U N I V E R S I T Y   O F   S A S K A T C H E W A N

DEPARTMENT OF ANIMAL HUSBANDRY

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled, "Factors Influencing Feed Utilization and Carcass Quality in Swine and Mice," submitted by Jens Ebbe Troelsen, B.Sc. (Agriculture) in partial fulfilment of the requirements for the degree of Master of Science.

PROFESSOR ____________________

PROFESSOR ____________________

PROFESSOR ____________________

Date ____________ PROFESSOR ____________________

FACTORS INFLUENCING FEED UTILIZATION AND CARCASS QUALITY IN SWINE AND MICE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE

IN THE DEPARTMENT OF

ANIMAL HUSBANDRY

by

JENS EBBE TROELSEN

WRITTEN UNDER THE SUPERVISION OF

PROFESSOR J. MILTON BELL

HEAD OF DEPARTMENT OF ANIMAL HUSBANDRY

SASKATOON SASKATCHEWAN

APRIL 1960

ACKNOWLEDGMENTS

The author wishes to express appreciation to Dr. J. Milton Bell for constructive advice in planning the investigations and helpful criticism in the development of this report, to the staff members of the Animal Husbandry Department, particularly B. D. Owen for valuable suggestions regarding analytical procedures and statistical treatments of the data, and to fellow students J. Erfle and A. Gorrill for kind assistance in the laboratory.

The author is also indebted to A. J. Binnie, swine herdsman of the University Farm for keen interest in, and skillful handling of, the experimental factors in the swine trial, to A. D. Munroe, J. Leask and staff of the Livestock and Livestock Products Division, Canada Department of Agriculture, Saskatoon, for obtaining all carcass measurements on the barrows, and to Professor N. Shklov and Mr. F. Vauter, Department of Mathematics, University of Saskatchewan, for carrying out statistical analyses on a part of the experimental data.

The encouragement and support given by Mr. J. B. Campbell, Officer-in-charge of the Pasture Section, and Mr. G. N. Denike, Superintendent of the Swift Current Experimental Farm, prior to and during this study, and in preparation of the report is sincerely acknowledged.

Financial assistance was contributed by the Saskatchewan Research Council by grants directed to the project and a scholarship to the author. The Research Branch, Canada Department of Agriculture granted the author leave of absence with part salary while performing the studies giving rise to this dissertation.

AUTOBIOGRAPHY

Jens Ebbe Troelsen

Born April 23, 1920, in the parish of Malling, Aarhus county, on the Peninsula of Jutland, Denmark. Brought up on parents' mixed dairy farm. Attended separate country school to the equivalent of grade eight. Attained grade twelve equivalent at the boarding schools: "Himmerlands Ungdomsskole," Haubro, 1937-38. "Asmildkloster Landbrugsskole," Viborg, 1940-41. "Lyngby Landboskole," 1941. In intervening years of junior matriculation, worked as farmhand on mixed dairy farm, as herdsman for purebred dairy herd and as R.O.P. inspector. During 1941-44 studied agriculture at the Royal Veterinary and Agricultural College, Copenhagen. Graduated in 1944 as Bachelor of Science, (Agriculture)(B.Sc.). From graduation worked as assistant consultant in milking, milk sanitation and milk classification for the Danish Federation of Co-operative Creameries Associations, Aarhus, Denmark. From 1946 to 1951 worked as agricultural representative assistant in soil fertility, plant production and 4H activity for the Farmers Union of Aalborg county. During the same period also functioned as inspector for the State Potato Export Board and as sampler for the State Seed Control. Immigrated to Canada in 1951, worked as herdsman during 1951-52 at "Scott Farms" Seaforth, Ontario. Since 1953 employed in the Research Branch, Canada Department of Agriculture at the Experimental Farm, Swift Current, Sask. Under leave of absence from September 1957 to May 1959, studied toward a M.Sc. degree in the Department of Animal Husbandry, University of Saskatchewan.

In 1945 J.E.T. married kindergarten teacher Ellen Skorstengaard, daughter of Danish dairy farmer. There are two children in the family, Hans born in 1946, and Anne Marie born in 1955.

TABLE OF CONTENTS

Page

INTRODUCTION

In an ever increasing world population the need for a food protein source of high biological value and of a short production cycle becomes increasingly urgent. Thriving on the by-products of a dense dairy industry in Western Europe, pork became a chief protein source in these people's diet. They learned early to breed and feed for lean pork carcasses. Restricted feeding did not pose a problem in the many small enterprises where manual labor was more abundant than in our mechanized agriculture.

With the approach of a population density warranting a quality market for pork it is becoming more important to adopt a self-feeding technique for swine which will restrict nutrient intakes during the finishing period to levels that will produce meaty, high quality carcasses. Since it is becoming generally accepted that a dilution of the nutrients by fibrous materials (termed "bulk" in this report) will serve this end, the purpose of this investigation was to compare the effects on feed utilization and carcass quality of varying levels of different bulks in finishing rations for swine.

Since sorting and wastage of diluted bulky rations is recognized as a problem in self-feeding of swine, the effect of pelleting of such rations was included in the project.

Obvious advantages of small pilot animals in nutritional studies prompted the inclusion of mice in the project to learn to which extent they could serve as such for swine. Identical rations were fed to the two species in identical experimental designs. Feed utilization and complete carcass analyses in mice were compared to feed utilization and characteristic carcass measurements in swine and reported in a separate section of the thesis.

Secondary aspects such as adjusting the protein digestibilities for protein intake, nonprotein dry matter intake and excretion, and physiological body size, separate determination of the digestibility of simultaneously fed bulk and basal fractions of the rations, etc., were also considered.

LITERATURE REVIEW

Proportional growth in swine conforms to the law of "developmental direction," exhibiting a well defined anterior-posterior gradient from earlier to later developing regions (86). The influence of various degrees of undernutrition upon growth processes in larger animals (87) was a lead in systematic studies of nutritional effects upon body development and body composition in the pig (88, 89). This revealed that the consequence of extremes in high and low nutritional planes was a pattern of growth, affecting parts of the body increasingly in the order: head, ears, neck, legs, body length, body depth, loins and hind quarters. The effect upon the major body tissues increased in the order: skin, tendon, glands, bone, muscle and fat (87).

Young bacon pigs exhibited various growth patterns, when fed at low (L) or high (H) plane of nutrition or combinations of these, during the growing and finishing periods. A high plane of nutrition in the finishing period advanced late developing parts of the body of which fat is a major tissue, while a low plane favored earlier developing parts dominated by bone and muscle. Restricted nutrition in the growing period (from weaning to about 100 pounds body weight) enhanced the above-mentioned effects (88, 89). The overall effect of the combinations of nutritional levels: LH, HH, HL and LL, on the major body tissues, was an increase in bone and muscle, and a decrease in fat, in the same sequence.

Under otherwise similar conditions gilts have been found to yield carcasses with less fat and more muscle than barrows, and thus attain higher commercial grades and AR*scores (11, 19, 52, 80, 120). Therefore it has often been recommended that gilts and barrows be fed at different nutritional

* Advanced Registry (90)

levels in order to yield carcasses of equally high quality.

Variation in nutritional plane has been achieved in different ways depending on feeding practices. For decades restricted handfeeding has been used to produce lean bacon carcasses for the demanding British market (55). At the same time, however, the desirable effects of various bulks have been appreciated. As an example, this is borne out in a report (22) by a Canadian commission studying swine husbandry on a tour of the United Kingdom and Denmark in 1909. Sections of the report read in part:

> "In England, tests on 720 pigs during five years gave rise to the conclusion that the five diets producing the best quality meat were, in decreasing order: Barley and Bran, Barley and Potatoes, Barley and Milk, Barley and Corn germs, and Barley alone."

further:

> "Roughage in the form of roots or other green fodder is considered an essential part of the successful pig-raisers' food supply."

and:

> "Another lesson gathered in each country was the common concept that young pigs should be raised on easily digestible food. As they get older, roughage should be added to the diet. Shortly before slaughtering, the ration should be made stronger to speed up finishing and to assure a higher quality of meat."

These paragraphs indicate that the fundamental principles in the production of high quality bacon carcasses were well known fifty years ago although the causes and effects were perhaps less well understood. The remarks suggest that actually the level of bulk in the rations was used to improve the bacon quality.

In experimental work the nutrition has been limited by restricting the feed supply when handfeeding is practiced (5, 21, 47, 126), or by limiting the feeding time when self-feeders are used (5, 13). Crampton (31) has pointed out that under practical conditions both of these methods are unsatisfactory, for the purpose of producing higher grade bacon carcasses, since aggressive animals still will be over fed, while the more timid individuals will be too much restricted.

Dilution of self-fed, mixed rations with fibrous, indigestible materials has been practiced in many experiments for the purpose of restricting the intake of nutrients. In experiments with mice (8, 9, 12), rats (85), poultry (29, 40, 41, 46) and swine (4, 7, 11, 17, 27, 34, 56, 70, 79, 80, 115, 120), this practice has been successful in modifying growth rates and carcass compositions.

The practice of designing an ad lib. fed ration to sustain a defined, intermediate level of growth, has enhanced the need for a ration unit which will denote the amount of digestible nutrients which a voluntary consumption of the ration will supply the organism (32). Such a unit must be based upon concentration of digestible nutrients, plus factors that will determine voluntary consumption of the ration e.g. bulk, palatability and rate of passage through the alimentary tract.

The primary effect of increased bulk in a ration is a decrease in the concentration of nutrients (9, 56) and, if the bulk replaces the different nutrients to various degrees, a change in the nutritive balance of the ration also occurs (60, 99). Depending on the acceptability (29, 45, 53, 56, 68) and bulkiness (4, 8, 12, 102, 127) of the fibrous fraction added, the animal will seek to adapt intake to requirement (44, 79, 112). This adaptation has been suggested to be governed mainly by the need for energy (58, 99), probably because of the magnitude of this factor in the context of nutritional demands under the conditions at hand.

A decreased intake of adequately balanced nutrients slows down the rate of growth (7, 42, 56, 79, 115) in association with leaner carcasses (4, 5, 11, 47, 124), higher percentages of ham, shoulder and loin (17, 21, 33), increased commercial grades (10, 13, 34) and lowered dressing percentage (80, 120, 127). An increased consumption of dry matter because of higher levels of bulk in the ration, has been suggested to enlarge the digestive tract (16) and thus cause lower dressing percentage (11, 17, 27).

The desirable level of bulk in a diet will depend on whether maximum gain, maximum feed efficiency, or a specific carcass composition is the goal. For maximum gain, a bulk level sufficient to ensure optimum physiological conditions in the gastrointestinal tract is required (40, 41, 77). Due to the difference between energy laid down in fat and in other body tissues (77), maximum feed efficiency is obtained at bulk levels somewhat higher than those for maximum gain (4, 5, 13). This effect is expected to be more noticeable in species with a higher tendency for fat deposition. Since swine is one of these species (13, 79, 87), and since too much fat is incompatible with a high carcass quality (90), the level of bulk in self-fed finisher rations must be high enough to reduce the available nutrients sufficiently to prohibit excessive deposition of fat.

Thus, in two series of cooperative experiments by several research institutions across Canada, Bell et al. (10, 11) showed that the feeding recommendations laid down by the U.S., N.R.C*, in "Nutrient Requirements for Swine," (94) produced inferior, over-finished carcasses in the Yorkshire

* National Research Council

breed under Canadian conditions. When the level of bulk in the ration was increased by substituting oats for barley, a decrease in fat deposition associated with improved carcass quality resulted.

Further studies are needed on physiological properties of bulks in order to explain differences in effects of these (8, 77). Density of the dry rations, crude fiber content and concentration of nutrients, were inadequate as indicators of the effects on feed intake and rate of passage. It is suggested that hydrophilic properties (8, 102, 113) of the diets during the various stages of digestion may be important factors influencing intake, stomach emptying time, peristaltic rates, appetite and in turn animal response (8).

Alfalfa meal in chick diets has been reported to contain factors adversely affecting palatability (29, 45, 53, 68) or growth (69, 76). The growth inhibiting factor has been identified in some cases as saponin (97, 98), the effect of which was counteracted by the addition of cholesterol to the diet. Growth promoting effects of low levels of alfalfa in rat diets (11) and of alfalfa, cellulose and wheat bran in chick diets (39, 40, 118) have been observed. It was suggested (60, 99) that similar results could occur if the added bulk caused a favorable change in the balance of nutrients. The presence of cellulose in rat diets has been observed to cause increased growth of B-vitamin synthesizing bacteria in the digestive tract (54). In another instance cellulose caused a retardation in growth of chickens at lower levels than did oat hulls (58). Also oat hulls have been reported as adversely affecting the palatability of rations for young pigs (35). The complexity of factors at work in the effect of various bulks on animal response (8, 77, 102, 113) is evident from the many controversial conclusions reached from apparently similar experimental treatments.

Some basic effects of inert materials in the gastrointestinal tract has been reported by Hoelzel (62), who personally ingested amounts of non-nutritive material sufficient to produce a marked sense of fullness. This did not dispel strong gastric hunger-like contractions of the stomach. Evidence was presented that although non-nutritive materials dispel the desire to eat only temporarily by filling the stomach, a more lasting effect was caused by the filling of the intestines. A study of the rate of passage of food through the alimentary tract of pigs (23) showed that a delay took place mainly in the large intestine.

Observations of the rate of passage (61) of such inert materials as cork, cotton thread, seeds, rubber, glass beads, aluminum, iron, silver or gold in: rabbits, guinea pigs, dogs, cats, rats, mice, monkeys, pigeons, hens or man, revealed considerable variation among species and among individuals. The lighter and the heavier materials were found to pass slower than the intermediate. A simple mechanical explanation (71) for the slower passage rate of particles either much lighter or much heavier than the main stool is, that particles less dense than the chyme are retarded in passing through intestinal loops positioned as an inverted "U," while heavy particles are retarded in passing through loops positioned as a "U."

The laxative effect of bulks depends on chemical as well as physical properties (77). Addition of cellulose (84) or wheat bran (103) to the diets of humans has been shown to increase the rate of passage. With increasing levels of wheat bran in human diets the rate of passage tended to increase while the digestibility of the fiber tended to decrease (30).

Castle and Castle (23) measured the rate of passage by stained inert food particles mixed in the ration for 50 - 180 lb. pigs. The function of excretion on time was a sigmoid curve with mean 5 and 95% excretion times of 21 and 53 hrs. respectively. The average retention time was 34.2 hrs. There was evidence that the faster passage gave lower protein digestibility, but had no effect on the digestibility of dry matter or crude fiber. Increasing amounts of water in the ration for pigs significantly decreased the retention time but had no effect on the digestibility of dry matter or protein, nor did it alter the moisture content of the feces. Similar rate of passage was obtained for two rations of widely different digestibilities (24).

In 1925 Fraps (51) concluded: "It is an even chance that differences in the digestion by individual animals may cause variations of about 3% of the productive value with corn, wheat and a few similar feeds, about 6% in the usual run of feeds and about 14% with some low-grade feeds." While these variations may have been reduced somewhat by improved management and experimental techniques since then, there is still evidence of wide variations in the digestibilities of fibrous feeds, and particularly in the "crude fiber" and "cellulose" fractions of these (40, 50, 65, 66, 83, 109, 110, 111, 115, 126, 127). In view of the mode of the maturing processes in fibrous plants (37, 63, 67) the variation in digestibility coefficients of the dry matter and, especially of the unspecific fractions "crude fiber" and "cellulose" within as well as between plant species, is not surprising.

It has long been realized that the fractions determined as crude fiber, nitrogen-free extract, cellulose, hemi-cellulose, etc. are unspecific in composition and physiological significance for the nutrition of man, animal and bird (36, 93, 105, 123), and that their main function is to furnish the organism with energy (31, 77, 93). In view of this it has been suggested that a fraction termed digestible energy could be used as an index of this function (11, 75, 116), especially because energy is simple to determine and specific in physiological significance and composition, which again minimizes the variability of its digestibility coefficients. As suggested by Crampton (32) the ideal feed unit would be the digestible nutrients furnished in the portion of feed which an individual would consume under otherwise similar conditions. As pointed out this feed unit will depend on the several properties which determine palatability, bulkiness, digestibility and nutrient balance of a diet.

The extent to which pelleting affects palatability, bulkiness, digestibility, and nutrient efficiency of a ration governs the change in nutritional value of the ration. According to suggestions derived from a large number of investigations, the primary effects of pelleting can be summarized as follows:

1. Increased feed consumption (1, 14, 20, 48, 119) due to increased density (6, 28, 57, 73, 95) and palatability (28, 100), the latter caused by decreased dustiness of the ration (59).

2. Increased availability of nutrients (1, 2, 14) due to increased digestibility (72), decreased fermentation losses (15, 100) and inactivation of growth inhibitors (2).

3. Decreased feed wastage (29, 59) and greater assurance of a balanced diet (100) since pelleting prevents sorting and refusal of coarse and more unpalatable particles.

It has been shown that pelleting of rations for swine (16, 43, 59) poultry (1, 2, 57, 73, 95), lambs (8, 48, 91) and cattle (3, 101, 106) increased feed efficiency and rate of gain. This effect is suggested to be associated with the level of roughage and quality of the feed. The higher level of roughage and the poorer quality of feed have been found to give greater advantage for pelleting (14, 25, 26, 28, 78, 92, 100). Pelleting of high quality, concentrated rations has been found to give no advantage (14, 26, 92) or even to result in decreased intake and rate of gain, but increased feed efficiency (96). An increased feed efficiency with decreased intake and rate of gain, as also experienced in ruminants by Axelson et al. (4), can probably be explained by energy differences in body tissues laid down at various rates of gain, especially in swine where fast gains produce much fat.

The nutritional value of a given protein depends to a large extent on its amino acid make-up (104). This is especially true in non-ruminants which do not possess a well-developed protein synthesizing microflora in the gut (77). The recommended protein requirements for swine (94) and other non-ruminants are therefore based on an assumed diversity of protein source to assure an adequate amino-acid balance in the diet. When this requirement is fulfilled the digestibility of the protein governs its nutritive value.

The ratio of excreted nitrogen to ingested nitrogen is the apparent indigestibility coefficient of protein. The fecal nitrogen has been shown to depend on protein intake (38, 64, 74, 121), the level of indigestible fiber in the ration (74, 81, 84, 115, 121), the amount of dry matter consumed (74, 107, 108) and body size (121, 122). It has further been found to have two sources of origin, one being indigestible dietary protein, the other digestive juices, enzymes and abraided cells plus the microflora of the gastrointestinal tract, the latter fraction termed metabolic fecal nitrogen (31, 77).

Since the metabolic fecal nitrogen is independent of protein intake (31, 38), the apparent protein digestibility is partly a function of the protein level in a ration. In determining the true protein digestibility it is necessary to know the metabolic fecal nitrogen value, which is then deducted from the total fecal nitrogen. The metabolic fecal nitrogen has been determined by feeding a protein free diet (82), the fecal nitrogen then being entirely of metabolic origin. It has been suggested that the metabolic fecal nitrogen from a protein free diet is not the same as that from a balanced diet (18), and that some species could not survive long enough on a protein free diet to give reliable experimental observations (82). A small amount of a completely digestible protein in an otherwise protein free diet has therefore been used (81, 82). As an alternative, an extrapolation of fecal nitrogen to zero protein intake in an experiment of graded protein levels in the rations has been shown to give metabolic fecal nitrogen values of realistic magnitude (18, 117, 122). Since it has been found that the major variation in metabolic fecal nitrogen can be accounted for by the variation in metabolic body size (107, 108), dry matter intake (81, 107, 108) and dry matter excretion (81, 107, 122), it would seem most advisable to estimate protein digestibility by adjusting the fecal nitrogen for independent variables such as nitrogen intake, non-nitrogenous dry matter intake, non-nitrogenous dry matter excretion, metabolic body size, etc., in a multiple regression.

EXPERIMENTAL PROCEDURE

Purpose and Design

In this study the effect of plane of nutrition upon performance and carcass quality of swine and mice were observed. Mice were included to elucidate the recurring question as to whether they can serve as pilot animals for swine in nutritional investigations.

Similar rations were fed to the two species and identical experimental designs were used, except that only male mice were used, whereas sex differences in swine were investigated.

Three planes of nutrition (table 1) were tested by means of graded levels of fiber in the rations. Five sources of fiber were included. Each ration was fed either as a meal or as pellets, to observe the effect of pelleting. A 3 x 5 x 2 x 2 factorial design was used, the last factor being the sexes (swine only).

A second experiment with mice was conducted to verify the digestibility coefficients of the bulks derived from trial 1, since it was felt that they did not agree well enough with values from previous work in this laboratory.

Table 1.- Experimental Designs.

Source of Fiber (Bulk)	Sex	62% TDN Meal	62% TDN Pellet	65% TDN Meal	65% TDN Pellet	68% TDN Meal	68% TDN Pellet
Oat hulls	M. F.	1a (1)	1b	6a	6b	11a	11b
Alfalfa	M. F.	2a	2b	7a	7b	12a	12b
Wheat bran	M. F.	3a	3b	8a	8b	13a	13b
Cellulose	M. F.	4a	4b	9a	9b	14a	14b
Corn cobs	M. F.	5a	5b	10a	10b	15a	15b

(1) Ration number.

Table 2.- The Ration Ingredients and Their Composition.

Ingredient	Dry matter (1)	TDN (2)	Crude protein	Gross energy (1)	Calcium (2)	Phosphorus (2)
	%	%	%	Cal./gm.	%	%
Wheat	92.5	70	15.2(1)	4.51	0.05	0.37
Barley	93.0	70	13.1(1)	4.46	0.09	0.47
Soybean oil meal	94.0	77	44.1(1)	4.85	0.25	0.60
Meat meal	94.9	77	47.5(1)	3.99	8.00	4.00
Oat hulls	94.9	27	3.0(2)	4.40	-	-
Alfalfa meal	94.4	45	17.0(2)	4.49	1.20	0.20
Wheat bran	92.6	57	16.0(2)	4.66	0.10	0.20(4)
Cellulose	96.4	0	0	4.16	-	-
Corn cobs	96.8	0	0	4.43	-	-
Casein	92.8	87	81.8	5.82	-	-
Calcium carbonate					38.50(3)	
Dicalcium phosphate					23.50(3)	18.70(3)

(1) Determined in the laboratory.

(2) Data obtained from recognized foodstuffs tables.

(3) Manufacturer's analyses.

(4) Phytin phosphorus not included (77).

Rations

The basal rations were made up from equal parts of wheat and barley as the major digestible energy source, and equal parts of soybean oil meal and meat meal as the major protein source. On the basis of the composition of the ingredients given in table 2, the rations were calculated to comply with the requirements for total digestible nutrients (TDN) and protein by solving the equations:

$$\frac{(T \times X) + (T \times Y) + (T \times Z)}{100} = \text{per cent TDN in the ration;}$$

$$\frac{(P \times X) + (P \times Y) + (P \times Z)}{100} = \text{per cent protein in the ration;}$$

$$\frac{X + Y + Z}{100} = 1.00;$$

where:

T = per cent TDN in component.

P = per cent protein in component.

X = per cent of "bulk" in the ration.

Y = per cent of wheat and barley in the ration.

Z = per cent of soybean oil meal plus meat meal in the ration.

Vitamins A and D were added in synthetic form (*). Since the carrier in this supplement was soybean oil meal it was substituted for equal amounts of this ingredient in the basal ration. A 50% safety margin above the recommended level (94) for swine was supplied, namely 150 I.U. of vitamin D and 1500 I.U. of A per pound of feed.

The calcium and phosphorus contents of the rations were adjusted to 150% of the requirements (94) by adding calculated amounts of calcium

---

(*) Vitamin A and D supplement supplied by N. D. Hogg Ltd., Toronto, Ont.

carbonate and dicalcium phosphate. One half per cent iodized salt was added to all rations. Fourteen per cent protein was provided in the rations for swine, this level was increased by adding 2% casein to the diets for mice. Table 1 in appendix contains detailed composition of all rations.

Swine Experiment

Experimental animals: Purebred Yorkshires of the University Farm herd were used. Sixty gilts and sixty barrows were randomly allotted to the thirty rations, two replicates to each sex. They were started on the test as they reached 100 ± 5 pounds live weight during the late spring and summer of 1958.

Experimental facilities: The trial was carried out in the experimental piggery which provides such facilities as individual self-feeding, automatic watering and cleaning systems, forced air ventilation and heating, raised sleeping platforms, and weighing equipment for feeders and animals. The rations for the pigs were made up in 1000 pound batches in the farm elevator. Pre-mixes of the protein, mineral and vitamin concentrates were prepared in a smaller mixer prior to the final blending of all the components. It was estimated that 60 tons of feed was needed for the experiment. The half of this was made into 3/16 inch pellets at the Federated Cooperatives Ltd.(*) Feed Plant at Saskatoon, and the entire requirement prepared prior to the beginning of the trial. The other half, which was fed as a meal, was mixed in 500 pound lots as needed during the experiment.

(*) Pelleting of the rations by the Federated Cooperatives Ltd., Saskatoon, and slaughtering of the barrows by the Empire Meat Co. Ltd., Saskatoon, is acknowledged.

Feeding practices: The feeding can be classified as partly restricted self-feeding (13). The pigs were allowed to eat for one hour twice daily (7 - 8 a.m. and 4 - 5 p.m.), during which timesthey were confined to individual feeding stalls without access to water. As a rule, less than an hour was required to satisfy the appetite. A limited amount of wastage was noted mainly in the unpelleted high fiber rations. However, any wastage was returned to the feeders or deducted from the feed supplied, giving feed records without loss. The pigs appeared to consume small amounts of the wheat straw used for bedding.

