1968

Dried Whey, Fish Solubles in Growing-Finishing Swine Rations and Effects of Distillers Dried Grains with Solubles on Ration Digestibility

Craig S. German

DRIED WHEY, FISH SOLUBLES AND DISTILLERS DRIED GRAINS WITH SOLUBLES IN GROWING-FINISHING SWINE RATIONS AND EFFECTS OF DISTILLERS DRIED GRAINS WITH SOLUBLES ON RATION DIGESTIBILITY

BY

CRAIG S. GERMAN

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Animal Science, South Dakota
State University

1968

DRIED WHEY, FISH SOLUBLES AND DISTILLERS DRIED GRAINS WITH SOLUBLES IN GROWING-FINISHING SWINE RATIONS AND EFFECTS OF DISTILLERS DRIED GRAINS WITH SOLUBLES ON RATION DIGESTIBILITY

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Animal Science Department Date

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Dr. R. C. Wahlstrom, Professor in Animal Science, for his guidance and supervision during the conduction of the study and the preparation of this manuscript.

The author's gratitude is extended to Dr. O. E. Olson and the staff of Station Biochemistry for their work on the chemical analysis of the feed and fecal samples.

Acknowledgment is also made to all those who helped collect the fecal samples and did the feeding and pen cleaning.

The author is deeply indebted to Dr. W. L. Tucker for his invaluable help with the statistical analysis of the data.

Appreciation is also extended to Janice German, wife of the author for her encouragement and assistance throughout the project and during the preparation of this thesis, and to Mrs. Carole Schwartz for typing this manuscript.

CSG

TABLE OF CONTENTS

LIST OF TABLES

Table

Page

Table Page

LIST OF APPENDIX TABLES

INTRODUCTION

Many workers have suggested the possibility of an unidentified growth factor(s) in certain feed ingredients. Feeding trials conducted to determine the effect of unidentified growth factor sources on growth rates have produced inconsistent results. One of the biggest problems has been the isolation and identification of the compound responsible for the growth stimulus often obtained when unidentified growth factor sources are fed. Empirical fractionations have been done with some unidentified growth factor sources. Growth stimulation has been reported with various fractions extracted with different organic solvents, with a water extract as well as the ash of growth factor sources.

The most common sources of unidentified growth factors are the by-product feeds, although claims have been made that these factors are also present in grass juices and dehydrated alfalfa meal. The by-product feeds are mainly from three industries - the beverage distillers, the cheese manufacturers and the fish processors. Their by-products are distillers dried solubles, distillers dried grains with solubles, dried whey and condensed fish solubles. These by-products are rich sources of many of the B-complex vitamins; often they contain more of these vitamins than the primary product. At one time these by-products were used as vitamin supplements in livestock feeds.

If these by-product do contain an unknown, required nutrient, the use of various sources of the unidentified growth factors might

result in more efficient conversion of feed to pork. However, the method by which the unidentified growth factor supplements produce a growth stimulus is not yet known. It is possible that they contain an unknown vitamin or a mineral not yet recognized as essential. Some workers have suggested that these feeds supplement a ration to provide a more optimum balance of known nutrients. Perhaps they affect ration digestibility so that animals can more efficiently use the nutrients in the ration.

The reasons for undertaking this study were:

(1) To determine the effect of distillers dried grains with solubles, dried whey and condensed fish solubles on the average daily gains and feed efficiency of growing-finishing swine.

(2) To determine the effect of distillers dried grains with solubles on ration digestibility when fed at levels of 5, 10 and 20 percent of the ration.

REVIEW OF LITERATURE

The standard swine ration used today is a corn-soybean meal ration that is fortified with minerals, commercially synthesized vitamins and antibiotics. Any other feedstuff added to this basic diet must significantly improve performance to justify its presence. Prior to the isolation and identification of the nutrients known as vitamins, nutritionists found that certain ingredients, when added to supposedly adequate purified diets, improved growth rates and feed efficiency. However, they did not know how or why this happened. A similar situation presently exists concerning unidentified growth factors (UGF). However, the results of feeding trials to determine the effects of UGF have not been conclusive and researchers have not yet been able to isolate and identify this unidentified factor(s).

Feeding trials

Feeding trials are the major tool used to determine the effects of various feed additives on growth rate and feed efficiency. If a feedstuff provides consistent beneficial effects then it is considered as an acceptable ingredient in practical rations.

Fairbanks et al. (1944) added 6% distillers dried solubles (DDS) or 12% distillers dried grains with solubles to a basal ration of corn, wheat flour middlings, soybean meal, tankage, fish meal, minerals and fortified cod liver oil. These rations were fed as creep feeds and there were no differences in rate of gain to weaning. After weaning, the pigs on the basal ration failed to grow normally. The

distillers by-products did provide a growth stimulus, and DDS produced a greater stimulus than did distillers dried grains with solubles. The basal diet was believed to supply adequate amounts of vitamins A, D, B_1, B_6, niacin, pantothenic acid and riboflavin.

Using the same basal diet as Fairbanks, Krider et al. (1944) reported the results of supplementing this ration with DDS and alfalfa meal. Both of these sources of UGF produced increased growth rates in growing-finishing swine. By assay the basal ration was adequate in pantothenic acid, niacin and riboflavin. The following four reasons were given as a possible explanation for the poor performance on the basal ration:

(1) the growing-finishing pig may have required more of the known vitamins than recommended at that time;

(2) there was a possibility that the basal ration was deficient in one or more known or unknown factors;

(3) the basal ration may have contained less vitamins than thought due to the lack of refined vitamin assays to accurately assess rations;

(4) these workers thought that possibly the synthetic vitamins used in purified diets used to assess vitamin requirements were more available than the vitamins in natural feedstuffs.

The addition of crystalline B vitamins to a basal ration of corn, soybean meal, tankage, fish meal, minerals and fortified cod liver oil provided a greater growth rate increase than either 6% of added DDS or 10% of added alfalfa meal. The average daily gains were

0.79, 0.93, 1.17 and 1.12 pounds for the basal, DDS, added B vitamins and alfalfa meal rations, respectively. These were the results of trials with growing and finishing pigs reported by Fairbanks et al. (1945).

Krider et al. (1949) reported the results of adding dried whey or alfalfa meal to a basal ration of corn, soybean meal and 5% meat scraps for weanling pigs. The low level of lactose (below 2%) present in the dried whey was laxative; however, the laxative effect did not seem harmful to the pigs since pigs receiving dried whey grew faster than pigs on the basal ration. The growth stimulation of dried whey was thought to be due to the presence of a B vitamin group which these authors called a B_2 vitamin complex. The growth response from the alfalfa meal was also thought to be due to the same B_2 vitamin complex.

Krider and Terrill (1950) studied the effect of adding fish, distillery and fermentation by-products to drylot rations of weanling pigs. The study compared pigs born and reared to weaning in drylot with pigs born and reared to weaning on pasture then moved to drylot facilites. The control ration was of the same composition as the one used by Fairbanks (1944). The addition of 5 mg of riboflavin per pound of ration produced a greater and more consistent response in pigs raised in drylot since birth and indicated a greater vitamin deficiency than in pigs born and reared to weaning on pasture. Several fish products, alfalfa meal and dried corn distillers solubles were the UGF sources studied. The addition of any of the UGF sources stimulated average daily gains in all pigs. Dried corn distillers solubles and

fish solubles produced larger growth increases than the addition of riboflavin to the basal ration. The conclusion drawn was that the growth response to UGF was due to the water-soluble vitamin content of the various by-products.

The addition of 1 or 2% fish solubles to a basal diet of corn, soybean oil meal, alfalfa meal and minerals significantly increased average daily gain, with the 2% level of fish solubles providing the largest stimulation (Geurin et al., 1950). These workers concluded that the basal ration was deficient in some factor or factors and that the fish solubles added some essential non-protein factor which greatly improved the value of the corn-soy diet for growing and finishing swine.

Oxytetracycline and oxytetracycline plus cod liver mycelium added to a corn-soy basal were the only two treatments that significantly improved the average daily gain of weanling pigs in the first trial of a study reported by Noland et al. (1955). In the second trial including fish solubles in the basal ration increased growth rates. A water or fat soluble fraction of cod liver mycelium fed at a level equal to 2% intact mycelium did not produce a growth response while the intact mycelium significantly increased growth rates of the pigs.

Gard et al. (1955) studied the effect of several UGF sources on growth rates of weaned pigs. The basal ration was fortified corn starch and isolated soybean protein. A grass juice concentrate was the only UGF source which produced a consistent significant

improvement in average daily gain. Response to the grass juice concentrate was thought to be caused by estrogens, but an assay found no more than 0.016 mg of estrogen per milliliter of grass juice. Pigs receiving a ration containing 5% dried whey gained significantly faster in one trial and slower in another trial than pigs receiving a control ration without whey. Alfalfa meal fed as 10% of the control ration significantly reduced average daily gain. Neither 3% of added fish solubles nor 10% of added dried brewer's yeast had any effect on growth rate of the pigs.

Several sources of UGF were studied in a 4 week feeding trial with baby pigs by Gage et al. (1961) using a corn, soybean meal and sugar creep feed fortified with B vitamins. Results indicated that distillers dried solubles contained some factor(s), other than that contained in the basal ration, which affected both gain and feed efficiency of the baby pig, the effect being greater on the latter. The addition of trace minerals did not significantly affect the response to DDS; however, there was an indication that the response was less in the absence of trace minerals for the group receiving ashed DDS. Adding 3% of fish solubles to the basal ration improved growth rates and feed efficiency. Fish solubles at increasing levels (0 to 6%) produced a linear improvement in 4 week gain and feed conversion. Since fish solubles and DDS were not used in the same trial a statistical comparison cannot be made, but their effects were nearly the same in separate trials. Another trial of the study was conducted to determine the effect of feeding iodinated casein to baby

pigs. When fed at a level of 150 mg/lb. iodinated casein produced thyrotoxic symptoms. Distillers dried solubles and corn steepwater did not counteract the thyrotoxicity.

Pigs fed isolated soybean protein and soybean oil in a semi-purified diet showed no significant response to the addition of 5% distillers dried solubles or concentrates of DDS. In a second trial corn oil and soybean oil were studied in separate diets. Five percent added DDS or DDS concentrates fed at a level equal to 5% distillers dried solubles had no significant effect on average daily gain or feed efficiency of pigs fed either of these diets. These studies were reported by Green et al. (1961).

