Arch. Biochem. 52:197.

Baker, D. H. 1973. Amino acid nutrition of swine and poultry. Proceedings of the Georgia Nutrition Conference. p. 11.

Barker, S. B. and N. H. Summerson. 1941. The colorimetric determination of lactic acid in biological material. J. Biol.Chem. 138:535.

Beeson, W. M. and T. W. Perry. 1958. Comparative feeding value of high moisture corn and low moisture corn with different feed additives for fattening beef cattle. J. Anim. Sci. 17:368.

Beeson, W. M., R. A. Pickett, E. T. Mertz, G. L. Cromwell and O. E. Nelson. 1966. Nutritive value of high lysine corn. Proc. Distillers Res. Conf. Cincinnati, Ohio. p. 70.

Beeson, W. M., T. W. Perry, V. M. Thomas and M. T. Mohler. 1973. Raw vs. opaque-2 vs. roasted corn and regular vs. opaque-2 corn silage for finishing beef cattle. Indiana Res. Rep.

Beeson, W. M., V. M. Thomas, T. W. Perry and M. T. Mohler. 1974. The nutritional value of regular, opaque-2 and waxy corn for finishing beef cattle. Indiana Res. Rep.

Bergen, W. G. and E. L. Potter. 1971. ε-N-methyl lysine metabolism in sheep. J. Anim. Sci. 32:1245.

Bothast, R. J., G. H. Adams, E. E. Hatfield and E. B. Lancaster. 1974. Preservation of high moisture corn. J. Anim. Sci. 39:193. (Abstr.).

Boundy, J. A., J. H. Woychik, R. J. Dimler and J. S. Wall. 1967. Protein composition of dent, waxy and high amylose corns. Cereal Chem. 44:161.

Bramen, W. L., E. E. Hatfield, F. N. Owens and J. D. Rincker. 1973. Waxy corn and N Sources for finishing lambs and steers fed all concentrate rations. J. Anim. Sci. 37: 1010.

Brookes, I. M., M. L. Hershbarger and R. W. Henderson. 1969. Opaque-2, higher-oil, higher-protein and regular corn in diets for growing lambs. J. Anim. Sci. 28:103.

Brown, J. A. and T. R. Cline. 1974. Urea excretion in the pig: an indicator of protein quality and amino acid requirements. J. Nutr. 104:542.

Burkhardt, J. D., L. B. Embry and R. M. Luther. 1969. Corn processing methods for high concentrate diets. J. Anim. Sci. 29:153. (Abstr.).

Clark, J. H. and K. E. Harshbarger. 1972. High moisture corn vs. dry corn in combination with either corn silage or hay on lactating cows. J. Dairy Sci. 55:1474.

Collins, G. N. 1909. A new type of Indian corn from China. U.S.D.A. Bur. Plant. Ind. Bul. 161.

Cromwell, G. L., J. C. Rogler, W. R. Featherston and R. A. Pickett. 1966. Nutritional value of opaque-2 corn for the chick. Poultry Sci. 46:705.

Cromwell, G. L., R. A. Pickett and W. M. Beeson. 1967. Nutritional value of opaque-2 corn for swine. J. Anim. Sci. 26:1325.

Cromwell, G. L., R. A. Pickett, T. R. Cline and W. M. Beeson. 1969. Nitrogen balance and growth studies of pigs with opaque-2 and normal corn. J. Anim. Sci. 28:478.

Drews, J. E., N. W. Moody, V. W. Hays, V. C. Speer and R. C. Ewan. 1969. Nutritional value of opaque-2 corn for young chicks and pigs. J. Nutr. 97:537.

Duncan, D. B. 1955. Multiple range and multiple "f" tests. Biometrics. 11:1.

Ely, D. G., C. O. Little, P. G. Woolfolk and G. E. Mitchell, Jr. 1967. Estimation of the extent of conversion of dietary zein to microbial protein in the rumen of lambs. J. Nutr. 91:314.

Featherston, W. R. and E. L. Stephenson. 1960. Dietary interrelations between methionine, glycine, choline, protein levels and energy content of the chick diet. Poultry Sci. 39:1023.

Florence, H. D., J. R. Riggs and G. D. Potter. 1968. Physical characteristics of reconstituted sorghum grain. J. Anim. Sci. 27:1163. (Abstr.).

Forsyth, J. G., J. B. Stone and D. N. Mowat. 1970. Propionic acid preserved corn in cattle rations. J. Anim. Sci. 31:1038. (Abstr.).