Experimental observations and sampling techniques: Body weights and feed consumptions were recorded at 14 day intervals. At 200 ± 5 pounds live weight the pigs were taken off test. The back fat thickness was measured on the live animals by means of the leanmeter as in a previous study in this department on measurement of carcass quality (125). The barrows were slaughtered at the Empire Meat Co. Ltd., Saskatoon. Their carcasses were scored according to the Advanced Registry (AR) specifications (90) by officers of the Production and Marketing Branch of the Canada Department of Agriculture. The detailed measurements are presented in the appendix table 2.

The digestibility and rate of passage of the diets were determined for all the animals by the chromic oxide indicator technique. One per cent chromic oxide (Cr_2O_3) was added to the pre-mix for a 500 pound batch of each ration. Half of each batch was pelleted. Each pig was fed its chromic oxide-containing ration for 7 consecutive days. The number of hours between the first feeding of chromic oxide and its appearance in the feces was recorded as rate of passage. "Grab samples" of the feces were obtained at 8 a.m., 1 p.m. and 5 p.m. during the three last days. As a preservative, 50 ml. of 4% boric acid and 1 ml. of toluene was used, for a day's collection. At the end of the sampling, all the feces from any one pig were combined, mixed with water, and homogenized in a five quart, high speed, Waring blendor. A part of the homogenate was poured into a dozen of $\frac{3}{4}$ ounce-portion paper-cups. In this condition the samples were frozen and kept until the time of analyses in the laboratory. The rations were sampled from the individual feeders, bulking identical diets.

Analyses were carried out on the feed and feces samples for gross energy by the oxygen bomb calorimeter; nitrogen by the micro Kjeldahl technique (*); and chromic oxide by the perchloric acid method (appendix).

Mouse Trial 1

Animals originating from the Carworth Farms No. 1 strain, which have been bred in this department for nearly eight years, were used in the experiment. Weanling male mice weighing between 8 and 9 grams and less than 21 days of age, were randomly allotted to four replicates of the thirty rations shown in table 1 and appendix table 1 and to individual cages of a battery in the thermostatically controlled laboratory. Feed and water were allowed _ad lib_. The trial lasted for 14 days during which time individual feed intakes and body gains were recorded. For the purpose of digestibility determinations the fecal production during the last 10 days was collected and its dry weight recorded.

At the end of the experiment the body composition of the mice was determined. After removal of food residue from the intestinal tracts the

---

(*) A steam distillation suitable for micro Kjeldahl analysis. R. Markham. Biochemical Journal, 36: 790-791. 1942.

carcasses were subjected individually to analyses for water, fat, ash and protein, the latter by difference (appendix).

Prior to the mixing of the rations the individual ingredients were finely ground in order to avoid sorting by the animals. To simulate pelleting, half of each ration was moistened, put through a meat chopper and dried in vacuum at 75° Centigrade. This process gave the mixtures a hard crumbled texture.

Gross energy determinations and nitrogen analyses were carried out on the feed and feces samples combined according to treatment.

Mouse Trial 2

Since the digestibility coefficients of the bulks obtained in trial 1 deviated markedly from values derived in earlier work in this laboratory, it was desirable to check them in an additional trial. In this, the experimental conditions were kept similar to those in trial 1 except that the bulk increments were added to basals of uniform composition, in an effort to reduce the effect of various basals on the digestibility of the bulks.

The uniform basal in this trial was identical to the basal fraction of ration number 2 in trial 1 (appendix table 1). The levels of bulk added were similar to those in trial 1 but rounded. In addition to these 15 rations, rations corresponding to the basals of nos. 2, 8 and 14 in trial 1 were fed without addition of bulk. This was done to check the digestibility of these basals obtained in simultaneous feeding in trial 1. Thus in trial 2 a total of 18 rations was fed in three replications. Pelleting was omitted.

For the purpose of determining rate of passage, the weight and per cent dry matter of the residue in the alimentary tract were obtained at termination of the experiment. Carcass analyses were not carried out. In all other respects the procedure was similar to that followed in trial 1.

RESULTS AND DISCUSSION

Swine Trial

Level of total digestible nutrients (TDN) in the rations: In formulating the rations the TDN unit was used because of its dominance in feeding stuffs tables and in recommendations for nutrients allowances. For comparative purposes the actual TDN in the rations listed in table 3, was calculated from gross energy content and its digestibility as determined by the chromic oxide technique. A conversion factor of 4.4 digestible Calories per gm. of TDN, as suggested by Crampton (31), was used.

The feeding of several levels of each bulk facilitated the calculation of separate TDN contents of the bulks and basals (table 4). For this purpose, a slight modification of "Carbery's Method of Determining Digestibility" as described by Crampton (31) was used (appendix).

For each type of bulk the regression ($Y = a + bX$) of fecal Calories (Y) on gross Calories ingested per 100 Calories in basal (X) was calculated. In this relationship the regression coefficient (b) is the ratio of fecal Calories from bulk to Calories ingested in the bulk increment which is the indigestibility coefficient of energy. Consequently the per cent energy digestibility of bulk is: $100 - (100b)$(appendix).

Since each value of X contains 100 Calories of the basal ration plus a number of Calories from the bulk component, the ratio of Y (estimated for $X = 100$) to 100, is the indigestibility coefficient of energy in the basal. Thus the per cent energy digestibility of the basal ration is: $100 - (100b + a)$(appendix). The confidence intervals of b and of estimated $\bar{Y}$ (114), serve as such for the digestibility coefficients of bulk and basal respectively.

Table 3.- Total Digestible Nutrients(1) in the Swine Rations (Per Cent).

Bulk type	Bulk level						Mean		
	High		Medium		Low		High	Medium	Low
	Meal	Pellet	Meal	Pellet	Meal	Pellet			
Oat hulls	56.6	63.6	58.6	67.1	65.5	72.6	60.2	62.8	68.9
Alfalfa	61.1	65.6	62.1	72.1	63.1	72.6	63.4	67.1	68.0
Wheat bran	58.1	64.6	60.1	65.1	71.1	69.6	61.3	62.7	70.4
Cellulose	64.1	69.1	60.6	71.6	69.6	72.1	66.6	66.1	70.9
Corn cobs	58.6	71.1	65.6	70.1	71.1	76.6	64.9	67.9	73.9
D(bulk type)($P<0.05$):5.5							: 4.0		
D(bulk level)($P<0.05$):5.0							: 3.5		
D(meal vs. pellet)($P<0.05$):4.0									

(1) 4.4 digestible Calories = 1 gm. of Total Digestible Nutrients.

D = difference necessary for significance at $P<0.05$ (114).

Table 4.- Total Digestible Nutrients Calculated Separately for Bulks and Basals in the Swine Rations.

Type of bulk	(1) Correlation coefficients (r_{yx})	% TDN		Significance of Deviation from linearity at P:
		(2) in bulk	(3) in basal	
Oat hulls	0.91	20 ± 17	70 ± 5	< 0.05
Alfalfa	0.91	51 ± 10	70 ± 3	> 0.25
Wheat bran	0.97	57 ± 6	73 ± 6	< 0.10
Cellulose	0.77	14 ± 30	73 ± 3	< 0.10
Corn cobs	0.78	-2 ± 37	75 ± 4	< 0.01

(1) y = Cal. excreted/100 Cal. in basal ration ingested.
x = Cal. ingested/100 Cal. in basal ingested.

(2) $$\frac{(100 - 100b) \times \text{Cal./gm.}}{4.4} = \%\ \text{TDN.}$$

(3) $$\frac{(100 - (100b + a)) \times \text{Cal./gm.}}{4.4} = \%\ \text{TDN.}$$

From table 3 it is particularly noticeable that pelleting increased the TDN levels significantly ($P < 0.05$) in all rations except the low levels of wheat bran and cellulose. Theoretically this increase could be due to chemical changes brought about by heat, pressure, moisture, or combinations of these in the pelleting process. (1, 2, 14, 15, 72, 100).

It is also obvious that most of the rations failed to comply with the desired TDN levels of 62, 65 and 68 per cent respectively in the high, medium and low bulk rations as set out in table 1. Furthermore the variability within bulk levels was too great to allow a distinction between the medium and either of the outside levels. However, when the effect of pelleting is neglected, for comparative purposes (table 3, columns 7-9), it is apparent that the failure of the various rations to measure up to expectations has several causes. For the oat hull rations it seems to be due to an over-estimation of the TDN level in the oat hulls (tables 2 and 4) and, an associative effect between the bulk and basal, as indicated by a deviation from linearity of the function of Y on X (table 4)(appendix I).

The alfalfa rations are closer to the design (tables 1 and 3) than any other, although the low and medium TDN levels are 1 to 2 per cent too high. The test for linearity suggests that the associative effect between alfalfa and basal is smaller than for the other four types of bulk used (appendix). In the wheat bran rations the disagreement with the design (tables 1 and 3) appears to be due mainly to associative effect, since the TDN levels of bulk and basal (table 4) agree fairly well with the proposed values in table 2, and since the function of Y on X deviates from linearity ($P < 0.10$) (table 4).

The cellulose rations disagree with the design (tables 1 and 3) apparently because of an underestimation of the TDN in cellulose (tables 2 and 4) and/or an associative effect indicated by a deviation from linearity at $P<0.10$ (table 4). Also the corn cob rations deviated from the designs (tables 1 and 3) mainly because of associative effects between bulk and basal as evidenced by a deviation from linearity of the regression of Y on X, which is significant at $P<0.01$ (table 4).

The 95 per cent confidence intervals on the TDN in the bulks (table 4) indicate a great variability between individual animal's abilities to digest fibrous material. However, it is essential to bear in mind that the magnitude of influence of associative effects and experimental errors is inversely proportional to the fraction of the ration constituted by the compound or mixture, for which the TDN is determined in simultaneous feeding, (appendix I).

Since in most rations the bulk is a minor part, the majority of the variability in TDN content could be due to experimental errors and/or associative effects between bulk and basals. Thus in the case of corn cobs, which is present in the rations in an average of 8 per cent (appendix table 1), an experimental error or associative effect causing a 1 per cent change in the TDN of the basal ration would change the apparent TDN in the corn cobs by 92/8 = 11.5%.

The 95 per cent confidence intervals on the TDN in the basal rations indicate that in spite of some variability in composition (appendix table 1), only the corn-cob-basals deviated significantly from oat hull and alfalfa-basals. This deviation could be due to a relatively large associative effect as indicated by the deviation from linearity of Y on X ($P<0.01$)(table 4).

Digestible crude protein (DCP) in the rations for swine: The designed 14 per cent crude protein in the rations was exceeded in all cases (table 5) for unknown reasons. However, since the feed samples were bulked for analyses, it is not known whether the deviations are statistically significant.

The apparent digestibility of the protein (table 5) was decreased significantly ($P < 0.05$) with increasing bulk levels only in the case of alfalfa and wheat bran. The high level of these two bulks also exhibited a significantly lower protein digestibility than the high level of the three remaining bulks. The medium alfalfa level gave DCP values significantly lower than the medium level of any of the other bulks, while the low alfalfa caused protein digestibilities lower ($P < 0.05$) than the corresponding levels of wheat bran, cellulose and corn cobs.

It has been shown that the apparent digestibility of crude protein is affected, through metabolic fecal nitrogen, by such factors as protein intake (38, 64, 74, 121), level of indigestible fiber in the ration (64, 81, 84, 115, 121), amount of dry matter consumed (74, 107, 108), and physiological body size (121, 122), thus an attempt has been made to adjust (appendix) for these variables (table 5, column 5). A multiple regression,

$$Y = 0.083 + 0.291X_1 + 0.067X_3 - 0.002X_4 - 0.031X_2$$

where Y = pounds of nitrogen x 6.25 excreted daily,

X_1 = pounds of nitrogen x 6.25 intake daily,

X_2 = pounds of nonprotein dry matter intake daily,

X_3 = pounds of nonprotein dry matter excreted daily,

and X_4 = physiological body weight ($\text{lbs.}^{0.75}$),

Table 5.- Protein in the Swine Rations.

Bulk Type	Bulk Level	Crude protein	Protein digestibility apparent	Protein digestibility adjusted(1)	Apparent digestible crude protein in feed	Apparent digestible crude protein in energy	Apparent digestible crude protein intake
		%	%	%	gm./lb.	gm./dig. Therm	gm./day
Oat hulls	High	15.2	79.0	84.2	54.2	45.2	278
	Medium	14.7	77.5	75.7	51.8	41.6	232
	Low	15.6	76.7	80.9	54.1	39.4	269
Alfalfa	High	15.5	69.4	66.4	48.8	38.6	211
	Medium	15.3	70.0	65.7	49.1	36.8	219
	Low	15.5	73.7	72.0	51.7	38.1	249
Wheat bran	High	15.5	73.2	69.6	51.5	42.2	222
	Medium	14.6	74.7	71.7	47.6	38.2	211
	Low	16.3	79.3	82.4	56.0	41.6	285
Cellulose	High	15.5	78.9	80.3	55.4	41.7	264
	Medium	15.1	77.2	78.3	52.8	40.0	241
	Low	14.6	79.2	76.6	52.5	37.1	254
Corn cobs	High	15.6	80.6	83.1	57.1	44.4	286
	Medium	15.3	79.5	82.0	54.9	40.5	275
	Low	14.1	79.7	81.4	50.8	34.5	252
D($P<0.05$)			4.6	2.3	3.2	1.7	34
	D($P<0.05$)		3.9	1.5	2.7	1.5	29
Meal			74.8	74.6	51.4	41.0	241
Pellet			78.5	78.7	54.0	39.0	258
D($P<0.05$)			1.2	1.0	0.8	0.5	9

(1) See appendix II.

was used in adjusting the nitrogen x 6.25 excreted for the four independent variables. The adjusted values were used in calculating the protein digestibility (table 5, column 5).

In the above regression the coefficients of X_1, X_3 and X_4 were significant at $P<0.01$, while X_2 was significant at $P< 0.05$. Of the total variability in the fecal protein (nitrogen x 6.25) 32.8 per cent was accounted for by the four independent variables. The variability in protein intake accounted for 64.3 per cent of this, variability in nonprotein dry matter excretion accounted for 28.6 per cent, physiological body weight for 5 per cent and nonprotein dry matter intake for 2.9 per cent.

The adjusted protein digestibilities (APD)(table 5) feature larger and more significant differences than the apparent values, indicating that some important causes of variability were not considered in the multiple regression.

The significantly lower APD in the high and medium alfalfa and wheat bran rations (table 5) than in the corresponding cellulose and corn cob rations suggest that protein source is one of the omitted factors. The same is indicated by the inverse relationship between APD and levels of alfalfa and wheat bran, and the increase in APD from medium to low oat hull level. In other words in oat hulls, alfalfa and wheat bran a portion of the protein could be tied up in fibrous material and thus prevented from digestion. Since cellulose and corn cobs contain no protein, such an effect could not take place in these rations.

The direct relationship between APD and levels of cellulose and corn cobs (table 5) could perhaps be explained by a simple dilution effect, i.e.

the greater bulk level could theoretically increase the exposure of the nutrients to digestive enzymes and intestinal absorption area causing a greater digestibility. The peculiar values for the three oat hull levels are unexplainable, except for the opposing effects of the above two theories.

The levels of apparent digestible crude protein per pound of feed, per digestible Therm and consumed per day, are shown in table 5, columns 6-8. The accuracy of these values is affected to some degree by the apparent protein digestibility and differences in the crude protein content of the rations. In the case of the alfalfa and wheat bran rations the increasing bulk levels significantly ($P<0.05$) decreased the digestible crude protein level in the rations. This trend, however, is reversed between the medium and low wheat bran rations, apparently due to a lower crude protein content in the medium rations. In the cellulose and corn cob rations the higher bulk levels show significantly higher levels of digestible crude protein, apparently due to a higher crude protein level.

Since all the rations were designed to contain the same level of crude protein, the ratio of digestible protein and digestible energy could be expected to increase with bulk level. This increase (table 5, column 7) was significant ($P< 0.05$) except between the low and medium levels of alfalfa and wheat bran. In these two cases the apparent protein digestibility (column 4) was increased sufficiently at the low bulk levels to change the sequence and reverse it in the case of wheat bran. Thus, despite the distortion by the apparent protein digestibilities, it appears obvious that in the higher bulk rations the animals received a greater fraction of the absorbed nutrients as protein.

The daily intake of apparent digestible crude protein (table 5, column 8) depends on feed intake, protein level and digestibility.

Peculiar variation and significant differences in these values can be explained by above criteria. Thus, the lower ($P<0.05$) intake in the medium--than in the low--oat hull rations, is caused mainly by the lower crude protein level, while the difference ($P<0.05$) between the medium and the high in addition is due to the difference in apparent digestibility (table 5) and an increasing feed intake with increasing bulk level (table 7). The significantly greater digestible protein intake in the low alfalfa and wheat bran rations coincides with a significantly greater apparent protein digestibility (table 5, column 4) and a decreasing feed consumption with increasing bulk level (table 7). In the corn cob rations, where the high level caused a greater ($P<0.05$) intake of digestible protein than the low level, this was associated with a higher crude protein level in the rations, and a higher apparent digestibility of the protein, although not significant. In addition, increasing bulk level was associated with increasing feed intake (table 7).

The effect of pelleting was a significant increase in apparent protein digestibility (table 5). This caused a greater ($P<0.05$) digestible crude protein level in the rations. A significant decrease in the ratio of digestible protein and digestible energy indicates that the digestibility of other components in addition to protein was increased by pelleting. Since pelleting did not increase feed intake significantly (table 9), the increase ($P<0.05$) in digestible crude protein intake appears to be due to the increased digestibility of protein (table 5).

No differences existed between sexes in any of the above discussed criteria (appendix tables 4, 7, 8 and 11).

Animal response as a ration unit: In most nutritional experiments in livestock production, the ration response is measured by gain in body weight, although the most economical gain may be the ultimate goal. Due to the transient nature of fluctuations in economical responses it is desirable to separate these from the biological effects by applying a measure which can be subjected to current economical structures. In bacon production body weight gain cannot be considered as such a measure because of consumer preference in quality.

The amounts of lean and fat are most accurately determined by complete carcass analyses, but this is impractical in the bacon carcass, and furthermore it does not indicate the distribution of these tissues. Commercial grading can be used as an adjunct to body weight gain to obtain a superior appraisal of ration response. The distribution of commercial grades in the swine experiment is listed in table 6. It is interesting to notice that the three B2 grades were due to underweight and that they originated in the high bulk rations of the two more bulky mixtures of alfalfa and wheat bran. The B1 grades due to underweight were distributed evenly among the three bulk levels, with the three cases in the low bulk rations originating in the alfalfa and wheat bran mixtures. The B1 grades due to overfinish all occurred in the low bulk rations. The highest percentage of grade A carcasses were obtained in the medium bulk level of corn cob and oat hull mixtures, which then would indicate that these were the more ideal rations from the grading view point. The physical condition of the rations appeared to have no effect on the carcass grading (table 6).

Table 6.- Distribution of Commercial Grades and Average Dressing Percentages.

Treatment	Total observations	Grade B1 (1)	A	B1 (2)	B2 (3)
Level of bulk					
High	20	-	13	4	3
Medium	20	-	16	4	-
Low	20	5	12	3	-
Type of bulk					
Oat hulls	12	1	10	1	-
Alfalfa	12	1	7	3	1
Wheat bran	12	-	5	5	2
Cellulose	12	2	8	2	-
Corn cobs	12	1	11	-	-
Physical condition					
Meal	30	4	18	6	2
Pellet	30	1	23	5	1
Total	60	5	41	11	3
Dressing percentage: D(0.05) = 0.7		73.6	72.8	70.2	68.0

(1) Overfinished and/or too much shoulder fat.
(2) Carcass wt. below 140 lbs. (only fault).
(3) Carcass wt. below 135 lbs. (only fault).

Since in all cases but five, the disqualification for grade A's was due to faulty carcass weight, the variability in carcass weights (Y) and its causes were studied. The first independent variable to consider was naturally the shipping weight (X_1). The dressing percentage, which is the ratio of chilled carcass weight and shipping weight, accounts for the remaining variability. It was therefore desirable to examine factors affecting the dressing percentage. As it has been suggested that bulky rations enlarge the gastrointestinal tract (16) and therefore cause decreased dressing percentage (11, 17, 27), the bulkiness of the rations in terms of daily intake of digestible Therms (X_2) was used as the second independent variable, giving the regression:

$$Y = 0.79X_1 + 2.50X_2 - 30.64.$$

The standard deviation of Y and the errors of estimate from X_1 and X_2 show that, of the variability in carcass weight (Y), 26.2% was due to shipping weight (X_1) and only 2.3% was caused by bulkiness of the ration in terms of digestible energy intake (X_2), while the remaining 71.5% was due to other factors including experimental errors.

Thus, it appears that if some of the major causes of the variability in dressing percentage were brought under control, all the rations fed could produce a high percentage of grade A carcasses by adjusting the shipping weight accordingly. However, this may not apply generally under <u>ad lib</u>. feeding, since in this experiment the pigs were restricted to feed for two hours per day during which time they had no access to water. And, both of these limitations have been shown to reduce the feed consumption (13,49), which again would affect the degree of finish, fatness and commercial grading. An estimate of the degree of restriction imposed by the feeding technique used, was obtained by comparing the maturity of the pigs in the experiment to the pigs simultaneously fed in the piggery, but not on test. The latter group consisted of twenty-eight barrows and sixty-one gilts, which were considered as one group, since the difference between sexes was not significant ($P < 0.05$). The experi-
(P 0.05)
mental pigs finished an average of ten days slower than the non-experimental ones despite the experimental rations containing an average of 66.3% TDN, while the commercial finishing ration was estimated to contain 64.9% TDN.

The main dressing percentages of the four groupings of commercial grades in table 6 are all significantly different ($P < 0.05$). It is typical that the dressing percentages decrease with decreasing degree of finish and decreasing carcass weights, probably reflecting the effect of a slower finishing rate upon carcass composition.

Feed intake: Due to the variability in TDN between types within levels of bulk (table 3), it was found convenient to compare bulk types by means of regressions of the various observations on per cent of bulk in the ration. In table 7 the effects of bulk type on feed intake, digestible energy (DE) in the ration, and digestible energy intake (DEI) are recorded.

In the "per cent bulk-digestible Calories per pound of feed" function, the regressions are all highly significant, whereas in the per cent bulk-DEI effect, changes and/or variability in feed intakes reduced the significance of the regressions in the case of the oat hull, cellulose and corn cob rations, but did not change them in the case of alfalfa and wheat bran rations, which latter may be attributed to the greater spread in the levels of these two bulks (table 1, appendix).

The changes in daily feed intake with increasing bulk level are shown in table 7, column 3. The 5% confidence intervals on the regression coefficients of feed intake on bulk level show that the effect of all the bulks were significant at the levels fed. That oat hull and corn cob rations were consumed in greater amount as the level of bulk increased, presumably was an attempt to compensate for decreases in the level of

Table 7.- The Effect of Bulk Type on Feed Intake, Digestible Energy Intake and Digestible Energy Content on the Rations for Swine.

Type of bulk	Mean % bulk	Feed intake (lbs./day) Mean	Feed intake (lbs./day) Change for each % increase in bulk	Digestible Calories per pound of feed Mean	Digestible Calories per pound of feed Change for each % increase in bulk	Digestible Calories consumed per day Mean	Digestible Calories consumed per day Change for each % increase in bulk
Oat hulls	12.7	4.86	+0.05 ± 0.016	1276	-11.7**	6200	-43.2
Alfalfa	20.3	4.52	-0.08 ± 0.008	1320	- 4.7**	6000	-43.5**
Wheat bran	38.6	4.55	-0.06 ± 0.005	1293	- 4.6**	5910	-36.3**
Cellulose	7.8	4.73	-0.04 ± 0.038	1355	- 9.7**	6400	-56.3
Corn cobs	7.8	5.00	+0.03 ± 0.029	1375	-20.0**	6860	-92.4*
D($P<0.05$)		0.32		47	-	329	

* Significant at $P<0.05$.
** Significant at $P<0.01$.

nutrients in the rations. The effect of these bulks would probably change to negative values if larger amounts of the bulk were used.

Apparently the higher levels of alfalfa and bran, and of the more voluminous cellulose exceeded the animals' capacity and/or desire for feed intake and thus brought about a decrease in addition to the declining DE level in the ration. Thus, while the magnitude of decline in DE of the rations depends on the digestibility of the bulk type and associative effect, the degree of decline in DEI in addition depends on palatability and bulkiness of the ration.

The significant differences between the mean feed intakes, digestible Calories per pound of feed and DEI (table 7), may be considered as due to failure to fully appreciate the full implications of DEI in the design of the rations. However, since the TDN unit does not consider the feed intake or DEI, one can only estimate what the level of bulk in the rations should have been on the basis of DE in the rations (table 8).

Table 8.- Levels of Bulk in the Rations for Swine.

Type of bulk	62% TDN		65% TDN		68% TDN	
	Provided	Should have been	Provided	Should have been	Provided	Should have been
	%	%	%	%	%	%
Oat hulls	20.2	16.4	12.5	11.4	5.5	6.2
Alfalfa	32.0	38.9	20.3	26.3	8.5	13.5
Wheat bran	60.5	50.5	38.8	37.7	16.5	24.6
Cellulose	12.3	20.8	7.8	14.7	3.3	8.5
Corn cobs	12.3	15.1	7.8	12.2	3.3	9.2

It cannot be overlooked, however, that intake of digestible energy is an even better criterion for desired bulk percentages than DE in the rations. For this purpose the nature of the relationship between bulk levels and intakes of DE for various bulk types could be studied further. The data in table 7, column 8 are derived from linear regressions in which only three levels of bulk were used. Only the regression for oat hulls deviates from linearity ($P<0.05$). This, however, is not satisfactory proof that the relationship between bulk level and intake for the remaining four types is rectilinear in the range covered, since three points on a sigmoid curve could fall on a straight line and thus show no deviation from linearity.