Experiments have been conducted to determine the effect of feeding unidentified growth factor sources to chicks and broilers. Norris (1954) tested several sources of unidentified chick growth factors. On a purified diet no improvement in chick growth was obtained by adding arginine, tryptophan or glycine or with increased amounts of trace minerals plus flourine and molybdenum or with doubled quantities of known vitamins. However, adding graded amounts of dried liver with and without fish solubles caused striking increases in growth. This may indicate that the purified diet was deficient in at least two unidentified chick growth factors. A second experiment produced evidence that an unidentified factor was present in distillers dried solubles and this factor was different from the growth factor in fish meal and penicillin mycelia meal. Combining DDS with the sources of the fish solubles factor produced normal growth. In a

third experiment Norris found that at hatching, chicks were occasionally more deficient in the fish solubles factor than in the factor found in distillers dried solubles.

Dam et al. (1957) used antiyeast and antibacterial agents in chick feeds to keep fecal yeast and bacteria counts at zero. Distillers dried solubles, fish solubles and dried whey product fed to chicks devoid of intestinal microorganisms produced a growth response. Combinations of thiotic acid, orotic acid, mevalonic acid and adenosine did not affect growth of chicks with no intestinal microbes. A combination of UGF supplements promoted a growth increase of 26% at 4 weeks of age.

Results of experiments conducted by Summers et al. (1959) indicated that there is no UGF in whey that cannot be supplied with fish solubles. Distillers dried solubles produced a growth response in the absence but not in the presence of penicillin, this tended to indicate a sparing effect between the two. Other trials in this study showed that over supplementation of practical diets with sources of unidentified factors tends to reduce growth rates of chicks.

Lillie et al. (1962) summarized the results of tests conducted over an eight year period. Fish solubles added to chick diets significantly increased growth rates.

Fractionation Studies

If the unidentified growth factor can be isolated, then it can be identified to determine whether or not it is a new nutrient. A

concentrated form of the UGF could make the results of feeding trials more consistent.

Couch et al. (1955) reported the results of their early attempts to concentrate the UGF in distillers dried solubles. The unidentified factor in DDS was destroyed by refluxing in 6N hydrochloric acid (HCl) for 24 hours, but was stable to autoclaving for 30 minutes in 6N HCl or 6N sodium hydroxide. The factor could be extracted, after autoclaving, at a pH of 1, 7 or 11; therefore, the extraction would appear to be independent of pH. The unidentified factor was partially soluble in methanol and insoluble in chloroform. The extracts of distillers dried solubles promoted an increase in chick growth larger than the increase obtained with untreated DDS. The active factor of DDS was water soluble and was precipitated with basic lead acetate or tungstic acid while 80% ethanol failed to precipitate the factor. Experimental results indicated that the ash of distillers dried grains produced a growth response equal to about half the response obtained with intact distillers dried solubles. These workers also tested aluminum, phosphorus, flourine, arsenic, sulfur, cobalt, lead and potassium and found them ineffective in duplicating the response due to DDS ash.

Condensed fish solubles was fractionated by hydrolysis, precipitation, extraction with immiscible solvents and absorption and passage in exchange resins. Murthy et al. (1957) found that the major portion of the active ingredient was in the anion fraction with smaller activities in the cation and deionized fractions, indicating

that the growth response was probably due to both organic and inorganic constituents. The fraction extracted with ether at pH 4.5 and the resulting gummy precipitate were both deleterious to chick growth. In some cases two active fractions added together gave a response considerably lower than either separately. These observations emphasize the importance of taking into consideration the effect of toxic factors present in unidentified growth factor sources while trying to assess the growth activity of fractions.

A growth stimulating component of distillers dried solubles was highly concentrated by a series of extractions with organic solvents in a study by Stelzner et al. (1959). Adding 2.5 gm of an impure isopropanol-insoluble component per kilogram to poult diets resulted in reproducible and statistically significant growth responses of 7 to 9%. A second component which was soluble in isopropanol produced a growth depression in 2 out of 3 experiments. The authors concluded that a toxic substance may have been extracted in the early stages of the extraction since the extraction is purely empirical in nature. Corn distillers dried solubles gave a growth response which averaged 8.2% in 2 of 3 trials, but had little effect (3.1%) in the third.

Couch and Stelzner (1961) autoclaved distillers dried solubles in sulfuric acid then fractionated with acetone, ether and isopropanol: chloroform to obtain an isopropanol: chloroform insoluble concentrate. Another fractionation was made with the only difference being that chloroform was not used in the final step and an isopropanol insoluble

concentrate was obtained. The isopropanol insoluble concentrate fed alone or in combination with 10% distillers dried solubles failed to stimulate growth in turkey poults. In a second trial, however, the insoluble concentrate improved gains 6.8% and when fed with 10% DDS a 23.7% response was obtained. The isopropanol: chloroform insoluble concentrate stimulated growth in two feeding trials. A slight additive effect was obtained by adding 10% DDS or a combination of 10% DDS and the isopropanol insoluble concentrate.

Plumlee et al. (1966) fed rats a purified basal diet containing 200% of NRC levels of vitamins and trace minerals. A benzene soluble extract of the water soluble fraction of corn distillers dried solubles produced a significantly smaller response in growth than other treatments. An ethanol soluble fraction of DDS gave a significantly greater growth response than the ethanol insoluble portion. In another trial with rats both DDS and reconstituted vitamins equal to those in DDS gave small growth increases on a basal diet containing 125% of NRC vitamin and trace mineral levels.

These same workers also reported the results of three experiments conducted with pigs. In experiment one a methanol soluble fraction of distillers dried solubles added to a semi-purified basal diet promoted a 16% increase in rate of gain. The response to DDS, ash of DDS and the methanol insoluble fraction was 11.4, 9.4 and 8.3%, respectively. Experiment two compared vitamin-free or commercial casein fed as 25.8% of the diet. The commercial casein produced 19% greater gains. Either DDS or the methanol soluble fraction improved

gains over the casein basal diets. The improvement in gain was greater on the vitamin-free casein diet. All distillers dried solubles additions improved gains over the vitamin-free casein basal diet in experiment three. The greatest response was 34% with intact distillers dried solubles. Distillers dried grains with solubles gave a 24% increase in rate of gain. Though most of the growth responses with the pigs were large on a percentage basis none were statistically significant.

Ashing fish solubles at 600° C in acid and alkaline conditions caused complete loss of the unidentified growth factor according to Steinke et al. (1961). The factor was reported to be 50% extractable with water and 40% soluble in 50 and 80 percent ethanol. Anion and cation exchange of the water extract indicated that the unidentified factor was a neutral compound. The solubility data indicated that two unidentified growth factors or two forms of the same factor may be present in menhaden fish solubles.

Five UGF sources were used in a mixture by Morrison et al. (1955) in an attempt to determine what component of the UGF sources caused growth responses. Corn distillers dried solubles, fish solubles, grass juice, dried whey product and penicillin mycelium meal were used in the mixture. The authors thought a portion of the growth response was due to a mineral or minerals in the UGF mixture. Added levels of all trace minerals known to be required by the chick or alteration of the Ca and P content of the diet did not influence growth. The authors, therefore, concluded that the active component

of the UGF supplements was a mineral not yet recognized as essential for the chick.

Scott et al. (1955) found that the ash of distillers dried solubles did not significantly affect growth while intact DDS did improve growth rates of chicks. Scott stated that it is conceivable that the balance of the inorganic constituents is important and not the actual unknown mineral; if this is the case, the ash from a single source may not have the balance of minerals as did the ash from the mixture used by Morrison (1955).

A purified diet adequate in all known amino acids, vitamins and minerals was used in a chick growth study by Morrison et al. (1956). A special study gave no evidence of a mineral imbalance. The addition of a mixture of unidentified growth factor supplements produced a growth response. The observed response was thought to be due to the presence of materials of both unidentified organic and inorganic constituents. The unidentified mineral(s) was involved in bone formation, was present in the boiling-water-insoluble portion of the supplement and was cationic in acid solution. There was no consistent effect of the ash upon the intestinal microflora or pH of the intestinal contents of the chicks.

Beeson and Conrad (1957) reported the results of a study of the effect of calcium and zinc levels on the response of young pigs to unidentified growth factors. The calcium level was 0.68% and the zinc level was 72 ppm in the semi-purified basal ration. Good gains were obtained when the pigs were fed the basal ration and the

addition of pepsin, adenosine, divalonic acid, bromine or 5% brewers dried yeast gave little response. When the calcium level was high (1.06%) and parakeratosis was a factor chlortetracycline hydrochloride fed at 25 mg/lb. apparently had little or no effect on the response to unidentified factors. When the levels of these two minerals were brought back into balance the antibiotic may have masked a part of the response to UGF.

Adding extra potassium and zinc to a purified diet produced a growth increase in chicks about equal to the increase from adding distillers dried solubles according to data reported by O'Dell and Savage (1957). When potassium, zinc and distillers dried solubles were fed in combination the resulting growth rate was superior to feeding either potassium, zinc or DDS alone. The authors concluded that their results indicated that zinc can replace part, if not all, of the unidentified minerals in distillers dried solubles.

Robertson and Barnhart (1961) conducted three experiments with young pigs to study the interrelationships between calcium, zinc and dried corn distillers solubles. In one experiment semipurified diets were fed with two levels of calcium, two levels of zinc and with or without corn distillers solubles. No significant differences were observed in rates of gain between treatments. Semipurified diets were used in experiment two. Various levels of calcium (up to 1.31%) were fed without occurrence of parakeratosis, however, the high calcium level did reduce average daily gain. Adding zinc to the high calcium diets improved rates of gain more than adding 5% corn distillers

solubles to these rations. Corn soy diets were fed in experiment three. In this trial the 1.31% calcium diets produced a 50% incidence of parakeratosis. A high calcium diet plus 5% corn distillers solubles resulted in 40% occurrence of parakeratosis but with less severe symptoms. Pigs fed diets with 5% corn distillers solubles gained 13.36% faster and required 15.5% less feed than pigs fed diets without corn distillers solubles. A significant interrelationship was found between calcium and zinc levels, but corn distillers solubles had no interrelationships with the two minerals.

