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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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

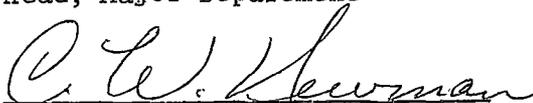Animal Science

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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 I. 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 I. 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.

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 drasti-
cally 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 struc-

ture 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 per-
formance 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 con-
tained a higher percentage of the 17 amino acids studied than did the
low sorghum grain. Nutritive value of the protein of low protein sorg-
hum 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 COMPAÑA 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 individ-
ually 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 pro-
cedure (Harvey, 1960) with initial weight as a covariate. The data in-
cluding 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. Composi-
tion and analysis are given in tables 9 and 10. Pigs were weighed and
feed consumption was measured weekly, and removed individually at approx-
imately 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.

TABLE 13. PERFORMANCE OF RATS FED TITAN AND COMPANA BARLEY STARCH ISOGENES, HULLESS VS. COVERED. TRIAL I[a]

Variety	Titan		Compana	
Isogene	Hulless	Covered	Hulless	Covered
No. animals	31	33	32	33
Avg. gain, g	90.0	88.8	91.6	92.4
Avg. feed, g	234.0	231.8	237.8	236.7
Avg. feed/gain ratio	2.61	2.69	2.60	2.57
Balance trial				
Observations/diet	13	15	15	15
Met. energy, %	91.2	91.3	91.7	90.9
Dig. energy, %	94.0	94.1	94.2	93.8
Met. nitrogen, %	37.3	39.8	35.5	34.8
Dig. nitrogen, %	96.1	96.2	96.4	96.4

[a]Least square means.

TABLE 14. PERFORMANCE OF RATS FED TITAN AND COMPANA BARLEY ISOGENE STARCHES AND CORNSTARCH DIETS. TRIAL I[a]

Variety	TLAC	TSAC	TLAH	TSAH	CLAC	CSAC	CLAH	CSAH	CORN
No. animals	16	17	17	14	17	16	17	15	17
Avg. gain, g	89.9	87.5	88.9	91.1	92.7	92.0	92.8	90.2	90.3
Avg. feed, g	231.5	232.3	232.7	235.2	239.1	234.5	238.2	237.6	242.5
Avg. feed/gain ratio	2.72	2.66	2.63	2.60	2.60	2.55	2.57	2.63	2.69
Balance trial									
Obervations/diet	7	8	7	6	7	8	7	8	7
Met. energy, %	91.4	91.2	91.7	90.6	90.9	91.0	91.2	92.0	90.1
Dig. energy, %	93.9	94.1	94.4	93.5	93.7	93.8	93.8	94.4	93.5
Met. nitrogen, %	42.3	34.2	37.0	38.2	35.3	35.5	32.7	36.4	34.7
Dig. nitrogen, %	96.2	96.2	96.2	96.1	96.6	96.2	96.2	96.7	96.3

[a]Least squares means.

Figure 1. Braybender amylograms for starch from the Titan isogenes.

Figure 2. Braybender amylograms for the starches from the Compana isogenes.

Trial II: Isonitrogenous Grain Diets

Rats fed Titan barley gained faster (P <.01), consumed more feed (P <.01), and were more efficient (P <.01) than those fed the Compana barley and corn diets (table 15). This difference was probably due to the greater percentage of the essential amino acids in the Titan isogenes (table 2). Rats fed the Compana barley diets gained faster, consumed more feed, and were more efficient than those fed corn diets (P <.01) (table 15). Protein efficiency ratios followed the same pattern as the efficiency and gain data (P <.01) (table 15).

Length of awn, within variety, had no statistically significant effect on the parameters measured (table 16). However, there were significant interactions between varieties for the awn characters effect on feed consumption (P <.01) and gain (P <.01). Rats fed Titan short-awn diets consumed 16.5 g more feed than those fed Titan long-awn diets, whereas rats fed Compana short-awn diets consumed 8.7 g less feed than those fed Compana long-awn diets. This difference was reflected in rates of gain, as rats that consumed the most feed gained the fastest.

Rats fed covered barleys in both varieties gained faster and consumed more feed (P <.05) (table 17). Average feed efficiency and PER values were not statistically different because of the hull character; but these parameters were superior, on the average, for those rats fed the covered barleys.