In view of the finding by various research groups, that pelleting is of greater advantage in more bulky rations, it is worth noticing that in this experiment pelleting had no significant effect on feed intake (table 9), nor was there any significant interaction between bulk types, bulk levels and physical condition (table 9, appendix), which might have been expected because of texture differences in the bulks.

Table 9.- The Effect of Pelleting on Intake of Nutrients in the Rations for Swine.

Bulk level	Feed intake lbs./day		Digestible energy intake Therms/day	
	Meal	Pellet	Meal	Pellet
High	4.72	4.71	5.63	6.27
Medium	4.54	4.65	5.57	6.43
Low	4.79	4.98	6.53	7.22
DL(1)	0.32		0.47	
DP	0.26		0.39	

(1) See footnote appendix table 3.

The digestible energy intake was increased significantly by pelleting, due mainly to increased digestibility of the rations (table 9).

Since it has been established that under similar conditions barrows produce a lower grade carcass than gilts, due to overfinish, it is important to notice that the males had a significantly greater daily intake of digestible energy than females (table 10, appendix). This was due to greater feed intake (table 9, appendix) rather than to increased digestibility, since the digestible energy in the rations between sexes was not significantly different (table 6, appendix).

Performance of swine: The slower gains produced by the alfalfa and wheat bran rations (table 10, section A) is a reflection of lower daily intakes of digestible energy (table 7) rather than a lower digestible energy efficiency. This is borne out by consideration of the gains adjusted for digestible energy intake and efficiency of DE utilization as shown by digestible energy per pound of gain (table 10).

The faster gains by the oat hull rations than by bran and alfalfa was due to a greater digestible energy efficiency (table 10), rather than to intake of total feed or digestible energy (table 7).

The data in table 10, section A indicate that when palatability and bulkiness of the bulks were considered in making up the rations to assure equal intakes of digestible energy, the oat hull rations appeared to give faster and more efficient gains than any of the other four bulks.

The various bulk levels (table 10, section B) had an expected effect on the rate of gain and feed- and energy-efficiency; the low levels producing significantly ($P<0.05$) faster gains than the high and medium levels, and giving significantly greater feed efficiency than the high levels.

Table 10.- Performance of Swine (Mean Values).

Treatment	Gains unadjusted	Gains adjusted for DEI(1)	Efficiency Feed/gain	Efficiency DE(2)/gain
	lbs./day	lbs./day	lbs./lbs.	Therms/lbs.
A. Bulk type				
Oat hulls	1.23	1.24	3.97	5.05
Alfalfa	1.09	1.14	4.21	5.54
Wheat bran	1.05	1.12	4.43	5.69
Cellulose	1.20	1.17	3.98	5.37
Corn cobs	1.30	1.18	3.88	5.32
$D(P<0.05)$	0.12	0.07	0.31	0.41
B. Bulk level				
High	1.13	1.20	4.22	5.31
Medium	1.13	1.19	4.12	5.35
Low	1.25	1.14	3.95	5.55
$D(P<0.05)$	0.08	0.05	0.20	0.27
C. Physical condition				
Meal	1.11	1.19	4.24	5.33
Pellet	1.23	1.16	3.95	5.47
$D(P<0.05)$	0.05	0.03	0.14	0.18
D. Sex				
Male	1.22	1.16	4.14	5.46
Female	1.13	1.19	4.06	5.34
$D(P<0.05)$	0.05	0.03	0.14	0.18

(1) Digestible energy intake.
(2) Digestible energy.

Although a trend apparently exists, no significant differences occurred in digestible energy efficiency as measured by the ratio of digestible energy to gain. However, it is interesting to notice that the gains adjusted for digestible energy intake are significantly greater for the high and medium, than for the low bulk levels. This controversy in significance of digestible energy efficiency can probably be accounted for by the error introduced in the digestible energy efficiency figures by the implied assumption that all of the digestible energy consumed is used for gain. This implication penalizes the better rations and favors the poorer ones thus bringing the difference below significance.

The effects of pelleting (table 10, section C) were significantly faster gain and greater feed efficiency, a reflection of the increased digestible energy level of the rations rather than from increased feed intake (table 9). The error introduced in the digestible energy efficiency figures (table 10, section C) by neglecting to deduct the energy used for maintenance appears to be great enough to reduce the difference between meal and pellets to below significance when the meal actually gave significantly ($P < 0.05$) higher digestible energy efficiency than the pellets, according to the gains adjusted for digestible energy intake.

The barrows gained significantly faster than the gilts (table 10, section D) due firstly to a significantly greater feed intake (appendix table 9) and, secondly since there was no sex difference in digestibility of energy (appendix table 6), to a significantly greater digestible energy intake (appendix table 10).

When the total feed and digestible energy used for maintenance were neglected in calculating the efficiency of these two criteria for gain (table 10, section D) no differences existed between sexes. However, the gains adjusted for digestible energy intake, show a significantly greater digestible energy efficiency by the female pigs. This latter effect is in accordance with the concept that as rates of gain increase the animal lays down increasing proportions of fat in the body tissues, which again calls for more energy per unit of gain due to energy differences between fat and protein. The fact that the barrows produced significantly ($P<0.05$) thicker average back fat than the gilts according to the leanmeter measurements (appendix table 16) supports the concept that on similar rations barrows will eat more feed, gain faster, produce more fat and exhibit a lower feed efficiency than gilts.

Carcass characteristics: The effect of bulk type on various carcass characteristics is shown in table 11, section A. As pointed out earlier the reliability of this comparison is lessened by the failure to design the rations so as to provide nearly equal intakes of digestible energy between types and within levels of bulk (appendix table 10).

The wheat bran rations resulted in significantly lower dressing percentages than the oat hull and corn cob rations (table 11, section A). This was associated with a slower growth rate (table 10, section A), lower intakes of total feed and digestible energy (table 7), less average back fat and per cent of middle (table 11, section A). There were also trends toward larger loin area and higher AR scores. However, these trends were not statistically significant and it is recognized that all of these effects are typical of finishing pigs on restricted energy intakes.

Table 11.- Carcass Characteristics of Swine (Males Only)(Mean Values).

Treatment	Dressing percentage	Ham	Middle	Shldr.	Shldr. fat	Average back fat Grader(1)	Average back fat Leanmeter	Loin area	AR score
		%	%	%	ins.	ins.	ins.	sq. ins.	
A. Bulk type									
Oat hulls	73.1	24.9	48.0	27.2	1.74	1.33	1.15	3.87	87.8
Alfalfa	72.2	25.1	47.5	27.4	1.73	1.31	1.20	3.93	89.6
Wheat bran	70.5	24.8	47.8	27.4	1.63	1.22	1.08	4.07	88.8
Cellulose	71.9	24.2	49.0	26.8	1.74	1.36	1.21	3.85	84.2
Corn cobs	73.0	24.7	48.2	27.1	1.71	1.34	1.21	3.70	85.3
$D(P<0.05)$	2.1	1.0	1.1	1.0	0.14	0.11	0.09	0.53	6.5
B. Bulk level									
High	71.4	25.0	47.7	27.4	1.65	1.26	1.11	3.93	90.1
Medium	72.1	24.6	48.1	27.3	1.70	1.29	1.17	4.03	88.8
Low	73.0	24.6	48.6	26.8	1.78	1.39	1.23	3.69	82.4
$D(P<0.05)$	1.4	0.7	0.7	0.6	0.09	0.07	0.06	0.35	4.3
C. Physical condition									
Meal	72.2	24.8	47.9	27.3	1.72	1.31	1.19	3.91	86.8
Pellet	72.1	24.7	48.3	27.1	1.70	1.32	1.15	3.86	87.4
$D(P<0.05)$	1.0	0.5	0.5	0.4	0.06	0.05	0.04	0.24	2.9

(1) As measured by the official meat grader.

With regard to feed intake, digestible energy intake (table 7), growth rate and feed and energy efficiency (table 10, section A), the alfalfa rations resembled the wheat bran rations. However, in the effects upon the carcasses by the two types of rations, only the percentage of middles, the loin area and the AR scores were of similar trends, while the average back fat, according to the leanmeter, was significantly thicker for the alfalfa rations than for the wheat bran rations (table 11, section A).

The oat hull, cellulose and corn cob rations did not produce effects significantly ($P<0.05$) different from one another in any of the measured carcass characteristics (table 11, section A).

The failure to design the rations so as to provide nearly equal DEI's between types and within levels of bulk (appendix table 10) tends to reduce the differences in carcass characteristics on an average basis between the three bulk levels (table 11, section B). In spite of this, the high bulk levels resulted in general carcass improvement as shown by significantly ($P<0.05$) lower dressing percentages, less per cent middles, shoulder fat and average back fat and higher per cent shoulder and AR score than the low bulk levels (table 11, section B). These effects were associated with lower ($P<0.05$) digestible energy intakes (appendix table 10), slower gains and higher feed and digestible energy efficiency, probably due to decreased relative body fat production, (table 10, section B). These results can all be regarded as typical for the treatment differences.

In no case did the effect of the medium bulk level upon performance and carcass characteristics of the swine differ significantly from that of the high level (tables 10 and 11, section B). This can perhaps partly be explained by the fact that the high bulk rations were consumed in relatively greater volumes than the medium ones (appendix table 9) in a progressing effort to compensate for the lower digestible energy levels, to the extent that no significant differences existed in the digestible energy intakes of the two sets of rations (appendix table 10). However, it is indicated that the medium bulk rations gave an intermediate effect by the fact that they were all intermediate in position except for the loin area (tables10 and 11, section B) and only in two cases did they deviate significantly from the low bulk rations, namely in the average back fat and the AR score (table 11, section B).

Although pelleting increased ($P < 0.05$) the level of digestible energy in the rations and the digestible energy intake (table 9), as well as the rate of gain (table 10, section C), it showed no significant effects on the carcass measurements (table 11, section C), except on the average back fat by the leanmeter, where a significant ($P < 0.05$) decrease resulted from pelleting. Since this is the only indication of an effect of pelleting on carcass quality, there could perhaps be reason to regard it as the one theoretical instance in twenty where the result is due to chance. This suggestion is also supported by the above finding that pelleting increased DEI and rate of gain, two effects which generally are found to be associated with an increase in back fat.

Since the gilts were not graded at the packing plant, the back fat measurements by the leanmeter is the only carcass criterionavailable for comparing the sexes. As could be expected from greater feed intakes and faster gains by the barrows, they also produced thicker ($P<0.05$) average back fat than the gilts (appendix table 16).

Since the formulation of the rations in regard to equal TDN levels **among** types and within levels of bulk (high, medium and low) was not met with a great deal of success (table 3), an attempt has been made to compare the effects upon carcass quality by types and levels of bulk on the basis of equal digestible energy intakes (DEI). The reason for using this criterion rather than TDN was firstly, that the TDN values would have to be calculated from the digestible energy (DE) levels in the rations and secondly, that by using the DEI the effects of variability in intake due to palatability, bulkiness, etc. could be eliminated in the same operation.

The simple correlation and regression coefficients of the various carcass characteristics on DEI are shown in table 12. These were used to adjust the observed means in table 11 giving rise to the adjusted means in table 12. Although the correlations, except for shoulder fat, were significant ($P<0.05$), the adjusted carcass characteristics did not deviate markedly from the observed values (tables 11 and 12). However, reduced variability in the adjusted data due to DEI also reduced the "D" values sufficiently to reveal some interesting differences ($P<0.05$).

When the effects of varying DEI were removed, the cellulose rations produced carcasses with less ham and more middle ($P<0.05$) than the other bulk types (table 12). Under the same conditions the wheat bran rations produced less ($P<0.05$) shoulder fat and average back fat than the other

Table 12.- Carcass Characteristics of Swine Adjusted for DEI (Mean Values).

Treatment	DEI	Ham	Middle	Shldr.	Shldr. fat	Average back fat Grader	Average back fat Leanmeter	Loin area	AR score
	Therms/day	%	%	%	ins.	ins.	ins.	sq. ins.	
Bulk type									
Oat hulls	6.40	24.9	48.1	27.2	1.74	1.34	1.16	3.84	87.3
Alfalfa	6.25	25.0	47.6	27.3	1.74	1.32	1.21	3.88	88.7
Wheat bran	6.29	24.7	47.9	27.3	1.64	1.23	1.09	4.04	88.0
Cellulose	6.79	24.2	48.9	26.9	1.74	1.35	1.20	3.88	84.7
Corn cobs	7.17	24.8	47.9	27.3	1.70	1.32	1.19	3.79	86.8
D($P < 0.05$)	0.54	0.5	0.7	0.5	0.07	0.06	0.05	0.22	3.3
Bulk level									
High	6.25	24.9	47.8	27.3	1.66	1.27	1.12	3.88	89.2
Medium	6.17	24.5	48.2	27.2	1.71	1.31	1.18	3.97	87.7
Low	7.31	24.7	48.3	27.0	1.76	1.33	1.20	3.80	84.3
D($P < 0.05$)	0.46	0.4	0.6	0.4	0.06	0.05	0.04	0.19	2.8
Correlation(r_{xy})		-0.22*	0.33**	-0.28*	0.16	0.36**	0.19*	-0.33**	-0.39**
Regression(b_{yx})		-0.20(1)	0.45(1)	-0.26*	0.02	0.04	0.04	-0.15*	-2.61**
Reduction in variability due to DEI(%)		1.6	5.0	3.2	0.4	6.0	0.9	4.8	7.2

(1) = significance at $P < 0.10$.
* = $P < 0.05$.
** = $P < 0.01$.

four bulk types, and larger ($P<0.05$) loin area than the corn cob rations. In addition the wheat bran and alfalfa rations resulted in higher ($P<0.05$) AR scores than did the cellulose rations.

Some of these differences could possibly be due to different DE efficiency as affected by the ratio of energy utilized for maintenance and gain. It could be expected that at the lower DEI in the alfalfa and wheat bran rations (table 12) a larger fraction of the DE is used for maintenance than at the higher DEI in cellulose and corn cob rations, mainly because at the lower DEI the growth was slower (table 10, column 2) and therefore the test period longer. An adjustment of the DEI values for maintenance energy would probably reveal whether other factors than the suggested ones were contributing to the differences shown.

The differences ($P<0.05$) among the effects of bulk levels (table 12), remaining after the adjustment for variability in DEI, can possibly be explained similarly to those between bulk types discussed above. In this case, the thinner ($P<0.05$) shoulder fat and average back fat, and the higher ($P<0.05$) AR scores produced by the high bulk rations, as compared to the low bulk rations, would be due to lower energy efficiency for gain, because a larger fraction of the DE was used for maintenance.

The correlation coefficients (table 12) show that as the DEI was increased the percentage of ham and shoulder, the loin area and the AR score decreased ($P<0.05$), while the percentage of middles and thickness of back fat increased ($P<0.05$). The magnitude of these effects is expressed in the regression coefficients (table 12). It is realized that these values are means for the range of DEI covered, and that a curve-linear regression possibly would fit the data better due to the changing relationship between energy requirement for maintenance and gain with changing DEI.

Summary: Finishing rations consisting of equal parts of wheat and barley, adjusted to contain 14 per cent protein with a 1:1 mixture of meat meal and soy bean oil meal, and containing three different levels of TDN (62, 65 and 68%) with each of the five bulks: oat hulls, alfalfa meal, wheat bran, cellulose and corn cobs, were fed as a meal and as pellets to sixty male and sixty female pigs in a 5 x 3 x 2 x 2 factorial experiment.

The pigs were on test from 100 to 200 pounds of body weight, during which time records were kept of feed consumption and weight gain. Chromium oxide was used as an indicator in digestibility determinations. At the end of the trial the back fat was measured by the leanmeter, and the males were AR scored by the official meat graders as they were slaughtered at a local packing plant.

Whereas the desired levels of TDN were 62, 65 and 68%, the over-all differences in TDN content in the rations, at the three bulk levels, were significant only between the two extremes. This apparently was due to incorrect preliminary estimation of TDN in some of the bulks, and to an associative effect between the digestibility of bulk and basal fractions of the rations plus the variability between animals.

The TDN in the various bulks were calculated to be 20 ± 17% in oat hulls, 57 ± 6% in wheat bran, 14 ± 30% in cellulose and -2 ± 37% in corn

cobs. The large confidence intervals ($P<0.05$) are due to the fact that the magnitude of variability is inversely proportional to the fraction of the ration contributed by the ingredient in question. Despite some differences in composition of the basal rations, only the corn cob basal showed a higher TDN content than the basal for oat hulls and alfalfa.

The variability in fecal nitrogen excretion was reduced 32.8% by adjusting for variability in protein intake, nonprotein dry matter excretion, physiological body size and nonprotein dry matter intake. The relative contribution by each of these co-variates was in turn: 64.3, 28.6, 5.0 and 2.9%. The data suggest that differences in protein digestibility could be due to source and/or degree of exposure to proteolytic enzymes and proximity to intestinal absorption surfaces, the proteins in the bulks perhaps being less digestible because of crude fiber involvements.

The consumption of the rations containing oat hulls and corn cobs increased with the level of "bulk," while the reverse took place in the alfalfa, wheat bran and cellulose rations ($P<0.05$). This effect was considered as a function of nutrient requirement and feed capacity in relation to "bulkiness" and/or palatability of the rations. Thus, while the levels of oat hulls and corn cobs were low enough to tax the animals' appetite and feed capacity only to a level allowing for increased feed intake in an effort to compensate for decreasing levels of digestible nutrients, the greater levels and/or bulkiness of alfalfa, wheat bran and cellulose overtaxed the animals' feed capacity and/or appetite causing decreased feed consumption.

The alfalfa and wheat bran rations were consumed in smaller amounts and produced slower gains than the remaining bulk types. These effects were associated with decreased efficiency of feed and digestible energy and a tendency for greater loin area and AR scores. In addition the wheat bran rations produced lower dressing percentage and less back fat than the oat hull and corn cob rations. When the various carcass measurements were adjusted for variability in DEI, the wheat bran rations were found to produce less back fat than the other bulk types, and larger loin area than the corn cob rations, while the cellulose rations produced less ham and more middle than all other rations, and lower AR scores than the alfalfa and wheat bran rations. Theoretically these effects could all be due to differences in digestible energy efficiency for gain, since at low DEI such as in the wheat bran and alfalfa rations, a larger fraction of the DE could be expected to be utilized for maintenance.

The low bulk rations gave significantly greater intake and lower efficiency of digestible energy, and significantly faster gains and higher feed efficiency than the medium and high bulk rations. These effects were associated with higher dressing percentages, higher percentage of middles, lower percentage of shoulders, more shoulder and average back fat, and lower AR scores. After removal of the effect of varying DEI from the carcass measurements, the high bulk rations still showed less shoulder and average back fat and higher AR scores than the low bulk levels. The explanations for these effects could be differences in DE efficiency as explained above for the differences between bulk types.

Pelleting increased the TDN level except in the rations with the low level of alfalfa and wheat bran. Also the apparent digestibility of crude protein was increased by pelleting. These effects could have been caused by chemical changes brought about by heat, pressure, moisture or combinations of these in the pelleting process. Pelleting had no effect on feed intake but due to the increase in TDN level significantly more digestible energy was obtained, resulting in faster gains and greater feed efficiency. None of the carcass characteristics were significantly affected by pelleting of the rations.

The male pigs exhibited greater daily feed intakes and faster gains and produced thicker back fat than the females, while the females showed greater digestible energy efficiency.

Faulty carcass weight due to variability in dressing percentage appeared to be the major cause of failure in the commercial grading.

Mouse Trials

Level of TDN in the rations: As in the swine data the TDN values (tables 13 and 14) are calculated from digestible energy levels, setting 4.4 digestible Calories equal to 1 gm. of TDN (31). The data in table 13 were obtained similarly to the swine data in table 4.

It is obvious from table 13 that the simulated pelleting had no effect on the digestibility of nutrients in any of the rations. It also appears that, except for the high level of oat hulls and the medium level of wheat bran, all the rations deviated significantly ($P < 0.05$) from the designed levels of 62, 65 and 68% TDN in the high, medium and low bulk rations respectively.

It is realized that a small portion of this deviation was due to the casein (2%) added to the rations. This would change the designed levels to 62.50, 65.44 and 68.38 % TDN for the three bulk levels respectively. An additional part of the deviation can be explained in the differences in TDN values as estimated for designing the rations (table 2) and as obtained in the experimental results (table 14). Another reason for some of the differences could be that the estimates were based on average values for swine and might not apply to mice.

From tables 1 and 13 it is clear that all the differences from the intended TDN values are positive, except for the high wheat bran ration. This suggests that the TDN level in some or all of the basal ingredients (table 2) was underestimated, which is confirmed by the values for the basal mixtures given in table 14, columns 6 and 7. In respect to the individual bulks, it appears from tables 2 and 14 that in designing the rations the TDN levels in oat hulls and wheat bran were overestimated, giving rise to a greater spread in TDN between the three levels of bulk than intended (table 13, columns 8-10). The cellulose and corn cobs (tables 2 and 14) were also overestimated for trial I, but not for trial II, hence too great a spread occurred in the three TDN levels (table 13, columns 8-10). The alfalfa agreed fairly well with the estimated TDN level (tables 2 and 14), confirmed by a difference between each of the three bulk levels (table 13, columns 8-10) close to the designed 3% TDN.

It will be noticed from table 14, comparing trial I with trial II, that the TDN levels in oat hulls, cellulose and corn cobs were significantly ($P < 0.05$) greater in trial II, while alfalfa's TDN value was significantly

Table 13.- Total Digestible Nutrients in the Mouse Rations (Trial I)(Per Cent).

Bulk type	Bulk level						Mean		
	High		Medium		Low				
	Meal	Pellet	Meal	Pellet	Meal	Pellet	High	Medium	Low
Oat hulls	60.9	62.4	68.2	69.2	75.0	74.8	61.6	68.7	74.9
Alfalfa	69.9	70.3	72.9	72.4	76.4	76.8	70.1	72.7	76.6
Wheat bran	57.3	59.4	66.2	67.0	74.4	72.4	58.9	66.6	73.4
Cellulose	68.2	67.1	73.0	72.3	76.2	76.8	67.7	72.7	76.5
Corn cobs	67.6	65.7	72.1	72.4	76.6	77.5	66.7	72.3	77.1
D(bulk type)(P<0.05):2.6							:1.8		
D(bulk level)(P<0.05):1.8							:1.6		
D(meal vs. pellet)(P< 0.05):2.2									

Table 14.- Total Digestible Nutrients Calculated Separately for Bulks and Basals in the Mouse Rations.

Type of bulk	Per cent of bulk				Per cent of basal	
			Adjusted for basal			
	Trial I	Trial II	Trial I	Trial II	Trial I	Trial II
Oat hulls	-7.4 ± 6.7	7.3 ± 6.2	-6.2	0.2	81.0 ± 1.1	79.7 ± 2.7
Alfalfa	53.0 ± 6.6	41.6 ± 5.1	47.6	42.0	78.9 ± 1.5	80.8 ± 1.3
Wheat bran	47.3 ± 3.6	49.0 ± 2.3	46.5	46.7	77.8 ± 3.2	79.1 ± 1.7
Cellulose	-20.7 ± 8.7	-8.0 ± 14.7	-14.2	-13.3	81.3 ± 0.8	80.0 ± 1.3
Corn cobs	-30.4 ± 7.9	-1.5 ± 16.1	-18.8	-3.8	81.7 ± 1.6	80.5 ± 1.3

lower. In the wheat bran rations in trial II an associative effect between the bulk and basal fractions of the rations was indicated by a deviation from linearity ($P<0.05$) of fecal Calories on Calories ingested per 100 Calories in basal (appendix). In addition associative effects occurred wherever negative TDN levels were obtained (appendix).

Thus it must be assumed that the differences in TDN level of the bulks between the trials are due to associative effects. The basal ration fed alone as an additional treatment in trial II was found to contain 80.7% TDN. This value was not significantly ($P<0.05$) different from any of the levels obtained for the basals in the simultaneous feeding (table 14, columns 6 and 7). When the TDN levels in the bulks in both trials are adjusted to this basal, (table 14, columns 4 and 5) a somewhat better agreement seems to exist. Furthermore, since the magnitude of variability in TDN values obtained in simultaneous feeding is inversely proportional to the size of the fraction in question (110), it is realized that the negative values for oat hulls, cellulose and corn cobs do not constitute any serious experimental errors. For example, the corn cobs in trial I showed a TDN value of -30.4% (table 14) which is significantly different from zero presumably due to an associative effect. If this value is adjusted to zero, keeping the TDN level for the total ration constant, the TDN in the basal must be decreased correspondingly. The amount of decrease would be $30.4 \times 8/92 = 2.6\%$ units, since on an average basis the corn cobs form 8% of these rations, leaving 92% to the basal fraction. This would give a TDN level in the basal of $81.7 - 2.6 = 79.1\%$, a value which is not significantly different from the TDN level of the basal when fed alone in trial II. From this it is understandable that the variability in TDN levels determined in simultaneous feeding often is large, especially when the fraction in question is small, as is usually the case for fibrous materials. To the author's knowledge there has been no mention as to whether this fact could be part of the answer to the large variabilities observed (40, 50, 65, 66) in digestion coefficients of fibrous feeds and particularly in the crude fiber and cellulose fractions of these.

Digestible crude protein in the rations for mice: As in the swine rations the designed crude protein levels (table 15, column 3) appear slightly too high, the average being 16.6% while it should have been 14% plus 1.6% in the added 2% casein. However the differences between the rations are quite small except perhaps in the alfalfa rations, where the differences are appreciable at the higher bulk levels. It is uncertain however whether the differences are statistically significant since the feed samples were bulked for analyses.

The apparent protein digestibility (table 15, column 4) increased with decreasing bulk level for all five bulk types, verifying the concept of increasing metabolic fecal nitrogen with increasing level of indigestible fiber. In the case of oat hulls and wheat bran, these increases were significant ($P < 0.05$) for each bulk increment, while in the alfalfa and cellulose rations only the difference between high and low levels of bulk were significant and in the corn cob rations the high level was significantly lower than medium and low.