Digestibility Determinations

In many feeding trials information on the digestibility of the experimental rations could help explain the results of the trial. Conventional methods of digestibility studies require individual stalls for each pig; therefore, fewer numbers are usually involved in the study. Under these conditions the digestibility may be different from the ration digestibility for the pigs on the feeding trial. A method whereby the pigs on the feeding trial can be used to collect digestibility data that is at least sufficient to compare the test rations has some advantage. Methods of indirect digestibility determination have been developed using indigestible indicators.

Schurch *et al.* (1952) reported the results of a study of the suitability of chromic oxide as an indicator for determination of digestibility in swine. Fecal samples were collected for four mornings after an initial feeding period. The four samples were composited and analyzed. The apparent digestibility coefficients

obtained by the chromic oxide method agreed very closely with coefficients obtained from a conventional seven day fecal collection.

Another researcher found that chromic oxide excretion reaches equilibrium with intake between three and four days after initial feeding. Experiments conducted by Clawson et al. (1955) found that apparent digestibility coefficients derived from chromic oxide content of feces collected at 8:30 p.m. were about one percentage point lower than digestion coefficients derived from chromic oxide content of feces collected at 5:30 a.m. Coefficients obtained by a conventional method agreed very closely with those determined by chromic oxide content of total 24 hour fecal collections. A highly significant difference was found among digestion coefficients determined with individual pigs self-fed the same ration in one lot.

Luce et al. (1964) conducted a study of using chromic oxide in digestibility determinations. Fecal collections were made at four times during the day; the 8:00 a.m. collection had the lowest digestibility for protein and dry matter in two of five treatments. Differences in digestibility by time of collection were significant, but the treatment by time interaction was not significant. Chromic oxide recovery rates tended to be slightly higher in the morning, but cold weather during the test affected the pigs so that the 8:00 a.m. collection was essentially the same as the 5:00 p.m. collection. The authors concluded that the lack of an interaction of treatment with time tended to indicate that one collection at any time of day would be sufficient for comparing treatments.

PROCEDURES

The eighty-four pigs used in this study were Hampshire X Yorkshire crossbred pigs from the South Dakota State University swine herd. The pigs were stratified by weight and litter and randomly allotted to the treatments; the treatments were randomized to pens to compensate for pen effects. Six pigs were allotted to each treatment and the treatments were equalized for sex. The pigs allotted to replicate one had an average weight of 40.3 pounds and an average age of 65.4 days. Replicate two was allotted one week after replicate one; these pigs had an average weight of 37.6 pounds and were an average of 73.1 days of age.

The pigs were fed ad libitum the rations shown in table 1. Ration A, the control or basal ration, contained 82.4% corn, 15% soybean meal plus vitamin and mineral fortification. Ration B contained 5% dried whey, the proximate analysis of dried whey is given in appendix table 1. Ration C included 7.5% of fish solubles product. This provided 5% fish solubles because the fish solubles product was a combination of two-thirds fish solubles and one-third soybean meal. The proximate analysis of the fish solubles is given in appendix table 3. Five percent whey and 5% fish solubles were combined in ration D. Rations E, F and G contained 5, 10 and 20% distillers dried grains with solubles, respectively. This distillers by-product contained 27% crude protein; the proximate analysis is given in appendix table 2. Adjustments were made in the corn and soybean meal content so that all

Table 1. Composition of Rations (pounds)

Ingredients	Rations						
	A	B	C	D	E	F	G
Ground yellow corn	1648	1556	1660	1573	1589	1526	1406
Soybean meal, 50%	300	294	140	134	260	223	144
Whey		100		100			
Fish solubles product[a]			150	150			
Distillers dried grains with solubles					100	200	400
Ground limestone	15	14	16	11	15	16	19
Dicalcium phosphate	17	16	14	12	16	15	12
Trace mineral salt, (0.8% Zn)	10	10	10	10	10	10	10
Vitamin mix[b]	10	10	10	10	10	10	10
Zinc oxide, gm.	70	70	70	70	70	70	70

[a] The fish solubles product was two-thirds fish solubles and one third soybean meal.

[b] Furnished by Merck and Company, supplied the following per ton of complete feed: Vitamin A, 3,000,000 I.U.; Vitamin D, 300,000 I.U.; riboflavin, 1 gm.; vitamin B_{12}, 16 mg.; pantothenic acid, 5 gm.; niacin, 15 gm.; choline 100 gm.; antibiotic, 20 gm. (Pro-Strep).

rations had a calculated crude protein content of approximately 15 percent.

The pigs were housed in the west wing of the main barn at the swine unit. These facilities provided inside sleeping quarters approximately 8 feet wide and 9 feet long and a concrete outside pen about 8 feet wide and 10 feet long. The inside pens were bedded with straw at all times and space heaters in the building provided extra heat during very cold weather. Self-feeders were placed in the outside pens and the automatic water fountains were located in the inside pens. Weights were taken on the pigs biweekly until they neared 200 pounds. At this time the weights were taken each week because the pigs were

removed from the experiment when each pig reached a weight of at least 200 pounds. One exception to this procedure was that a single pig was never left in a pen, that is, the slowest gaining pig was removed from the test regardless of his weight when the next slowest gaining pig weighed 200 pounds.

Digestibility was determined by the chromic oxide indicator method. Rations A, E, F and G were the diets studied to determine the effect of distillers dried grains with solubles on ration digestibility. Chromic oxide was added as 0.5% of the feed and the feed was thoroughly mixed. After mixing, four samples were taken at random from each ration. The chromic oxide feeds were initially fed on Thursday morning and fecal collections began on Saturday morning. At the first collection period samples were taken on Saturday morning only. At the second collection period samples were taken on Saturday and Sunday mornings. The first collection was made on December 9, 1967 and the second collection was made on the weekend of January 6 and 7, 1968. Collections were made at 7:00 a.m. on each morning. Samples were collected individually from each pig in replicate one. For the collections the pigs were left in their pens, and the samples were collected by hand. This method was necessary since these pigs were used for the growth and feed efficiency study and putting them in collection crates would have been expected to affect the feeding trial results. Most samples were collected without their touching the floor. For replicate two composite pen samples were collected. Six composite samples were taken for each pen. These were collected from the pen floor.

Whenever possible samples were taken which had not been saturated with urine. Any straw in the samples was removed after drying. All feed and fecal samples were dried in a force-air drying oven at 70° C for 48 hours. Feed samples were ground through a 2 millimeter screen in a Wiley mill. The hard corn endosperm could not be ground completely, but it was pulverized sufficiently for the chemical analysis. The fecal samples were ground in a small CRC pulverizer since sample loss was too large in the Wiley mill. This provided a satisfactory sample for analysis.

A colorimetric procedure was used for chromic oxide analysis. The chromic oxide was precipitated during digestion with nitric acid and heat. Color development and chromic oxide solution was achieved by heating the digested material in the presence of 70% perchloric acid. Color intensity was read on an Evelyn colorimeter with a 440 mu filter. Samples were read against a perchloric acid and water blank. The chromic oxide content was calculated by first calculating an L value, which is equal to 2-log of the galvanometer reading, for each galvanometer reading. A value, K, was calculated from readings on solutions of known chromic oxide concentration. The K value of a standard solution is equal to the milligrams of chromic oxide per flask divided by the L value of that solution. K values were calculated for several known chromic oxide solutions and then averaged. This average K value is used to calculate the percent chromic oxide in the feed and fecal samples.

$$\% \, Cr_2O_3 \text{ in sample} = \frac{K \times L}{(\text{sample wt. in gm.}) \quad (10)}$$

All analytical procedures were standard AOAC procedures (Official Methods of Analysis of the Association of Official Agricultural Chemists, ninth edition, 1960). All samples were tested for moisture to determine the hygroscopic water content. The samples were also analyzed for ash, crude protein, crude fiber and ether extract. Nitrogen free extract (NFE) was obtained by difference. Chromic oxide, ash, crude protein, crude fiber, ether extract and NFE percentages were adjusted to a moisture free basis. Apparent digestibility coefficients were calculated according to the following equation.

$$\text{Dig.} = 100 - \left(100 \times \frac{\% \text{ indicator in feed}}{\% \text{ indicator in feces}} \times \frac{\% \text{ nutrient in feces}}{\% \text{ nutrient in feed}}\right)$$

The average daily gain data were analyzed by analysis of variance with the least squares method. Least squares was used because two pigs were removed from the test. The apparent digestibility coefficient data were analyzed by standard analysis of variance methods since numbers were equal between treatments. Data from individual and composite samples were separately analyzed for variability within and between treatments. Multiple regression and correlations were performed on fecal chromic oxide and nutrient content data to determine their combined effect on the calculated apparent digestibility coefficients. Fecal chromic oxide content of samples collected on the first and second days of collection in period two were tested for variability to determine whether chromic oxide excretion was less

variable within treatments on the second day of collection. When significant differences were obtained for a given set of data Dunnett's "t" procedure was used to determine which treatments were significantly different (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Growth Study

The addition of dried whey, fish solubles, a combination of dried whey and fish solubles or distillers dried grains with solubles to the control ration did not significantly affect the average daily gain of the pigs used in this study. Table 2 gives the mean squares from the analysis of variance for final weight, days on test and average daily gain. While there was no significant treatment effect on average daily gain, there was a significant difference ($P < .05$) between replicates for average daily gain.

Table 2. Least Squares Analysis of Variance for Final Weight, Days on Test and Average Daily Gain

Source of variation	df	mean squares		
		Final weight	Days on test	Average daily gain
Treatment	6	77.73	22.64	0.03
Rep	1	421.94*	487.20**	0.20*
Treatment x Rep	6	47.07	30.47	0.02
Error	68	129.40	45.93	0.03
Total	82			

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

The difference in average daily gain between replicates was probably due to the difference in weight for age at the start of the test. The pigs in replicate one were an average of 65.4 days old and weighed an average of 40.3 pounds and the pigs in replicate two had an average weight of 37.6 pounds at an average of 73.1 day of age.

