Feed value of Titan and Compana barleys as affected by the length of awn and the presence or absence of hulls
by Ralph Clarence Rasmuson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Animal Science
Montana State University

Abstract:
Seventeen 3-week-old rats were used in each of two trials to determine the feeding value of four isogenes of Titan and Compana barleys, long- and short-awn, covered and hulless kernels. Starch extracted from each barley was used in isonitrogenous, isocaloric 20% protein purified diets with a cornstarch control in trial 1. Diets were balanced with minerals and vitamins and casein was the source of protein. Whole barleys and corn were used to formulate 10.5% protein isonitrogenous diets in trial II. Cornstarch was used to equalize the protein in the barley and zein to increase the protein of corn. Feed and water were supplied ad libitum. Nitrogen and energy balance studies were conducted for both trials using 7 rats per diet in 3-day preliminary and 3-day collection periods, with feed restricted to approximately 13 g intake daily and water ad libitum. Four isogenes of Titan barley were fed to 57 pigs stratified in two replications for sex, initial weight, and litter in trial III. Five or 6 pigs were allotted to 10 pens equipped with self-feeders and automatic waterers. Average daily gains were analyzed by least-squares with initial weight as a covariate. Amino acids were determined on all barleys, revealing 17.4%, 18.6% and 7.9% more lysine, methionine, and threonine, respectively, in the Titan barley when compared to Compana barley. Rats fed the short-awn Titan barley starches gained slightly less in the feeding trial, however, no significant difference in rat performance was observed in trial 1. Rats fed the titan barleys consumed more feed, gained faster and were more efficient ($P< .01$) than those fed Compana barley or corn diets (trial II). Rats fed Compana barley retained the same advantage over those fed corn ($P< .01$). Protein efficiency ratios followed the same pattern as gain and efficiency data ($P< .01$). Length of awn had no effect on gain, efficiency or feed consumed although rats fed covered barleys gained faster and consumed more feed ($P< .01$). The average digestible energy (DE), metabolizable energy (ME) and digestible nitrogen (DN) of the Titan isogenes were less than that of Compana isogenes ($P< .01$). However, rats fed the Titan isogenes retained more nitrogen ($P< .05$) than those fed the Compana isogenes in trial II.

Hogs fed the short-awn covered barley diet gained significantly less ($P< .05$) than the other three isogenes or corn control. Hogs fed the long-awn covered barley performed equally as well as those fed the long- and short-awn hulless isogenes.

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Date April 18, 1972

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by

RALPH CLARENCE RASMUSON

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

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Approved:

R. Blackwell
Head, Major Department

C. W. Newman
Chairman, Examining Committee

Henry L. Parsons
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

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ABSTRACT

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INTRODUCTION

Barley is the major feed grain produced in Montana, accounting for 7% of the total cash receipts for farm commodities from 1964 through 1968. However, a sizable portion of the barley crop in Montana was marketed through cattle and hogs. The number of hogs marketed for slaughter in Montana increased from 185,000 to 291,000 from 1960 through 1969. The number of grain-fed cattle marketed in Montana during this same period increased from 100,000 to 176,000. Barley is well suited to semi-arid climates and represents about 10% of the world's total cereal production.

Considerable variation has been noted in the physical and chemical characteristics of barley attributed to variety, cultural practices and ecological factors. Many of these differences have been related to the value of barley for malt production and more recently, to the nutritional value. It is conceivable that a barley can be genetically altered to provide a cereal grain with superior nutritive qualities for all animals including man. The development of a cereal grain that would furnish high quality protein in addition to a large supply of available energy would have a tremendous influence on world nutrition. The commonly accepted concept of barley as a feed for domestic animals may be drastically changed with improved nutrient content and nutrient availability. Barley may well become a source of essential nutrients for man in many parts of the world which are now classed as undernourished.

The discovery of high-lysine mutant in corn has revolutionized concepts in animal and human nutrition. More recently, a barley has been discovered that contains considerably more lysine and other essential amino acids than do commonly produced varieties. Many areas of the world will not permit corn production due to lack of water and/or cool temperatures, whereas barley is ideally suited to many of these locations.

A study was initiated to evaluate the nutrient properties of barley for nonruminants. This thesis included a series of feeding and metabolism trials with Compana and Titan isogenic barleys. The isogenes were for length of awn and presence or absence of hulls.

REVIEW OF LITERATURE

Barley has been coined as having inferior feeding qualities to that of corn. Some undesirable characteristics in barley may be improved through genetic alterations. Certain barley varieties have superior chemical and physical properties and to some degree this has been expressed in terms of animal performance. Barley varieties exhibit extreme variation in the content of different nutrients; thus it is genetically and culturally possible to obtain a variety that will promote optimum animal growth and production.

Isogenic lines within a variety allows the effect of a particular gene to express its merits agronomically and possibly nutritionally. It may be possible to study specific nutritional qualities with specific isogenic lines as isogenes reduce the variation and that may be due to other genetic factors.

The concern of this thesis is the correlation of the nutritional responses with the chemical and physical properties expressed by four isogenic lines within two varieties.