The average digestible energy (DE), metabolizable energy (ME), and digestible nitrogen (DN) of the Titan isogenes were less than that of the Compana isogenes (P <.01). However, rats fed the Titan isogenes retained more nitrogen than those fed Compana isogenes, although the difference was not statistically significant (table 15).

A significant interaction (P <.01) for DN occurred between variety and hull character (table 17). Covered Titan isogenes had a greater percentage of DN (non-significant), whereas in the Compana variety, the hulless isogene has a greater percentage of DN (P <.05). This trend was also noted for the metabolizable nitrogen (MN) (P <.1).

A significant interaction (P <.05) for DE and ME also occurred between variety and hull character. The hulless isogenes had more available energy in both varieties but the difference was twice as great in the Compana barleys (table 18).

Awn length had no effect on DN or MN. A significant interaction (P <.01) for DE and ME was noted between length of awn and variety (table 16). There were no differences in DE or ME due to awn in the Compana variety but the short-awn isogene in the Titan variety was less digestible (P <.01) for DE and ME than the long-awn isogenes.

The rat performance on each isogenic line and corn is shown in table 18. The differences between varieties, isogenic characters and interactions can be observed. It is of interest to note that the lowest digestible and metabolizable energy values were observed on the Titan

short-awn hulless and covered isogenes. The starch from the latter had

the greatest viscosity (figure 1) followed by the short-awn hulless

starch. Although differences in animal growth in trial I were not

correlated with the amylogram data, there may have been a relationship

with the available energy in the whole grain diets.

The lysine screening method described by Mossberg (1966) was veri-

fied in the data obtained in trial II. The protein percentage difference

obtained with the Udy and Kjeldahl procedures tended to be highest on

those barleys with the greater percentage of lysine per unit of protein

(table 19). Relative gains could have been predicted almost entirely,

using the difference in the percentage of total protein obtained by the

two methods. The greater gains in rats fed covered barleys could also

have been predicted with the method of Mossberg (1966) although only

small differences in lysine and other basic amino acid composition

(table 3) were detected between covered and hulless barleys. This could

possibly be related to the differences in the number of terminal amino

acids and consequently, differences in protein molecular weight in the

covered and hulless barleys.

TABLE 15. AVERAGE PERFORMANCE OF RATS FED TITAN AND COMPANA BARLEY AND CORN DIETS. TRIAL II[e]

Variety	Titan	Compana	Corn
No. animals	65	62	16
Avg. gain, g	57.9^a	46.8^b	26.4^c
Avg. feed, g	257.9^a	234.5^b	200.5^c
Avg. feed/gain ratio	4.53^c	5.09^b	7.00^a
Avg. PER[d]	2.10^a	1.87^b	1.25^c
Balance trial			
Observations/diet	31	28	
Met. energy, %	82.82^b	86.68^a	
Dig. energy, %	84.24^b	88.15^a	
Met. nitrogen, %	44.0^a	41.8^a	
Dig. nitrogen, %	76.9^b	79.6^a	

[a],[b],[c]Means bearing different superscript letters, differ significantly (P < .01).

[d]Protein efficiency ratio.

[e]Least squares means.

TABLE 16. PERFORMANCE OF RATS FED TITAN AND COMPANA ISOGENES. LONG-AWN VS. SHORT-AWN[e]. TRIAL II

| Variety | Titan | | Compana | |
Isogene	Long-awn	Short-awn	Long-awn	Short-awn
No. animals	32	33	30	32
Avg. gain, g	55.9^a	59.8^a	48.5^a	45.2^a
Avg. feed, g	249.7^{ab}	266.2^a	238.8^{bc}	230.1^c
Avg. feed/gain ratio	4.52^b	4.55^b	4.99^a	5.19^a
Avg. PER[d]	2.09^a	2.11^a	1.90^b	1.84^b
Balance trial				
Observations/diet	16	15	13	15
Met. energy, %	84.7^b	81.0^c	86.4^a	87.0^a
Dig. energy, %	86.0^b	82.5^c	87.8^a	88.5^a
Met. nitrogen, %	44.2^a	43.8^a	42.3^a	41.4^a
Deg. nitrogen, %	76.5^a	77.2^a	78.9^a	80.1^a

a,b,cMeans bearing different superscript letters, differ significantly, (P <.05).

[d] Protein efficiency ratio.

[e] Least square means.