It would, therefore, appear that the pigs on replicate one were more thrifty at the time the experiment was initiated since they had a better rate of gain to this time. This faster rate of gain was maintained throughout the experiment and is demonstrated in the significant difference in growth rate and days on test between replicates. The difference in final weight between replicates was significant ($P < .05$). This was due to the procedure of removing the slowest growing pig from each lot at the same time as the next slowest growing pig weighed 200 pounds. In replicate two the slowest growing pig in each pen weighed less than the slowest growing pig in each pen in replicate one.

The production data is shown in table 3. In replicate one, pigs receiving ration E which contained 5% distillers dried grains with solubles gained 0.10 pound per day faster than pigs receiving the control ration and required 0.27 pound less feed per pound of gain. This is in agreement with the work of Fairbanks et al. (1944) who reported that 12% distillers dried grains with solubles added to a ration of corn, wheat middlings, tankage and fish meal produced a nonsignificant increase in average daily gains of weaned pigs. Pigs fed ration G containing 20% distillers dried grains with solubles had the slowest daily gains in both replicates. The increasing levels of distillers dried grains with solubles reduced the calculated lysine content of the feed from 0.65% for ration A to 0.51% for ration G. This could have produced an imbalance in the amino acids which would tend to retard growth rates and decrease feed efficiency. The crude

Table 3. Results of the Feeding Trial

Item	Treatments A	B	C	D	E	F	G
				Rep 1			
No. of pigs	6	6	6	6	6	6	6
Initial weight, lb.	40.3	40.5	39.7	40.3	40.5	40.5	40.5
Final weight, lb.	204.8	200.8	201.2	203.2	210.3	203.3	201.2
Average daily gain, lb.	1.79	1.71	1.76	1.77	1.89	1.77	1.72
Feed efficiency	3.36	3.20	3.11	3.16	3.09	3.19	3.60[b]
Average days on test	92.3	94.5	92.3	92.3	90.0	92.3	93.5
				Rep 2			
No. of pigs	6	6	6	6	6	6	4[a]
Initial weight, lb.	37.5	37.7	37.5	37.7	37.5	37.5	39.5
Final weight, lb.	198.0	202.3	201.5	198.3	201.3	194.7	195.5
Average daily gain, lb.	1.68	1.78	1.64	1.64	1.69	1.67	1.56
Feed efficiency	3.06	3.33	3.14	3.18	3.30	3.15	3.57[c]
Average days on test	96.3	93.5	100.7	98.8	97.8	95.2	100.5

[a] Six pigs started and two were removed because of disease. Data represents four pigs.

[b,c] Means bearing superscripts are significantly different from the control treatment A.

Table 4. Analysis of Variance for Feed Efficiency on a Pen Basis

Source of variation	df	mean square
Treatment	6	0.07*
Replicate	1	0.00
Residual	6	0.01
Total	13	

*$P < .05$

fiber content of the feed also increases as increasing amounts of distillers dried grains with solubles are added (appendix table 5), adding 20% distillers dried grains with solubles to the control ration increased the crude fiber content of the rations by 36.87%. This resulted in lowering the energy content of the rations and could account for reduced growth rates with the higher levels of distillers dried grains with solubles. Both of these factors probably were involved in the lower average daily gain and feed efficiency of pigs fed this ration.

In replicate two, pigs fed ration B containing 5% dried whey gained at the faster rate while in replicate one ration B did not affect average daily gain. This trend was nearly the same as that reported by Gard et al. (1955) who found that pigs receiving a ration containing 5% dried whey gained significantly faster in one trial and slower in another trial than pigs receiving a control ration without dried whey.

Analysis of variance of pen feed efficiency (table 4) found a significant difference ($P < .05$) between treatments with pigs receiving ration G having a significantly reduced feed efficiency. The amino acid imbalance and increased crude fiber level discussed above may have caused the depressed feed efficiency.

The vitamin premix used in the rations of this experiment contained the antibiotic Pro-Strep. The presence of the antibiotic may have masked some of the response to the UGF sources. Beeson and Conrad (1957) reported that the addition of chlortetracycline hydrochloride to test rations reduced the response to the UGF sources

studied. Also, Summers et al. (1959) found that distillers dried solubles fed to chicks produced a growth response in the absence but not in the presence of penicillin.

Digestibility Determinations

The individual fecal samples were collected at 7:00 a.m. on each morning that samples were taken. The apparent digestion coefficients for samples taken at this time are probably higher than if the samples had been taken at a later time since the feed was in the digestive tract of the pig all night. Luce et al. (1964) studied ration digestibility by the chromic oxide method. Fecal collections were made at several times during the day and no treatment by time interaction existed which led them to conclude that one collection during the day would be sufficient to compare treatments. This was why collections were made at one time during the day. The morning was chosen since collection would be easier.

Collection period one - individual fecal samples. The apparent digestion coefficients are listed in table 5 and the analysis of variance mean squares are given in table 6. The first fecal collection was made on December 9, 1967. The pigs had been on test 16 days and averaged 81 days of age.

The apparent digestibility of crude protein was significantly different ($P < .01$) between treatments, rations containing any level of distillers dried grains with solubles had lower apparent digestion coefficients than the control ration. The reduction in digestibility

Table 5. Apparent Digestion Coefficients (in percent) for the Pigs and Treatment Averages for Individual Samples of Collection Period One[1]

Sex	Treatment A	E	F	G
		Crude Protein		
Barrow	80.32	76.70	76.82	69.78
Barrow	84.33	72.52	71.50	59.66
Barrow	79.64	65.94	71.43	72.32
Gilt	76.06	69.05	72.55	73.98
Gilt	77.58	74.46	73.07	67.80
Gilt	73.56	68.35	79.27	70.13
Average	78.58	71.17[a]	74.11[a]	68.95[a]
		Dry Matter		
Barrow	82.82	83.51	82.32	78.20
Barrow	85.48	80.41	81.38	67.81
Barrow	83.95	74.96	77.06	75.78
Gilt	77.25	78.25	77.41	78.81
Gilt	82.49	82.68	81.49	76.44
Gilt	81.63	80.48	77.49	78.27
Average	82.27	80.05[a]	79.53[a]	75.89[a]

[1] All values are given on moisture free basis.

[a] Means bearing superscripts are significantly different from control treatment A.

Table 6. Analysis of Variance for Chromic Oxide and Nutrient Content of the Feces and Apparent Digestion Coefficients for Individual Samples of Collection Period One

Source of Variation	df	Mean Squares: Chromic Oxide Content of the Feces	Mean Squares: Nutrient Content of the Feces	Mean Squares: Apparent Digestion Coefficient
		Crude Protein		
Treatment	3	0.38*	0.02	1.04**
Sex	1	0.05	0.13	0.01
Treatment x Sex	3	0.18	0.07	0.24
Residual	16	0.10	0.04	0.16
Total	23			
		Dry Matter		
Treatment	3	0.38*	0.00	0.42*
Sex	1	0.05	0.01	0.00
Treatment x Sex	3	0.18	0.00	0.16
Residual	16	0.10	0.01	0.10
Total	23			

*P < .05
**P < .01

Table 7. Average Chromic Oxide and Nutrient Content of the Individual Fecal Samples for Collection Period One

	Treatments: A	E	F	G
	%	%	%	%
Crude Protein	22.78	25.38	21.97	22.78
Dry Matter	92.82	93.69	93.44	93.84
Chromic Oxide	2.74	2.53	2.49	2.13

of crude protein was largest between treatments A and G, the control ration had an apparent digestion coefficient of 78.58% compared to 68.95% for ration G which contained 20% distillers dried grains with solubles. Rations E and F which contained 5 and 10% distillers dried grains with solubles, respectively, had apparent digestion coefficients of 71.17 and 74.11%. The crude protein content of the feces was not different between treatments (table 7).

Dry matter apparent digestibility was significantly ($P < .05$) depressed by all levels of distillers dried grains with solubles. The reduction in digestibility was as much as 7.76% from treatment A to treatment G. The decrease in digestibility was almost linear with apparent digestion coefficients of 82.27, 80.05, 79.53 and 75.89% for 0, 5, 10 and 20% levels of distillers dried grains with solubles, respectively. The fecal dry matter content was not significantly different between treatments, the differences represent the differences in digestibility.

The differences in apparent digestibility may be due, at least in part, to the decrease in lysine content of the diet with increasing levels of distillers dried grains with solubles. The calculated lysine content of ration A was 0.65% and for ration G 0.51%. The lower lysine content with the increasing levels of the distillers by-product could have depressed the crude protein digestibility as well as the digestibility of other ration components. Also, the crude fiber content of the feed increased from 2.26% to 3.58% by adding 20% of distillers dried grains with solubles to the control ration. This

increase in crude fiber could also have depressed ration digestibility, especially for these young pigs. This would agree with work reported by Pond et al. (1962) that increasing the crude fiber content of a low protein ration from 4.5 to 8.7% significantly reduced the apparent digestibility of dry matter, NFE and crude protein for growing and finishing pigs.

The chromic oxide content of the feces was significantly different ($P < .05$) between treatments. The treatment means were 2.74, 2.53, 2.49 and 2.13% for treatments A, E, F and G. This difference is expected with the significant differences in ration digestibility. As different amounts of nutrients are absorbed by the pigs the amount of concentration of the chromic oxide will be different.

Ether extract and crude fiber were also analyzed for this first set of samples. The apparent digestion coefficients varied radically and many were negative. The amount of these components in the feed was small (2.3 - 4.2%) and any errors in analysis would be magnified when the digestion coefficients were computed. The analysis of variance for chromic oxide and nutrient content of the feces is given in appendix table 4. Nitrogen free extract values were also calculated for these samples and the analysis of variance mean squares are shown in appendix table 4. NFE digestibility was significantly decreased ($P < .05$) by treatments E, F and G.

Collection period one - composite fecal samples. These samples were collected from pigs in replicate two after they had been on test 9 days and were an average of 82 days old. The composite samples were

collected to determine whether or not they would show the same trends in apparent digestibility as found by the individual fecal samples. The apparent digestion coefficients for the composite samples and the treatment averages are given in table 8 and the analysis of variance mean squares are shown in table 9. The composite samples showed essentially the same trends in digestibility as the individual fecal samples. Ration E containing 5% distillers dried grains with solubles had a higher digestion coefficient for crude protein than ration A while rations F and G had lower coefficients. Treatment means were 71.80, 72.46, 65.29 and 65.20% for rations containing 0, 5, 10 and 20% distillers dried grains with solubles, respectively. These differences were significant ($P < .01$). There were nonsignificant differences in fecal crude protein content which reflect the differences in digestibility. Some of the feces in the composite fecal samples were contaminated with urine. Thus it is possible that urinary nitrogen may have caused the higher fecal crude protein in the composite than in the individual samples. The average crude protein content of the composite feces was 24.94% and of the individual fecal samples 23.72%. This resulted in the lower apparent digestion coefficients for the composite samples with a range of 72.46% to 65.20% compared to a range of 78.58% to 68.95% for the individual fecal samples.