As in the swine data an attempt was made to adjust the apparent protein digestibility for variations in metabolic fecal nitrogen due to protein level in the rations, nonprotein dry matter consumption and excretion

Table 15.- Protein in the Mouse Rations.

Bulk Type	Level	Crude protein	Digestibility	Adjusted digestibility(1)
		%	%	%
Oat hulls	High	16.1	57.4	66.2
	Medium	16.6	65.4	69.5
	Low	16.5	68.1	64.2
Alfalfa	High	17.5	65.0	61.7
	Medium	17.4	66.3	64.2
	Low	16.7	67.2	61.4
Wheat bran	High	16.3	58.6	60.8
	Medium	16.6	62.1	64.0
	Low	16.4	67.7	67.1
Cellulose	High	16.0	67.5	70.2
	Medium	16.9	69.3	68.0
	Low	16.0	69.9	64.8
Corn cobs	High	16.2	62.5	65.4
	Medium	16.7	66.5	67.2
	Low	16.6	67.6	67.4
D($P < 0.05$)			2.2	1.8
	D($P < 0.05$)		1.9	1.7
Meal			64.7	65.3
Pellet			66.3	65.7
D($P < 0.05$)			1.6	1.3

(1) Adjusted for variability in protein intake, non-nitrogen dry matter intake and excretion, and physiological body size.

and body size. The regression relating these variables is:

$$Y = 0.276 + 0.410X_1 - 0.047X_2 + 0.098X_3 - 0.076X_4$$

where Y = grams of nitrogen x 6.25 excreted in 14 days,

X_1 = grams of nitrogen x 6.25 consumed in 14 days,

X_2 = grams of non-nitrogen dry matter consumed in 14 days,

X_3 = grams of non-nitrogen dry matter excreted in 14 days,

and X_4 = physiological body size (weight in gm.$^{0.75}$).

The levels of significance of the coefficients of the independent variables are: for X_1 $P<0.01$, for X_2 $P<0.06$, for X_3 $P<0.001$ and for X_4 $P<0.25$. The total variability of Y was reduced by 61.8% by adjusting for the four independent variables. Of this reduction 42.3% was contributable to X_1, 1.6% to X_2, 55.7% to X_3 and 0.4% to X_4. Thus, in this experiment the majority of the variability in fecal nitrogen was due to non-nitrogen dry matter excretion and protein intake, while the effect of non-nitrogen dry matter intake and body size was insignificant ($P<0.05$).

Since the relative effect on the variability in the dependent variable (Y) by any one of the independent variables (X_1, X_2, X_3 and X_4) can be attributed to its degree of variability in the observed sample and its closeness of association with the dependent variable, it is interesting that the nonprotein dry matter excretion (X_3) which caused the greatest amount of reduction (55.7%) in the variability of fecal nitrogen excretion (Y), also had the greatest variability, namely a coefficient of variability of 21.4%, while the physiological body size (X_4), reducing the variability in Y by only 0.4%, exhibited a low coefficient of variability of 5.7%. The protein intake (X_1), which accounted for 42.3% of the reduction in the variability of Y, had a coefficient of variability of 11.1%, while the nonprotein dry matter intake (X_2) had a coefficient of variability of 12.2% and reduced the variability in Y by only 1.6%. This can only mean that under any circumstances X_2 is less closely associated with Y than is X_1.

Although simulated pelleting had no effect on TDN level (table 13), feed intake and feed efficiency (appendix tables 26 and 28), the apparent digestibility of protein in the pelleted rations was significantly ($P<0.05$) greater than in the meal (table 15, column 4). An explanation for this could be that the moistening and drying of the rations caused changes in the proteins, increasing the digestibility. However, since the protein digestibility adjusted for the four independent co-variates (X_1 to X_4) (column 5), was not significantly different between pellets and meal, it appears that simulated pelleting in some way affected the level of metabolic fecal nitrogen and did not alter the true digestibility of protein.

As in the swine data, large and significant differences are present in the adjusted protein digestibilities (table 15, column 5), suggesting that some major factors affecting the fecal nitrogen excretion were omitted in the multiple regression. From the lower ($P<0.05$) digestibilities in the high and medium alfalfa and wheat bran rations as compared to the corresponding levels in the other bulks, it can be concluded, as in the swine experiment, that the protein source was one important factor that was neglected. The lower ($P<0.05$) adjusted digestibility of protein in the low oat hull, alfalfa and cellulose rations could perhaps be explained by the dilution effect in the higher bulk rations similar to that in the swine rations. That the wheat bran and corn cob rations do not exhibit the same pattern in regard to a dilution effect may be due to a difference in bulkiness from the other rations, the wheat bran rations being extremely bulky due to the higher percentage and bulky texture of wheat bran, and the corn cob rations being low in bulkiness due to a low percentage and a low bulkiness of ground corn cobs.

Feed intake and efficiency: When rations are diluted for the purpose of limiting intake of nutrients, the effect of the diluent may be separated into two main functions, the first being to reduce the concentration of digestible nutrients, the second to influence the weight or volume of feed voluntarily eaten. The latter function which ordinarily depends on "bulkiness" and/or palatability is complicated by the organism's natural urge to satisfy its energy requirements. In this light the differences and trends in the dry matter and digestible energy intakes (table 16) offer interesting clues.

That the high alfalfa and wheat bran rations were consumed in significantly smaller quantities than the other three bulks (table 16) indicates greater "bulkiness" and/or inferior palatability due to the addition of these bulks. Thus the dilution effects were enhanced causing an additional drop in digestible energy intake and body weight gain (table 16, columns 5 and 6).

When the feed intakes were adjusted for digestible energy levels in the rations (column 4), distinct, significant differences between bulk levels appeared. Only the high and medium cellulose levels showed no significant ($P<0.05$) differences. The adjusted feed intakes illustrate the effect of increasing bulk level on feed intake unaffected by the organism's natural urge to satisfy its energy requirement. In other words they express more clearly the actual effects of the levels of the various bulks and thus a better basis for comparison of these.

It is obvious that the inclusion of increasing amounts of any of the five bulks had a retarding effect on feed intake. No difference ($P < 0.05$) appeared between the low level of the various types, except for the alfalfa which depressed the intake to a greater ($P < 0.05$) extent than the other bulks. This could perhaps suggest a palatability effect which could be supported by the medium bulk levels where the intake of the alfalfa rations was below ($P < 0.05$) that of oat hull, cellulose and corn cob rations. However, the volume effect could have been involved in this, as appears to be the case in the wheat bran ration with an intake lower ($P < 0.05$) than the other four bulk types. The high bulk levels show a similar trend for the oat hull and corn cob rations, whereas the cellulose ration deviates ($P < 0.05$) somewhat. This is an unexplained effect which perhaps is due to natural chance, the probability being less than 5%. The high wheat bran and alfalfa rations follow sharply declining trends which for the former was established already by the low and medium bulk levels. The explanation for this probably is the higher percentage of these bulks (appendix table 1) in the rations. Especially the wheat bran rations had a bulky appearance, whereas the apparent bulkiness of the alfalfa rations could lead one to suggest that low palatability was a contributing factor to declining intakes.

By comparing the actual and adjusted dry matter intakes (table 16 columns 3 and 4) one can obtain a good illustration of the relative effect upon "the organism's natural urge to satisfy its requirement" by the various energy levels and bulk types. It is noticeable that only the alfalfa rations were not consumed in increasing amounts with the declining digestible energy levels.

This again suggests that palatability could have been limiting in the intake of these rations. The increase in intake due to declining energy level was greatest in the wheat bran rations, probably due to the great bulkiness of these. Next in line and in descending order were the effects in oat hull, cellulose and corn cob rations. By chance or otherwise, this was the apparent order of bulkiness of the rations as caused by level and type of bulk. Only the alfalfa rations did not fall into this line.

Despite a relatively low digestible energy intake of the alfalfa rations (table 16, column 4) the dry matter intake of the medium level was significantly less than for the corresponding level of oat hulls and tended to be lower than for the same levels of the other bulks. Similarly the low level of alfalfa was significantly lower than the low level of wheat bran and tended to be lower than the corresponding levels of the other bulks. This could indicate that the low intakes of the alfalfa rations were caused partly by depressed acceptability rather than increased bulkiness, particularly since a given level of wheat bran on a percentage basis was greater than the corresponding level of alfalfa (table 8).

The higher bulk level decreased the dry matter intake significantly only in the case of wheat bran (table 16, column 3), causing a pronounced decrease in digestible energy intake (column 5) for each bulk increment. Despite no significant differences in dry matter intake between levels of the other bulks (table 16, column 3), the digestible energy intakes on the high bulk levels were lower ($P < 0.05$) than for the low levels , except in the case of the cellulose rations where no differences appeared. In the latter rations the mice apparently managed to adjust feed consumption to compensate for the differences in digestible energy levels in the rations.

Table 16.- Feed Consumption and Efficiency and Body Gain in Mouse Trial I.

Bulk Type	Level	Dry matter intake actual	Dry matter intake adj.(1)	Dig. energy intake	Body gain actual	Body gain adj.(2)	Dig. Cal./gm. gain
		gm./14 days	gm./14 days	Cal./14 days	gm./14 days	gm./14 days	
Oat hulls	High	48.9	41.3	132	12.0	12.2	11.1
	Medium	47.9	46.5	145	13.2	12.1	11.0
	Low	44.9	48.8	148	12.8	11.3	11.6
Alfalfa	High	36.9	36.9	114	10.6	12.8	10.8
	Medium	39.9	41.9	127	11.4	12.2	11.3
	Low	40.6	45.9	137	11.1	10.8	12.5
Wheat bran	High	38.1	28.5	98	8.9	12.9	11.6
	Medium	41.8	38.5	123	12.5	13.8	9.8
	Low	45.9	48.4	148	13.9	12.4	10.8
Cellulose	High	47.0	44.7	140	13.5	12.9	10.4
	Medium	43.0	44.9	137	12.2	11.9	11.3
	Low	44.8	50.0	151	13.5	11.7	11.2
Corn cobs	High	44.7	41.6	129	12.1	12.7	10.7
	Medium	44.8	46.4	142	12.5	11.7	11.5
	Low	43.2	48.8	147	13.3	12.0	11.1
D(Type)		5.9	1.7	18	2.4	1.4	1.6
D(Level)		5.1	1.4	15	2.0	1.2	1.4

(1) Adjusted for digestible Calories per gm. of feed (covariance significant at $P < 0.05$).
(2) Adjusted for digestible Calorie intake (covariance significant at $P < 0.05$).

The total body weight gain was decreased significantly by the increased bulk level only in the wheat bran rations (table 16, column 6), where the high bulk level caused a slower gain than the medium and low levels. Between the bulks, differences were significant for the high and low levels of alfalfa and the corresponding levels of cellulose. While the high wheat bran rations gave lower ($P < 0.05$) gains than the high levels of all except the alfalfa rations.

When body weignt gains were adjusted for digestible energy intake (table 16, column 7), it was found that the low alfalfa rations gave significantly lower digestible energy efficiency than the medium and high levels of alfalfa. This is also supported by the calculation of digestible Calories per gram of gain (table 16, column 8), where the low alfalfa rations required significantly more digestible Calories per gram of gain than the high alfalfa rations. In the wheat bran rations the medium level gave greater ($P<0.05$) digestible energy efficiency than the low level (table 16, column 7), whereas the high level was intermediate in position. This agrees with Axelson _et_ _al_.(4) when they state that a smaller daily intake of metabolizable energy, than that causing maximal weight gain, yield the highest efficiency. Apparently the high wheat bran ration was the only "high" bulk ration which was consumed in amounts causing below maximal digestible energy efficiency. It is realized that since no adjustment in energy utilization has been made for maintenance requirement, the rations consumed at lower levels and causing slower growth, will exhibit lower energy efficiency for gain, due to the greater maintenance requirement than in faster growing animals.

Simulated pelleting of the rations had no significant effect on any of the criteria listed in table 16 (appendix tables 26, 27, 32 and 33).

Carcass composition: The mean values of the carcass composition of the 120 mice from trial I are presented in table 17. The scarcity of significant differences in body fat level (column 3) can possibly be attributed to physiological age, since in a rapid growth period animals are less prone to fattening. Only the high wheat bran rations were dilute and "bulky" enough to cause a significant ($P < 0.05$) decline in per cent body fat as compared to the low wheat bran and the high oat hull, cellulose and corn cob rations.

As is commonly the case, the percentage of water in the body (column 4) was inversely related to percentage of fat. The correlation coefficient ($r = -0.76$) was significant at $P < 0.01$. The high wheat bran ration gave higher ($P < 0.05$) body water level than the medium and low wheat bran and the high oat hull, cellulose and corn cob rations. Also the high alfalfa ration gave higher ($P < 0.05$) body water level than the medium ration. The difference in body fat (column 3) between these rations was close to significance at $P < 0.05$.

In order to determine whether the increased body water levels were attributable entirely to the decreases in body fat, the body water was adjusted (column 5) for body fat. This reduced the variability by 37.5% and revealed more significant differences, indicating that the high levels of alfalfa and wheat bran gave higher ($P < 0.05$) body water content than the medium and low levels of the same bulks, regardless of the fatness of the animals. The high oat hull ration caused higher ($P < 0.05$) water level than the medium ration and the low alfalfa ration higher ($P < 0.05$) level

Table 17.- Carcass Composition of Mice (Figures in Per Cent).

Bulk		Total carcass					Fat free carcass		
Type	Level	Fat	Water observed	Water Adj. for fat	Protein	Ash	Water	Protein	Ash
Oat hulls	High	5.69	71.0	70.9	20.2	3.10	75.3	21.4	3.28
	Medium	5.98	70.5	70.6	20.5	3.02	75.0	21.8	3.23
	Low	6.15	70.5	70.8	20.3	3.01	74.8	21.6	3.20
Alfalfa	High	4.81	72.2	71.4	19.9	3.08	75.8	20.9	3.23
	Medium	5.87	70.7	70.8	20.2	3.21	75.1	21.5	3.41
	Low	5.79	71.2	71.1	20.0	3.05	75.6	21.2	3.24
Wheat bran	High	4.34	73.1	72.0	19.6	3.00	76.4	20.5	3.14
	Medium	5.39	71.5	71.2	20.3	2.88	75.5	21.4	3.04
	Low	6.09	70.7	70.9	20.4	2.94	74.8	21.6	3.13
Cellulose	High	6.41	70.6	71.1	20.0	3.02	75.4	21.4	3.22
	Medium	6.12	70.7	70.9	20.3	2.95	75.3	21.6	3.16
	Low	6.53	70.4	71.0	20.1	2.97	75.3	21.5	3.17
Corn cobs	High	5.99	70.7	70.8	20.3	3.06	75.2	21.6	3.26
	Medium	5.87	70.9	71.0	20.1	3.08	75.3	21.4	3.27
	Low	5.84	70.8	70.8	20.3	3.08	74.9	21.9	3.25
D($P<0.05$)		1.28	1.3	0.5	0.9	0.23	1.1	1.0	0.24
	D($P<0.05$)	1.09	1.1	0.3	0.8	0.19	0.9	0.8	0.21
Meal		5.99	70.9	71.0	20.1	2.97	75.3	21.5	3.16
Pellet		5.60	71.1	70.9	20.2	3.08	75.4	21.4	3.28
D($P<0.05$)		0.33	0.3	0.2	0.2	0.06	0.3	0.3	0.06

than the medium ration. The latter of these differences opposes the trend that the higher bulk levels produced higher body water levels. However, it is noticeable that when the rate of gain (table 16, column 6) is compared to adjusted body water level (table 17, column 5), a slow gain is always associated with a high body water level particularly within the rations containing oat hulls, alfalfa and wheat bran. The percentages of protein and ash (table 17, columns 6 and 7) were fairly constant regardless of bulk type and level. Only the high wheat bran ration brought about lower ($P<0.05$) protein levels than the low wheat bran.

Since the regression of body water on body fat was -0.77, signifying that 1% increase in body fat caused a drop of 0.77% in water content, it was considered worthwhile to compare the body composition on a fat free basis to give a clear picture of what took place. This comparison is shown in table 17, columns 8, 9 and 10. The data show that aside from the effect on body fat, only the high wheat bran ration brought about significant changes in body composition. This ration gave higher ($P<0.05$) body water level than the low wheat bran and the high oat hull and cellulose rations, and lower ($P<0.05$) protein level than the medium and low wheat bran and high cellulose rations.

Although simulated pelleting had no significant effect on TDN level (table 13), feed intake or rate of gain (appendix tables 26 and 27), it caused a decrease ($P<0.05$) in per cent body fat and an increase ($P<0.05$) in ash content (table 17). On a fat free basis, the ash content was still increased ($P<0.05$) by the pelleted rations, indicating that this effect was not just a counteraction of the decrease in body fat. The reasons for these effects remain unanswered.

Summary: The rations from the previous swine experiment, fortified with 2% casein to increase the protein to a level suitable for rapid growth, were fed to 120 weanling male mice for a period of two weeks in a 5 x 3 x 2 factorial experiment. The pelleting process was simulated by moistening and granulating the rations in a meat chopper followed by drying in vacuum.

During the experiment records were kept of feed consumption, excretion of feces and body weight gains. At termination, analyses for water, fat, protein and ash were carried out on all the carcasses. The TDN level in the rations was determined from the conventional feces-feed ratios and the digestible energy levels, assuming 4.4 digestible Calories to be equal to 1 gm. TDN.

In all the rations except the high level of oat hulls and the medium level of wheat bran, the TDN levels deviated significantly from the designed 62, 65 and 68%. The TDN in the various bulks appeared to be lower than those obtained in the swine trial, although it cannot be concluded that the differences are statistically significant. In spite of some variability in composition of the basal ration-fractions, no significant differences were found in TDN levels.

The variability in fecal nitrogen excretion was reduced by 61.8% by adjusting for variability in protein intake, intake and excretion of non-nitrogenous dry matter and physiological body size. The relative contribution by each of these factors were 42.3, 1.6, 55.7 and 0.4% respectively. As in the swine data it is indicated that protein source and dilution effect in the intestinal tract were two important factors in determining the digestibility of the protein.

It is suggested that the bulkiness of wheat bran and the palatability of alfalfa decreased the intake of these rations to levels below the rations containing the other three bulk types. Only in the wheat bran rations were the body weight gains slowed down by increasing bulk levels. The high wheat bran rations also gave slower gains than the high level of the four other bulk types.

The feed intakes adjusted for variability in digestible energy level showed that increasing bulk levels decreased the feed intakes significantly. A comparison of the observed and adjusted intakes indicated that the effect upon feed intake by the organism's natural urge to satisfy its energy requirement was a significant factor. The relative magnitude of this effect as shown by the difference between the observed and adjusted intakes of the various bulk types was in descending order: wheat bran, oat hulls, corn cobs, cellulose and alfalfa. It could be due to a low palatability that alfalfa is last in this succession despite its relatively low digestible energy intakes. The other rations occur in the array according to apparent bulkiness except perhaps for corn cobs and cellulose which possibly could be interchanged in this respect.

In regard to body composition the high wheat bran ration produced significantly less body fat than other rations. In general, body fat was significantly correlated ($r = -0.76$) with body water. The regression indicated that a 1% increase in fat resulted in a 0.77% decrease in water. The levels of protein and ash in the carcasses were not affected by the level and type of bulk in the rations except in the case of the high level of wheat bran which produced a significantly lower body protein level than the low wheat bran ration. The high wheat bran ration also gave higher levels of body water and lower levels of body protein on a fat free basis.

Simulated pelleting had no effect on the intake or digestibility of the rations nor the rates of gain. However, a decrease in per cent body fat and an increase in per cent ash took place in the animals fed pelleted rations. The ash content was also greater on a protoplasmic basis indicating that it was more than a counter-effect of the change in body fat. Simulated pelleting appeared to decrease the metabolic fecal nitrogen whereas it did not change the true digestibility of protein.

Comparison of Species

The advantages of a smaller pilot animal are generally recognized. In this section an attempt has been made to compare the effects of identical experimental rations on swine and mice. The object of this was an appraisal of the suitability of mice as pilot animals for swine in nutrition studies.

Among the various observations in the two species the more obvious comparisons were plotted in scatter diagrams. In the case of an indication of a relationship the correlation was determined. The following list contains the criteria considered and the primary results of the comparisons.

Criteria compared:

Feed intake - correlated ($P<0.01$).

Digestible energy intake - correlated ($P<0.01$).

Dry matter digestibility - correlated ($P<0.01$).

Protein digestibility - no apparent relationship.

Body weight gain - correlated ($P < 0.05$).

Feed efficiency - no apparent relationship.

Energy efficiency - no significant correlation.

Average back fat in swine vs. per cent fat in carcasses of mice - correlated ($P < 0.01$).

Per cent ham in swine vs. per cent protein in carcasses of mice - no significant correlation.

Loin area in swine vs. per cent protein in carcasses of mice - no apparent relationship.

The significant correlations and corresponding regressions are shown in table 18. Due to the differences in units and magnitude of response between the two species, the mean values and ratios of these were included. The latter were used to determine if the effect upon the species deviated significantly from each other. Had the units and the magnitude of response been similar, as is the case in the per cent DMD, a significant deviation of the regression coefficient (b) from one would indicate a different effect in the two species. The ratio of the means is the best estimate available of the value from which b should deviate significantly to indicate a difference in effect between the species by similar rations.

The correlation in feed intake (table 18) between swine (X_1) and mice (X_2) was significant at $P < 0.01$. The regression of X_1 on X_2 shows that a one gram increase in feed intake in a fourteen day period by the mice corresponded to 0.052 pounds increase in intake per day by the swine. Since the value of $b_{x_1x_2}$ (0.052 ± 0.035) was significantly ($P < 0.05$)

Table 18.- Correlation of Various Effects by Identical Rations in Swine and Mice.

Criteria	Units: Swine (X_1)	Units: Mice (X_2)	Correlation Coefficient (r)	Regression: a	Regression: $b_{x_1x_2}$	Mean: $\bar{x}_1$	Mean: $\bar{x}_2$	Mean: $\bar{x}_1/\bar{x}_2$
Feed intake	lbs./day	gm./14 days	0.67**	2.47 ± 1.74(1)	0.052 ± 0.035	4.73	43.5	0.11
DMD	%	%	0.96**	18.2 ± 8.84	0.71 ± 0.13	68.0	70.2	0.97
DEI	Therms/day	Cal./14 days	0.79**	2.09 ± 2.08	0.033 ± 0.015	6.28	135	0.047
Rate of gain	lbs./day	gm./14 days	0.63*	0.47 ± 0.37	0.058 ± 0.030	1.18	12.2	0.097
Body fat	Av. in. back fat	% of carcass	0.70**	0.77 ± 0.34	0.094 ± 0.058	1.31	5.79	0.23

* Significant at $P<0.05$.

** Significant at $P<0.01$.

(1) Confidence interval at $P<0.05$.

Table 19.- Comparison of Various Effects by Identical Rations in Swine and Mice.

Bulk type	Bulk level	Feed intake Swine	Feed intake Mice	DMD Swine	DMD Mice	DEI Swine	DEI Mice	Gain Swine	Gain Mice	Body fat Swine	Body fat Mice
		lbs. per day	gm./14 days	%	%	Therms per day	Cal./14 days	lbs. per day	gm./14 days	Av. in. back fat	% of carcass
Oat hulls	High	5.14	48.9	62.5	61.8	6.17	132	1.26	12.0	1.26	5.69
	Medium	4.47	47.9	64.3	69.1	5.62	145	1.15	13.2	1.32	5.98
	Low	4.96	44.9	71.0	75.8	6.83	148	1.28	12.8	1.40	6.15
Alfalfa	High	4.33	36.9	65.1	69.8	5.50	114	1.02	10.6	1.25	4.81
	Medium	4.45	39.9	69.2	72.4	5.98	127	1.07	11.4	1.29	5.87
	Low	4.79	40.6	71.1	76.6	6.52	137	1.20	11.1	1.39	5.79
Wheat bran	High	4.30	38.1	60.9	58.3	5.26	98	0.94	8.9	1.17	4.34
	Medium	4.48	41.8	63.6	65.3	5.60	123	0.98	12.5	1.23	5.39
	Low	4.87	45.9	71.1	72.9	6.86	148	1.24	13.9	1.27	6.09
Cellulose	High	4.77	47.0	67.1	67.2	6.34	140	1.17	13.5	1.30	6.41
	Medium	4.58	43.0	68.4	72.1	6.03	137	1.16	12.2	1.34	6.12
	Low	4.83	44.8	73.4	76.7	6.85	151	1.26	13.5	1.45	6.53
Corn cobs	High	5.02	44.7	67.8	67.1	6.48	129	1.29	12.1	1.31	5.99
	Medium	5.00	44.8	69.7	71.0	6.80	142	1.31	12.5	1.29	5.87
	Low	4.97	43.2	75.0	76.6	7.32	147	1.30	13.3	1.43	5.84
DT($P < 0.05$)		0.57	6.0	3.7	2.0	0.83	18	0.17	2.4	0.18	1.28
DL($P < 0.05$)		0.49	5.1	3.2	1.7	0.71	15	0.12	2.0	0.16	1.09
C(Variability Coefficient)		5.78	8.02	6.01	7.9	9.64	10.8	10.3	10.8	5.91	9.87

C = The standard deviation as per cent of the mean.

smaller than the mean ratio of pounds of feed consumed per day by swine ($\bar{x}_1 = 4.73$) and grams of feed consumed during fourteen days by mice ($\bar{x}_2 = 43.5$) namely $4.73/43.5 = 0.11$, the effect of the various rations upon feed intake in the two species was considered to be different ($P < 0.05$).