Physical Characteristics

Barley is graded into six categories consisting of U. S. No. 1, 2, 3, 4, 5 and U. S. sample grade. The grade is determined by minimum limits of test weight per bushel and soundness of the barley. Six maximum limits of different types of impurities may affect the grade of barley. They are as follows: total damaged kernels, heat damaged kernels, foreign material, broken kernels, thin barley and black barley. Malting barley has only three grades, U. S. No. 1, 2, and 3 and these have the same categories as previously listed (Official Grain Standards of United States, 1970).

Barley phenotype is often altered for more than one characteristic by the genotype of isogenic lines. The four isogenic lines which were studied were short-awn and long-awn in both covered and hulless types. Awn length and kernel size have a direct relationship, the shorter the awn the smaller the kernel. The hulless varieties generally have a higher bushel weight, lower fiber but a lower yield when compared to the covered barleys. Six row (Titan) and two row (Compana) barleys also differ physically. Six row barleys generally have a smaller kernel, lighter test weight, and shorter straw than its counter isogenic two row barley (Eslick, personal communication).

The covered varieties contain three to four percent more crude fiber than hulless varieties (Joseph, 1924; Gill, Oldfield and England, 1966; and Newman and Eslick, 1970). Crude fiber is relatively indigestible to the nonruminant (Maynard and Loosli, 1969).

Chemical Characteristics

Barley grain has been reported to contain beta, 1, 3-D glucopyranosyl units which are water soluble and are related to the malting process. The polyglucans, generally referred to as glucans, have a chemical structure related to cellulose which is composed primarily of beta, 1, 4 glucose units. However, cellulose is insoluble in water due to its high degree of linear orientation and strong intermolecular bonding. Glucans have a beta, 1, 3 linkage distributed among every three to four units of normal cellulose structure. The beta, 1, 3 linkage makes it soluble in water, thus the glucans are extracted with the starch portion of the kernel (Patrick, 1965).

A large portion of all cereal grains consist of starches. These polysaccharides when hydrolized with acid or enzymes, are broken down to dextrin, maltose, and finally to glucose. Differences exist in size and shape of starch granules with regard to the source of starch. Starches, in general, are not pure carbohydrates for they contain small amounts of acid radicals, which might contain some phosphorus (Maynard and Loosli, 1969).

Starch has two distinct molecular forms, alpha amylose and amylopectin. Alpha amylose is composed of long, straight, unbranched chains of D-glucose units bound by alpha, 1, 4 linkage. Amylopectin is a highly branched starch molecule having branches about every 12 glucose units. These branches are also approximately 12 glucose units long with alpha, 1, 4 linkages except for alpha, 1, 6 links where the branched chain connects (Lehninger, 1970).

Goering, Eslick and Ryan (1957) studied 30 samples from Compana barley and found a range of 10 to 23% amylose. A total of 44 different varieties analyzed in this study resulted in a range between 13 to 24% amylose at the expense of amylopectin. Some genetic freaks in barley were shown to range between 11 and 26% amylose. This study showed Compana and Titan barleys to have an average of 21 and 23% amylose, respectively. The variation observed indicated that differences in starch composition were due to genotype.

Various types of cereal starches with varying levels of amylose and amylopectin were subjected to alpha amylase (Leach and Schock, 1961). Speculation was made that the more susceptible starch granules possessed porous or sponge-like structure with openings of adequate size that enhanced the enzyme molecules.

Sandstedt et al. (1962) reported large variation between raw starches in their susceptibility to the action of pancreatic alpha-amylase. It was concluded that the resistance to digestion was not directly associated with the amylose in all cases. A high-amylose corn, which had a high resistance to alpha-amylase action, proved to be highly resistant to digestion when fed to rats and chicks.

Goering and Imsande (1960) reported varying quantities of amino acids within six varieties studied. These varieties also had distinct differences in the physical characteristics of their respective starch.

After a study of a number of varieties, it was found that amino acid composition varied between varieties (Newman and Eslick, unpublished data).

Variation among barley varieties for chemical composition have been reported. The following are accepted values for average composition of barley.

Barley Kernel Composition[1]

General Analysis, %

Dry matter	88.7
Crude protein	13.7
Ether extract	2.1
Ash	3.1
N.F.E.	75.7

Energy

Gross Kcal/kg	4599
Digestible Kcal/kg	3128
Metabolizable Kcal/kg	2921
Starch, %	64.6

Macro Minerals, %

Calcium	.08
Phosphorus	.42
Potassium	.56
Magnesium	.12
Sulphur	.19
Sodium	.02
Iron	.005

Trace Minerals, mg/kg

Copper	7.60
Cobalt	.1
Zinc	15.3
Manganese	16.3

Vitamins, mg/kg

Thiamine	5.1
Riboflavin	2.0
Pantothenic acid	6.5
Niacin	57.4
Pyridoxine	2.9
Choline	1030.0

Amino Acids, %

Tryptophan	0.2
Valine	0.7
Methionine	0.2
Cystine	0.2
Glutamic acid	3.4
Serine	0.5
Tyrosine	0.4
Arginine	0.6
Histidine	0.3
Isoleucine	0.6
Leucine	0.9
Lysine	0.6
Phenylalanine	0.7
Threonine	0.4

[1] National Academy of Science NRC, Nutrient Requirement of Swine, 6th edition, Publication 1959, 1968.