Dry matter apparent digestibility was significantly different ($P < .01$) between treatments with means of 79.58, 80.78, 76.71 and 74.17% for treatments A, E, F and G, respectively. Treatment G which contained 20% distillers dried grains with solubles had the

Table 8. Apparent Digestion Coefficients (in percent) for Composite Samples and Treatment Averages for Collection Period One

Sample Number	Treatments			
	A	E	F	G
		Crude Protein		
1	71.29	74.25	62.63	69.58
2	72.43	72.97	66.89	67.15
3	70.92	73.77	68.04	60.68
4	69.96	75.96	66.98	65.28
5	75.60	72.46	61.87	65.28
6	70.61	65.36	65.35	68.01
Average	71.80	72.46	65.29[b]	65.20[b]
		Dry Matter		
1	77.66	81.78	75.52	75.63
2	76.76	81.19	78.55	73.37
3	78.97	82.13	78.31	71.08
4	80.06	85.02	77.28	74.39
5	84.09	80.02	73.69	76.07
6	79.94	74.50	76.91	74.46
Average	79.58	80.78	76.71	74.17[b]

[b] Means bearing superscripts are significantly different from control treatment A.

Table 9. Analysis of Variance for Chromic Oxide and Nutrient Content of the Feces and Apparent Digestion Coefficients for Composite Samples of Collection Period One

Source of Variation	df	Mean Squares: Chromic Oxide Content of the Feces	Nutrient Content of the Feces	Apparent Digestion Coefficients
			Crude Protein	
Treatment	3	0.45**	5.24	95.27**
Residual	20	0.07	2.60	9.69
Total	23			
			Dry Matter	
Treatment	3	0.45**	6.56	52.79**
Residual	20	0.07	2.18	6.33
Total	23			

**P <.01

Table 10. Average Chromic Oxide and Nutrient Content of the Composite Fecal Samples of Collection Period One

	Treatments: A	E	F	G
	%	%	%	%
Crude Protein	25.65	24.88	25.59	23.64
Dry Matter	90.91	92.27	92.65	93.41
Chromic Oxide	2.32	2.60	2.15	1.95

significantly lower dry matter digestibility as determined by Dunnett's procedure. There were differences in fecal dry matter content (table 10) which essentially reflect the differences in digestibility, but these differences were nonsignificant. The results obtained with the composite samples showed essentially the same trends in ration digestibility as the results from the individual fecal samples.

The chromic oxide content of the feces was significantly different ($P < .01$) between treatments with means ranging from 2.60% for treatment E with 5% distillers dried grains with solubles to 1.95% for treatment G which contained 20% distillers dried grains with solubles.

Collection period two day one - individual fecal samples. These samples were collected on January 6, 1968 after the pigs had been on test 44 days and were an average of 109 days of age. The apparent digestion coefficients and treatment averages are given in table 11; the analysis of variance mean squares are shown in table 12. The differences in apparent crude protein digestibility were not significant. Ration F containing 10% distillers dried grains with solubles had the highest average crude protein digestibility of 77.85% and those fed ration E which contained 5% distillers dried grains with solubles had the second highest digestibility of 76.41%. The control ration A had an average coefficient of 75.33% and the lowest average apparent digestion coefficient for crude protein was 72.46% for pigs receiving ration G which contained 20% distillers dried grains with solubles. The differences in the crude protein content of the feces

Table 11. Apparent Digestion Coefficients (in percent) for the Pigs and Treatment Averages for Individual Samples of Collection Period Two-Day One

Sex	Treatments A	E	F	G
		Crude Protein		
Barrow	77.99	79.94	79.41	75.00
Barrow	82.69	77.63	76.87	67.86
Barrow	82.13	73.75	75.44	72.45
Gilt	61.21	75.50	80.40	71.43
Gilt	71.67	77.72	78.31	75.71
Gilt	72.28	73.93	76.67	72.30
Average	75.33	76.41	77.85	72.46
		Dry Matter		
Barrow	81.05	80.49	79.23	77.58
Barrow	82.65	82.26	78.21	71.59
Barrow	83.57	78.18	76.24	73.85
Gilt	66.13	80.93	78.79	74.89
Gilt	72.48	80.85	80.76	77.77
Gilt	81.00	79.93	78.98	73.83
Average	77.81	80.44	78.70	74.92

Table 12. Analysis of Variance for Chromic Oxide and Nutrient Content of the Feces and Apparent Digestion Coefficients for Individual Samples of Collection Period Two-Day One

Source of Variation	df	Mean Squares: Chromic Oxide Content of the Feces	Mean Squares: Nutrient Content of the Feces	Mean Squares: Apparent Digestion Coefficients
			Crude Protein	
Treatment	3	0.40*	6.84	31.27
Sex	1	0.17	2.65	37.57
Treatment x Sex	3	0.41*	0.94	53.04
Residual	16	0.08	2.30	13.17
Total	23			
			Dry Matter	
Treatment	3	0.40*	2.64**	31.95*
Sex	1	0.17	1.04*	14.35
Treatment x Sex	3	0.41*	0.45	39.73*
Residual	16	0.08	0.20	9.82
Total	23			

*P < .05
**P < .01

Table 13. Average Chromic Oxide and Nutrient Content of the Individual Fecal Samples for Collection Period Two-Day One

	Treatments: A	E	F	G
	%	%	%	%
Crude Protein	20.12	22.19	19.78	20.83
Dry Matter	93.24	92.89	94.17	94.20
Chromic Oxide	2.59	2.81	2.64	2.20

were also nonsignificant with means ranging from 22.19% for treatment E down to 19.78% for treatment F.

The apparent digestibility of dry matter was significantly ($P < .05$) different between treatments with means of 77.81, 80.44, 78.70 and 74.92% for 0, 5, 10 and 20% levels of distillers dried grains with solubles. As was true with crude protein digestibility pigs receiving rations E and F had slightly higher apparent digestibilities for dry matter than pigs fed rations A and G and pigs fed ration G had the lowest apparent digestibility of dry matter. The treatment times sex interaction was significant ($P < .05$). The barrows had higher digestion coefficients in treatment A while in treatments E, F and G the gilts had higher digestion coefficients.

The treatment by sex interaction was probably a result of the significant difference between treatments ($P < .01$) and between sexes ($P < .05$) for fecal dry matter content. The treatment averages for fecal dry matter were 93.24, 92.89, 94.17 and 94.20% for treatments A, E, F and G, respectively (table 13). Fecal dry matter content was 93.84% for barrows and 93.42% for the gilts, although this was a very small difference it was statistically significant ($P < .05$).

The chromic oxide content of the feces was significantly different ($P < .05$) between treatments (table 13) with means of 2.59, 2.81, 2.64 and 2.20% for 0, 5, 10 and 20% levels of distillers dried grains with solubles. The treatment by sex interaction was significant ($P < .05$) with the barrows having higher fecal chromic oxides in treatment A while the gilts had higher values in treatments E, F and G.

This was the same as the trend in digestion coefficients for the treatment by sex interaction for apparent dry matter digestibility. The interaction for fecal chromic oxide may have contributed to the significant treatment by sex interaction of dry matter digestibility since the calculated digestion coefficients are highly dependent upon the percent of chromic oxide in the feces. The within treatment variability for chromic oxide content of the feces was relatively large, especially for treatment A where one gilt had 1.60% fecal chromic oxide compared to a high of 3.26% thus the digestion coefficients for that gilt (table 11) were the lowest in the pen. Presumably, equilibrium for chromic oxide excretion had not been reached on the morning of the third day after initial feeding of the chromic oxide feeds. Clawson et al. (1955) reported that chromic oxide excretion reaches equilibrium with intake between three and four days after initial feeding of the chromic oxide feed. During this collection period there was an extreme cold period and this probably reduced feed consumption since the feeders were outside and the pigs did not go out to eat very often, thus the time required to reach equilibrium of chromic oxide excretion would be lengthened.

None of the samples from collection period two were analyzed for ether extract or crude fiber. Therefore, NFE could not be calculated for these samples.

Collection period two day one - composite fecal samples. The pigs had been on test 37 days at the time of this collection and were an average of 110 days old. The apparent digestion coefficients are

Table 14. Apparent Digestion Coefficients (in percent) for Composite Samples and Treatment Averages for Collection Period Two-Day One

Sample Number	Treatments			
	A	E	F	G
		Crude Protein		
1	72.96	72.57	76.30	70.37
2	77.98	70.43	76.03	68.07
3	73.14	71.92	71.96	72.61
4	74.73	65.67	73.83	66.00
5	73.48	63.75	75.15	74.82
6	71.92	42.97	72.01	67.46
Average	74.03	64.55[b]	74.21	69.89
		Dry Matter		
1	78.42	77.77	80.19	72.73
2	80.50	75.30	79.73	73.16
3	78.94	75.62	75.90	73.97
4	79.07	74.93	76.96	68.93
5	78.81	74.31	79.24	75.92
6	79.01	52.21	77.85	69.62
Average	79.12	71.69[b]	78.31	72.39

[b] Means bearing superscripts are significantly different from control treatment A.

Table 15. Analysis of Variance for Chromic Oxide and Nutrient Content of the Feces and Apparent Digestion Coefficients for Composite Samples of Collection Period Two-Day One

Source of Variation	df	Mean Squares: Chromic Oxide Content of the Feces	Mean Squares: Nutrient Content of the Feces	Mean Squares: Apparent Digestion Coefficients
			Crude Protein	
Treatment	3	0.57**	7.80*	123.85**
Residual	20	0.07	1.83	35.92
			Dry Matter	
Treatment	3	0.57**	1.87**	90.37*
Residual	20	0.07	0.31	27.72
Total	23			

*P < .05
**P < .01

Table 16. Average Chromic Oxide and Nutrient Content of the Composite Fecal Samples of Collection Period Two-Day One

	Treatments: A	E	F	G
	%	%	%	%
Crude Protein	22.35	23.36	22.41	20.63
Dry Matter	92.67	93.67	93.34	93.97
Chromic Oxide	2.56	2.08	2.57	1.99

listed in table 14 and the analysis of variance mean squares are given in table 15.