TABLE 17. PERFORMANCE OF RATS FED TITAN AND COMPANA ISOGENES. HULLESS
          VS. COVERED. TRIAL II[e]

| Variety | Titan | | Compana | |
Isogene	Hulless	Covered	Hulless	Covered
No. animals	33	32	31	31
Avg. gain, g	55.5[b]	60.2[a]	44.7[d]	49.0[c]
Avg. feed, g	250.9[a]	265.2[b]	226.2[c]	242.7[a]
Avg. feed/gain ratio	4.60[a]	4.47[a]	5.19[b]	4.99[b]
Avg. PER[f]	2.07[a]	2.13[a]	1.86[b]	1.88[b]
Balance trial				
Observations/diet	14	17	15	13
Met. energy, %	83.9[b]	81.7[c]	89.2[a]	83.9[b]
Dig. energy, %	85.5[b]	83.0[c]	90.7[a]	85.4[b]
Met. nitrogen, %	41.7[ab]	46.1[a]	43.3[ab]	40.3[b]
Dig. nitrogen, %	76.1[c]	77.7[c]	80.9[a]	78.1[b]

[a,b,c,d] Means bearing different superscript letters, differ significantly,
(P <.05), except those means reported in Met. nitrogen which differ
significantly, (P <.1).

[f] Protein efficiency ratio.

[e] Least square means.

TABLE 18. PERFORMANCE OF RATS FED TITAN AND COMPANA BARLEY ISOGENES
            AND CORN DIETS. TRIAL II[a]

Variety	TLAC	TSAC	TLAH	TSAH	CLAC	CSAC	CLAH	CSAH
No. animals	15	17	17	16	15	16	15	16
Avg. gain, g	61.7	59.1	50.5	60.6	48.2	49.6	48.7	40.8
Avg. feed, g	265.7	265.7	234.8	267.2	238.4	246.5	239.2	213.9
Avg. feed/gain ratio	4.31	4.60	4.71	4.49	4.96	5.05	5.04	5.35
Avg. PER[b]	2.20	2.06	1.99	2.15	1.88	1.88	1.92	1.78
Balance trial								
Observations/ diet	9	8	7	7	6	7	7	8
Met. energy, %	83.5	79.8	85.9	82.1	84.2	83.8	88.6	90.2
Dig. energy, %	84.6	81.3	87.5	83.6	85.8	85.2	89.9	91.8
Met. nitrogen, %	47.0	45.0	41.0	42.7	38.8	41.6	45.5	41.3
Dig. nitrogen, %	78.8	76.5	74.1	78.1	77.8	78.2	80.1	82.0

[a]Least square means.
[b]Protein efficiency ratio.

TABLE 19. RELATIONSHIP OF UDY DYE BINDING CAPACITY AND KJELDHAL PROTEIN
            DETERMINATION WITH THE LYSINE CONTENT AND RAT PERFORMANCE.
            TRIAL II

Diet	Lysine	Percentage Protein, dry matter			Gain, g
		Udy -	Kjeldahl =	Difference	
TLAC	3.5	15.9	14.6	0.7	61.7
TSAC	3.6	15.2	13.3	1.9	59.1
TLAH	3.5	15.4	15.0	0.4	50.5
TSAH	3.2	13.2	13.9	-0.7	60.6
CLAC	2.7	16.7	16.7	0.0	48.2
CSAC	3.1	16.1	15.5	0.6	49.6
CLAH	2.9	15.1	17.2	-2.1	48.7
CSAC	2.7	16.0	17.5	-1.5	40.8

Trial III: Titan Isogenes Fed to Swine

Data obtained from the swine feeding trial with the four Titan isogenes and corn control diets are shown in table 20. Animals fed the short-awn covered barley gained significantly less (P <.05) than those fed the other four diets. Pigs fed the long-awn covered barley diet performed equally as well as those fed the hulless long- and short-awn isogenic diets. Data in table 21 compares the isogene counterparts, covered vs. hulless; long-awn vs. short-awn. This analysis indicated that the reduction of gain and efficiency was due to the short-awn gene when associated with the covered character. It is again of interest to note, that the Titan covered short-awn starch had the greatest viscosity in the amylogram (figure 1) and may have been correlated to the available energy in the starch.