General Feeding Trials with Barley

Nonruminants:

Joseph (1924) compared hulless Guy Mayle barley to covered Smyrna barley in swine diets. He found that the hulless barley was superior to the covered barley and equal to corn as measured by pig performance.

Gill et al. (1966) conducted a feeding trial to compare covered Hannchen barley and Utah hulless barley, Gaines wheat, and corn in rations for growing-finishing swine. Gains were improved with hulless barley diets compared to the covered barley diets, and equal to wheat, but were less than gains of pigs fed the corn ration. Feed efficiency was not significantly different for the hulless barley, corn, or wheat ration, but these were better than the covered variety.

Larsen and Oldfield (1961) postulated two theories for the decrease in the feeding value of covered barley varieties when compared to hulless counterparts. 1) The increased fiber content lowered the available energy and 2) the hull may have contained factors which inhibited nutrient digestion, absorption, or utilization. Their data suggested that the barley hull did more than dilute the available nutrients. Pigs responded differently to the fiber of barley hulls than to purified wood cellulose added to corn or pearled barley diets.

Newman, Thomas and Eslick (1968) reported a study comparing hulless and normal barley isogenes of two varieties on the performance of weanling pigs. This data suggested that difference may have existed in the nutritive value of the hulless barley other than a lower crude fiber content. A hulless barley developed from Compana was superior to covered Compana, but a hulless Glacier isogene was of no greater value nutritionally than the covered Glacier.

Newman and Eslick (1970) designed a study to determine the feed value of Compana barley isogenes (covered and hulless) with and without supplemental protein compared to corn. The data reported showed no statistical significant difference among treatments during the starting and grower phase. Rate of gain and feed efficiency were significantly greater ($P < .05$) in the finishing phase in favor of the hulless isogene and corn. There were large differences ($P < .01$) between high and low protein levels; however, there were no interactions between basal grain and protein level.

The effects of barley diets were studied in six trials on 12-day-old crossbred broiler chicks (Arscott, Hutto and Rachapactoyakam, 1964). A significant decrease in body weight gains were noted in chicks fed diets containing a high percentage of barley as compared to corn diets. Reduced gains were partially corrected when amylolytic enzymes were added. Feed efficiency was drastically lowered in chicks fed barley diets and only slightly corrected when the enzyme was added. Pancreas weights were greatly increased in the barley diets; however, they were slightly reduced when the amlolytic enzymes were added.

Arscott, Rose and Harper (1960) were able to increase the feeding value of barley for chicks by soaking it in water. They assumed that the treatment destroyed or removed an inhibitor or the inhibitory action.

They also reported increased feeding value of barley by the addition of an amylotic enzyme.

Jensen et al. (1957) added a blend of two enzymes (Takadiastase and Clarase) at various levels in barley diets fed to chicks. Each level of enzyme supplementation in normal barley significantly improved feed utilization when compared to a pearled barley control diet. It was suggested in these findings that there were carbohydrates in the barley not readily hydrolyzed by natural enzymes of the chick.

Fry et al. (1957) proved that the nutritive value of barley, pearled barley, oats, and corn were improved with a simple water-soaking process. The nutritional value of pearled barley was improved when autoclaved at 15 P.S.I. for 15 minutes either before or after the water-soaking process. This suggested that possibly the enzymatic action during water treatment of pearled barley was not responsible for the change in nutritional value.

A hulless barley when compared to a normal, covered barley was equal in feeding value as measured by chick performance (Dobson and Anderson, 1958). The nutritional value of hulless barley was improved by the addition of a crude fungal bacteria enzyme, cottonseed oil, and by water soaking. An extract from corn when added to a soaked barley diet increased growth and improved feed efficiency.

Berg (1959) studied the effects of enzyme supplementation to chick and laying hen diets. Fungal and bacteria enzymes had no effect on the laying hen when added to diets in terms of the following parameters:

rate of lay, feed per dozen eggs, body weight gains, hatch of fertile eggs, and egg quality. The enzymes had a positive effect on the growth and feed efficiency of the young chick.

An experiment was conducted with chicks fed diets containing corn or barley. The barley was subjected to number of treatments that included soaking, autoclaving, soaking plus drying, soaking plus autoclaving and soaking plus enzymes added (Arscott, Rose and Harper. 1960). The growth and fecal dropping accumulation data showed that autoclaving did not alter the beneficial effects derived from soaking but did eliminate the improvement due to enzyme supplementation. Water soaking was shown to be responsible for removing an inhibitor or inhibitory action which was also overcome with supplemental enzymes.

Dinnuson, Nystuen and Bolin (1958) supplemented barley containing 13.8% protein with D-lysine for swine. The addition of lysine at all levels resulted in an increased gain and feed conversion to 45 kg. When the data were extrapulated over the entire feeding period to 91 kg, supplemental lysine improved average daily gains in all trials.

Pick and Meade (1971) reported data which indicated that the current accepted requirements of the growing rat for isoleucine, lysine, methionine + cystine, phenylalanine + tryosine, and threonine may be slightly excessive.