A highly significant difference ($P < .01$) was found between treatments for apparent crude protein digestibility. The average apparent digestion coefficient for crude protein in ration E containing 5% distillers dried grains with solubles was 64.55%. This was significantly lower than the mean crude protein digestion coefficient for the control treatment A of 74.03% while the average apparent crude protein digestion coefficients for treatment F (74.21%) and treatment G (69.89%) were not significantly different from the control as determined by Dunnett's procedure. The crude protein content of the feces was significantly different ($P < .05$) between treatments with means of 22.35, 23.36, 22.41 and 20.63% for 0, 5, 10 and 20% levels of distillers dried grains with solubles, respectively. The average apparent digestion coefficient for crude protein obtained with the individual samples (75.51%) was higher than obtained with the composite fecal samples (70.67%). The difference was probably due to the presence of urinary nitrogen in the composite samples.

Ration E which contained 5% distillers dried grains with solubles also had a significantly ($P < .05$) lower apparent digestibility of dry matter. Treatment A had the highest average dry matter digestibility (79.12%) compared to treatments F (78.31%) and G (72.39%), these differences were nonsignificant. The dry matter content of the feces was significantly different ($P < .01$) between treatments

(table 16). Means ranged from 93.97% for treatment G to 92.67% for treatment A.

There was a highly significant ($P<.01$) difference in chromic oxide content of the fecal samples between treatments with means of 2.56, 2.08, 2.57 and 1.99% for treatments A, E, F and G, respectively. The within pen variability of chromic oxide content of the individual samples was relatively large and since the calculated digestion coefficients were so dependent on fecal chromic oxide content the digestion coefficients were quite variable within pens. The composite samples were less subject to variability of fecal chromic oxide since each sample represented more than one pig.

Collection period two day two - individual fecal samples. Apparent digestion coefficients are given in table 17 and the analysis of variance mean squares are shown in table 18. There was a highly significant difference ($P<.01$) between treatments for the apparent digestibility of crude protein. Increasing levels of distillers dried grains with solubles produced an almost linear decrease in crude protein digestibility with means of 81.88, 79.61, 76.84 and 73.72% for the 0, 5, 10 and 20% levels of the distillers by-product. This amounted to an 9.97% reduction in apparent digestibility. The average crude protein content of the feces ranged from 20.07% for treatment A to 21.30% for treatment G (table 19), but the differences were not significant.

Dry matter digestibility was also significantly ($P<.01$) lowered by increasing levels of distillers dried grains with solubles. The

Table 17. Apparent Digestion Coefficients (in percent) for the Pigs and Treatment Averages for Individual Samples of Collection Period Two-Day Two

Sex	Treatments			
	A	E	F	G
		Crude Protein		
Barrow	79.30	82.24	78.09	77.52
Barrow	82.40	80.59	76.06	72.13
Barrow	86.30	75.59	76.70	72.36
Gilt	76.91	80.82	72.42	70.47
Gilt	85.27	82.42	78.16	72.02
Gilt	81.07	76.00	79.62	77.85
Average	81.88	79.61[a]	76.84[a]	73.72[a]
		Dry Matter		
Barrow	82.25	83.96	80.12	79.06
Barrow	85.29	82.85	77.71	76.14
Barrow	86.29	78.09	77.96	73.18
Gilt	80.53	83.30	74.21	74.21
Gilt	85.06	83.74	79.55	76.45
Gilt	84.34	79.75	80.75	81.64
Average	83.96	81.95[a]	78.38[a]	76.78[a]

[a] Means bearing superscripts are significantly different from control treatment A.

Table 18. Analysis of Variance for Chromic Oxide and Nutrient Content of the Feces and Apparent Digestion Coefficients for Individual Samples of Collection Period Two-Day Two

Source of Variation	df	Mean Squares: Chromic Oxide Content of the Feces	Mean Squares: Nutrient Content of the Feces	Mean Squares: Apparent Digestion Coefficients
			Crude Protein	
Treatment	3	1.20**	0.02	0.74**
Sex	1	0.00	0.01	0.02
Treatment x Sex	3	0.04	0.01	0.01
Residual	16	0.14	0.02	0.12
Total	23			
			Dry Matter	
Treatment	3	1.20**	0.02*	0.64**
Sex	1	0.00	0.00	0.00
Treatment x Sex	3	0.04	0.00	0.02
Residual	16	0.14	0.004	0.08
Total	23			

*P < .05
**P < .01

Table 19. Average Chromic Oxide and Nutrient Content of the Individual Fecal Samples for Collection Period Two-Day Two

	Treatments: A	E	F	G
	%	%	%	%
Crude Protein	20.07	20.69	20.11	21.30
Dry Matter	91.96	92.60	93.03	93.18
Chromic Oxide	3.35	3.07	2.58	2.37

means for treatments A, E, F and G were 83.96, 81.95, 78.38 and 76.78%, respectively. The average fecal dry matter content ranged from 91.96% for treatment A to 93.18% for treatment G; the treatment differences were significant ($P < .05$).

The chromic oxide content of the feces was significantly different ($P < .01$) between treatments with treatment means of 3.35, 3.07, 2.58 and 2.37% for treatments A, E, F and G, respectively. These differences essentially reflect the differences in ration digestibility since different amounts of the nutrients absorbed by the pigs will result in different concentrations of chromic oxide in the feces. The within pen variability for fecal chromic oxide content was negligible thus the individual fecal samples of day two gave more precise indications of treatment effects on ration digestibility than did the day one individual samples.

The average apparent digestion coefficient for crude protein obtained with the individual samples of collection period two (average of days one and two) was 76.76% which was higher than the average coefficient of 73.20% for collection period one. Average apparent dry matter digestion coefficients obtained with the individual fecal samples were nearly the same for collection period one and collection period two (average of days one and two) with values of 79.44 and 79.12%, respectively. The increase in crude protein digestibility may be due to the fact that the amino acid imbalance caused by the addition of distillers dried grains with solubles was less critical as the pigs became older. The increased crude fiber in the feeds

with increased levels of the distillers by-product may have been less important with the older pigs.

Collection period two day two - composite fecal samples. The apparent digestion coefficients are given in table 20 and the analysis of variance mean squares are given in table 21.

Average apparent crude protein digestibility for treatments A, E, F and G were 77.24, 74.53, 71.96 and 72.99%, respectively, but none of the differences were significant. Results obtained with the individual fecal samples indicated that distillers dried grains with solubles significantly reduced crude protein digestibility although results obtained with the composite samples also indicated a lower digestibility of crude protein in rations containing the distillers by-product the differences were not significant. Apparent digestion coefficients within treatments were less uniform than for individual samples. There were no significant differences in crude protein content of the feces with means (table 22) of 22.32, 23.12, 22.70 and 22.14% for 0, 5, 10 and 20% levels of distillers dried grains with solubles.

Results obtained with the composite fecal samples showed that there was a significant difference ($P < .05$) in apparent dry matter digestibility between treatments with rations containing 10 and 20% distillers dried grains with solubles having the significantly lower digestion coefficients as compared to the control ration. Means for treatment A (81.45%) and treatment E (79.63%) were nearly the same but higher than means of 76.80% and 76.75% for treatments F and G,

Table 20. Apparent Digestion Coefficients (in percent) for Composite Samples and Treatment Averages for Collection Period Two-Day Two

Sample Number	Treatments			
	A	E	F	G
		Crude Protein		
1	78.33	77.53	76.97	72.17
2	77.24	73.75	65.98	68.22
3	77.57	71.83	62.44	78.12
4	78.16	74.66	76.87	74.66
5	70.82	76.35	71.37	73.42
6	81.34	73.08	78.12	71.37
Average	77.24	74.53	71.96	72.99
		Dry Matter		
1	80.72	82.52	79.67	75.83
2	81.74	79.60	74.16	74.11
3	82.63	77.82	68.38	79.56
4	81.73	79.10	79.64	77.10
5	78.65	80.35	77.94	76.60
6	83.26	78.36	80.97	77.26
Average	81.45	79.63	76.80[b]	76.75[b]

[b] Means bearing superscripts are significantly different from control treatment A.

Table 21. Analysis of Variance for Chromic Oxide and Nutrient Content of the Feces and Apparent Digestion Coefficients for Composite Samples of Collection Period Two-Day Two

Source of Variation	df	Mean Squares: Chromic Oxide Content of the Feces	Mean Squares: Nutrient Content of the Feces	Mean Squares: Apparent Digestion Coefficients
			Crude Protein	
Treatment	3	0.38*	1.11	31.70
Residual	20	0.08	2.01	17.59
Total	23			
			Dry Matter	
Treatment	3	0.38*	3.01*	31.80*
Residual	20	0.08	0.67	7.81
Total	23			

*P $\leq$ .05

Table 22. Average Chromic Oxide and Nutrient Content of the Fecal Samples of Collection Period Two-Day Two

	Treatments: A	E	F	G
	%	%	%	%
Crude Protein	22.32	23.12	22.70	22.14
Dry Matter	94.03	93.33	93.46	94.89
Chromic Oxide	2.94	2.72	2.47	2.38

respectively. The digestion coefficients obtained with the composite samples indicated the same trends in digestibility of dry matter as did the individual samples. Results from the individual samples indicated that treatments E, F and G significantly reduced dry matter digestibility as compared to treatment A. Dry matter content of the feces was significantly different ($P < .05$) between treatments. The highest mean was 94.89% for treatment G and the lowest was 93.33% for treatment E.

The chromic oxide content of these composite fecal samples was significantly different ($P < .05$) between treatments with means of 2.94, 2.72, 2.47 and 2.38% for treatments A, E, F and G in that order. The differences essentially represent differences in ration digestibility.

Comparison of individual fecal samples from days one and two of collection period two. Large differences were noted between apparent digestion coefficients of day one and day two (table 23) therefore, the two sets of data were combined for statistical analysis. The resultant mean squares are given in table 24.