The fact that the ratio of $\bar{X}_1$ and $\bar{X}_2$ was greater ($P < 0.05$) than $b_{x_1x_2}$ shows that the increasing bulk levels affected the feed intake in mice to a greater extent than in swine. In other words the swine appeared to be better equipped to handle bulky rations than the mice.

An inspection of the feed intake data in table 19 shows certain relative similarities between the two species. Both consumed less ($P < 0.05$) of the high level alfalfa and wheat bran rations than of the corresponding levels of corn cobs and cellulose. Also the high wheat bran rations were consumed in smaller amounts than the low levels by both species. Relatively few additional significant differences were present in any of the species.

Various similar trends were present. Although not statistically significant the intake of oat hull and corn cob rations tended to increase with the level of these bulks in the ration. In the alfalfa rations the intake tended to be inversely related to the bulk level. In the cellulose rations the medium level tended to be consumed in smaller quantities than either the low or high levels for both species.

In regard to feed intake it would then appear that generally the swine and the mice readted similarly to the rations studied. The only difference appeared to be a more pronounced effect in the mice than in the swine.

The correlation of DMD between the species (table 18) was extremely high. That the regression coefficient was smaller ($P < 0.01$) than the ratio of the two means, and that the intercept (a) of the regression line on the X_1 axis was greater ($P < 0.01$) than zero, show that the effect of increasing bulk levels again was greater in the mice than in the swine. A simple examination of the DMD values in table 19 gives an indication of the above conclusion. It is noticeable that at the high levels of oat hulls, wheat bran and corn cobs, the swine tend to exhibit greater DMD's. In the cellulose ration no difference was apparent, whereas in the alfalfa ration the mice showed the greater DMD. In the medium level of all the bulk types the mice tended to exhibit higher DMD's than the swine. In the high level the same trend continued with an increasing margin for the mice over the swine.

It is realized that the 2% casein added to the rations for mice (appendix table 1), should render these more digestible and it could well be the reason why the mean DMD by the mice was 2.2% higher than that for the swine (table 18). From these observations it would therefore appear that the major difference in DMD of the rations studied between the two species was a more pronounced retardation by increasing bulk levels in mice than in swine.

The DEI by the two species were correlated at $P< 0.01$ (table 18). An increase in one Calorie during fourteen days by mice corresponded to an increase of 0.033 Therms or 33 Calories per day by swine as indicated by the regression coefficient ($b_{x_1x_2}$). The effect of the bulks on DEI cannot be considered to differ between the two species, since b was not significantly ($P< 0.05$) different from the ratio of the means ($\bar{x}_1/\bar{x}_2 = 0.047$). However, since 'a' was greater ($P< 0.05$) than zero, it must be assumed that generally the DEI by the swine was relatively larger than by the mice.

The fact that the effect of bulk on the DEI was not different ($P<0.05$) for the two species, when feed intake and digestibility were both affected to a greater ($P<0.05$) extent in mice, can only be explained by a greater variability in DEI than in feed intake and DMD. That this is the case is indicated at the bottom of table 19, where the DEI indeed shows greater variability coefficients than the feed intake and the DMD.

A gain of one gram during fourteen days by the mice corresponded to 0.058 pounds or 26 grams per day by swine. Since b was significantly smaller ($P<0.05$) than the ratio of the means (table 18), it is indicated that the effect of the bulks was greater in the mice than in the swine. This corresponds to the effect upon feed intake and DMD, which both were greater ($P<0.05$) in the mice.

Average inches of back fat in swine, as measured by the official carcass graders, and per cent of fat in carcasses of mice were correlated at $P<0.01$ (table 18). The regression coefficient shows that a one per cent increase in carcass fat in the mice corresponds to 0.094 inches increase in the average back fat thickness of the swine. That b was greater ($P<0.05$) than the ratio of the means indicates that the effect of the bulks upon fat deposition was more severe in the mice than in the swine, which corresponds to the effects upon feed intake, DMD and body weight gain.

The previous discussion of the data in tables 18 and 19 would suggest certain similarities in the response to various rations in the swine and the mice. However, the swine appeared to be better equipped to consume and digest increasing levels of the bulks studied than the mice. This ability manifested itself in correspondingly greater gains and fat depositions from the more bulky rations in the swine. The results of the comparison suggest that further investigations as to the feasibility of using mice as pilot animals in swine nutrition studies would be desirable. It could be suggested that the effect of differences in physiological age and physiological body size be considered in possible future work. This is prompted by the realization that younger and faster growing animals are less prone to fattening, and that nutritional effects are most likely to be tied in with physiological body size, which then perhaps could be the basis for translation of results between species.

GENERAL SUMMARY AND CONCLUSION

The Effect of Bulk Type and Level upon Feed Intake, Digestible Energy (DE) Level and Digestible Energy Intake (DEI)

In comparing oat hulls, alfalfa, wheat bran, cellulose and corn cobs, as bulk additives to rations for finishing pigs and weanling mice, it appeared that the limiting effect upon feed intake was greater by wheat bran and alfalfa. This however could be due to the higher levels of these bulks required to equalize the concentration of nutrients in the various rations.

In rations fed to swine the digestible energy (DE) level decreased by 11.7, 4.7, 4.6, 9.7 and 20 Calories per pound of feed for a one per cent increase in each of the five bulks respectively. The levels of nutrients furnished were complicated by differences in effect upon feed intake between the bulks. Thus a one per cent increase in each of the bulks caused a drop in digestible energy intake (DEI) of 43, 44, 36, 56 and 92 Calories per day respectively, when the ranges of bulks were 6-20, 9-32, 17-61, 3-12 and 3-12 per cent of the rations respectively.

Feed intakes by the mice were not affected significantly by the varying levels of any of the bulk types, although strong trends prevailed of an inverse relationship between level and intake in the alfalfa and wheat bran rations, and a direct relationship in the oat hull rations. The intakes adjusted for levels of DE in the rations showed an inverse relationship between bulk level and feed intake for all bulk types. This was proposed to mean that as the bulk levels were increased, the mice increased their feed intakes to partly compensate for lower nutrient levels. A similar conclusion was reached from the swine data.

The DEI by the mice was decreased significantly from the low to the high level of all bulk types except cellulose. A strong trend in this direction existed for each increment of all the bulk types.

The Effect of Bulk Type and Level upon Digestibility of Energy in the Bulk and Basal Ration Fractions

The digestibility of energy in the bulk and basal fractions of the rations were determined by a modification of "Carbery's Method of Determining Digestibility." Great variability in the energy digestibility of the bulks included in the rations at low levels were proposed to be due to the simple mathematical relationship that the effect of experimental errors upon the standard deviation of observed data is inversely proportional to the relative numerical magnitude of the observations.

When the five bulks were included at average levels of 13, 20, 39, 8 and 8 per cent of the rations respectively, the per cent total digestible nutrients (TDN) and 5% confidence intervals were: by swine, 20 ± 17, 51 ± 10, 57 ± 6, 14 ± 30, -2 ± 37; by mice in trial 1, -7 ± 7, 53 ± 7, 47 ± 4, -21 ± 9, -30 ± 8, and by mice in trial 2, 7 ± 6, 42 ± 5, 49 ± 2, -8 ± 15, -2 ± 16 respectively in oat hulls, alfalfa, wheat bran, cellulose and corn cobs. Although some of the differences within bulks appear to be real, this cannot be concluded since associative effects in digestibility between the bulk and basal fractions were apparent in all the observations except the alfalfa rations, the wheat bran rations fed to mice in trial 1 and the oat hull rations fed to mice in trial 2.

The above mentioned associative effects will also influence the TDN levels in the basal ration fractions. However, in spite of a slight variation in the composition of the basals, no significant differences in TDN were present between bulks and within species of animals. The mice appeared to digest the basal fractions to a greater degree than the swine, this difference could be due partly to associative effects, and partly to the inclusion of an extra 2% casein in the mouse rations for an adequate protein supply for rapid growth.

The Effect of Bulk Type and Level upon Protein Digestibility

The effect upon apparent protein digestibility by protein intake, nonprotein dry matter intake and excretion, and physiological body size ($weight^{0.75}$) was studied. The variability in fecal nitrogen due to above independent co-variates was found to be: in swine, 21, 1, 9 and 2, and in mice, 26, 1, 35 and 0.2 per cent respectively. In both species the variability in fecal nitrogen unaccounted for was suggested to be due mainly to protein source, bulkiness of the ration and experimental error.

The Effect of Bulk Type and Level upon Animal Performance

Lower intakes of the alfalfa and wheat bran rations by swine resulted in slower gains and decreased efficiency of feed and DE. The reason for lower DE efficiency was concluded to be due to a greater maintenance requirement since slower gaining animals were on test for a longer period than faster gaining ones. When the gains were adjusted for variability in DEI, the oat hull rations appeared to give faster and more efficient gains than any of the bulk types studied.

Generally the low bulk rations produced faster gains and greater feed efficiency in swine. However, despite the suggestion that slower gaining animals use more energy for maintenance and therefore utilize the DE less efficiently for gain, it was indicated that the high bulk rations gave greater DE efficiency. This may be explained by energy differences in the body tissues laid down at different rates of gain, the faster gains being more expensive due to greater proportions of fat.

The high level of wheat bran in the rations for mice caused slower gains than the corresponding levels of the other bulks except alfalfa, and slower gains than the medium and low levels of wheat bran. The medium level of wheat bran showed greater DE efficiency than the high level, while the low level was intermediate in this regard. This was explained by the opposing effects of the two theories that in slower gains more energy is required for maintenance, and that faster gains are less efficient because of greater fat proportions. The high wheat bran rations appeared to be the only "high bulk" ration consumed in amounts causing below maximum DE efficiency.

The Effect of Bulk Type and Level upon Carcass Characteristics

The effect of bulk types and levels upon carcass characteristics in swine were analyzed on the basis of equal DEI in order to eliminate the influences of varying feed intakes and DE levels in the rations. This was done by adjusting the various carcass measurements for variability in DEI. On this basis the cellulose rations produced less ham and more middle than the other bulk types. The wheat bran rations produced less shoulder fat and average back fat than the other bulks, and larger loin area than the corn cob rations. The alfalfa and wheat bran rations caused higher advanced registry (AR) scores than the cellulose rations.

Generally the high bulk rations produced less shoulder fat and average back fat, and higher AR scores than the low bulk rations. Since the carcass characteristics were based upon equal DEI's, the differences were considered as due to differences in DE efficiency for gain as affected by rate of gain.

Correlations of the various carcass measurements upon DEI, showed an inverse relationship for ham, shoulder, loin area and AR score, and a direct relationship for middles and back fat.

The unadjusted carcass measurements indicated that the wheat bran rations resulted in lower dressing percentage than the oat hull and corn cob rations, and less average back fat than any of the other bulks. The high bulk rations as a whole caused lower dressing percentage, less middle, shoulder fat and average back fat, and more shoulder and higher AR scores than the low bulk levels.

In mice the high wheat bran rations produced carcasses with less fat and protein and more water than the low levels of wheat bran, and less fat and more water than the high levels of oat hulls, cellulose and corn cobs. Body fat and body water were inversely correlated ($r = -0.77$).

The Effect of Pelleting

Pelleting of the rations fed to swine increased the TDN level except in the low alfalfa and wheat bran rations. It had no effect upon feed intake. The increased TDN levels resulted in greater TDN intakes which in turn caused faster gains and greater feed efficiencies. None of the measured carcass characteristics were affected by pelleting.

To simulate pelleting in the mouse rations half of each ration mixture was moistened, passed through a meat chopper and dried in vacuum at 65° C. This gave the rations a hard, crumbled texture. No effect of this treatment appeared in feed intake, digestibility or gain. However, a decrease in body fat and an increase in ash took place in the mice fed the "pelleted" rations. Simulated pelleting appeared to decrease the metabolic fecal nitrogen, but did not affect the true protein digestibility.

Sex Differences

The male pigs showed a greater daily feed intake, produced faster gains and thicker back fat, whereas the females exhibited greater DE efficiency.

Comparison of Species

Significant correlations between mice and swine existed in feed intakes, dry matter digestibilities, digestible energy intakes, rates of gain and levels of body fat (per cent of fat in carcasses of mice and average inches of back fat in swine). It was suggested that physiological body size and age could be compared in the two species in a search for a basis for translating results from mice to swine.

REFERENCES

1. Allred, J. B., L. T. Jensen, and J. McGinnis. Factors affecting the response of chicks and poults to feed pelleting. Poultry Sci. 36: 517-523. 1959.

2. Allred, John B., R. E. Fry, L. T. Jensen, and James Fry. Studies with chicks in improvement in nutritive value of feed ingredients by pelleting. Poultry Sci. 36: 1284. 1957.

3. Anderson, T. E., N. C. Fine, W. L. Stangel, G. C. Williams, and J. H. Jones. Use of cottonseed hulls with different methods of processing and feed additives in fattening steers. Texas Agr. Exp. Sta. Progress Rept. 2004. (Cattle Series 144). 1958.

4. Axelson, J., and T. Eriksson. The optimum crude fibre level in rations for growing pigs. J. Animal Sci. 12: 881-891. 1953.

5. Barber, R. S., R. Braude, and K. G. Mitchell. Comparison of six different levels of feeding for fattening pigs. J. Agr. Sci. 48(3): 347-351. 1957.

6. Bearse, G. E., L. R. Berg, C. F. McClary, and D. L. Miller. Effect on chick growth of pelleting rations with different fiber levels. Poultry Sci. 31: 907. 1952.

7. Becker, D. E., I. F. Hanson, A. H. Jensen, S. W. Terril, and H. W. Nortan. Dehydrated alfalfa meal as a dietary ingredient for swine. J. Animal Sci. 15(3): 820. 1956.

8. Bell, J. M. A comparison of fibrous feedstuffs in non-ruminant rations. Effects on growth responses, digestibility, rates of passage and ingesta volume. Unpublished data.

9. Bell, J. M. The effects of frost damage on the nutritional value of wheat. II. Feeding tests on various mill fractions. Can. J. Animal Sci. 38: 1-9. 1958.

10. Bell, J. M., J. P. Bowland, C. D. T. Cameron, E. W. Crampton, R. B. Carson, R. DePape, E. V. Evans, L. E. Lloyd, M. E. Seale, and A. J. Wood. Nutrient requirements for Canadian Yorkshire swine. I. A study of the U.S. N.R.C. (1953) standards. Can. J. Animal Sci. 37: 79-89. 1957.

11. Bell, J. M., J. P. Bowland, C. D. T. Cameron, E. W. Crampton, L. E. Lloyd, M. E. Seale, and F. Whiting. Nutrient requirements for Canadian Yorkshire swine. II. The effects of barley and oat finishing rations on rate of gain, feed utilization and carcass quality of pigs marketed at 185 and 200 pounds live-weight. Can. J. Animal Sci. 38: 73-83. 1958.

12. Bell, J. M., and Mary Gidyk. The effect of frost damage on the nutritional value of wheat. Can. J. Agr. Sci. 34: 305-312. 1954.

13. Berg, T., and J. P. Bowland. Restricted feed intake in market swine. The 37th Annual Feeder's Day, U. of A. The Press Bull. pp. 4-5. 1958.

14. Black, D. J. G., R. C. Jennings, and T. R. Morris. The relative merits of pellets and mash for laying stock. Poultry Sci. 37: 707. 1958.

15. Blaxter, K. L., and N. M. Graham. The effects of the grinding and cubing process on the utilization of energy of dried grass. J. Agr. Sci. 47: 207. 1957.

16. Bohman, V. R., F. E. Kidwell, and J. A. McCormick. High levels of alfalfa in the rations of growing fattening swine. J. Animal Sci. 12: 876-880. 1953.

17. Bohman, V. R., J. E. Hunter, and J. McCormick. The effect of graded levels of alfalfa and aureomycin upon growing fattening swine. J. Animal Sci. 14: 449-506. 1955.

18. Bosshardt, D. K., and R. H. Barnes. The determination of metabolic fecal nitrogen and protein digestibility. J. Nutrition 31: 13. 1946.

19. Bowland, J. P., and R. T. Berg. Energy-protein relationship in swine ration. The 37th Annual Feeder's Day, U. of A. The Press bull. pp. 13-15. 1958.

20. Bowstead, J. E. Pelleted rations for fattening lambs. The 37th Annual Feeder's Day, U. of A. The Press Bull. pp. 25-27. 1958.

21. Brugman, H. H. Effect of plane of nutrition on carcass quality of a line of swine based on Chester white and Danish Landrace cross. J. Animal Sci. 9: 602, 1950.

22. Can. Dept. Agr. Swine husbandry in the United Kingdom and Denmark. Report of a Canadian Commission. 1909.

23. Castle, Elisabeth J., and M. E. Castle. The rate of passage of food through the alimentary tract of pigs. J. Agr. Sci. 47: 196-203. 1956.

24. Castle, Elisabeth J., and M. E. Castle. Further studies of the rate of passage of food through the alimentary tract of pigs. J. Agr. Sci. 49: 106-112. 1957.

25. Cate, H. A., J. M. Lewis, R. J. Webb, M. E. Mansfield, and U. S. Garrigus. The effect of pelleting rations of varied quality on feed utilization by lambs. J. Animal Sci. 14: 137. 1955.

26. Cmarik, G. F., R. J. Webb, and H. A. Cate. The response of fattening yearling steers self-fed complete pelleted rations of varying ratios of concentrate to roughage. J. Animal Sci. 16: 1805. 1957.

27. Coey, W. E., and K. L. Robinson. Some effect of dietary crude fiber on live weight gains and carcass conformation of pigs. J. Agr. Sci. 45: 41. 1954.

28. Conrad, H. J. Feeding hogs tomorrow. Feedstuffs pp. 38. Aug. 30, 1958.

29. Cooney, W. T., J. S. Butts, and L. E. Bacon. Alfalfa meal in chick rations. Poultry Sci. 27: 828-830. 1948.

30. Cowgill, George R., and Albert J. Sullivan. Further studies on the use of wheat bran as a laxative. The Journal of the American Medical Association 100: 795-802. 1933.

31. Crampton, E. W. Applied Animal Nutrition. W. H. Freeman and Co., San Francisco. 1956.

32. Crampton, E. W. Interrelations between digestible nutrient and energy content, voluntary dry matter intake, and the overall feeding value of forages. J. Animal Sci. 16: 546-551. 1957.

33. Crampton, E. W., G. C. Ashton, and L. E. Lloyd. The effect of restricting feed intake of market hogs during the finishing period on the quality of the bacon carcass. J. Animal Sci. 13: 321. 1954.

34. Crampton, E. W., G. C. Ashton, and L. E. Lloyd. Improvement of bacon carcass quality by the introduction of fibrous feeds into the hog finishing ration. J. Animal Sci. 13: 327. 1954.

35. Crampton, E. W., and J. M. Bell. The effect of fineness of grinding on the utilization of oats by market hogs. J. Animal Sci. 5: 200-210. 1946.

36. Crampton, E. W., and L. A. Maynard. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutrition. 15: 383. 1938.

37. Crampton, E. W., and I. R. C. Jackson. Seasonal variation in chemical composition of pasture herbage and the relation to its digestibility by steers and sheep. J. Animal Sci. 3: 333. 1944.

38. Crampton, E. W. and B. Elaine Rutherford. Apparent digestibility of dietary protein as a function of protein level. J. Nutrition 54: 445-451. 1954.

39. Gravens, W. W., A. W. Bruins, M. L. Lunde, and E. E. Snell. Evidence of two unidentified factors required by the chick. Federation Proceedings 10: 379. 1951.

40. Davis, Frank and George M. Briggs. The growth-promoting action of cellulose in purified diets for chicks. J. of Nutrition 34: 259-300. 1947.

41. Davis, Frank and George M. Briggs. Sawdust in purified chick rations. Poultry Sci. 27: 117-118. 1948.

42. Dinusson, W. E., E. W. Klosterman, E. L. Losley, and L. M. Buchanan. Cobalt, alfalfa and meat scraps in drylot rations for growing-fattening pigs. J. Animal Sci. 12: 623-627. 1953.

43. Dinusson, W. E., Merle R. Light, E. W. Klosterman, and M. F. Buchanan. Preparation of feeds. Grinding vs. pelleting of rations for swine. J. Animal Sci. 10: 1045. 1951.

44. Donaldson, W. E., G. F. Cambs, and G. L. Romoser. Studies on energy levels in poultry rations. 3. Effect of calorie-protein ratio of the ration on growth, nutrient utilization and body composition of poults. Poultry Sci. 37: 614. 1958.

45. Dove, W. F. A study of individuality in the nutritive instincts and of the causes and effects of variations in the selection of food. American Naturalist 69: 649. 1935.

46. Draper, E. I. A comparison of suncured and dehydrated alfalfa meal in the diet of the chick. Poultry Sci. 27: 659. 1948.

47. Ellis, N. R. and J. H. Zeller. Utilization of feed by swine as affected by the level of intake. American Society of Animal Production pp. 270. 1931-32.

48. Esplin, A. L., U. S. Garrigus, E. E. Hatfield, and R. M. Forbes. Some effects of pelleting a ground mixed ration on feed utilization by fattening lambs. J. Animal Sci. 16: 863. 1957.

49. Food intake and water relationships. Nutrition Reviews 16: 2. February, 1958.

50. Forbes, R. M. and T. S. Hamilton. The utilization of certain cellulosic materials by swine. J. Animal Sci. 11: 480. 1952.

51. Fraps, G. S. Energy-production coefficients of American feedingstuffs. Texas Agr. Exp. Sta. Bull. 329, pp. 62. 1925.

52. Fredeen, H. T. Genetic aspects of Canadian bacon-hog production. Publication 889. Canada Dept. Agr. Ottawa. 1953.

53. Graham, W. R. Can we learn anything from a free choice of feeds as expressed by chickens? Poultry Sci. 11: 365. 1932.

54. Guerrant, N. B. On the use of roughage in rat diets. Science 108: 82-83. 1948.

55. Hanson, L. E. Fifty years of progress in swine nutrition. J. Animal Sci. 17: 1029. 1958.

56. Hanson, L. J., D. E. Becker, S. W. Terril, A. H. Jensen, and H. W. Norton. The inhibitory effect of dehydrated alfalfa meal in the diet of swine. J. Animal Sci. 15: 830. 1956.

57. Heyvang, B. W. and R. B. Morgan. Pelleted and unpelleted all-mash diet for growing chickens. Poultry Sci. 23: 16-20. 1944.

58. Hill, F. W. and L. M. Dansky. Studies of the energy requirement of chickens. 1. The effect of dietary energy level on growth and feed consumption. Poultry Sci. 33: 112-119. 1954.

59. Hoefer et al. (Michigan State University). Meal versus pelleted feed with varying oat levels for swine. Feedstuffs pp. 50. October 25, 1958.

60. Hoelzel, F. and J. Carlson. Comments and communications. Science 108: 82-83. 1947.

61. Hoelzel, F. Rate of passage of inert materials through the digestive tract. American J. Physiology 92: 466. 1930.

62. Hoelzel, F. Use of non-nutritive materials to satisfy hunger. American J. Digestive Diseases 14: 401. 1947.

63. Homb, Thor. Chemical composition and digestibility of grassland crops. Acta Agriculturae Scaninavica 111: 1-32. 1953.

64. Homb, T. and K. Breirem. The use of fecal nitrogen as a measure of dry matter intake and of digestibility of organic matter in forage. J. Animal Sci. 11: 496. 1952.

65. Hummel, Frances Cape, Marion L. Shepherd, and Icie Macy. Disappearance of cellulose and hemicellulose from the digestive tract of children. J. of Nutrition 25: 59-70. 1943.

66. Hvidsten, H. and T. Homb. A survey of cellulose and Beckmann-treated straw as a feed. Inst. Animal Nutrition, Royal Agr. College of Norway. Rept. No. 62, pp. 14. 1947.

67. Johns, A. T. Pasture quality and ruminant digestion. 1. Seasonal change in botanical and chemical composition of pasture. New Zealand J. of Sci. 37: 301-311. 1955.

68. Jukes, C. L. Selection of diet in chicks as influenced by vitamins and other factors. J. Comparative Psychology 26: 135. 1938.

69. Kodras, R. W., W. T. Cooney, and J. S. Butts. Chick growth depression factor in sundried and dehydrated alfalfa meals. Poultry Sci. 30: 280-292. 1951.

70. Kidwell, J. F. and J. E. Hunter. The utilization of a high level of alfalfa by growing-fattening swine. J. Animal Sci. 15: 1067. 1956.

71. King, K. W. and W. E. C. Moore. Density and size as factors affecting passage rate of ingesta in the bovine and human digestive tracts. J. Dairy Sci. 40: 528-536. 1957.

72. Lang, T. A., A. B. Nelson, and Robert MacVicar. Effect of grinding and pelleting upon digestibility of a ration by lambs. J. Animal Sci. 14: 947. 1955.

73. Lanson, R. K. and J. R. Smyth. Pellets vs. mash plus pellets vs. mash for broiler feeding. Poultry Sci. 24: 234-235. 1955.

74. Lloyd, L. E. and E. W. Crampton. The apparent digestibility of the crude protein of the pig ration as a function of its crude protein and crude fiber content. J. Animal Sci. 14: 693-699. 1955.

75. Lofgreen. G. P. The use of digestible energy in the evaluation of feeds. J. Animal Sci. 10: 344-351. 1951.

76. Lepkovsky, S., W. Shaeleff, D. Peterson, and R. Perry. Alfalfa inhibitor in chick rations. Poultry Sci. 29: 208-213. 1950.

77. Maynard, Leonard A. and John K. Loosli. Animal Nutrition. Fourth edition. McGraw-Hill Book Company, Inc. Toronto. 1956.

78. Menzies, C., T. D. Bell, R. Richardson, R. F. Cox, and W. D. Striegel. The relationship of physical balance to the utilization of pelleted and non-pelleted rations for lambs. Kansas Agr. Exp. Sta. Circular 349. 1957.