The results with the covered and hulless barleys were not in complete agreement with the findings of Joseph (1924), Gill et al. (1966), Newman et al. (1968) and Newman et al. (1970). However, Joseph (1924) and Gill et al. (1966) fed diets to pigs prepared from hulless and covered barleys of completely different genotype. The hulless Compana fed in the work of Newman et al. (1968) was derived from a different donor parent (Stamm) for the hulless character than for the hulless Titan (Sermo) fed in this study. Isogenic covered and hulless Glacier were found to have equal value in terms of pig gain, feed consumption and efficiency (Newman et al. 1968). There were no differences in gains during the growing phase of

the work with covered and hulless Compana reported by Newman et al.
(1970); however, a significant difference, in favor of the pigs fed the
hulless isogene was noted during the finishing period (45 kg - 90 kg).
The hulless Compana fed by these authors was derived from the same
parentage (Stamm) as was the earlier work (Newman et al., 1968).

A significant interaction occurred between sex and hull character
(table 22). The females fed the hulless diets had greater average
daily gains (P <.05) than those fed the other three isogenic diets with
respect to sex. There is no explanation for this, other than it happened
per chance.

TABLE 20. COMPARISON OF TITAN BARLEY ISOGENES WITH CORN IN SWINE
FINISHING RATIONS. TRIAL III

Isogene	Hulless		Covered		
	Long-awn	Short-awn	Long-awn	Short-awn..	Corn
No. animals	12	12	11	11	11
Avg. daily gain^c, kg	.79^a	.79^a	.80^a	.72^b	.82^a
Avg. daily feed, kg	3.03	2.94	3.16	3.07	3.05
Avg. feed/gain ratio	3.97	3.86	4.01	4.26	3.72
Avg. PER^d	1.65	1.78	1.71	1.65	1.91

[a,b]Means bearing different superscript letters, differ significantly,
(P <.05).
[c]Least square means.
[d]Protein efficiency ratio.

TABLE 21. COMPARISON TO TITAN BARLEY ISOGENES IN SWINE FINISHING RATIONS.
          COVERED VS. HULLESS: LONG-AWN VS. SHORT-AWN. TRIAL III

Ration	Covered	Hulless	Long-awn	Short-awn
No. animals	22	24	23	23
Avg. daily gain, kg	.75	.76	.78[a]	.74[b]
Avg. daily feed, kg	3.11	2.99	3.09	3.01
Avg. feed/gain ratio	4.13	3.91	3.99	4.05
Avg. PER[c]	1.68	1.71	1.68	1.71

[a,b]Means in the same line bearing different superscript letters, differ
significantly (P <.05).

TABLE 22. EFFECT OF SEX ON THE ISOGENIC DIETS. TRIAL III

Isogene	Hulless		Covered	
	Female	Male	Female	Male
No. animals	10	14	10	12
Avg. daily gains, kg[a]	.86[b]	.72[c]	.76[c]	.76[c]

[a] Least square means.
[b,c]Means bearing different superscript letters, differ significantly,
(P <.05).

SUMMARY

Two rat feeding and metabolism trials and one swine feeding trial were conducted to evaluate the nutritional value of four isogenes of Titan and four isogenes of Compana barley and corn. Only the Titan isogenes were fed to the swine. No differences were observed between purified starch diets as measured by rat performance in terms of gain, feed consumption, feed efficiency, nitrogen and energy digestibility and retention. Whole-grain diets prepared from Titan barleys were superior to those prepared from Compana barleys in rat feeding trials. The Titan barleys had an average lower digestible and metabolism energy and digestible nitrogen than the Compana barleys. However, rats fed Titan consumed more feed in the feeding trial and thus retained more total energy and nitrogen than rats fed the Compana. Covered barleys were superior for feeding rats in this trial according to results based on weight gain. Significant interactions were noted in the metabolism trials between variety and the hull and awn characters.

There was reduced gain and feed efficiency in pigs fed the short-awn covered Titan isogene diet. On the average, the covered barleys produced gains equal to those produced by pigs fed the hulless barleys. This performance was not in complete accordance with the findings of earlier research at Montana and Oregon.

These findings revealed differences in protein and starch composition between barley varieties and genotypes within varieties. The chemical composition was in certain aspects, related to the morphological

characteristics studied and the nutritional value for rats and swine.
Further acquisition of data of this nature will aid the barley
geneticists in developing barleys that will be of superior nutritional
value and more closer meet the nutritional needs of animals.