Day of collection had a significant ($P < .05$) effect upon the calculated digestion coefficient for crude protein. The mean digestibility of crude protein on day one was 75.51% and the mean for day two was 78.01%. The treatment means averaged over days were 78.60, 78.01, 77.34 and 73.09% for 0, 5, 10 and 20% levels of distillers dried grains with solubles and the treatment differences were highly significant ($P < .01$). The crude protein content of the

Table 23. Treatment Average Apparent Digestion Coefficients (in percent) for Days One and Two of Collection Period Two (individual samples)

	Treatments				Day Average
	A	E	F	G	
		Crude Protein			
Day One	75.33	76.41	77.85	72.46	75.51
Day Two	81.88	79.61	76.84	73.72	78.01
Average	78.60	78.01	77.34	73.09	
		Dry Matter			
Day One	77.81	80.44	78.70	74.92	77.97
Day Two	83.96	81.95	78.38	76.78	80.27
Average	80.88	81.19	78.54	75.85	

Table 24. Analysis of Variance for Chromic Oxide and Nutrient Content of the Feces and Apparent Digestion Coefficients Between Day One and Day Two of Collection Period Two (individual samples)

Source of Variation	df	Mean Squares: Chromic Oxide Content of the Feces	Mean Squares: Nutrient Content of the Feces	Mean Squares: Apparent Digestion Coefficients
			Crude Protein	
Day	1	0.95**	0.43	75.05*
Treatment	3	1.25**	6.40*	75.02**
Day x Treatment	3	0.35*	2.45	30.69
Sex	1	0.10	3.89	27.42
Day x Sex	1	0.08	0.11	11.78
Treatment x Sex	3	0.34*	0.42	32.55
Day x Treatment x Sex	3	0.11	1.32	21.41
Residual	32	0.11	1.92	12.39
Total	47			
			Dry Matter	
Day	1	0.95**	10.47**	63.46*
Treatment	3	1.25**	3.83**	73.82**
Day x Treatment	3	0.35*	0.59	22.47
Sex	1	0.10	0.61	6.70
Day x Sex	1	0.08	0.43	7.67
Treatment x Sex	3	0.34*	0.81	27.50*
Day x Treatment x Sex	3	0.11	0.06	14.21
Residual	32	0.11	0.28	8.78
Total	47			

*P < .05
**P < .01

feces (table 25) was not significantly different between days which would tend to indicate that the difference in crude protein digestion coefficients between days was not due to different rates of absorption within pens between the two days. However, the crude protein content of the feces was significantly different ($P < .05$) between treatments; the means ranged from 19.94% for treatment F to 21.44% for treatment E.

The difference in dry matter digestibility between days was 2.87 percent (table 23) and this difference was significant ($P < .05$). Also, the difference between treatments was significant ($P < .01$) with means ranging from 81.19% for treatments E to 75.85% for treatment G. The treatment times sex interaction was significant ($P < .05$) probably because of the same interaction being significant for the day one samples. The fecal dry matter content was significantly different ($P < .01$) between days, but the difference was only 0.93 percentage units and this small difference probably did not cause the significant difference in apparent digestion coefficients between days. A highly significant difference ($P < .01$) was found in fecal dry matter between treatments. Treatments A, E, F and G had means of 92.60, 92.74, 93.60 and 93.69%, respectively.

Chromic oxide content of the fecal samples (table 26) was significantly different ($P < .01$) between days, the mean for day one was 2.56% and for day two 2.84%. This is a small difference but the calculated apparent digestion coefficients change quickly with small changes in fecal chromic oxide content. Treatment differences in chromic oxide content of the feces were highly significant ($P < .01$)

Table 25. Average Nutrient Content (in percent) of the Individual Fecal Samples from Days One and Two of Collection Period Two

	Treatment				Day Average
	A	E	F	G	
			Crude Protein		
Day One	20.12	22.19	19.78	20.83	20.73
Day Two	20.07	20.69	20.11	21.30	20.54
Average	20.09	21.44	19.94	21.06	
			Dry Matter		
Day One	93.24	92.89	94.17	94.20	93.62
Day Two	91.96	92.60	93.03	93.18	92.69
Average	92.60	92.74	93.60	93.69	

Table 26. Average Chromic Oxide Content (in percent) of the Individual Fecal Samples of Days One and Two of Collection Period Two

	Treatment				Day Average
	A	E	F	G	
Day One	2.59	2.81	2.64	2.20	2.56
Day Two	3.35	3.07	2.58	2.37	2.84
Average	2.97	2.94	2.61	2.28	

with treatment averages ranging from 2.97% for treatment A down to 2.28% for treatment G. The day times treatment interaction was significant ($P < .05$) because fecal chromic oxide content from day one to day two increased for treatments A, E and G and decreased for treatment F (table 26).

The fecal samples collected on day two were high in chromic oxide content and also were less variable within pens. Therefore, the digestion coefficients obtained with the day two samples were less variable within pens and probably more reliable than those for the day one samples. Results of the second collection period indicated that within pen uniformity of chromic oxide excretion was not reached until the morning of the fourth day after initial feeding of the chromic oxide feeds. This may have been caused by the extremely cold temperatures at the time of the second collection period which probably kept the pigs from going out to eat as often as they normally did.

Multiple regressions and correlations were computed to determine the combined effect of the chromic oxide and nutrient content of the feces upon the calculated apparent digestion coefficients. These were not independent variables; therefore, the multiple regression and correlation values were of little or no use in the evaluation of the results. Therefore they were not included in the discussion of the results.

SUMMARY AND CONCLUSIONS

Eighty-two growing-finishing pigs were utilized in a replicated feeding trial to study the effect of adding unidentified growth factor sources to a control ration of corn and soybean meal fortified with vitamins, minerals and an antibiotic. Additions to the control ration were: 5% dried whey, 5% fish solubles, a combination of 5% dried whey and 5% fish solubles and 5, 10 and 20% distillers dried grains with solubles. The average daily gains of the pigs used in this study were not significantly affected by the addition of any of the UGF sources to the control ration. In replicate one the pigs fed the ration containing 5% distillers dried grains with solubles gained 0.1 of a pound per day faster than pigs fed the control ration and required 0.27 of a pound less feed per pound of gain. In replicate two the pigs receiving the ration which contained 5% dried whey gained 0.1 of a pound more per day and required 0.27 of a pound less feed per pound of gain than pigs fed the control ration. Also in replicate two pigs which were fed the ration containing 20% distillers dried grains with solubles gained 0.12 of a pound less per day than the control pigs. In both replicates pigs fed the ration containing 20% distillers dried grains with solubles had a significantly ($P < .05$) lower feed efficiency than the control pigs. They required 0.24 of a pound more feed in replicate one and in replicate two 0.51 of a pound of extra feed was required per pound of gain. The UGF sources apparently did not supply any required nutrient(s) not already supplied by the fortified corn

and soybean meal control ration. Average daily gain was significantly different ($P < .05$) between replicates, the pigs allotted to replicate two were an average of 8 days older and 3 pounds lighter than the pigs allotted to replicate one.

The control ration and the three rations containing 5, 10 or 20% of distillers dried grains with solubles were studied to determine the effect of distillers dried grains with solubles on crude protein and dry matter digestibility. Apparent digestion coefficients were determined by the chromic oxide indicator method. Fecal samples were collected on December 9, 1967 and the weekend of January 6 and 7, 1968. Results obtained with the individual samples of collection period one indicated that the 5, 10 and 20% levels of distillers dried grains with solubles added to the control ration significantly reduced the apparent digestibility of crude protein ($P < .01$) and dry matter ($P < .05$). For collection period two-day one there was a significant difference between treatments for digestibility of dry matter ($P < .05$) while no significant difference was found for crude protein digestibility. Results obtained with the individual samples of collection period two-day two indicated that all three levels of distillers dried grains with solubles significantly decreased the apparent digestibility of crude protein ($P < .01$) and dry matter ($P < .01$).

Composite fecal samples were collected each time individual samples were collected. Apparent digestion coefficients were calculated for the composite samples and the results were compared to results from the individual samples. The composite samples gave

digestion coefficients showing trends in ration digestibility similar to trends shown by the individual fecal samples. The composite samples were not as accurate in showing differences in digestibility and larger differences were needed to show significance with the composite samples than with the individual samples.

Statistical analysis of the results from day one and day two individual samples of the second collection period showed a significant difference between days for apparent digestibility of crude protein ($P < .05$) and dry matter ($P < .01$). In both cases the digestion coefficients were higher on day two. Chromic oxide content of the feces was higher on day two and less variable within pens; therefore, the samples from day two gave a more accurate indication of the effect of the treatments on ration digestibility.

LITERATURE CITED

A. O. A. C. 1960. Official Methods of Analysis. (9th ed.) Association of Official Agricultural Chemists, Washington, D. C.

Beeson, W. M. and J. H. Conrad. 1957. Effect of calcium and trace minerals on the response of young pigs to unidentified growth factors. Proc. Twelfth Distillers Feed Conference. 12:48.

Clawson, A. J., J. T. Reid, B. E. Sheffy and J. P. Willman. 1955. Use of chromium oxide in digestion studies with swine. J. Animal Sci. 14:700.

Couch, J. R., B. L. Reid, A. A. Camp, W. N. Dannenburg and E. E. Rozacky. 1955. Distillers dried solubles in the diets of chicks. Proc. Tenth Distillers Feed Conference. 10:47.

Couch, J. R. and H. D. Stelzner. 1961. Vitamin-like unidentified growth factors from corn distillers dried solubles. Proc. Sixteenth Distillers Feed Conference. 16:65.

Dam, R., L. C. Norris and F. W. Hill. 1957. Further studies on unidentified chick growth factors. Poultry Sci. 36:1110. (Abstr.).

Fairbanks, B. W., J. L. Krider and W. E. Carroll. 1944. Distillers' by-products in swine rations. I Creep-feeding and growing-fattening rations. J. Animal Sci. 3:29.

Fairbanks, B. W., J. L. Krider and W. E. Carroll. 1945. Distillers' by-products in swine rations. III Dried corn distillers' solubles, alfalfa meal and crystalline B-vitamins compared for growing-fattening pigs in drylot. J. Animal Sci. 4:420.