Gipp, W. F. 1968. Nutritional evaluation of opaque-2 and floury-2 corns for non-ruminant animals. M.S. Thesis. Purdue Univ. Lafayette, Indiana.

Gipp, W. F. and T. R. Cline. 1972. Nutritional studies with opaque-2 and high protein opaque-2 corn. J. Anim. Sci. 34:963.

Goodrich, R. D., F. H. Gharib and J. C. Meiske. 1970. The value of high lysine and conventional corn silage for growing steers. Minnesota Res. Rep.

Goodrich, R. D. and J. C. Meiske. 1974. Comparison of four types of corn. Minnesota Res. Rep.

Hanson, L. E. 1946. Waxy corn vs. non-waxy corn for growing fattening pigs in dry lot. J. Anim. Sci. 5:36.

Heuberger, G. I., G. E. Mitchell, Jr., W. W. Albert and A. L. Neuman. 1959. The effect of moisture content of field shelled corn on harvesting and storage losses and on its feeding value for beef cattle. J. Anim. Sci. 18:1527. (Abstr.).

Klein, R. G., W. M. Beeson, T. R. Cline and E. T. Mertz. 1971. Opaque-2 and floury-2 corn studies with growing swine. J. Anim. Sci. 32:256.

Klein, R. G., W. M. Beeson, T. R. Cline and E. T. Mertz. 1972. Lysine availability of opaque-2 corn for rats. J. Anim. Sci. 35:551.

Long, T. A. 1973. Acid treating grains and forages. Pennsylvania State Univ. Rep. AS-BC-73-1.

Lynch, P. B., D. H. Baker, B. G. Harmon and A. H. Jensen. 1974. Chemically treated high moisture corn in diets for swine. 66th National Meeting Amer. Soc. Anim. Sci. p. 185. (Abstr.).

Maner, J. H. 1971. Performance of rats and swine fed Columbian floury-2, Columbian opaque-2 or normal corn. J. Anim. Sci. 33:791.

Marroquin, C. R., G. L. Cromwell and V. M. Hays. 1974. Nutritional value of several varieties of opaque-2 and normal corn for growing swine. J. Anim. Sci. 36:253.

McDonald, I. W. 1954. The extent of conversion of food protein to microbial protein in the rumen of sheep. Biochem. J. 56:120.

McDonald, T. A. 1973. Waxy corn feeding trial results. Kent Feeds of Iowa. Muscatine, Iowa. Mimeo. Rep.

McDonald, T. A. and G. A. Mente. 1973. Waxy corn and source of protein for finishing steers. J. Anim. Sci. 37:350.

McKnight, D. R., G. K. MaCleod, J. G. Buchanan-Smith and D. N. Mowat. 1973. Utilization of ensiled or acid treated high moisture shelled corn by cattle. Can. J. Anim. Sci. 53:491.

McLaren, R. J. and J. K. Matsushima. 1968. Digestion of ensiled reconstituted corn. J. Anim. Sci. 27:1170. (Abstr.).

Meisinger, D. J., G. H. Kroening and H. H. Hodson, Jr. 1974. High moisture acid treated corn for weanling pigs. J. Anim. Sci. 39:186. (Abstr.).

Mertz, E. T., L. S. Bates and O. E. Nelson. 1964. Mutant gene that changes protein composition and increases lysine content of maize endosperm. Science. 145:279.

Mertz, E. T., O. A. Veron, L. S. Bates and O. E. Nelson. 1965. Growth of rats fed on opaque-2 maize. Science. 148:1741.

Mertz, E. T. 1966. Growth of rats on opaque-2 maize. Proc. High-Lysine Corn Conf. Corn Industry-Research Foundation, Inc., 1001 Conn. Ave., Washington, D. C. p. 19.

Miller, J. I., J. B. Robertson and R. Logan. 1969. Acid preservation of high moisture corn for beef cattle. Mimeo. Report. Cornell Univ., Ithaca, N. Y.

Miller, J. I., J. B. Robertson and R. Logan. 1972. Preservation of high moisture corn with propionic acid. Mimeo. Report. Cornell Univ., Ithaca, N. Y.

Miller, J. I. and R. Logan. 1972. Summer storage and feeding of high moisture shelled corn preserved with propionic acid or a mixture of acetic-propionic acid. Mimeo. Rep. Cornell Univ., Ithaca, N. Y.