Rama Rao, Metta and Johnson (1959) determined minimum requirements for essential amino acids by the weanling rat for maximum growth. The requirements for lysine, histidine, tryptophan, isoleucine, leucine, valine, threonine, methionine + cystine, and phenylalanine + tryosine are: 0.9, 0.21, 0.11, 0.55, 0.69, 0.56, 0.51, 0.49, and 0.72% of the diet, respectively.

Sure (1955) supplemented pearled barley with D-L threonine, L-lysine, and D-L methionine. The pearled barley was fed at the 8% level of protein fed to rats. Rations supplemented with 0.4% L-lysine results showed a 57.2% increase growth and 50.0% increase in protein efficiency ratios (PER). The further addition of 0.5% D-L threonine was followed by a 78.6% additional gain in body weight and 118.4% further increase in protein efficiency. The supplementation of pearled barley with L-lysine, D-L threonine and 0.5% D-L methionine resulted in 15.3% additional growth and 56.3% increase in protein utilization.

Howe, Jansen and Gilfillan (1965) reported maximum PER when barley was supplemented with 0.2% L-lysine, 0.2% D-L methionine, 0.1% D-L threonine and 0.05% tryptophan. A PER of 2.28 was obtained with rats fed barley so supplemented as compared to a PER of 1.66 for unsupplemented barley.

Zein does not have any or very little lysine and is low in other essential amino acids. When supplemented to theoretically adequate levels with the essential amino acids, optimum gains were not reached in rats (Klinger and Krehl, 1950).

Hageberg and Karlsson (1969) recognized the need for screening barley varieties for lysine content. They investigated the possible correlation of total protein content obtained by the Kjeldahl method and the dye-binding capacity (DBC) of protein. The DBC measures the basic amino acid content (lysine, arginine, and histidine) and terminal amino acids which indicates protein quality and quantity. These two investigators found a correlation of r=0.93 between DBC and grams of lysine per 100 grams of protein. This method was credited for selecting a few barley varieties out of the World Barley Collection which were high in the amino acid lysine.

Hiproly barley was selected from the World Barley Collection by the DBC technique and found to have a high-protein, high-lysine content (Munck, Karlsson, and Hagberg, 1968). This barley originated in Ethiopia. Hiproly was found to contain twice the protein and 30% more lysine when compared with standard varieties. Thus, the protein and amino acid composition of Hiproly showed more resemblance to low- than to high-protein barley.

Munck, Karlsson and Hagberg (1970) reported mice and rat feeding trials fed Hiproly and a reference barley. The mice were fed individually *ad libitum* and rats were individually restricted. The diets were isonitrogenous 9.4% protein. Mice fed Hiproly diets resulted in an increased protein efficiency ratio. True digestibility, the biological value of protein and the net protein utilization were also improved with rats fed Hiproly diets.

Ruminants

Saba *et al*. (1964) reported data from digestion trials conducted with steers and heifers to determine the digestibility of rations high in corn or barley and all-milo and all-barley rations. There was greater digestibility of protein and nitrogen-free extract in favor of the ration high in barley. The protein digestion co-efficients were 55.2% and 77.1% for all-milo and all-barley rations, respectively, and corresponding values for nitrogen-free extract were 79.3 and 90.8%, respectively. Total digestible nutrient value of 75.3 and 84.9% were calculated for milo and barley, respectively. "The lower digestibility of the milo nitrogen-free extract may have been due to the lower digestibility of milo starch."

Thomas, Myers and Matz (1962) reported a study comparing light (.58 kg/liter) and heavy (.64 kg/liter) barley to steers. The two barleys had no effect on rate of gain, although the heavier barley was more efficiently utilized. The same trend was noted when a protein supplement was added to these two barley diets.

A similar experiment as the previous trial was conducted comparing the feeding value of thin and plump barley with or without protein supplementation (Thomas and Krall, 1965). The plump barley weighed .64 kg/liter, whereas the thin barley weighed .54 kg/liter. Steers fed thin barley gained faster and more efficiently than steers fed plump barley. This advantage was maintained with or without supplementary protein.

Nutritional Work with Other Grains

The Opaque-2 mutant gene of corn caused a distinct increase in the amount of lysine content and altered the amino acid pattern. The reduction in the ratio of zein to glutelin as well as the increase in zein fraction resulted in the differences (Mertz, Bates and Nelson, 1964).

Cromwell, Pickett and Beeson (1967a) reported improved gains and feed efficiency of pigs fed Opaque-2 corn as compared to normal corn. The lysine and tryptophan content were 104 and 67% greater, respectively, in Opaque-2 corn than the normal corn. Normal corn, when supplemented with lysine to the level found in Opaque-2 corn, did not give the same response. When supplemented with tryptophan, a greater response to normal corn was noted but the response was not equal to Opaque-2 corn alone. This response suggested that tryptophan was possibly more a limiting amino acid than lysine in corn.

Chicks' diets were prepared from Opaque-2 corn and normal corn with and without supplemented lysine (Cromwell _et al_. 1967b). When normal corn was supplemented to the same level as in Opaque-2 corn, the chicks responded to the supplemented corn diets equally as to the Opaque-2 diet.

Cromwell _et al_. (1968) reported Floury-2 corn to be superior to normal corn in diets fed to chicks, because of increased methionine and lysine content. Opaque-2 corn held a slight advantage over normal corn. With supplementation of methionine, Opaque-2 corn was much superior to normal corn.