APPENDIX A

APPENDIX TABLE I. MEAN SQUARES OF DATA FROM PURIFIED BARLEY STARCH DIETS
FED TO RATS. TRIAL I

Source of variation	Degree of freedom	Gain	Feed consumed	Feed/ gain
Total	129			
Variety (A)	1	228.2954	609.6719	14.1524
Awn (B)	1	22.4556	6.5265	1.0094
Hull (C)	1	1.7542	83.0331	1.6507
Replication	1	8.8701	2638.7498	36.5795
A X B	1	16.6625	147.1479	2.0903
A X C	1	36.0775	8.9529	8.2639
B X C	1	12.3208	66.6741	4.0982
Covariate	1	4.1178	1955.7441	27.6514
Error	120	150.8586	428.9504	9.7543

APPENDIX TABLE II. MEAN SQUARES OF DATA FROM PURIFIED BARLEY STARCH DIETS
AND CORNSTARCH DIETS FED TO RATS. TRIAL I

Source variation	Degree of freedom	Gain	Feed consumed	Feed/ gain
Total	146			
Diets	8	51.6223	224.2272	4.9671
Replication	1	54.6826	2499.1660	20.9665
Covariate	1	39.1667	2639.5483	12.5998
Error	135	101.2654	418.3994	9.0635

APPENDIX TABLE III. MEAN SQUARES COMPUTED FROM ENERGY BALANCE OF BARLEY
STARCH DIETS. TRIAL I

Source of	Degrees of freedom	Metabolizable energy	Digestible energy
Total	58		
Variety (A)	1	.02567	.0594
Awn (B)	1	.07659	.0000
Hull (C)	1	1.2263	.5821
A X B	1	3.7874	1.5682
A X C	1	2.6568	.8271
B X C	1	.0004	.2185
Error	51	88.8293	.9603

APPENDIX TABLE IV. MEAN SQUARES COMPUTED FROM NITROGEN BALANCE OF BARLEY
STARCH DIETS. TRIAL I

Source of variation	Degrees of freedom	Metabolizable nitrogen	Digestible nitrogen
Total	56		
Variety (A)	1	163.0429	.8935
Awn (B)	1	2.5269	.0013
Hull (C)	1	10.6647	.0409
A X B	1	74.7818	.0927
A X C	1	34.5516	.0358
B X C	1	239.7122	.6608
Error	49	83.8527	.7256

APPENDIX TABLE V. MEAN SQUARES COMPUTED FROM ENERGY BALANCE OF BARLEY
STARCHES AND CORNSTARCH DIETS. TRIAL I.

Source of variation	Degrees of freedom	Metabolizable nitrogen	Digestible nitrogen
Total	65		
Diets	8	2.3427	.8447
Replications	3	1.5494	.9015
Error	53	1.9691	1.2592

APPENDIX TABLE VI. MEAN SQUARES COMPUTED FROM NITROGEN BALANCE OF BARLEY
STARCH DIETS. TRIAL I

Source of variation	Degrees of freedom	Metabolizable nitrogen	Digestible nitrogen
Total	62		
Diets	8	49.7748	.3077
Replications	3	423.9767	.5435
Error	50	58.1369	.8022

APPENDIX TABLE VII.   MEAN SQUARES OF DATA FROM WHOLE BARLEY DIETS FED TO
                      RATS.   TRIAL II

Source of variation	Degree of freedom	Gain	Feed consumed	Feed/ gain	PER
Total	128				
Variety (A)	1	38.6405[a]	17512.5508[a]	9.9414[a]	1.6723[a]
Awn (B)	1	.0259	491.2229	.4233	.0176
Hull (C)	1	6.4741[b]	7540.9688[b]	.8759	.0534
Replication	1	14.0824	1911.6072[a]	7.4462[a]	1.2851[a]
A X B	1	4.0243[c]	4973.4336[b]	.2625	.0466
A X C	1	.0138	34.4982	.0289	.0124
B X C	1	.2953	.2324	.1619	.0725
Covariate	1	.2.0927	5784.5586	.0389	.0055
Error	118	1.2278	1190.4502	.2968	.0470

[a] $P < .01$
[b] $P < .05$
[c] $P < .1$

APPENDIX TABLE VIII.   MEAN SQUARES OF DATA FROM WHOLE BARLEY DIETS AND
                       CORNSTARCH FED TO RATS.   TRIAL II