79. Merkel, R. A., R. W. Bray, R. H. Grummer, P. H. Phillips, and G. Bohstedt. The influence of limited feeding, using high fiber rations, upon growth and carcass characteristics of swine. I. Effect upon feed lot performance. J. Animal Sci. 17: 3. 1958.

80. Merkel, R. A., R. W. Bray, R. H. Grummer, P. H. Phillips, and G. Bohstedt. The influence of limited feeding using high fiber rations, upon growth and carcass characteristics of swine. II. Effects upon carcass characteristics. J. Animal Sci. 17: 13. 1958.

81. Meyer, James H. Influence of dietary fiber on metabolic and endogenous nitrogen excretion. J. of Nutrition 58: 407-413. 1956.

82. Mitchell, H. H. and G. G. Carman. The biological value for maintenance and growth of the proteins of whole wheat, eggs and pork. J. Biological Chemistry 60: 613. 1924.

83. Mitchell, H. H. and T. S. Hamilton. True and apparent digestibility of oat hulls and alfalfa meal by swine, with special reference to the ability of swine to digest cellulose and crude fibre. J. Agr. Research 47: 425-435. 1933.

84. Morgan, H. The laxative effect of regenerated cellulose in the diet. Its influence on mineral retention. J. Am. Medical Assoc. 102: 995. 1934.

85. McCay, C. M. The effect of roughage on growth. Proc. Soc. Exptl. Biol. Med. 27: 209. 1929.

86. McMeekan, C. P. I. Growth and development in the pig with special reference to carcass quality characters. J. Agr. Sci. 30: 276. 1940.

87. McMeekan, C. P. II. The influence of the plane of nutrition on growth and development. J. Agr. Sci. 30: 387. 1940.

88. McMeekan, C. P. III. Effects of the plane of nutrition on the form and composition of the bacon pig. J. Agr. Sci. 30: 511. 1940.

89. McMeekan, C. P. and J. Hammond. Improvement of carcass quality in pigs. J. Ministry Agr. 46: 238. 1939.

90. National Bacon Hog Policy. Record of performance and advanced registry for purebred swine. Issued by Production Service Department of Agriculture, Ottawa. October, 1954.

91. Neale, P. E. Alfalfa cube mixtures for fattening lambs. New Mexico Agr. Exp. Sta. Bull. 398. 1955.

92. Noble, Robert L., Calvin Wright, and Robert MacVicar. Fattening trials with western feeder lambs. Okla. Agr. Exp. Sta., Misc. Publ. MP-45, MP-43 and MP-34. 1956.

93. Norman, A. G. Biochemical approach to grass problems. J. Am. Soc. Agron. 31: 751. 1939.

94. Nutrient Requirements for Swine. Publication 295. Revised August, 1953. National Research Council. Washington 25, D.C.

95. Patton, J. W., H. H. Buskirk, and L. A. Rauls. A study of the relative merits of pellets and mash poultry feeds. Vet. Med. 32: 423. 1937.

96. Perry, T. W., W. D. Whitefield, and W. M. Beeson. Pelleted feed versus meal with and without hygromycin for self-feeding Angus calves. Purdue Agr. Exp. Sta. A. H. Mimeo. 228. 1958.

97. Peterson, D. W. Effect of sterols on the growth of chicks fed high alfalfa diet or a diet containing Quillaja saponin. J. Nutrition 42: 597. 1950.

98. Peterson, D. W. Some properties of a factor in alfalfa meal causing depression of growth in chicks. J. Biological Chemistry 183: 647. 1950.

99. Peterson, D. W., C. R. Grau, and N. E. Peek. Growth and food consumption in relation to dietary levels of protein and fibrous bulk. J. Nutrition 52: 241-257. 1954.

100. Pope, L. S. Pelleting feeds for beef cattle and sheep. (A review). Feedstuffs, pp. 7. February 7, 1959.

101. Pope, L.S., R. F. Hendrickson, Lowell Waller, George Walters, and W. D. Campbell. Effect of rolling vs. pelleting milo, previous implantation and certain feed additives on the feed lot performance of steer- and heifer-calves. Okla. Agr. Exp. Sta., Misc. Publ. MP-51. 1958.

102. Proctor, F. and N. C. Wright. Bulk in animal feeding. J. Agr. Sci. 17: 392-406. 1927.

103. Rose, M. S. The influence of bran on the alimentary tract. J. Am. Dietetic Assoc. 8: 133-156. 1932.

104. Rose, W. C. The nutritive significance of the amino acids. Physiol. Revs. 18: 109-136. 1938.

105. Richards, C. R. and J. T. Reid. The digestibility and interrelationships of various carbohydrate fractions of pasture herbage and a resolution of the components of crude fibre and nitrogen free extracts. J. Dairy Sci. 36: 1006-1015. 1953.

106. Richardson, D., E. F. Smith, B. A. Koch, and R. F. Cox. Fundamental studies of sorghum roughages and grains. I. A study of the value of pelleting sorghum grain. Kansas Agr. Exp. Sta. Circ. 358. 1958.

107. Schneider, H. B. The relationship of the metabolic nitrogen of the feces to body weight and to food intake for rats. Biochem. J. 28: 360-364. 1934.

108. Schneider, H. B. The subdivision of the metabolic nitrogen in the feces of the rat, swine and man. J. Biol. Chem. 109: 249-278. 1935.

109. Schneider, H. Burch, Henry L. Lucas, Helen M. Pavlech, and Mary Ann Cipo'lloni. Estimation of digestibility of feeds from their proximate composition. J. Animal Sci. 10: 706-713. 1951.

110. Schneider, B. H. and H. L. Lucas. The magnitude of certain sources of variability in digestibility data. J. Animal Sci. 9: 504-512. 1950.

111. Schneider, B. H., H. L. Lucas, H. M. Pavlech, and M. A. Cipo'lloni. The value of average digestibility data. J. Animal Sci. 9: 373-379. 1950.

112. Sibbald, Ian R., R. T. Berg, and J. P. Bowland. Digestible energy in relation to food intake and nitrogen retention in the weanling rat. J. Nutrition 50: 385-391. 1956.

113. Smith, J. Bulk in animal rations. B.S.A. Thesis. 1956. Department of Animal Husbandry, University of Saskatchewan.

114. Snedecor, George W. Statistical Methods, Fifth Edition. The Iowa State College Press. Ames, Iowa. 1956.

115. Teague, H. S. and L. E. Hanson. The effect of feeding different levels of a cellulose material to swine. J. Animal Sci. 13: 206. 1954.

116. Tillman, Allen D. On evaluation of energy feeding standards. Feedstuffs. pp. 36. December 13, 1958.

117. Titus, Harry W. The nitrogen metabolism of steers on rations containing alfalfa as the sole source of the nitrogen. J. Agr. Research 34: 1-49. 1927.

118. Vavich, M. G., Anne Wertz, and A. R. Kemmerer. Growth stimulating factors in alfalfa for chicks. Poultry Sci. 32: 433-436. 1953.

119. Webb, R. J., G. F. Cmarik, and H. A. Cate. Comparison of feeding three forages as baled hay, chopped hay, hay pellets and silage to steer calves. J. Animal Sci. 16: 1057. 1957.

120. Whatley, J. A. Jr., D. I. Gard, J. V. Whiteman, and J. C. Hillier. Influence of breeding and energy content of the ration on pork carcasses. J. Animal Sci. 10: 1030. 1951.

121. Whiting, F. and L. M. Bezeau. The metabolic fecal nitrogen excretion of the pig as influenced by the amount of fiber in the ration and by body weight. Can. J. Animal Sci. 37: 95-105. 1957.

122. Whiting, F. and L. M. Bezeau. The metabolic fecal nitrogen excretion of the pig as influenced by the type of fiber in the ration and by body weight. Can. J. Animal Sci. 37: 106-113. 1957.

123. Williams, R. D. and W. H. Olmstead. A biochemical method for determining indigestible residue in feces: crude fibre, lignin, cellulose and non-water-soluble hemicellulose. J. Biol. Chem. 108: 653. 1935.

124. Winthers, L. M., C. F. Sierk, and J. N. Cummings. The effect of plane of nutrition on the economy of production and carcass quality of swine. J. Animal Sci. 8: 132. 1949.

125. Wismer, W. W. An evaluation of the leanmeter as a measurement of carcass quality. B.S.A. Thesis. 1958. Department of Animal Husbandry, University of Saskatchewan.

126. Woodman, H. E. and R. E. Evans. The nutritive value of fodder cellulose from wheat straw. I. Its digestibility and feeding value when fed to ruminants and pigs. J. Agr. Sci. 37: 202-210. 1947.

127. Woodman, H. E. and R. E. Evans. The nutritive value of fodder cellulose from wheat straw. II. The utilization of cellulose by growing and fattening pigs. J. Agr. Sci. 37: 211-221. 1947.

APPENDIX

I. Calculation of Separate Digestibility Coefficients for Energy in the Fractions of Supplement (Bulk) and Basal in Mixed Rations

The principle in this method is basically "Carbery's Method of Determining Digestibility" as described by Crampton (31).

Since each of the five bulks were fed in three levels, it was possible to determine the regression of "total fecal Calories for every 100 Calories of the basal fraction consumed" (Y) on "total Calories consumed per 100 Calories in the basal fraction" (X). The regression coefficient (b) in this function is obviously the ratio of "Calories excreted due to the added bulk" to "Calories consumed in the bulk increments." This in turn is the indigestibility coefficient of the bulk. Therefore the digestibility percentage of the bulk is: 100 - 100b.

Since each value of X contains 100 Calories of the basal fraction of the ration plus the energy in the bulk increment, the ratio of Y (estimated for X = 100) to 100, is the indigestibility coefficient of energy in the basal fraction, i.e. the energy indigestibility coefficient in the basal fraction = Y/X, when X = 100 and Y = a + bX. The digestibility coefficient therefore is: $1 - \frac{a + bX}{X} = 1 - \frac{a + 100b}{100}$; and the digestibility per cent is: $100 - 100(1 - \frac{a + 100b)}{100} = 100 - (100b + a)$.

Some interesting aspects are revealed by an examination of this system of calculating the digestibility of the energy in the basal and bulk fractions of a ration. An associative effect between the two ration fractions is indicated by a regression coefficient (b) larger than 1 or smaller than zero and/or a curvilinear function of Y on X. This is born out firstly by the fact that when b is larger than 1, the energy excreted due to the bulk increment exceeds the energy consumed in the bulk increment, giving a negative digestibility. Secondly, if b is negative the energy excreted due to the bulk increment is a negative value giving a digestibility of bulk-energy above 100% which can only be accomplished by an associative effect increasing the energy digestibility in the basal fraction of the ration. Thirdly, when the function of Y on X is curvilinear, a change in the ratio of "Calories excreted due to bulk" to "Calories consumed in bulk" occurs. This can only take place with a change in the digestibility of energy in bulk and/or basal with a changing ratio of these fractions and therefore must be considered as an associative effect between them.

Whenever a curvilinear function of Y on X is being expressed by a linear regression, b is only an average value for the continuously changing ratio of Y and X, and will cause an error in the estimation of the 'a' value. Both of these effects are likely to give inaccurate estimates of the digestibility of the energy in the two ration fractions, basal and bulk. A concave function expressed by a linear regression will cause a low 'a' value which means too low a digestibility of the basal energy fraction when dealing with a positive regression and too high a digestibility in a negative regression. The reverse of this takes place in a convex function.

Since the proportionate effect of a unit change in a number is inversely related to the magnitude of the number, it is obvious that when a fraction of a ration is studied, all experimental errors in this fraction will increase its standard deviation to the above degree.

II. Adjustment of Apparent Protein Digestibility Coefficients by Multiple Independent Co-variates.

The fecal nitrogen x 6.25 (Y) was adjusted for variability in protein intake (X_1), nonprotein dry matter intake (X_2), nonprotein dry matter excretion (X_3) and physiological body size (weight$^{0.75}$)(X_4).

The partial regression coefficients (b_1 to b_4) of Y on each independent X in the multiple regression: $Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$, were used in this adjustment by means of the equation: adjusted $Y = \bar{y}_i - b_1(\bar{x}_i - \bar{\bar{x}})_1 - b_2(\bar{x}_i - \bar{\bar{x}})_2 - b_3(\bar{x}_i - \bar{\bar{x}})_3 - b_4(\bar{x}_i - \bar{\bar{x}})_4$, (114 pp. 130 and 413-445), where:

$\bar{y}_i$ = the mean of Y for any individual experimental treatment,

$\bar{x}_i$ = the mean of X for the corresponding experimental treatment,

$\bar{\bar{x}}$ = the overall mean of X, and

$(\bar{x}_i - \bar{\bar{x}})_1$ to $(\bar{x}_i - \bar{\bar{x}})_4$ = the difference between $\bar{x}_i$ and $\bar{\bar{x}}$ for each of the four independent co-variates (X_1 to X_4).

The adjusted fecal nitrogen x 6.25 was then used in calculation of the adjusted protein digestibilities in tables 5 and 15 by the conventional formula: $100 - 100 \times \frac{\text{adjusted fecal nitrogen} \times 6.25}{\text{observed protein intake}}$

III. Procedure for Chromic Oxide Analysis

The following was the standard procedure for chromium oxide analysis in the laboratory of the Department of Animal Husbandry, University of Saskatchewan. It was based upon the report by: "D. W. Bolin, R. P. King and E. W. Klosterman. A simplified method for the determination of chromic oxide (Cr_2O_3) when used as an index substance. Science 116: 634. 1952," plus personal communication between Dr. J. Milton Bell and Dr. E. W. Crampton, Professor and Chairman, Department of Nutrition, Macdonald College, Quebec.

Procedure

1. Weigh 1 g. samples of feeds and 0.5 g. samples of feces. Place in 100 ml. Kjedahl flasks calibrated to 110 ml. The samples must not exceed 1.000 g. because of explosion danger.
2. Add 10 ml. of oxidizing reagent, plus glass beads, and heat until organic matter has been oxidized (green color). Allow flasks to cool.
3. Add an additional 10 ml. of oxidizing reagent, washing down any particles adhering to the neck and sides of the flasks. Resume heating until all Cr_2O_3 has been oxidized (yellow, orange or red). Swirl flask, rotate 180° and continue heating for 2-3 minutes.
4. Cool flasks to room temperature, and make up to volume (110 ml.).
5. Filter through a medium paper (Whatman #40) discarding the first 25 ml. of filtrate.
6. Prepare dilutions if necessary.
7. Read % transmittance at 440 mμ against distilled water at 100.
8. Using calibration chart prepared from standard curve, determine mg. Cr_2O_3 in 110 ml. of solution. Correct to mg. Cr_2O_3 in 1 g. sample.

Preparation of standard curve

1. Digest 0.1000 g. Cr_2O_3 as indicated above. Dilute to volume in 100 ml. volumetric flask (reference solution contains 1 mg. Cr_2O_3 per ml.).
2. Make up dilutions of 10 μg. through 100 μg. per ml.
3. Read % transmittance (T) at 440 mμ against distilled water set at 100.
4. Plot on one-cycle semi-logarithmic graph paper % T vs. μg. Cr_2O_3 per ml.

5. Determine regression equation ($Y = a + bX$), ($Y = \log T$), ($X = \mu g.$ Cr_2O_3 per ml.).

Oxidizing reagent

1. Dissolve 5 g. of sodium molybdate in one liter of water.
2. Add one liter of perchloric acid (70-72%) to this solution and mix thoroughly.

IV. Procedure for Carcass Analyses in Mice

The following was the standard procedure adopted by Professor J. Milton Bell, for carcass analyses of mice in the Laboratory of the Department of Animal Husbandry at the University of Saskatchewan.

1. Asphyxiate the animal in a large beaker using a few drops of chloroform on a piece of cotton.
2. Remove the contents from the stomach and the intestines.
3. Cut open the shoulder and rump to speed up drying and fat extraction.
4. Record the weight of a dry alundum thimble.
5. Place carcass in the dry thimble.
6. Record weight of thimble plus carcass.
7. Dry thimble plus carcass in vacuum at 65° C for 6 hours.
8. Record the weight of the dried thimble plus carcass.
9. Calculate loss in weight upon drying as per cent water in the carcass.
10. Extract the carcass in the thimble with Skellysolve F for 12 hours.
11. Dry thimble and carcass in vacuum at 65° C for 2 hours.
12. Record the dry weight of thimble plus carcass.
13. Calculate loss in weight upon extraction as per cent of fat in the carcass.

14. Ignite thimble and carcass in muffle furnace for 6 to 8 hours at 300-400° C in order to avoid boiling-over and loss of material, then increase temperature to 800° C for 2-4 hours.
15. Weigh and record the weight of the thimble plus ash.
16. Calculate loss in weight upon ignition as per cent of protein in the carcass.
17. Calculate the remaining ash as per cent of ash in the carcass.

An ideal recording sheet for these analyses should contain the following columns:

1. Mouse number.
2. Thimble number.
3. Dry thimble weight.
4. Weight of total carcass.
5. Weight of cleaned carcass plus thimble.
6. Weight of cleaned carcass.
7. Weight of dried carcass plus thimble.
8. Weight of water lost in drying.
9. Per cent of water in carcass.
10. Weight of dried extracted carcass plus thimble.
11. Weight of fat lost in extraction.
12. Per cent of fat in carcass.
13. Weight of ash plus thimble after ignition.
14. Weight of protein lost in ignition.
15. Per cent of protein in carcass.
16. Weight of ash.

17. Per cent of ash in carcass.

18. Fat free body weight.

19. Per cent of water in fat free carcass.

20. Per cent of protein in fat free carcass.

21. Per cent of ash in fat free carcass.

Table 1.- Composition of Experimental Rations (Pounds or Grams of Ingredients).

	62% TDN					65% TDN					68% TDN				
Ration No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Oat hulls	20.2					12.5					5.5				
Alfalfa meal		32.0					20.3					8.5			
Wheat bran			60.5					38.8					16.5		
Cellulose				12.3					7.8					3.3	
Corn cobs					12.3					7.8					3.3
Barley	39.4	34.0	19.8	39.6	39.6	40.0	39.4	30.3	42.9	42.9	44.8	44.8	40.7	46.1	46.1
Wheat	39.4	34.0	19.8	39.6	39.6	40.0	39.4	30.3	42.9	42.9	44.8	44.8	40.7	46.1	46.1
Soy bean oil meal	4.9	0	0	4.1	4.1	3.6	.3	.2	3.1	3.1	2.3	.8	.9	2.1	2.1
Vitamin A and D supplement (1)	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2
Meat meal	5.1	0	0	4.3	4.3	3.8	.5	.4	3.3	3.3	2.5	1.0	1.1	2.3	2.3
Calcium carbonate	.81	.39	1.01	1.01	1.01	1.04	.73	1.17	1.14	1.14	1.25	1.14	1.22	1.27	1.27
Dicalcium phosphate	.86	1.76	2.14	.75	.75	.91	.50	1.76	.91	.91	.96	1.28	1.44	1.02	1.02
Iodized salt	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5
Casein (2)	2.0	2.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

(1) N. D. Hogg Ltd., Toronto.
(2) In the mouse rations only.

Table 2.- Carcass Characteristics of the Male Pigs.

Ration	Pig No.	Days on test	Total gain lbs.	Shipping wt. lbs.	Carcass wt. lbs.	Av. length of sides ins.	Fat measurements shldr. ins.	Fat measurements back ins.	Fat measurements loin ins.	Weight (lbs.) ham lbs.	Weight (lbs.) middle lbs.	Weight (lbs.) shldr. lbs.	Loin area sq. ins.	Grade	Belly grade	AR Score
1a	43N	84	96	196	144	31.1	1.8	.9	1.2	31.5	59.0	36.0	3.85	A	E	91
	110N	77	96	198	143	31.2	1.6	.7	1.0	31.0	57.0	35.5	3.98	A	E	95
1b	14N	75	97	199	145	32.5	1.8	1.0	1.4	30.5	61.0	35.0	3.66	A	E	86
	140N	74	96	198	138	31.5	1.7	.9	1.1	29.0	58.5	32.0	3.81	B1	G	94
2a	104N	109	100	199	147	31.3	1.6	.9	1.1	32.5	61.0	36.0	4.12	A	E	98
	208N	74	93	195	133	30.4	1.6	.8	1.1	29.5	56.0	31.5	4.48	B2	E	98
2b	48N	90	97	199	144	31.6	1.7	1.0	1.4	31.0	61.5	33.0	3.67	A	G	87
	170N	103	104	204	146	31.8	1.8	.8	1.2	32.5	60.5	35.5	3.84	A	E	93
3a	60N	88	96	197	133	30.4	1.5	.7	1.1	29.5	52.0	33.5	3.92	B2	F	87
	173N	123	98	194	135	31.3	1.6	.7	1.1	31.0	53.5	33.5	5.41	B1	F	87
3b	242N	109	98	195	133	31.1	.7	.9	1.1	28.0	56.5	32.0	3.96	B2	E	95
	182N	110	102	198	139	31.0	1.5	.8	1.2	30.0	57.0	33.0	3.79	B1	E	96
4a	61N	75	97	200	144	30.7	1.6	.8	1.1	31.0	58.5	35.5	4.13	A	F	88
	132N	97	94	197	139	31.3	1.6	.9	1.1	30.5	60.0	32.0	3.69	B1	G	97
4b	223N	72	104	200	141	31.4	1.6	.9	1.5	29.5	60.0	33.0	3.53	A	G	82
	219N	85	114	210	153	30.9	1.9	1.1	1.5	32.5	62.0	37.5	4.11	A	G	80
5a	45N	75	102	198	145	30.6	1.4	.9	1.3	30.0	61.0	34.0	3.51	A	G	86
	189N	96	108	210	155	32.1	1.5	1.0	1.3	34.0	63.0	36.0	3.05	A	G	82
5b	75N	70	102	202	151	31.6	1.7	1.0	1.4	32.5	63.5	35.0	4.01	A	G	89
	126N	62	104	203	141	31.1	1.8	1.0	1.4	34.5	62.0	32.0	4.14	A	E	91

Table 2.- Carcass Characteristics of the Male Pigs. (Continued)

Ration	Pig No.	Days on test	Total gain lbs.	Shipping wt. lbs.	Carcass wt. lbs.	Av. length of sides ins.	Fat measurements shldr. ins.	back ins.	loin ins.	Weight (lbs.) ham lbs.	middle lbs.	shldr. lbs.	Loin area sq. ins.	Grade	Belly grade	AR Score
6a	69N	95	99	197	146	30.9	1.6	1.0	1.4	32.5	59.0	34.5	3.97	A	E	89
	141N	81	99	197	148	30.5	1.7	.9	1.2	32.5	65.0	32.5	4.62	A	E	98
6b	88N	67	105	205	145	30.0	1.7	1.0	1.4	32.5	60.5	34.0	3.47	A	E	81
	142N	81	106	204	149	30.3	1.8	.9	1.2	32.0	63.0	35.0	4.62	A	G	89
7a	51N	116	98	196	145	30.9	1.8	1.0	1.2	31.5	58.5	37.0	4.23	A	E	90
	165N	95	94	194	136	32.2	1.7	.7	1.2	30.0	54.0	33.5	3.65	Bl	E	93
7b	217N	68	92	194	136	30.8	1.6	1.0	1.5	29.5	57.0	31.5	3.68	Bl	G	81
	192N	85	98	197	146	30.5	1.7	.9	1.2	32.0	58.0	34.5	4.16	A	G	94
8a	58N	95	96	196	139	31.6	1.8	.9	1.1	29.5	58.5	33.0	3.54	Bl	G	86
	147N	83	100	204	143	32.2	1.7	.8	1.1	29.0	61.5	33.0	4.06	A	G	93
8b	240N	119	96	199	140	29.5	1.7	.8	1.2	32.0	57.0	33.5	5.13	A	E	86
	149N	94	101	201	141	30.3	1.6	.9	1.1	30.0	60.0	33.5	3.70	A	G	93
9a	133N	88	94	199	139	32.5	1.8	1.0	1.5	28.0	62.5	32.0	3.37	Bl	G	74
	121N	90	104	202	148	31.7	1.8	.9	1.3	32.0	64.0	35.0	4.00	A	G	91
9b	56N	84	98	196	146	30.4	1.8	1.0	1.3	31.0	63.0	35.0	4.26	A	G	89
	89N	88	103	202	143	30.6	1.6	.9	1.2	29.5	59.5	34.0	4.48	A	E	95
10a	50N	84	98	198	145	31.4	1.7	.9	1.4	30.5	61.5	35.0	4.08	A	G	86
	129N	90	98	196	142	30.2	1.9	1.1	1.4	30.0	60.0	35.0	3.92	A	E	84
10b	112N	63	96	200	148	30.6	1.5	.9	1.3	32.0	63.0	36.5	4.22	A	E	92
	193N	71	96	194	144	31.4	1.6	.7	1.1	31.0	58.0	36.0	3.49	A	E	92

Table 2.- Carcass Characteristics of the Male Pigs. (Continued)