Opaque-2 corn supported greater nitrogen retention on an absolute and a percentage basis than did normal corn, when fed in isonitrogenous 11.2% or 8.2% protein diets. Therefore indicating that Opaque-2 corn is more digestible and has a higher biological value than normal corn (Cromwell *et al*. 1969).

Growing pigs were fed various levels of supplemented soybean meal in Opaque-2 corn and normal corn diets. Rate and efficiency of gain were improved on both Opaque-2 and normal corn diets with increased increments of soybean meal. However, the improvements were more great in pigs fed Opaque-2 corn diets (Sihombing, Cromwell and Hays, 1969).

Approximately 5% less soybean meal was required in diets containing Opaque-2 corn than in those with normal corn, to support maximum performance of pigs and chicks (Drews *et al*. 1969).

The nutritive value of protein of two sorghum grains containing 7.6% and 11.5% protein were studied with rats (Waggle, Parrish and Deyoe, 1966). An amino acid assay showed that the higher protein grains contained a higher percentage of the 17 amino acids studied than did the low sorghum grain. Nutritive value of the protein of low protein sorghum grain was superior to the high protein sorghum grain, when fed as an isonitrogenous diet.

Shoup *et al*. (1969) studied the nutritional value of six commercial sorghum grain hybrids. Isonitrogenous 17% protein diets were fed chicks, with the addition of cornstarch to equilibrate the amount of crude protein from the grains to 6%. With the addition of soybean meal to the diets, the overall protein level was 17%. There were no significant differences noted, although the grains which had a higher crude protein gave reduced gains as measured by chick performance. Thus, the lower protein sorghum grains had a slightly higher nutritional value. When 20% of the sorghum grains were replaced with pure amino acids, no improvement in growth was obtained, indicating that the amino acids in sorghum grain were readily available or that the free amino acids were not utilized.

EXPERIMENTAL

Barleys

The barleys studied in this experiment consisted of two varieties with four isogenes within each variety. These were as follows: Titan long-awn covered (TLAC), Titan short-awn covered (TSAC), Titan long-awn hulless (TLAH), Titan short-awn hulless (TSAH), Compana long-awn covered (CLAC), Compana short-awn covered (CSAC), Compana long-awn hulless (CLAH), and Compana short-awn hulless (CSAH). The short-awn and hulless characters were derived from Sermo barley. Corn was employed as a control in the feeding trials with both swine and rats. Only the four isogenes of the Titan variety were fed to hogs. The Compana isogenes will be fed to hogs at a later date.

Proximate analyses (AOAC, 1960), calcium (Delory, 1949) and phosphorus (Fiske and Subbarow, 1925) of Titan and Compana isogenes and corn are shown in table 1. Amino acid content of the barley isogenes were determined with a Beckman 120C automatic amino acid analyzer (Spackman, Stein, and Moore, 1958) (table 2). Table 3 shows the same amino acids extrapolated to the percentage of protein recovered. The amino acid content of the Titan and Compana barleys are shown as an average of their respective isogenes on the basis of the percentage of protein recovered (table 4).

Protein was estimated on the barleys using the Udy Dye Binding Capacity procedure as outlined by Udy, 1956.

Standard Braybender viscosity curves were prepared on pure starches extracted from the barley iogenes (Smith, 1964).

TABLE 1. PROXIMATE ANALYSIS, CALCIUM-PHOSPHORUS COMPOSITION AND PHYSICAL CHARACTERISTICS OF TITAN AND COMPANA BARLEY ISOGENES AND CORN. TRIAL I, II AND III

Item	H_2O	Protein	E.E.	C.F.	Ash	Ca	P	Thin	Plump	Kernel Wt.	Kg/liter
	%	%	%	%	%	%	%	%	%	mg	kg
Corn	9.1	9.3	4.5	2.5	1.2	.02	.31	--	--	--	--
TLAC	7.8	13.5	2.0	4.8	2.6	.06	.33	11.8	55.7	35.7	.59
TSAC	7.6	12.3	1.8	5.2	2.3	.05	.25	9.0	65.9	36.1	.62
TLAH	6.9	14.0	2.1	3.0	2.1	.07	.33	24.6	36.5	30.3	.61
TSAH	6.9	12.9	2.1	4.9	2.8	.13	.32	34.2	23.9	30.2	.66
CLAC	8.7	15.2	2.2	4.2	2.3	.05	.32	4.0	92.8	58.1	.63
CSAC	7.4	14.3	2.0	4.3	2.4	.05	.32	3.0	92.1	56.8	.64
CLAH	7.6	16.1	2.0	2.1	2.0	.05	.33	26.0	46.2	45.9	.70
CSAH	7.5	16.2	2.0	1.9	2.0	.05	.34	15.3	66.8	50.0	.64

TABLE 2. AMINO ACID COMPOSITION OF TITAN AND COMPAÑA BARLEYS. PERCENTAGE OF WHOLE GRAIN[a]