Source of variation	Degree of freedom	Gain	Feed consumed	Feed/ gain	PER
Total	143				
Diets	8	19.3696[a]	8730.3203[a]	13.6623[a]	1.2015
Replications	1	14.6044[a]	1513.2131	13.5809[a]	1.4853
Covariate	1	.2.4424	6962.9258[b]	.1393	.0024
Error	132	1.0398	1106.6992	.3588	.0402

[a] $P < .01$
[b] $P < .05$

APPENDIX TABLE IX.   MEAN SQUARES COMPUTED FROM ENERGY AND NITROGEN BALANCE. TRIAL II

Source of variation	Degree of freedom	Metabolizable energy	Digestible energy	Metabolizable nitrogen	Digestible nitrogen
Total	59				
Variety (A)	1	217.2371[a]	222.8641[a]	67.7107	101.4263[a]
Awn (B)	1	34.7041[a]	28.2288[a]	6.7795	11.4662
Hull (C)	1	212.3225[a]	224.0079[a]	5.4659	6.3937
A X B	1	69.8026[a]	67.6861[a]	.7811	.4483
A X C	1	36.4555[a]	29.7352[a]	189.3059	72.6523[b]
B X C	1	2.6741	2.9369	7.2443	57.3125[b]
Error	51	3.4789	3.3389	50.1388	11.5093

[a] P < .01
[b] P < .05

APPENDIX TABLE X.   MEAN SQUARES COMPUTED FROM ENERGY AND NITROGEN BALANCE OF BARLEY AND CORNSTARCH DIETS.   TRIAL II

Source of variation	Degree of freedom	Metabolizable energy	Digestible energy	Metabolizable nitrogen	Digestible nitrogen
Total	59				
Diets	7	85.5342[a]	86.9723[a]	55.9263	39.8169
Replications	1	1.4361	1.5865	68.3240	42.4022
Error	50	3.4684	3.2254	49.1023	11.3351

[a] P < .01

APPENDIX TABLE XI.   MEAN SQUARES OF AVERAGE DAILY GAIN DATA FROM SWINE FED TITAN BARLEY ISOGENES.   TRIAL III

Source of variation	Degree of freedom	Average Daily gain
Total	46	
Hull (A)	1	.0368
Awn (B)	1	.0857[b]
Sex (C)	1	.2588[a]
Replications	1	.0262
A X B	1	.0732[b]
A X C	1	.2746[a]
B X C	1	.0001
Covariate	1	.0583
Error	37	.0180

[a] P < .01
[b] P < .05

APPENDIX B

Analytical Procedures: Macro-Kjeldahl

Principle: The sample is digested with sulfuric acid and a catalyst to convert all nitrogen to ammonium sulfate. It is then boiled with an excess of sodium hydroxide to neutralize the acid and release the ammonium which is distilled into boric acid. The ammonia becomes ammonium borate which is titrated with hydrochloric acid of known strength.

Reagents:

1. Sulfuric Acid - concentrated.

2. Catalyst - 3.2 parts copper sulfate and 100 parts sodium sulfate.

3. Sodium Hydroxide - 50% sodium hydroxide. (500 g sodium hydroxide pellets per liter).

4. Boric Acid - 4% boric acid plus indicator. (40 g boric acid per liter dissolved with moderate heat). Cool and then 5 ml of methyl red indicator is added.

5. Methyl Red - 200 mg methyl red are put in 50 ml of ethyl alcohol and diluted to 100 ml with distilled water.

6. Hydrochloric Acid - 0.1 hydrochloric acid standardized.

Procedure:

One to two g of feed are placed in an 800 ml Kjeldahl flask (a blank is included), also 10 g of the catalyst, 25 ml concentrated hydrosulfuric acid, and glass beads are added. The contents within the Kjeldahl flask is digested until clear (about 45 minutes), then cooled and 250 ml of distilled water added and mixed well. It is cooled again. Fifty ml of 4% boric acid (containing indicator) is measured into a 500 ml erlenmyer flask and placed under the condenser making sure the condensing

tube extends below the liquid level. To the cooled digestion flask, 75 ml of 50% sodium hydroxide mixture is added slowly to layer the sodium hydroxide beneath the acid and sample. The flask is connected to the condenser without agitation and then mixed. The water line is turned on to cool the condenser. Then the burner is turned on and approximately 150 ml of distillate is collected. The contents in the erlenmyer flask are titrated with 0.1 Normal hydrochloric acid to endpoint.