Ration	Pig No.	Days on test	Total gain lbs.	Shipping wt. lbs.	Carcass wt. lbs.	Av. length of sides ins.	Fat measurements shldr. ins.	back ins.	loin ins.	Weight (lbs.) ham lbs.	middle lbs.	shldr. lbs.	Loin area sq. ins.	Grade	Belly grade	AR Score
11a	108N	95	112	210	155	30.9	1.8	1.1	1.5	32.0	65.0	36.0	4.53	A	G	83
	164N	57	93	198	144	31.6	1.9	.9	1.5	31.0	60.0	34.0	2.98	Bl	G	76
11b	76N	74	98	200	149	31.5	1.8	1.0	1.4	32.5	62.5	34.5	3.61	A	G	86
	194N	95	97	197	149	32.1	1.7	.9	1.3	32.0	60.5	35.5	3.36	A	G	85
12a	87N	77	92	194	141	30.8	1.9	1.1	1.4	29.5	60.5	33.5	3.80	A	E	87
	174N	129	104	200	148	31.6	1.8	.8	1.2	37.0	57.0	34.0	3.80	A	F	86
12b	47N	79	100	204	153	30.9	1.9	1.0	1.6	32.0	64.0	36.5	4.12	Bl	G	78
	210N	67	100	198	138	31.6	1.7	1.0	1.2	28.0	61.0	33.0	3.60	Bl	G	90
13a	52N	87	106	201	150	30.5	1.7	.9	1.2	31.5	61.0	35.0	3.98	A	G	83
	113N	62	92	194	139	30.4	1.6	.9	1.2	30.5	60.0	33.0	4.40	Bl	G	93
13b	39N	75	101	203	148	31.1	1.6	.8	1.2	31.5	59.0	36.5	3.42	A	G	88
	181N	63	99	198	138	31.2	1.6	1.0	1.5	29.0	61.5	31.0	3.49	Bl	G	78
14a	128N	77	95	193	141	30.5	2.1	1.3	1.6	29.0	63.5	30.5	3.11	Bl	P	62
	180N	71	91	196	144	31.0	1.7	1.1	1.5	31.0	62.0	34.0	3.91	Bl	G	82
14b	130N	74	101	199	141	30.9	1.6	.9	1.3	28.5	60.5	32.0	3.64	A	G	88
	148N	66	104	202	149	32.0	1.8	1.0	1.5	32.0	63.5	34.5	4.00	A	G	82
15a	86N	77	102	202	149	30.5	2.1	1.1	1.6	32.0	64.5	34.0	3.20	Bl	G	74
	218N	64	99	199	144	30.8	1.8	.9	1.4	31.0	59.5	34.0	3.86	A	G	86
15b	120N	77	101	198	145	30.6	1.6	.9	1.4	30.0	61.5	34.0	3.51	A	G	81
	171N	97	95	196	141	30.8	1.9	1.0	1.5	30.5	58.5	31.5	3.43	A	E	81

Table 3.- Dry Matter Digestibility (%) of Rations Fed to Swine.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)(1)				(T L P)		(T L S)		(T L)
Oat hulls	High	59.7	58.2	65.4	66.6	58.9	66.0	62.6	62.4	62.5
	Medium	56.3	64.2	69.7	66.8	60.2	68.2	63.0	65.5	64.3
	Low	69.0	66.7	73.6	74.6	67.8	74.1	71.3	70.7	71.0
Alfalfa	High	65.4	59.7	67.3	67.6	62.5	67.4	66.4	63.7	65.1
	Medium	64.0	65.5	73.4	73.7	64.7	73.6	68.8	69.6	69.2
	Low	67.3	65.6	75.2	76.1	66.4	75.6	71.3	70.9	71.1
Wheat bran	High	57.4	57.9	64.4	63.6	57.6	64.0	60.9	60.8	60.9
	Medium	63.7	59.6	64.9	66.0	61.6	65.4	64.3	62.8	63.6
	Low	73.9	70.7	70.2	69.4	72.3	69.7	72.1	70.1	71.1
Cellulose	High	63.0	66.9	69.2	69.3	64.9	69.2	66.1	68.1	67.1
	Medium	61.7	65.1	74.7	72.0	63.4	73.3	68.2	68.6	68.4
	Low	74.0	71.3	73.4	74.9	72.6	74.2	73.7	73.1	73.4
Corn cobs	High	62.3	61.5	72.7	74.5	61.9	73.6	67.5	68.0	67.8
	Medium	66.4	68.6	72.8	70.7	67.4	71.8	69.6	69.7	69.7
	Low	72.6	72.9	76.9	77.5	72.7	77.2	74.8	75.2	75.0
		DT: 7.47(2)				DT: 5.29		DT: 5.29		DT: 3.74
		DL: 6.38				DL: 4.52		DL: 4.52		DS: 3.19
		DP: 5.31				DP: 3.76		DS: 3.76		
		DS: 5.31								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		61.7	63.0	69.6	69.3	62.3	69.4	67.5	66.1	65.9
Alfalfa		65.6	63.6	72.0	72.5	64.5	72.2	68.8	68.0	68.4
Wheat bran		65.0	62.7	66.5	66.3	63.8	66.4	65.8	65.0	65.1
Cellulose		66.2	67.8	72.4	72.1	67.0	72.2	69.3	69.9	69.6
Corn cobs		67.1	67.7	74.1	74.2	67.4	74.2	70.6	70.9	70.8
		DT: 4.31				DT: 3.05		DT: 3.05		DT: 2.16
		DP: 3.07				DP: 2.17		DS: 2.17		
		DS: 3.07								
		(L P S)				(L P)		(L S)		(L)
	High	61.5	60.8	67.8	68.3	61.2	68.1	64.7	64.6	64.6
	Medium	62.4	64.6	71.1	69.8	63.5	70.5	66.8	67.2	67.0
	Low	71.3	69.4	73.8	74.5	70.4	74.2	72.6	72.0	72.3
		DL: 2.86				DL: 2.02		DL: 2.02		DL: 1.43
		DP: 2.38				DP: 1.68		DS: 1.68		
		DS: 2.38								
		(P S)				(P)		(S)		Mean
		65.1	64.9	70.9	70.9	65.0	70.9	68.0	67.9	68.0
		DP: 1.37				DP: 0.97		DS: 0.97		
		DS: 1.37								

(1) Interaction. T = Bulk type. L = Bulk level. P = Physical condition (Meal or Pellet). S = Sex.

(2) D = Difference required for significance at $P<0.05$, (G. W. Snedecor, Statistical Methods, Fifth Ed., page 251.)

Table 4.- Apparent Protein Digestibility (%) of Rations Fed to Swine.

Bulk Type	Bulk Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	77.5	75.5	81.8	81.1	76.4	84.1	79.7	78.3	79.0
	Medium	75.3	76.7	79.4	78.7	76.0	79.0	77.4	77.7	77.5
	Low	85.6	73.1	79.4	78.6	74.3	79.0	82.5	75.9	76.6
Alfalfa	High	69.4	66.9	70.4	70.9	68.2	70.6	69.9	68.9	69.4
	Medium	68.5	66.8	73.6	73.9	67.6	73.8	71.1	70.4	70.0
	Low	69.3	67.7	77.8	80.1	68.4	78.9	73.6	73.9	73.7
Wheat bran	High	73.6	70.1	74.9	74.4	71.8	74.6	74.3	72.3	73.2
	Medium	77.8	72.9	72.5	75.7	75.3	74.1	75.2	74.3	74.7
	Low	81.3	80.6	78.4	76.9	81.0	77.6	79.9	78.8	79.3
Cellulose	High	74.8	80.8	79.9	80.3	77.8	80.1	77.4	80.6	78.9
	Medium	70.5	73.5	83.9	81.1	72.0	82.5	77.2	77.3	77.2
	Low	79.5	78.0	78.1	81.2	78.8	79.7	78.8	79.6	79.2
Corn cobs	High	76.5	78.5	82.3	85.2	77.4	83.7	79.4	81.9	80.6
	Medium	77.1	79.3	82.0	79.8	78.2	80.9	79.6	79.6	79.5
	Low	77.9	78.4	79.4	84.2	78.0	81.8	78.7	81.3	79.6
		DT: 9.17				DT: 6.49		DT: 6.49		DT: 4.58
		DL: 7.83				DL: 5.54		DL: 5.54		DS: 3.92
		DP: 6.52				DP: 4.61		DS: 4.61		
		DS: 6.52								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		79.5	75.1	80.2	79.5	77.3	79.8	79.9	77.3	77.7
Alfalfa		69.1	67.1	73.9	75.0	68.1	74.4	71.5	71.1	71.2
Wheat bran		77.6	74.5	75.3	75.7	76.0	75.4	76.5	75.1	75.8
Cellulose		74.9	77.4	80.6	80.9	76.2	80.7	77.8	79.2	78.5
Corn cobs		77.2	78.7	81.2	83.1	77.9	82.1	79.2	80.9	80.0
		DT: 5.30				DT: 3.75		DT: 3.75		DT: 2.65
		DP: 3.77				DP: 2.66		DS: 2.66		
		DS: 3.77								
		(L P S)				(L P)		(L S)		(L)
	High	74.4	74.4	77.9	78.6	74.4	78.3	76.2	76.5	76.2
	Medium	73.8	73.8	78.3	77.8	73.8	78.1	76.1	75.8	75.9
	Low	78.7	75.6	78.6	80.2	77.2	79.4	78.7	77.9	77.8
		DL: 3.51				DL: 2.48		DL: 2.48		DL: 1.75
		DP: 2.92				DP: 2.07		DS: 2.07		
		DS: 2.92								
		(P S)				(P)		(S)		Mean
		75.6	74.6	78.3	78.9	74.8	78.5	76.9	76.8	76.9
		DP: 1.68				DP: 1.19		DS: 1.19		
		DS: 1.68								

Table 5.- Digestibility (%) of Energy in Rations Fed to Swine.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	60.0	57.9	65.3	67.1	58.9	66.2	62.7	62.5	62.6
	Medium	56.7	64.0	70.5	67.2	60.3	68.8	63.6	65.6	64.6
	Low	68.4	66.2	74.1	75.3	67.3	74.6	71.3	70.8	71.1
Alfalfa	High	65.7	60.4	67.9	68.2	63.0	68.0	66.8	64.3	65.6
	Medium	62.8	64.6	73.2	73.8	63.7	73.4	68.0	69.2	68.6
	Low	66.9	64.5	75.4	76.3	65.7	75.8	71.2	70.4	70.8
Wheat bran	High	58.4	59.1	65.6	65.1	58.7	65.3	62.0	62.1	62.1
	Medium	64.1	58.1	65.2	66.1	61.1	65.6	64.7	62.1	63.4
	Low	74.9	71.6	71.5	70.8	73.2	71.1	73.2	71.2	72.2
Cellulose	High	64.0	67.8	70.5	70.6	65.9	70.5	67.3	69.2	68.3
	Medium	61.6	64.8	76.0	73.3	63.2	74.6	68.8	69.1	69.0
	Low	73.9	70.9	74.5	75.8	72.4	75.1	74.2	73.4	73.8
Corn cobs	High	62.1	60.8	73.9	74.9	61.4	74.4	68.0	67.9	68.0
	Medium	66.7	69.0	73.9	71.4	67.8	72.8	70.3	70.5	70.4
	Low	72.5	72.4	77.5	78.2	72.4	77.8	75.0	75.3	75.2
		DT: 8.46				DT: 5.99		DT: 5.99		DT: 4.23
		DL: 7.23				DL: 5.11		DL: 5.11		DS: 3.61
		DP: 6.01				DP: 4.26		DS: 4.26		
		DS: 6.01								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		61.7	62.7	70.0	69.9	62.2	69.9	65.9	66.3	66.0
Alfalfa		65.1	63.2	72.2	72.8	64.1	72.4	68.7	68.0	68.3
Wheat bran		65.8	62.9	67.4	67.3	64.4	67.3	66.6	65.1	65.8
Cellulose		66.5	67.8	73.7	73.2	67.2	73.4	70.1	70.5	70.3
Corn cobs		67.1	67.4	75.1	75.0	67.2	75.0	71.1	71.2	71.1
		DT: 4.88				DT: 3.45		DT: 3.45		DT: 2.44
		DP: 3.47				DP: 2.46		DS: 2.46		
		DS: 3.47								
		(L P S)				(L P)		(L S)		(L)
	High	62.0	61.2	68.6	69.2	61.6	68.9	65.3	65.2	65.2
	Medium	62.4	64.1	71.8	70.5	63.3	71.2	67.1	67.3	67.2
	Low	71.3	69.1	74.6	75.3	70.2	75.0	73.0	72.2	72.6
		DL: 3.23				DL: 2.29		DL: 2.29		DL: 1.62
		DP: 2.69				DP: 1.90		DS: 1.90		
		DS: 2.69								
		(P S)				(P)		(S)		Mean
		65.2	64.8	71.7	71.7	65.0	71.6	68.5	68.3	68.4
		DP: 1.15				DP: 1.10		DS: 1.10		
		DS: 1.15								

Table 6.- Digestible Therms Per Pound of Ration Fed to Swine.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	1.15	1.11	1.26	1.29	1.13	1.27	1.21	1.20	1.20
	Medium	1.10	1.24	1.37	1.31	1.17	1.34	1.24	1.28	1.25
	Low	1.33	1.28	1.44	1.46	1.30	1.45	1.39	1.37	1.38
Alfalfa	High	1.27	1.17	1.31	1.32	1.22	1.31	1.29	1.25	1.26
	Medium	1.23	1.26	1.43	1.44	1.24	1.44	1.33	1.35	1.34
	Low	1.29	1.24	1.45	1.46	1.26	1.45	1.37	1.35	1.36
Wheat bran	High	1.15	1.17	1.29	1.29	1.16	1.29	1.22	1.23	1.22
	Medium	1.27	1.15	1.29	1.31	1.20	1.30	1.28	1.23	1.25
	Low	1.46	1.40	1.39	1.38	1.42	1.38	1.43	1.39	1.40
Cellulose	High	1.25	1.32	1.38	1.38	1.28	1.38	1.32	1.35	1.33
	Medium	1.18	1.24	1.46	1.41	1.21	1.43	1.32	1.33	1.32
	Low	1.42	1.36	1.43	1.46	1.39	1.44	1.43	1.41	1.42
Corn cobs	High	1.18	1.16	1.41	1.43	1.17	1.42	1.30	1.30	1.30
	Medium	1.29	1.33	1.43	1.39	1.31	1.40	1.36	1.36	1.36
	Low	1.43	1.42	1.52	1.54	1.42	1.53	1.48	1.48	1.48
		DT: 0.16				DT: 0.11		DT: 0.12		DT: 0.08
		DL: 0.14				DL: 0.10		DL: 0.10		DL: 0.07
		DP: 0.12				DP: 0.08		DS: 0.08		
		DS: 0.12								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		1.19	1.21	1.36	1.35	1.20	1.35	1.28	1.28	1.28
Alfalfa		1.26	1.22	1.40	1.41	1.24	1.40	1.33	1.32	1.32
Wheat bran		1.29	1.24	1.32	1.33	1.26	1.32	1.31	1.29	1.29
Cellulose		1.28	1.31	1.42	1.42	1.29	1.42	1.35	1.36	1.36
Corn cobs		1.30	1.30	1.45	1.45	1.30	1.45	1.38	1.38	1.38
		DT: 0.10				DT: 0.07		DT: 0.07		DT: 0.05
		DP: 0.07				DP: 0.05		DS: 0.05		
		DS: 0.07								
		(L P S)				(L P)		(L S)		(L)
	High	1.20	1.19	1.33	1.34	1.19	1.33	1.27	1.26	1.26
	Medium	1.21	1.24	1.40	1.37	1.23	1.38	1.31	1.31	1.30
	Low	1.39	1.34	1.45	1.46	1.36	1.45	1.42	1.40	1.41
		DL: 0.06				DL: 0.05		DL: 0.05		DL: 0.03
		DP: 0.05				DP: 0.04		DS: 0.04		
		DS: 0.05								
		(P S)				(P)		(S)		Mean
		1.27	1.26	1.39	1.39	1.26	1.39	1.33	1.32	1.32
		DP: 0.03				DP: 0.02		DS: 0.02		
		DS: 0.03								

Table 7.- Digestible Crude Protein, Grams Per Pound of Ration, Fed to Swine.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	53.2	51.9	56.2	55.7	52.5	56.0	54.7	53.8	54.2
	Medium	50.3	51.2	53.0	52.6	50.8	52.8	51.7	51.9	51.8
	Low	53.3	51.6	56.0	55.4	52.4	55.7	54.7	53.5	54.1
Alfalfa	High	48.8	47.0	49.4	49.8	47.9	49.6	49.1	48.4	48.8
	Medium	47.6	46.4	51.1	51.3	47.0	51.2	49.4	48.9	49.1
	Low	48.7	47.5	54.6	56.2	48.1	55.4	51.7	51.9	51.7
Wheat bran	High	51.8	49.3	52.7	52.3	50.6	52.5	52.3	50.8	51.5
	Medium	49.5	46.4	46.2	48.2	48.0	47.2	47.9	47.3	47.6
	Low	60.0	59.5	57.8	56.7	59.7	57.2	58.9	58.1	56.0
Cellulose	High	52.5	56.7	56.0	56.3	54.6	56.2	54.3	56.5	55.4
	Medium	48.2	50.2	57.3	55.4	49.2	56.4	52.8	52.8	52.8
	Low	52.8	51.7	51.8	53.9	52.2	52.8	52.3	52.8	52.5
Corn cobs	High	54.2	55.6	58.3	60.4	54.8	59.3	56.3	58.0	57.1
	Medium	53.3	54.8	56.6	55.1	54.0	55.8	55.0	55.0	55.0
	Low	49.5	49.9	50.5	53.6	49.7	52.0	50.0	51.8	50.9
		DT: 6.38				DT: 4.51		DT: 4.51		DT:
		DL: 5.45				DL: 3.86		DL: 3.86		3.19
		DP: 4.54				DP: 3.21		DS: 3.21		DS:
		DS: 4.54								2.73
		(T P S)				(T P)		(T S)		(T)
Oat hulls		52.3	51.6	55.1	54.6	51.9	54.8	53.7	53.1	53.4
Alfalfa		48.4	47.0	51.7	52.4	47.6	52.1	50.1	49.7	49.9
Wheat bran		53.8	51.7	52.2	52.4	52.7	52.3	53.0	52.1	52.5
Cellulose		51.2	52.9	55.0	55.2	52.0	55.1	53.1	54.1	53.5
Corn cobs		52.3	53.4	55.1	56.4	52.8	55.7	53.7	54.9	54.3
		DT: 3.69				DT: 2.61		DT: 2.61		DT:
		DP: 2.62				DP: 1.85		DS: 1.85		1.84
		DS: 2.62								
		(L P S)				(L P)		(L S)		(L)
	High	52.1	52.1	54.5	54.9	52.1	54.7	53.3	53.5	53.4
	Medium	49.8	49.8	52.8	52.5	49.8	52.7	51.3	51.1	51.2
	Low	52.9	52.0	54.1	55.2	52.5	54.7	53.5	53.6	53.5
		DL: 2.44				DL: 1.73		DL: 1.73		DL:
		DP: 2.03				DP: 1.44		DS: 1.44		1.22
		DS: 2.03								
		(P S)				(P)		(S)		Mean
		51.6	51.3	53.8	54.2	51.4	54.0	52.7	52.8	52.8
		DP: 1.17				DP: 0.83		DS: 0.83		
		DS: 1.17								

Table 8.- Grams Digestible Crude Protein Per Therm Digestible Energy in Rations Fed to Swine.

Bulk Type	Bulk Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	46.3	46.8	44.8	43.2	46.6	44.0	45.6	45.0	45.2
	Medium	45.7	41.6	38.7	40.3	43.7	39.5	42.2	41.0	41.6
	Low	40.2	40.3	39.1	38.0	40.3	38.6	39.7	39.2	39.4
Alfalfa	High	38.5	40.3	37.7	38.0	39.4	37.9	38.1	39.2	38.6
	Medium	38.8	36.8	35.8	35.7	37.8	35.8	37.3	36.3	36.8
	Low	37.8	38.3	37.8	38.5	38.1	38.2	37.8	38.4	38.1
Wheat bran	High	45.1	42.3	40.9	40.7	43.7	40.8	43.0	41.5	42.2
	Medium	39.2	41.0	35.9	36.9	40.1	36.4	37.6	39.0	38.2
	Low	41.2	42.6	41.6	41.0	41.9	41.3	41.4	41.8	41.6
Cellulose	High	42.2	43.0	40.8	41.0	42.6	40.9	41.5	42.0	41.7
	Medium	40.8	40.5	39.4	39.4	40.7	39.4	40.1	40.0	40.0
	Low	37.2	38.1	36.2	37.0	37.7	36.6	36.7	37.6	37.1
Corn cobs	High	45.9	47.9	41.4	42.3	46.9	41.9	43.7	45.1	44.4
	Medium	41.5	41.2	39.7	39.8	41.4	39.8	40.6	40.5	40.5
	Low	34.7	35.1	33.2	34.9	34.9	34.1	34.0	35.0	34.5
		DT: 3.45				DT: 2.44		DT: 2.44		DT: 1.72
		DL: 2.94				DL: 2.08		DL: 2.08		DL: 1.47
		DP: 2.45				DP: 1.73		DS: 1.73		
		DS: 2.45								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		44.1	42.9	40.9	40.5	43.5	40.7	42.5	41.7	42.0
Alfalfa		38.4	38.5	37.1	34.1	38.5	35.6	37.8	36.3	37.8
Wheat bran		41.8	42.0	39.5	39.5	41.9	39.5	40.7	40.8	40.7
Cellulose		40.1	40.5	38.8	39.1	40.3	39.0	39.5	39.8	39.6
Corn cobs		40.7	41.4	38.1	39.0	41.1	38.6	39.4	40.2	39.8
		DT: 1.99				DT: 1.41		DT: 1.41		DT: 1.00
		DP: 1.42				DP: 1.00		DS: 1.00		
		DS: 1.42								
		(L P S)				(L P)		(L S)		(L)
	High	43.6	44.1	41.1	41.0	43.8	41.1	42.3	42.6	42.4
	Medium	41.2	40.2	37.9	38.4	40.7	38.1	39.6	39.3	39.5
	Low	38.2	38.9	37.6	37.9	38.5	37.7	37.9	38.4	38.1
		DL: 1.32				DL: 0.93		DL: 0.93		DL: 0.66
		DP: 1.10				DP: 0.78		DS: 0.78		
		DS: 1.10								
		(P S)				(P)		(S)		Mean
		41.0	41.1	38.9	39.1	41.0	39.0	40.0	40.1	40.1
		DP: 0.63				DP: 0.45		DS: 0.45		
		DS: 0.63								

Table 9.- Pounds of Feed Consumed Per Day by Swine.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	5.26	5.09	4.97	5.24	5.18	5.11	5.12	5.16	5.14
	Medium	4.38	4.45	5.26	3.80	4.42	4.53	4.82	4.12	4.47
	Low	5.28	4.42	4.92	5.22	4.85	5.07	5.10	4.82	4.96
Alfalfa	High	4.54	3.74	4.58	4.48	4.14	4.53	4.56	4.10	4.33
	Medium	4.14	4.26	4.96	4.44	4.20	4.70	4.55	4.35	4.45
	Low	4.59	4.42	5.37	4.78	4.51	5.08	4.98	4.60	4.79
Wheat bran	High	4.20	4.30	4.35	4.36	4.25	4.36	4.27	4.33	4.30
	Medium	4.77	4.09	4.61	4.45	4.43	4.53	4.69	4.27	4.48
	Low	5.32	3.87	5.50	4.82	4.60	5.16	5.40	4.34	4.87
Cellulose	High	5.01	4.74	5.44	3.90	4.88	4.67	5.22	4.32	4.77
	Medium	4.84	4.61	4.35	4.52	4.73	4.44	4.59	4.56	4.58
	Low	5.16	4.49	5.33	4.36	4.83	4.85	5.24	4.42	4.83
Corn cobs	High	5.55	4.76	5.53	4.23	5.16	4.88	5.54	4.50	5.02
	Medium	4.72	5.14	5.29	4.88	4.93	5.09	5.00	5.00	5.00
	Low	5.77	4.57	4.54	4.99	5.17	4.77	5.16	4.78	4.97
		DT: 1.14				DT: 0.81		DT: 0.81		DT: 0.57
		DL: 0.97				DL: 0.69		DL: 0.69		DL: 0.49
		DP: 0.81				DP: 0.57		DS: 0.57		
		DS: 0.81								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		4.97	4.65	5.05	4.75	4.81	4.90	5.01	4.70	4.86
Alfalfa		4.42	4.14	4.97	4.57	4.28	4.76	4.70	4.36	4.52
Wheat bran		4.76	4.09	4.82	4.54	4.42	4.68	4.79	4.32	4.55
Cellulose		5.00	4.61	5.04	4.26	4.81	4.65	5.02	4.44	4.73
Corn cobs		5.35	4.82	5.12	4.70	5.08	4.91	5.24	4.76	5.00
		DT: 0.66				DT: 0.47		DT: 0.47		DT: 0.33
		DP: 0.47				DP: 0.43		DS: 0.43		
		DS: 0.47								
		(L P S)				(L P)		(L S)		(L)
	High	4.91	4.52	4.97	4.44	4.72	4.71	4.98	4.48	4.71
	Medium	4.57	4.51	4.89	4.42	4.54	4.66	4.73	4.47	4.60
	Low	5.22	4.35	5.13	4.83	4.79	4.98	5.18	4.59	4.88
		DL: 0.44				DL: 0.31		DL: 0.31		DL: 0.22
		DP: 0.36				DP: 0.26		DS: 0.26		
		DS: 0.36								
		(P S)				(P)		(S)		Mean
		4.90	4.46	5.00	4.56	4.68	4.78	4.95	4.51	4.73
		DP: 0.21				DP: 0.15		DS: 0.15		
		DS: 0.21								