Amino Acid	TLAC	TSAC	TLAH	TSAH	CLAC	CSAC	CLAH	CSAH
Lysine	.37	.34	.41	.38	.34	.38	.48	.43
Methionine[a]	.16	.14	.16	.16	.11	.14	.19	.23
Threonine	.34	.37	.39	.37	.38	.38	.52	.49
Histidine	.21	.20	.25	.26	.22	.24	.30	.29
Arginine	.56	.52	.62	.58	.53	.57	.72	.69
Valine	.50	.49	.59	.55	.57	.57	.76	.69
Isoleucine	.34	.32	.39	.39	.44	.41	.57	.52
Leucine	.68	.63	.77	.76	.84	.79	1.11	1.01
Phenylalanine	.54	.49	.61	.67	.69	.70	.89	.90
Tyrosine	.37	.36	.44	.43	.43	.46	.58	.58
Aspartic acid	.58	.56	.66	.60	.65	.64	.89	.78
Serine	.44	.42	.51	.50	.48	.51	.69	.65
Glycine	.35	.34	.39	.37	.37	.38	.51	.47
Alanine	.36	.36	.44	.40	.42	.42	.56	.50
Glutamic acid	3.07	2.72	3.44	3.73	3.89	3.82	5.11	5.03
Proline	1.26	1.02	1.29	1.26	1.50	1.59	1.90	1.98
Ammonia	.32	.28	.36	.40	.56	.40	.51	.48
Residue Sum	10.45	9.56	11.72	11.81	12.42	12.37	16.29	15.95
NX 6.25	12.86	12.27	14.55	14.58	14.91	14.35	16.23	15.80

[a] Tryptophan was destroyed in the acid hydrolysis; only a trace of cystine was recovered and the methionine recovery was possibly reduced due to the acid hydrolysis and presence of excess carbohydrate.

TABLE 3. AMINO ACID COMPOSITION OF TITAN AND COMPANA BARLEY ISOGENES. PERCENTAGE OF PROTEIN RECOVERED[a]

Amino acid	TLAC	TSAC	TLAH	TSAH	CLAC	CSAC	CLAH	CSAH
Lysine	3.5	3.6	3.5	3.2	2.7	3.1	2.9	2.7
Methionine[a]	1.5	1.5	1.4	1.4	0.9	1.1	1.2	1.5
Threonine	3.3	3.9	3.3	3.1	3.1	3.1	3.2	3.1
Histidine	2.0	2.1	2.1	2.2	1.8	1.9	1.8	1.8
Arginine	4.4	5.4	5.3	4.9	4.3	4.6	4.4	4.4
Valine	4.8	5.1	5.0	4.7	4.6	4.6	4.7	4.6
Isoleucine	3.3	3.3	3.3	3.3	3.5	3.3	3.5	3.3
Leucine	6.5	6.6	6.6	6.4	6.8	6.4	6.8	6.4
Phenylalanine	5.2	5.1	5.2	5.7	5.6	5.7	5.5	5.7
Tyrosine	3.5	3.8	3.8	3.6	3.5	3.7	3.6	3.7
Aspartic acid	5.6	5.9	5.6	5.1	5.2	5.2	5.5	5.0
Serine	4.2	4.4	4.4	4.2	3.9	4.1	4.2	4.1
Glycine	3.3	3.6	3.3	3.1	3.0	3.1	3.4	3.0
Alanine	3.5	3.8	3.8	3.4	3.4	3.4	3.4	3.2
Glutamic acid	29.4	28.5	29.4	31.6	31.3	30.9	31.4	31.9
Proline	12.1	10.7	11.0	10.7	12.1	12.9	11.7	12.6
Ammonia	3.1	2.9	3.1	3.4	4.5	3.2	3.1	3.0

[a] No tryptophan was recovered, only a trace of cycstine was reported and the methionine recovery was possibly reduced due to the acid hydrolysis and presence of excess carbohydrate.

TABLE 4. AMINO ACID COMPOSITION OF TITAN AND COMPANA BARLEYS. PERCENTAGE OF PROTEIN RECOVERED

Amino Acid	Titan	Compana
Lysine	3.45[a]	2.85
Methionine	1.45	1.18
Threonine	3.40	3.13
Histidine	2.10	1.83
Arginine	5.00	4.43
Valine	4.90	4.60
Isoleucine	3.30	3.40
Leucine	6.53	6.60
Phenylalanine	5.30	5.63
Tyrosine	3.68	3.63
Aspartic acid	5.55	5.23
Serine	4.30	4.08
Glycine	3.33	3.13
Alanine	3.63	3.35
Glutamic acid	29.73	31.38
Proline	11.13	12.33
Ammonia	3.13	3.45

[a] Each mean represents the average of the four isogenes.

Trial 1

One hundred thirty-six Holtzman rats weighing about 50 g were used in two feeding studies of 8 and 9, respectively, per diet. Diets were purified isonitrogenous, isocaloric 20% protein, which were prepared with starches extracted from barley (Watson, 1964) and commercial cornstarch (table 5). Chemical analysis are in table 6. Rats were stratified to each diet by initial weight and cage level. Animals were maintained in a temperature controlled room. Feed and water were provided individually and *ad libitum*. Weight gain and feed consumption were measured weekly for three weeks. Total gain, feed consumption, feed efficiency, and protein efficiency ratios were computed for individuals. Data from the barley starch diets were analyzed factorally by least squares procedure (Harvey, 1960) with initial weight as a covariate. The data including that obtained with the rats fed the cornstarch diets, were reanalyzed for diet effect by analysis of variance with initial weight as a covariate (Snedecor, 1956). Means were tested for significance by the multiple range test (Duncan, 1955) where significances were indicated.