Mussehl, F. E. 1944. Growth promoting value for chicks of waxy corn. Nebr. Agr. Exp. Sta. Ann. Rep. 57. p. 79.

National Research Council. 1960. Nutrient requirements of domestic animals, No. 1 - Nutrient requirements of poultry. Pub. 827. National Acad. Sci. N.R.C. Washington, D. C.

National Research Council. 1964. Nutrient requirements of domestic animals, No. 1 - Nutrient requirements of swine. Pub. 1192. National Acad. Sci. N.R.C. Washington, D. C.

National Research Council. 1973. Nutrient requirements of domestic animals, No. 2 - Nutrient requirements of swine. National Acad. Sci. N.R.C. Washington, D. C.

Nelson, L. F., R. I. Pick and F. Diaz. 1971. Normal and opaque-2 corn for feeding steers. J. Anim. Sci. 33: 1168. (Abstr.).

Osborne, T. B. and L. B. Mendel. 1914. Amino acids in nutrition and growth. J. Biol. Chem. 7:325.

Pickett, R. 1966. Opaque corn in swine nutrition. Proc. High-Lysine Corn Conf. Corn Industry-Research Foundation, Inc., 1001 Conn. Ave., Washington, D. C. p. 19.

Polzin, H. W., D. E. Otterby, J. M. Murphy and D. G. Johnson. 1972. Utilization of ensiled, acid treated and dry corn by lambs. J. Anim. Sci. 35:1133. (Abstr.).

Robinson, G. N., E. E. Hatfield and D. L. Hixon. 1974. Waxy Corn as a dietary ingredient. 66th Amer. Soc. of Anim. Sci. p. 251. (Abstr.).

Rogler, J. C. 1966. Comparison of opaque-2 and normal corn for chicks. Proc. High-Lysine Corn Conf. Corn Industry-Research Foundation, Inc., 1001 Conn. Ave., Washington, D. C. p. 23.

Sihombing, D. T. H., G. L. Cromwell and V. W. Hays. 1969. Nutritional value and digestion of opaque-2 and normal corn for growing pigs. J. Anim. Sci. 29:921.

Tonroy, B. R., T. W. Perry and W. M. Beeson. 1974. Dry, ensiled high moisture, ensiled reconstituted high moisture and VFA treated high moisture corn for growing-finishing beef cattle. J. Anim. Sci. 39:931.

Veum, T. L., W. H. Pfander, C. G. Bellamy and H. B. Hedrick. 1974. Opaque-2 and normal corn as amino acid sources for barrows and gilts. J. Anim. Sci. 36:877.

Wahlstrom, R. C. and G. W. Libal. 1973. Performance of swine fed opaque-2 or normal corn free choice. J. Anim. Sci. 36:898.

Welch, J. G., R. H. Cordts and G. W. Vander Noot. 1966. Effect of lysine, methionine and tryptophan supplementation upon N retention of barrows. J. Anim. Sci. 25:806.

APPENDIX

TABLE A-1

ACTUAL FEED VALUES PER BODY WEIGHT

Average Weight	Corn Silage	Shelled Corn
204	54	16
211	56	17
218	58	17
225	60	18
232	62	19
238	63	19
245	65	20
252	67	20
259	69	21
265	71	22
272	73	22
279	74	23
286	76	23
293	78	24
299	80	24
306	82	24
313	84	25
320	85	25
327	87	26
333	89	27
340	91	27
347	93	28
354	95	28
361	96	29
367	98	29
374	100	30
381	102	30
388	104	31
395	106	32
401	107	32
408	109	33
415	111	33
422	113	34
429	115	34
435	117	35
442	118	35
449	120	36
456	122	36
463	124	37
469	126	38
476	127	38

[1] all weights in kilograms

TABLE A-2

FEED ANALYSIS OF SILAGES AND CORNS

SILAGES

Item	Dent	Opaque-2	Waxy
D.M., %	36.55	38.11	33.27
pH	4.12	4.09	4.09
Total N, %	1.97	2.03	2.21
Crude protein, % (DM)	12.31	12.69	13.81
Lactic Acid, %	8.87	8.62	9.26
Acetic Acid, %	1.05	1.29	1.02
Butyric Acid, %	.12	.11	.13

SHELLED CORN

Item	Dent	Opaque-2	Waxy
D.M., %	79.48	79.02	74.19
pH	4.51	4.58	4.43
Lactic Acid, %	.23	.26	.24
Total N, %	1.66	1.76	1.75
Crude protein, % (DM)	10.36	11.00	10.95