Gage, J. W., Jr., R. D. Wilber, V. W. Hays, V. C. Speer and D. V. Catron. 1961. Sources of unidentified growth factors for baby pigs. J. Animal Sci. 20:168.

Gard, D. I., D. E. Becker, S. W. Terrill, H. W. Norton and A. V. Nalbandov. 1955. Sources of unidentified factors for the pig. J. Animal Sci. 14:532.

Geurin, H. B., J. A. Hoefer and W. M. Beeson. 1950. Fish solubles and liquid fish for growing and fattening swine. J. Animal Sci. 9:94.

Green, J. D., M. P. Plumlee, J. H. Conrad, W. H. Smith and W. M. Beeson. 1961. Concentrates from distillers dried solubles as sources of unidentified growth factors. J. Animal Sci. 20:933. (Abstr.).

Krider, J. L., B. W. Fairbanks and W. E. Carroll. 1944. Distillers' by-products in swine rations. II Lactation and growing-fattening rations. J. Animal Sci. 3:107.

Krider, J. L., D. E. Becker, L. V. Curtin and R. F. VanPoucke. 1949. Dried whey products in drylot rations for weanling pigs. J. Animal Sci. 8:112.

Krider, J. L. and S. W. Terrill. 1950. Fish, distillery and fermentation by-products studied in drylot rations of weanling pigs. J. Animal Sci. 9:101.

Lillie, R. J., H. Menge and C. A. Denton. 1962. Evaluation of condensed fish solubles as a chick growth stimulant in an 8-year study. Poultry Sci. 41:1202.

Luce, W. G., E. R. Peo, Jr. and D. B. Hudman. 1964. Effect of amino acid supplementation of rations containing meat and bone scraps on rate of gain, feed conversion and digestibility of certain ration components for growing-finishing swine. J. Animal Sci. 23:521.

Morrison, A. B., R. Dam, L. C. Norris and M. L. Scott. 1956. Further evidence on the requirement of the chick for unidentified minerals. J. Nutr. 60:283.

Morrison, A. B., M. L. Scott and L. C. Norris. 1955. Evidence for an unidentified mineral required by the chick. Poultry Sci. 34:738.

Murthy, V. R., H. D. Stelzner, B. L. Reid and J. R. Couch. 1957. Fractionation studies on chick growth factors in condensed fish solubles. Poultry Sci. 36:1145. (Abstr.).

Noland, P. R., E. L. Stephenson and B. Diggs. 1955. The value of several supplements as sources of unidentified growth factors for swine. J. Animal Sci. 14:628.

Norris, L. C. 1954. Unidentified chick growth factors in distillers dried solubles. Proc. Ninth Distillers Feed Conference. 9:20.

O'Dell, B. L. and J. E. Savage. 1957. Potassium, zinc and distillers dried solubles as supplements to a purified diet. Poultry Sci. 36:459.

Plumlee, M. P., R. L. Harrold, J. H. Conrad and W. M. Beeson. 1966. Response of rats and young pigs to fractions of corn distillers dried solubles. Proc. Twenty-first Distillers Feed Conference. 21:25.

Pond, W. G., R. S. Lowrey and J. H. Maner. 1962. Effect of crude fiber level on ration digestibility and performance in growing-finishing swine. J. Animal Sci. 21:692.

Robertson, J. C. and C. E. Barnhart. 1961. The growth-promoting factors in dried distillers solubles and possible interrelationships between solubles and certain minerals. J. Animal Sci. 20:62.

Schürch, A. F., E. W. Crampton, S. R. Haskell and L. E. Lloyd. 1952. The use of chromic oxide in digestibility studies with pigs fed ad libitum in the barn. J. Animal Sci. 11:261.

Scott, H. M., W. D. Morrison and P. Griminger. 1955. Studies on unknown growth factors in distillers dried solubles. Poultry Sci. 34:1446.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., New York.

Steinke, F. H., H. R. Bird and F. M. Strong. 1961. Studies on an unidentified growth factor (UGF) for chicks in fish solubles. Poultry Sci. 40:1460. (Abstr.).

Stelzner, H. D., R. E. Davies, M. D. Stasney and J. R. Couch. 1959. Unidentified growth factors in corn distillers dried solubles-present status. Proc. Fourteeneth Distillers Feed Conference. 14:35.

Summers, J. D., W. F. Pepper and S. J. Slinger. 1959. Sources of unidentified factors for practical poultry diets. 2. The value of fish solubles, dried whey, dried distillers solubles and certain fermentation products for chick and broiler diets. Poultry Sci. 38:846.

APPENDIX

Table 1. Proximate Analysis of Dried Whey

Nutrient	Amount
Gross Analysis	
Crude Protein	13.10%
Lactose	68.10%
Fat	1.30%
Fiber	0.08%
Ash (all milk minerals)	7.95%
Acidity (as lactic acid)	2.00%
Moisture	3.85%
Minerals	
Calcium	0.79%
Phosphorus	0.66%
Chlorides (expressed as NaCl)	2.40%
Vitamins	
Riboflavin	9.8 mg./lb.
Pantothenic acid	26.8 mg./lb.
Niacin	5.2 mg./lb.
Choline	1100.0 mg./lb.
Thiamine	1.9 mg./lb.
Amino Acids[1]	
Arginine	0.44%
Glutamic acid	1.09%
Histidine	0.22%
Isoleucine	1.00%
Leucine	1.54%
Lysine	1.21%
Methionine	0.40%
Cystine	0.40%
Phenylalanine	0.44%
Tyrosine	0.33%
Tryptophan	0.22%
Threonine	0.88%
Valine	0.77%

[1]Stated as percent of the feed.

Table 2. Proximate Analysis of Distillers Dried Grains with Solubles

Nutrient	Amount
Gross Analysis	
Crude Protein	27.0%
Fat	8.0%
Fiber	8.5%
Ash	4.5%
Metabolizable energy, Cal/lb	1190
Moisture	9.0%
Minerals	
Calcium	0.35%
Phosphorus	0.95%
Potassium	0.95%
Magnesium	0.37%
Iron	0.03%
Chlorine	0.17%
Sodium	0.05%
Sulfur	0.30%
Copper	36.00 mg./lb.
Manganese	12.90 mg./lb.
Cobalt	0.05 mg./lb.
Zinc	98.00 mg./lb.
Vitamins	
Riboflavin	4.0 mg./lb.
Pantothenic acid	5.0 mg./lb.
Niacin	35.0 mg./lb.
Choline	1200.0 mg./lb.
Thiamine	1.5 mg./lb.
Pyridoxine	1.0 mg./lb.
Carotene	2.0 mg./lb.
Folic acid	0.4 mg./lb.
Biotin	0.3 mg./lb.
Amino Acids[1]	
Arginine	1.0%
Glutamic acid	3.7%
Histidine	0.7%
Isoleucine	1.1%

[1] Stated as percent of the feed.

Table 2. (Continued)

Nutrient	Amount
Amino Acids[1] (continued)	
Leucine	2.5%
Lysine	0.7%
Methionine	0.5%
Cystine	0.5%
Phenylalanine	1.2%
Tyrosine	0.8%
Threonine	1.0%
Tryptophan	0.2%
Valine	1.5%
Glycine	1.0%
Serine	1.0%
Fatty Acid	
Linoleic acid	4.5%

[1] Stated as percent of the feed.

Table 3. Proximate Analysis of Fish Solubles

Nutrient	Amount
Gross Analysis	
Crude Protein[1]	52.50%
Digestible Protein	44.65%
Fat	8.35%
Fiber	3.35%
NFE	17.60%
Ash	12.45%
Productive Energy	725 Cal/lb.
Metabolizable Energy	1170 Cal/lb.
Minerals	
Calcium	0.32%
Phosphorus - Total	1.14%
- Available	0.92%
Vitamins	
Riboflavin	7.35 mg./lb.
Pantothenic acid	19.40 mg./lb.
Niacin	82.80 mg./lb.
Choline	2002.50 mg./lb.
Vitamin B-12	0.30 mg./lb.
Amino Acids[2]	
Arginine	4.20%
Glutamic acid	20.00%
Histidine	3.05%
Isoleucine	2.80%
Leucine	4.20%
Lysine	4.05%
Methionine	1.25%
Cystine	0.70%
Phenylalanine	2.50%
Tyrosine	0.90%
Tryptophan	0.80%
Valine	2.30%

[1] This product is a combination of dried condensed fish solubles and soybean meal.

[2] Stated as a percent of the feed.

Table 4. Analysis of Variance for Chromic Oxide and Nutrient Content of the Feces and Apparent Digestion Coefficients for Individual Samples from Collection Period One (Crude Fiber, Ether Extract and NFE)

Source of Variation	df	Mean Squares: Chromic Oxide Content of the Feces	Mean Squares: Nutrient Content of the Feces	Mean Squares: Apparent Digestion Coefficients
			Crude Fiber	
Treatment	3	0.38*	0.07**	
Sex	1	0.05	0.40*	
Treatment x Sex	3	0.18	0.01	
Residual	16	0.10	0.01	
Total	23			
			Ether Extract	
Treatment	3	0.38*	0.01	
Sex	1	0.05	0.15**	
Treatment x Sex	3	0.18	0.03	
Residual	16	0.10	0.02	
Total	23			
			NFE	
Treatment	3	0.38*	0.06	0.22*
Sex	1	0.05	0.00	0.00
Treatment x Sex	3	0.18	0.02	0.07
Residual	16	0.10	0.06	0.05

*P < .05
**P < .01

Table 5. Proximate Analysis of Rations Studied in Digestibility Determinations

	Rations			
	A	E	F	G
	%	%	%	%
	Collection Period One			
Crude Protein	19.58	18.11	17.90	18.17
Crude Fiber	2.26	2.55	2.70	3.58
Ether Extract	2.33	3.21	3.18	4.22
NFE	70.02	70.99	71.43	68.75
Ash	4.85	4.65	4.29	4.78
Dry Matter	96.56	96.86	96.62	96.71
Chromic Oxide	0.50	0.51	0.52	0.52
	Collection Period Two			
Crude Protein	18.96	19.34	19.48	19.41
Ash	4.46	4.34	4.57	4.85
Dry Matter	97.66	97.64	96.54	96.38
Chromic Oxide	0.56	0.58	0.57	0.56