Three successive digestion and metabolism determinations were conducted at the end of the growth study, using three rats per diet. Diets were randomly allotted and fed for a 3-day preliminary period followed by urine and fecal collections at 12-hour intervals for 72 hours. Feed was restricted to 13 g per rat daily and water was supplied *ad libitum*. Fecal and urine samples for each rat were analyzed for nitrogen (AOAC, 1960) and energy by standard procedures with a Parr oxygen bomb calorimeter. Data were analyzed in a 2 x 2 x 2 factorial analysis of variance.

TABLE 5. PERCENTAGE COMPOSITION OF BARLEY STARCH AND CORNSTARCH DIETS FED TO RATS, TRIAL I

Ingredients, %	
Starch	61.3
Casein	22.5
Alphacel[a]	5.0
Corn oil	5.0
Vitamin mix[b]	2.2
Mineral mix[c]	4.0

[a] Nutritional Biochemical Company, non-nutritive cellulose.
[b] Nutritional Biochemical Company, Vitamin Diet Fortification Mixture.
[c] Salt mixtures, USP XIV.

TABLE 6. CHEMICAL ANALYSIS OF PURIFIED DIETS FED TO RATS FORMULATED WITH STARCH FROM TITAN AND COMPANA BARLEY ISOGENES AND CORNSTARCH

Item	H_2O	Protein	E.E.	Ash	Ca	P
	%	%	%	%	%	%
Corn	7.9	19.8	6.4	3.1	.42	.23
Titan long-awn covered	6.8	20.5	6.3	3.1	.43	.28
Titan short-awn covered	6.9	20.0	6.0	3.2	.42	.28
Titan long-awn hulless	7.0	19.8	7.2	3.0	.43	.29
Titan short-awn hulless	7.3	19.7	6.4	3.1	.43	.28
Compana long-awn covered	7.3	19.8	6.0	3.2	.46	.28
Compana short-awn covered	6.0	19.7	5.9	3.2	.44	.26
Compana long-awn hulless	6.0	19.5	6.3	3.2	.43	.23
Compana short-awn hulless	8.1	19.6	6.6	3.1	.45	.28

Trial II

Isonitrogenous, isocaloric 10.5% protein diets were prepared from whole barley isogenes and corn (table 7). Proximate analysis and calcium and phosphorus composition of diets are shown in table 8. Barley diet protein was adjusted with cornstarch and zein was added to the corn diet. The number or rats fed, the parameters measured, and the method of analyses were the same as in trial I. The corn diet was deleted from this metabolism study as the rats would not eat the minimum amount consumed by those fed the barley diets.

TABLE 7. PERCENTAGE COMPOSITION OF WHOLE GRAIN DIETS FED TO RATS. TRIAL II

Ration	TLAC	TSAC	TLAH	TSAH	CLAC	CSAC	CLAH	CSAH	CORN
Barley	77.21	85.37	75.00	81.40	69.10	73.43	64.82	64.82	--
Corn	--	--	--	--	--	--	--	--	83.35
Cornstarch	11.59	3.43	13.80	7.40	10.70	15.37	23.98	23.98	--
Corn oil	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.50
Vitamin mix[a]	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
Mineral mix[b]	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Zein	--	--	--	--	--	--	--	--	2.95
Alphacel[c]	--	--	--	--	--	--	--	--	4.00

[a] Nutritional Biochemical Company, vitamin diet fortification mixture
[b] Salt mixture, USP XIV.
[c] Nutritional Biochemical Company, non-nutritive cellulose.

TABLE 8. PROXIMATE ANALYSIS, CALCIUM AND PHOSPHORUS COMPOSITION OF RAT DIETS FORMULATED WITH TITAN AND COMPANA BARLEY ISOGENES AND CORN. TRIAL II

Item	H_2O	Protein	E.E.	C.F.	Ash	Ca	P
	%	%	%	%	%	%	%
Corn	6.7	10.4	7.1	4.7	4.7	.58	.46
Titan long-awn covered	6.3	10.5	6.4	3.5	5.4	.60	.48
Titan short-awn covered	6.2	10.6	6.5	4.1	5.8	.61	.50
Titan long-awn hulless	6.1	10.8	6.4	2.1	5.3	.59	.52
Titan short-awn hulless	6.2	10.5	6.8	3.8	5.8	.63	.54
Compana long-awn covered	6.2	10.8	6.3	2.8	5.0	.58	.51
Compana short-awn covered	6.3	10.9	6.6	3.2	5.1	.56	.52
Compana long-awn hulless	5.9	10.5	6.4	1.3	4.7	.56	.52
Compana short-awn hulless	6.1	10.5	6.4	1.3	4.8	.56	.52

Trial III

Fifty-seven crossbred pigs weighing approximately 45.5 kg were stratified in two replications for sex, initial weight, litter, and assigned to one of five rations consisting of Titan barley isogenes or corn. Five or six pigs were allotted to ten, 4.6 x 9.14 meter pens equipped with self-feeders and automatic waterers housed in a heated and ventilated total confinement facility with slotted floors. Rations were ground to a medium fineness and fed as a meal *ad libitum*. Composition and analysis are given in tables 9 and 10. Pigs were weighed and feed consumption was measured weekly, and removed individually at approximately 90.9 kg. Average daily gains were computed for individual pigs and analyzed by least-squares method (Harvey, 1960) with initial weight as a covariate.