Calculations:

$$\% \text{ protein} = \frac{\text{ml HCl used x N or HCl x meq wt of N x protein factor x 100}}{\text{sample weight in grams}}$$

meq weight of nitrogen = .014

protein factor for feeds = 6.25

Inorganic Phosphate: Adapted for Feeds   - Fisk and Subbarow

Reagents:

1. 10% Trichloroacetic Acid (TCA): Dissolve 10 grams of TCA
    in distilled water and dilute to 100 ml.

2. Molybdate Solution: Dissolve 25 g. of ammonium molybdate
    in about 200 ml of distilled water. In a liter flask,
    place 300 ml of 10 normal sulfuric acid. Add the molybdate
    solution and dilute with washings to 1 liter with distilled
    water.

3. Aminonaphtholsulfonic Acid Reagent (ANS): Place 195 ml of
    15% sodium bisulfite in a glass cylinder. Add 0.5 g of
    1, 2, 4 ANS. Add 5 ml of 20% sodium sulfite. Mix with
    magnetic stirrer. If the solution is not complete, add
    more sodium sulfite (1 ml at a time to avoid excess).
    Transfer to a brown bottle and store in refrigerator.
    Keeps about 4 weeks.

5. 15% Sodium Bisulfite: 30 gms of sodium hydrosulfate added
    to 200 ml of distilled water. If turbid, allow to stand
    several days, then filter.

6. 20% Sodium Sulfite: 20 grams sodium sulfite diluted to
    100 ml. Filtered if necessary.

7. Standard Phosphate Solution: Dissolve exactly 0.351 g of
    pure, dry monopotassium phosphate in distilled water.
    Add 10 ml of 10 N hydrogen sulfate and dilute to 1 liter
    with distilled water. There is 0.4 mg phosphorus in 5 ml
    stable.

8. Working Phosphate Standard: Dilute 5 ml of the above to
    50 ml with 10% TCA. This is 0.04 mg standard.

Procedure:

Ten g of feed samples are ashed and dissolved with 2 Normal
hydrochloric acid and diluted to 100 milliliters. The 10 ml of the
above are diluted again to 100 ml, 1 ml of this is used for the test
(d.f. 1000). The sample is placed in a 25 ml volumetric flask. One
ml of molybdate solution is added and mixed; 0.4 ml ANS is added and
mixed. It is diluted to the mark and let stand 15 minutes. The optical
density is read at 700.

For the blank sample, 1 ml molybdate and 0.4 ml ANS are added and mix in order. Then the sample is diluted to the mark.

For the standard sample, 5 ml of 0.04 mg phosphorus standard is used, to which 1 ml molybdate and 0.4 ml ANS are added and mixed, in order. The sample is then diluted to the mark.

Calculations:

$$\frac{Optical\ density\ unknown}{Optical\ density\ Standard} \times concentration\ of\ Standard\ in\ mg \times 1000\ d.f. = mg\ P$$

$$mg\ P\ to\ \frac{g\ \ P}{sample\ wt\ in\ grams} \times 100 = \%\ P$$

Calcium Determination: Adapted for Feeds

"Newer Methods of Nutritional Biochem."

Reagents:

1. Stock diluent: Dissolve with moderate heat 50 g of manganous sulfate in about 600 ml water in a liter flask. Cool and add 350 ml of concentrated sulfuric acid. When solution is thoroughly cool, dilute to 1 liter with water.

2. Stock Standard Permanganate: Dissolve 3.5 g of potassium permanganate in 1 liter of the stock diluent (0.1 N). Refrigerate.

3. Working Permanganate Standard: Dilute 4 ml of the stock permanganate to 100 ml with the stock diluent.

4. Ammonium Hydroxide Solution: Dilute 2 ml of concentrated ammonia with water to 100 ml.

5. Ammonium Oxalate Solution: Dissolve 2 g of ammonium oxalate in 100 ml of water.

6. Nitric Acid Solution: Dilute 50 ml of concentrated nitric acid with water to make 100 ml (approximately 8 Normal).

7. Stock Standard Calcium: 175.8 mg of calcium acetate are dissolved in 100 ml water. This stock contains 1.758 mg of calcium acetate per ml or .4 mg of calcium per ml.

8. Working Standards: .01 mg calcium per ml is made by diluting 25 ml of stock up to 100 ml with water. 0.2 mg caclium per ml is made by diluting 50 ml of stock up to 100 ml with water.