TABLE 9. PERCENTAGE COMPOSITION OF BARLEY[a] AND CORN DIETS FED TO SWINE. TRIAL III

Ingredients, %	Barleys	Corn
Ground barley	93.05	--
Ground corn	--	87.60
Soybean meal, 50%	3.00	7.20
Meat and meal, 50%	1.00	3.00
Limestone	1.25	0.80
Monosodium phosphate	0.70	0.40
Salt	0.50	0.50
Premix[b]	0.25	0.25
Antibiotic[c]	0.25	0.25

[a] Barleys were not adjusted for differences in protein or crude fiber content.

[b] Contained the following in units (vitamin A and D) or mg/kg of premix riboflavin, 1,543; niacin, 8,818; d-pantothenic acid 4,409; choline Cl, 220,460; vitamin B_{12}, 8.8; vitamin A, 1,102,300 USP; vitamin D_3, 220,460 IC; vitamin E, 2,205; vitamin K, 99.2; zinc 30,027; iron, 15,013; manganese, 8,257; copper, 1,651; cobalt, 150; iodine, 225.

[c] 100 grams aureomycin, 100 grams of sulfamethazine and 50 grams of penicillin per 907 kg of complete feed.

TABLE 10. PROXIMATE ANALYSIS AND CALCIUM AND PHOSPHORUS COMPOSITION OF SWINE FINISHING RATIONS FORMULATED FROM TITAN BARLEY ISOGENES AND CORN. TRIAL III

Item	H_2O	Protein	E.E.	C.F.	Ash	Ca	P
	%	%	%	%	%	%	%
Corn	6.9	14.1	3.7	2.5	4.5	.65	.43
Long-awn covered	7.7	14.6	1.6	5.2	4.8	.56	.27
Short-awn covered	7.3	14.3	1.5	4.9	4.7	.56	.33
Long-awn hulless	7.3	15.3	1.7	3.2	5.1	.63	.31
Short-awn hulless	7.4	14.6	1.8	2.5	4.3	.52	.28

RESULTS AND DISCUSSION

Trial I: Isonitrogenous and Isocaloric Starch Diets

No large differences in rate of gain, feed consumption or efficiency of gain were observed in different starch sources (tables 11, 12, 13, 14). Metabolism data supported the growth trial data in that digestible and metabolizable energy and nitrogen were not affected by source of starch. Rats fed short-awn Titan barley starches gained slightly less in the feeding trial, although differences were not statistically significant.

Braybender viscosity curves for Titan and Compana isogenes are presented in figures 1 and 2, respectively. A major increase was noted in the starch viscosity for the Titan short-awn, covered isogene (figure 1). The short-awn isogenes, regardless of hull character, had greater viscosity than the long-awn isogenic lines in the Titan variety. This was not true in the Compana variety, as the long-awn covered isogene had the greatest viscosity on the amylogram (figure 2). These data do not agree with that reported by Goering, Eslick and De Haas (1970). They noted very little difference in Braybender amylograms of starches from the short-awn hulless and covered Titan isogenes. They reported higher viscosity curves for the hulless isogenes, whereas, in the present study the covered isogenes showed the greater viscosity in both varieties.

There were no correlations between amylograms and animal performance because there was no difference in the latter due to diet starch.

TABLE 11. PERFORMANCE OF RATS FED DIETS PREPARED FROM TITAN AND COMPANA BARLEY STARCHES. TRIAL I[a]

Variety	Titan	Compana
No. animals	64	65
Avg. gain, g	89.4	91.9
Avg. feed, g	232.9	237.3
Avg. feed/gain ratio	2.65	2.58
Balance trial		
Observations/diet	28	31
Met. energy, %	91.3	91.3
Dig. energy, %	94.0	94.0
Met. nitrogen, %	38.5	35.1
Dig. nitrogen, %	96.2	96.4

[a]Least squares means.

TABLE 12. PERFORMANCE OF RATS FED TITAN AND COMPANA BARLEY STARCH ISOGENES. LONG-AWN VS. SHORT-AWN[a], TRIAL I

Variety	Titan		Compana	
Isogene	Long-awn	Short-awn	Long-awn	Short-awn
No. animals	33	31	34	31
Avg. gain, g	89.4	89.3	92.8	91.2
Avg. feed, g	232.1	233.8	238.6	236.0
Avg. feed/gain ratio	2.67	2.63	2.58	2.59
Balance trial				
Observations/diet	14	14	14	15
Met. energy, %	91.6	91.0	91.1	91.5
Dig. energy, %	94.2	93.9	93.8	94.1
Met. nitrogen, %	39.9	37.2	34.2	36.1
Dig. nitrogen, %	96.2	96.1	96.4	96.5

[a]Least square means.