Procedure:

A 10 g feed sample is ashed and diluted to 100 ml. Then 10 ml are removed and diluted to 100 ml again. Two ml of this final dilution are used for the test. Four ml of 2% ammonium oxalate are added to Standard 1 -- 1 ml of 0.1 mg. calcium standard, Standard 2 -- 1 ml of 0.2 mg calcium standard, and a blank -- 5 ml of .004 Normal potassium permangante. These are mixed and allowed to stand 30 minutes or longer. Then they are centrifuged for 10 minutes at 3,000 revolutions per minute. The supernatant is poured off and allowed to drain 5 minutes on filter paper. Three ml of dilute ammonia are added in such a way as the first amount disturbs the precipitate and the remaining amount washes down the sides of the tube. It is then mixed well. Again the samples are

centrifuges for 10 minutes at 3,000 revolutions per minute. The super-
natant is poured away and drained 5 minutes on filter paper. The
precipitate is dissolved in 0.1 ml of 8 Normal nitric acid. Five ml
of the dilute potassium permanganate is added to the Standards, samples
and blank. They are mixed and allowed to stand 30 minutes. The Optical
Density is read at 540.

Calculations:

$$\text{mg sample} = \frac{\text{O.D. Blank-O.D.Unknown}}{\text{O.D. Blank-O.D. Standard}} \times \text{concentration of Standard}$$

mg sample x 500 d.f. = mg caclium

$$\frac{\text{grams calcium}}{\text{weight in gms}} \times 100 = \% \text{ calcium}$$

Operation of the Adiabatic Oxygen Bomb Calorimeter

Preparation:

a. Feed and fecal samples should be air-dry (8-12% moisture) and finely ground prior to pelleting in pelleting press. Use no more than 1.1 grams of material per pellet.

b. Urine samples should be dried on cotton of known heat of combustion prior to burning in the bomb. (Cotton need not be pelleted). Use 1 ml of urine per sample.

Procedure:

Add exactly 2,000 g of distilled water to the bucket of the calorimeter. Place the weighed pelleted sample into the copper capsule, which is in turn, placed into the holder of the bomb head. Attach 10 cm of fuse wire to the electrodes on the bomb head, passing the wire just above the sample in the capsule. Then wet the rubber gasket surrounding the head of the bomb to assure a good seal; place bomb head into the body of the bomb. Tighten the screw down onto the bomb by hand. Place the bomb into the clamp and attach to it, the oxygen hose. Then, by regulating the valve on the oxygen bottle, allow not more than 20 atmospheres to go into the bomb. If more than 20 atmospheres are allowed to escape into the bomb, remove the oxygen hose from the bomb, release the oxygen by pushing down on the pressure release valve at the top of the bomb. Then refill the bomb. Once the bomb is filled to desired pressure, submerge the bomb into the bucket. Connect the wire from the bucket electrode to the bomb head. Lower the bucket into the body of calorimeter. Swing the cover of the calorimeter into place and allow the cover to drop down onto the body. Lower the thermometers into the calorimeter and start the motor which activates the two stirring propellors, one of which is in the bucket, and the other in the jacket of the calorimeter. Inject cold or hot water into the calorimeter to equilabrate the jacket temperature with that of the bucket. Once this temperature has been reached, allow it to stand for 5 minutes to make sure the temperature has been equalized. Then record this temperature and discharge the bomb by pressing the button on the ignition box. Then add hot water slowly to the jacket, to relatively the same temperature as it rises within the bucket. Take readings at one minute intervals for three minutes after the temperature appears to have stabilized. Record the final temperature. Shut the motor off and wait a few seconds for the water to clear in the cover of the calorimeter. Lift the thermometers up and swing cover off the body of the calorimeter and remove bucket. Remove

the bomb from within the bucket and release the residual pressure from
the bomb. After removing the bomb head, examine the copper capsule to
make sure complete combustion occurred. Measure the wire that was not
burned and record the length. Flush out the bomb and lid of the bomb
into the beaker and titrate.

Calculations:

$$H = \frac{t(W) - e_1 - e_2}{m}$$

where: H - heat of combustion in calories per g
        t - temperature rise in degrees F
        m - mass of sample in g
        e_1 - correction in cal for heat formation in nitric acid.
        e_2 - correction in cal for heat formation in wire fuse.

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