Table 10.- Intake of Digestible Therms Per Day by Swine.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	6.04	5.64	6.24	6.74	5.84	6.49	6.14	6.19	6.17
	Medium	4.81	5.48	7.20	4.96	5.15	6.08	6.01	5.22	5.62
	Low	7.02	5.63	7.06	7.62	6.33	7.34	7.04	6.62	6.83
Alfalfa	High	5.76	4.35	6.00	5.88	5.06	5.94	5.88	5.12	5.50
	Medium	5.05	5.38	7.08	6.39	5.22	6.74	6.07	5.88	5.98
	Low	5.88	5.48	7.74	6.98	5.68	7.36	6.81	6.23	6.52
Wheat bran	High	4.83	5.01	5.59	5.61	4.92	5.60	5.21	5.31	5.26
	Medium	6.02	4.66	5.94	5.79	5.34	5.87	5.98	5.22	5.60
	Low	7.74	5.40	7.64	6.65	6.57	7.15	7.69	6.02	6.86
Cellulose	High	6.56	5.52	7.78	6.06	6.04	6.92	6.86	5.82	6.34
	Medium	6.06	6.82	7.53	6.76	6.44	7.15	6.02	6.04	6.03
	Low	8.21	6.48	6.90	7.65	7.35	7.28	7.48	6.22	6.85
Corn cobs	High	6.25	6.27	7.48	5.36	6.26	6.47	7.17	5.79	6.48
	Medium	5.70	5.73	6.33	6.34	5.72	6.34	6.80	6.79	6.80
	Low	7.32	6.10	7.64	6.32	6.71	6.98	7.56	7.07	7.32
		DT: 1.66				DT: 1.17		DT: 1.17		DT: 0.83
		DL: 1.41				DL: 1.00		DL: 1.00		DL: 0.71
		DP: 1.18				DP: 0.86		DS: 0.86		
		DS: 1.18								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		5.96	5.58	6.83	6.44	5.77	6.64	6.40	6.01	6.20
Alfalfa		5.57	5.07	6.94	6.42	5.32	6.68	6.26	5.75	6.00
Wheat bran		6.20	5.02	6.39	6.02	5.61	6.20	6.30	5.52	5.90
Cellulose		6.94	6.27	7.40	6.82	6.23	6.58	7.17	6.55	6.40
Corn cobs		6.42	6.03	7.15	6.01	6.61	7.11	6.79	6.02	6.86
		DT: 0.96				DT: 0.68		DT: 0.68		DT: 0.48
		DP: 0.68				DP: 0.48		DS: 0.48		
		DS: 0.68								
		(L P S)				(L P)		(L S)		(L)
	High	5.89	5.36	6.62	5.93	5.63	6.28	6.26	5.65	5.95
	Medium	5.28	5.61	6.82	6.05	5.45	6.44	6.05	5.83	6.00
	Low	7.23	5.82	7.39	7.04	6.53	7.22	7.31	6.43	6.87
		DL: 0.63				DL: 0.45		DL: 0.45		DL: 0.32
		DP: 0.53				DP: 0.37		DS: 0.37		
		DS: 0.53								
		(P S)				(P)		(S)		Mean
		6.13	5.60	6.94	6.34	5.91	6.64	6.58	5.97	6.28
		DP: 0.30				DP: 0.22		DS: 0.22		
		DS: 0.30								

Table 11.- Intake of Digestible Crude Protein in Grams Per Day by Swine.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	280	263	279	292	271	285	279	277	278
	Medium	220	228	279	200	224	239	249	214	232
	Low	284	227	275	289	255	282	279	258	269
Alfalfa	High	221	176	226	223	198	225	223	199	211
	Medium	196	198	254	228	197	241	225	213	219
	Low	223	210	293	269	217	281	258	239	249
Wheat bran	High	218	212	229	229	215	229	223	220	222
	Medium	236	189	213	206	213	209	224	197	211
	Low	319	230	318	273	274	295	318	251	285
Cellulose	High	263	269	305	219	266	262	284	244	264
	Medium	233	233	250	250	233	250	241	242	241
	Low	272	232	277	234	252	256	275	233	254
Corn cobs	High	301	265	322	256	283	289	312	260	286
	Medium	252	281	300	269	266	284	276	275	275
	Low	285	228	229	267	256	248	257	247	252
		DT: 68				DT: 48		DT: 48		DT: 34
		DL: 58				DL: 41		DL: 41		DL: 29
		DP: 49				DP: 34		DS: 34		
		DS: 49								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		261	239	278	260	250	269	269	250	260
Alfalfa		213	195	291	240	204	249	254	217	226
Wheat bran		257	210	253	236	234	244	255	223	239
Cellulose		256	245	277	234	250	256	266	239	253
Corn cobs		279	258	284	264	268	274	281	261	271
		DT: 39				DT: 28		DT: 28		DT: 20
		DP: 28				DP: 20		DS: 20		
		DS: 28								
		(L P S)				(L P)		(L S)		(L)
	High	256	237	272	244	247	258	264	240	252
	Medium	227	226	259	230	226	245	243	228	236
	Low	276	225	278	266	251	272	277	246	262
		DL: 26				DL: 18		DL: 18		DL: 13
		DP: 22				DP: 15		DS: 15		
		DS: 22								
		(P S)				(P)		(S)		Mean
		253	229	270	247	241	258	262	255	258
		DP: 13				DP: 9		DS: 9		
		DS: 13								

Table 12.- Pounds of Gain in Body Weight Per Day by Swine.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	1.20	1.22	1.27	1.36	1.21	1.32	1.23	1.29	1.26
	Medium	1.13	0.99	1.44	1.02	1.06	1.23	1.29	1.01	1.15
	Low	1.40	1.12	1.17	1.42	1.26	1.30	1.29	1.27	1.28
Alfalfa	High	1.09	0.85	1.04	1.08	0.97	1.06	1.07	0.97	1.02
	Medium	0.92	0.96	1.25	1.14	0.94	1.20	1.08	1.05	1.07
	Low	1.00	1.06	1.38	1.33	1.03	1.36	1.19	1.20	1.20
Wheat bran	High	0.94	0.86	0.92	1.02	0.90	0.97	0.93	0.94	0.94
	Medium	1.10	0.92	0.94	0.94	1.01	0.94	1.02	0.93	0.98
	Low	1.35	0.88	1.46	1.24	1.12	1.35	1.41	1.06	1.24
Cellulose	High	1.13	1.12	1.39	1.03	1.13	1.21	1.26	1.08	1.17
	Medium	1.12	1.16	1.17	1.18	1.14	1.18	1.14	1.18	1.16
	Low	0.88	1.26	1.24	1.47	1.07	1.36	1.36	1.15	1.26
Corn cobs	High	1.24	1.24	1.57	1.08	1.24	1.33	1.41	1.16	1.29
	Medium	1.13	1.28	1.44	1.40	1.21	1.42	1.28	1.34	1.31
	Low	1.44	1.18	1.14	1.42	1.31	1.28	1.29	1.30	1.30
		DT: 0.41				DT: 0.29		DT: 0.29		DT: 0.17
		DL: 0.35				DL: 0.25		DL: 0.25		DL: 0.12
		DP: 0.29				DP: 0.21		DS: 0.21		
		DS: 0.29								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		1.24	1.11	1.29	1.27	1.18	1.28	1.27	1.19	1.23
Alfalfa		1.00	0.96	1.22	1.18	0.98	1.20	1.11	1.07	1.09
Wheat bran		1.13	0.89	1.11	1.07	1.01	1.09	1.12	0.98	1.05
Cellulose		1.04	1.18	1.27	1.23	1.11	1.25	1.16	1.21	1.20
Corn cobs		1.27	1.23	1.38	1.30	1.25	1.34	1.33	1.27	1.30
		DT: 0.24				DT: 0.17		DT: 0.17		DT: 0.12
		DP: 0.17				DP: 0.12		DS: 0.12		
		DS: 0.17								
		(L P S)				(L P)		(L S)		(L)
	High	1.12	1.06	1.24	1.11	1.09	1.18	1.18	1.09	1.13
	Medium	1.08	1.06	1.25	1.14	1.07	1.20	1.17	1.10	1.13
	Low	1.29	1.07	1.32	1.32	1.18	1.32	1.31	1.20	1.25
		DL: 0.16				DL: 0.11		DL: 0.11		DL: 0.08
		DP: 0.13				DP: 0.09		DS: 0.09		
		DS: 0.13								
		(P S)				(P)		(S)		Mean
		1.16	1.06	1.27	1.19	1.11	1.23	1.22	1.13	1.18
		DP: 0.08				DP: 0.05		DS: 0.05		
		DS: 0.08								

Table 13.- Pounds of Feed Consumed by Swine Per Pound of Gain in Body Weight.

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	4.42	4.18	3.84	3.87	4.30	3.86	4.13	4.03	4.08
	Medium	3.89	4.48	3.67	3.72	4.19	3.70	3.78	4.10	3.94
	Low	3.78	3.87	4.25	3.72	3.83	3.99	4.02	3.80	3.91
Alfalfa	High	4.20	4.41	4.39	4.12	4.31	4.26	4.30	4.27	4.29
	Medium	4.52	4.49	3.97	3.88	4.51	3.93	4.25	4.19	4.22
	Low	4.77	4.15	3.93	3.75	4.46	3.84	4.35	3.95	4.15
Wheat bran	High	4.52	5.05	4.76	4.39	4.79	4.58	4.64	4.72	4.68
	Medium	4.31	4.44	4.96	4.75	4.38	4.86	4.64	4.60	4.62
	Low	3.86	4.44	3.78	3.89	4.15	3.84	3.82	4.17	4.00
Cellulose	High	4.46	4.23	3.91	3.79	4.35	3.85	4.19	4.01	4.10
	Medium	4.35	3.96	3.73	3.86	4.16	3.80	4.04	3.91	3.98
	Low	4.10	4.04	3.63	3.68	4.07	3.66	3.87	3.86	3.87
Corn cobs	High	4.50	3.83	3.53	3.95	4.17	3.74	4.02	3.89	3.96
	Medium	4.19	4.00	3.69	3.50	4.10	3.60	3.94	3.75	3.85
	Low	4.02	3.86	4.04	3.53	3.94	3.79	4.03	3.70	3.87
		DT: 1.05				DT: 0.75		DT: 0.75		DT: 0.53
		DL: 0.90				DL: 0.64		DL: 0.64		DL: 0.45
		DP: 0.75				DP: 0.53		DS: 0.53		
		DS: 0.75								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		4.03	4.18	3.92	3.77	4.11	3.85	3.95	3.97	3.97
Alfalfa		4.50	4.35	4.10	3.92	4.43	4.01	4.30	4.14	4.21
Wheat bran		4.23	4.64	4.50	4.34	4.44	4.42	4.36	4.49	4.43
Cellulose		4.30	4.08	3.76	3.77	4.19	3.77	4.02	3.93	3.98
Corn cobs		4.24	3.90	3.75	3.66	4.07	3.71	4.00	3.78	3.88
		DT: 0.61				DT: 0.43		DT: 0.43		DT: 0.31
		DP: 0.43				DP: 0.31		DS: 0.31		
		DS: 0.43								
		(L P S)				(L P)		(L S)		(L)
	High	4.42	4.34	4.09	4.02	4.38	4.06	4.26	4.18	4.22
	Medium	4.25	4.27	4.00	3.94	4.26	3.97	4.13	4.11	4.12
	Low	4.11	4.07	3.93	3.71	4.09	3.82	4.02	3.89	3.95
		DL: 0.40				DL: 0.29		DL: 0.29		DL: 0.20
		DP: 0.34				DP: 0.24		DS: 0.24		
		DS: 0.34								
		(P S)				(P)		(S)		Mean
		4.26	4.23	4.01	3.89	4.24	3.95	4.14	4.06	4.10
		DP: 0.19				DP: 0.14		DS: 0.14		
		DS: 0.19								

Table 14.- Digestible Therms Consumed by Swine Per Pound of Gain in Body Weight.

Bulk Type	Bulk Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	5.07	4.64	4.82	5.00	4.85	4.90	4.95	4.82	4.89
	Medium	4.28	5.52	5.02	4.85	4.90	4.94	4.65	5.19	4.92
	Low	5.00	4.94	6.10	5.43	4.97	5.77	5.55	5.19	5.37
Alfalfa	High	5.33	5.14	5.75	5.42	5.23	5.58	5.54	5.28	5.41
	Medium	5.54	5.71	5.68	5.58	5.62	5.63	5.61	5.65	5.63
	Low	6.06	5.14	5.68	5.48	5.60	5.58	5.87	5.31	5.59
Wheat bran	High	5.19	5.87	6.12	5.62	5.53	5.87	5.66	5.75	5.71
	Medium	5.45	5.06	6.39	6.20	5.25	6.29	5.92	5.63	5.78
	Low	5.62	6.19	5.26	5.38	5.90	5.32	5.44	5.79	5.62
Cellulose	High	5.55	5.58	5.37	5.21	5.56	5.29	5.46	5.40	5.43
	Medium	5.12	4.91	5.42	5.42	5.02	5.42	5.27	5.17	5.22
	Low	5.82	5.49	5.19	5.36	5.65	5.27	5.51	5.43	5.47
Corn cobs	High	5.29	4.44	4.98	5.65	4.86	5.31	5.14	5.05	5.10
	Medium	5.38	5.32	5.27	4.84	5.35	5.05	5.33	5.08	5.21
	Low	5.74	5.48	6.13	5.41	5.60	5.77	5.94	5.45	5.70
		DT: 1.40 DL: 1.20 DP: 1.00 DS: 1.00				DT: 0.99 DL: 0.85 DP: 0.70		DT: 0.99 DL: 0.85 DS: 0.70		DT: 0.70 DL: 0.60
		(T P S)				(T P)		(T S)		(T)
Oat hulls		4.78	5.03	5.31	5.09	4.91	5.20	5.05	5.06	5.06
Alfalfa		5.64	5.33	5.70	5.49	5.49	5.60	5.67	5.41	5.54
Wheat bran		5.42	5.71	5.92	5.73	5.57	5.82	5.67	5.72	5.69
Cellulose		5.50	5.33	5.33	5.33	5.42	5.33	5.42	5.33	5.37
Corn cobs		5.47	5.08	5.46	5.30	5.28	5.38	5.47	5.19	5.32
		DT: 0.81 DP: 0.57 DS: 0.57				DT: 0.57 DP: 0.41		DT: 0.57 DS: 0.41		DT: 0.41
		(L P S)				(L P)		(L S)		(L)
	High	5.29	5.13	5.41	5.38	5.21	5.40	5.35	5.26	5.31
	Medium	5.15	5.30	5.56	5.38	5.23	5.47	5.36	5.34	5.35
	Low	5.65	5.45	5.67	5.41	5.55	5.54	5.66	5.43	5.55
		DL: 0.54 DP: 0.45 DS: 0.45				DL: 0.38 DP: 0.32		DL: 0.38 DS: 0.32		DL: 0.27
		(P S)				(P)		(S)		Mean
		5.36	5.29	5.55	5.39	5.33	5.47	5.46	5.34	5.40
		DP: 0.26 DS: 0.26				DP: 0.18		DS: 0.18		

Table 15.- Rate of Passage of the Ingesta Through the Alimentary Canal of Swine (Hours).

Bulk Type	Bulk Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	26.3	28.3	34.0	30.0	27.3	32.0	30.2	29.2	29.7
	Medium	29.0	29.0	28.5	31.0	29.0	29.8	28.8	30.0	29.4
	Low	28.8	31.5	27.0	26.8	30.2	26.9	27.9	29.2	28.6
Alfalfa	High	24.8	34.0	27.5	35.5	29.4	31.5	26.2	34.8	30.5
	Medium	25.0	29.0	25.8	31.0	27.0	28.4	25.4	30.0	27.7
	Low	28.5	29.5	31.3	32.3	27.7	31.8	28.6	30.9	29.8
Wheat bran	High	27.3	26.0	25.0	30.3	26.7	27.7	26.2	28.2	27.2
	Medium	24.0	25.0	25.0	24.5	24.5	24.8	24.5	24.8	24.7
	Low	24.8	29.5	25.8	26.3	27.2	26.1	25.3	27.9	26.6
Cellulose	High	26.0	25.3	25.0	25.0	25.7	25.0	25.5	25.2	25.4
	Medium	25.0	29.8	26.5	26.5	27.4	26.5	25.8	28.2	27.0
	Low	27.3	28.8	25.8	28.8	28.1	27.3	26.6	28.8	27.7
Corn cobs	High	26.8	29.0	29.3	29.3	27.9	29.3	28.1	29.2	28.7
	Medium	27.8	31.3	24.0	26.5	29.6	25.3	25.9	23.9	24.9
	Low	31.0	29.3	25.3	27.3	30.2	26.3	28.2	28.3	28.3
		DT: 10.1				DT: 7.1		DT: 7.1		DT: 5.0
		DL: 8.6				DL: 6.1		DL: 6.1		DL: 4.3
		DP: 7.2				DP: 5.1		DS: 5.1		
		DS: 7.2								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		28.0	29.6	29.8	29.3	28.8	29.6	28.9	29.5	29.2
Alfalfa		25.2	30.8	28.2	32.9	28.0	30.6	26.7	31.9	29.3
Wheat bran		25.4	26.8	25.3	27.0	26.1	26.2	25.4	26.9	26.1
Cellulose		26.1	28.0	25.8	26.8	27.1	26.3	26.0	27.4	26.6
Corn cobs		28.5	29.9	26.2	27.7	29.2	27.0	27.4	28.8	28.0
		DT: 5.8				DT: 4.1		DT: 4.1		DT: 2.9
		DP: 4.1				DP: 2.9		DS: 2.9		
		DS: 4.1								
		(L P S)				(L P)		(L S)		(L)
	High	26.2	28.5	28.2	30.0	27.4	29.1	27.2	29.3	28.3
	Medium	26.2	28.8	26.0	27.9	27.5	26.5	26.1	28.3	27.2
	Low	27.5	29.7	27.0	28.3	28.6	27.7	27.3	28.0	27.7
		DL: 3.9				DL: 2.7		DL: 2.7		DL: 1.9
		DP: 3.2				DP: 2.3		DS: 2.3		
		DS: 3.2								
		(P S)				(P)		(S)		Mean
		26.6	29.0	27.1	28.7	27.8	27.9	26.8	28.9	27.9
		DP: 1.9				DP: 1.3		DS: 1.3		
		DS: 1.9								

Table 16.- Average Back Fat in Inches Measured on Live Swine by the "Leanmeter."

Bulk Type	Level	Meal Male	Meal Fem.	Pellet Male	Pellet Fem.	Meal	Pellet	Male	Fem.	
		(T L P S)				(T L P)		(T L S)		(T L)
Oat hulls	High	1.08	1.05	1.14	1.03	1.06	1.08	1.11	1.04	1.08
	Medium	1.05	1.27	1.10	1.07	1.16	1.09	1.08	1.17	1.13
	Low	1.32	1.24	1.20	1.17	1.28	1.18	1.26	1.21	1.24
Alfalfa	High	1.27	1.09	1.17	1.07	1.18	1.12	1.22	1.08	1.15
	Medium	1.08	1.14	1.20	1.22	1.11	1.21	1.14	1.18	1.16
	Low	1.25	1.27	1.30	1.25	1.26	1.28	1.28	1.26	1.27
Wheat bran	High	1.00	1.10	1.04	0.93	1.05	0.98	1.02	1.02	1.02
	Medium	1.08	0.97	1.22	1.12	1.02	1.16	1.15	1.05	1.10
	Low	1.22	1.07	1.10	1.10	1.14	1.10	1.16	1.09	1.13
Cellulose	High	1.15	1.02	1.30	1.08	1.08	1.19	1.23	1.05	1.14
	Medium	1.35	1.18	1.17	1.14	1.26	1.16	1.26	1.16	1.21
	Low	1.49	1.30	1.20	1.03	1.39	1.12	1.35	1.17	1.26
Corn cobs	High	1.19	1.17	1.27	1.02	1.18	1.14	1.23	1.10	1.17
	Medium	1.27	1.22	1.10	1.22	1.24	1.16	1.19	1.22	1.21
	Low	1.47	1.12	1.25	1.20	1.29	1.22	1.36	1.16	1.26
		DT: 0.31				DT: 0.22		DT: 0.22		DT: 0.16
		DL: 0.27				DL: 0.19		DL: 0.19		DL: 0.13
		DP: 0.22				DP: 0.16		DS: 0.16		
		DS: 0.22								
		(T P S)				(T P)		(T S)		(T)
Oat hulls		1.15	1.19	1.15	1.09	1.17	1.12	1.15	1.14	1.15
Alfalfa		1.21	1.17	1.22	1.18	1.19	1.20	1.22	1.18	1.20
Wheat bran		1.10	1.05	1.12	1.05	1.08	1.09	1.11	1.05	1.08
Cellulose		1.33	1.17	1.22	1.08	1.25	1.15	1.28	1.13	1.21
Corn cobs		1.31	1.17	1.21	1.15	1.24	1.18	1.26	1.16	1.21
		DT: 0.30				DT: 0.13		DT: 0.13		DT: 0.09
		DP: 0.22				DP: 0.09		DS: 0.09		
		DS: 0.22								
		(L P S)				(L P)		(L S)		(L)
	High	1.14	1.09	1.18	1.03	1.12	1.11	1.16	1.06	1.11
	Medium	1.17	1.16	1.16	1.15	1.17	1.16	1.17	1.16	1.17
	Low	1.35	1.20	1.21	1.15	1.28	1.18	1.28	1.18	1.23
		DL: 0.12				DL: 0.09		DL: 0.09		DL: 0.06
		DP: 0.10				DP: 0.07		DS: 0.07		
		DS: 0.10								
		(P S)				(P)		(S)		Mean
		1.22	1.15	1.18	1.11	1.19	1.15	1.20	1.13	1.17
		DP: 0.06				DP: 0.04		DS: 0.04		
		DS: 0.06								

Table 17.- Dressing Percentage of Male Swine.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	72.8	71.3	72.1
	Medium	74.6	71.9	73.2
	Low	73.3	75.1	74.2
Alfalfa	High	71.1	72.0	71.5
	Medium	72.1	72.1	72.1
	Low	73.4	72.4	72.9
Wheat bran	High	68.6	69.2	68.9
	Medium	70.5	70.3	70.4
	Low	73.1	71.3	72.2
Cellulose	High	71.3	71.7	71.5
	Medium	70.1	72.7	71.4
	Low	73.3	72.4	72.8
Corn cobs	High	73.5	72.2	72.8
	Medium	72.8	74.1	73.5
	Low	73.1	72.6	72.8
		DT: 5.21		DT: 3.69
		DL: 4.45		DL: 3.15
		DP: 3.70		
		(T P)		(T)
Oat hulls		73.6	72.7	73.1
Alfalfa		72.2	72.2	72.2
Wheat bran		70.7	70.3	70.5
Cellulose		71.6	72.2	71.9
Corn cobs		73.1	72.9	73.0
		DT: 3.01		DT: 2.13
		DP: 2.14		
		(L P)		(L)
	High	71.4	71.3	71.4
	Medium	72.0	72.2	72.1
	Low	73.2	72.7	73.0
		DL: 2.0		DL: 1.4
		DP: 1.7		
		(P)		Mean
		72.2	72.1	72.1
		DP: 0.96		

Table 18.- Advanced Registry Score of Male Swine.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	93.0	90.0	91.5
	Medium	93.5	85.0	89.2
	Low	79.5	85.5	82.5
Alfalfa	High	98.0	90.0	94.0
	Medium	91.5	87.5	89.5
	Low	86.5	84.0	85.2
Wheat bran	High	87.0	95.5	91.2
	Medium	89.5	89.5	89.5
	Low	88.0	83.0	85.5
Cellulose	High	92.5	81.0	86.6
	Medium	82.5	92.0	87.2
	Low	72.0	85.5	78.5
Corn cobs	High	84.0	90.0	87.0
	Medium	85.0	92.0	88.5
	Low	80.0	81.0	80.5
		DT: 16.0		DT: 11.3
		DL: 13.7		DL: 9.7
		DP: 11.4		
		(T P)		(T)
Oat hulls		88.7	86.8	87.8
Alfalfa		92.0	87.2	89.6
Wheat bran		88.2	89.3	88.8
Cellulose		82.3	86.0	84.2
Corn cobs		83.0	87.7	85.3
		DT: 9.3		DT: 6.5
		DP: 6.6		
		(L P)		(L)
	High	90.9	89.3	90.1
	Medium	88.4	89.2	88.8
	Low	81.2	83.7	82.4
		DL: 7.2		DL: 4.3
		DP: 5.1		
		(P)		Mean
		86.8	87.4	87.1
		DP: 2.9		

Table 19.- Inches of Shoulder Fat on Male Swine.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	1.70	1.75	1.72
	Medium	1.65	1.75	1.70
	Low	1.85	1.75	1.80
Alfalfa	High	1.60	1.75	1.68
	Medium	1.75	1.65	1.70
	Low	1.85	1.80	1.82
Wheat bran	High	1.55	1.60	1.58
	Medium	1.75	1.70	1.73
	Low	1.65	1.60	1.62
Cellulose	High	1.60	1.75	1.68
	Medium	1.80	1.70	1.75
	Low	1.90	1.70	1.80
Corn cobs	High	1.45	1.75	1.60
	Medium	1.80	1.55	1.68
	Low	1.95	1.75	1.85
		DT: 0.33		DT: 0.23
		DL: 0.29		DL: 0.20
		DP: 0.24		
		(T P)		(T)
Oat hulls		1.73	1.75	1.74
Alfalfa		1.73	1.73	1.73
Wheat bran		1.65	1.62	1.64
Cellulose		1.77	1.72	1.75
Corn cobs		1.73	1.68	1.71
		DT: 0.19		DT: 0.14
		DP: 0.14		
		(L P)		(L)
	High	1.58	1.72	1.65
	Medium	1.75	1.66	1.70
	Low	1.84	1.72	1.78
		DL: 0.15		DL: 0.09
		DP: 0.10		
		(P)		Mean
		1.72	1.70	1.71
		DP: 0.06		

Table 20.- Average Inches of Fat on Shoulder, Back and Loin of Male Swine.

Bulk Type	Bulk Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	1.20	1.32	1.26
	Medium	1.30	1.34	1.32
	Low	1.45	1.35	1.40
Alfalfa	High	1.19	1.32	1.25
	Medium	1.27	1.32	1.29
	Low	1.37	1.40	1.39
Wheat bran	High	1.13	1.20	1.17
	Medium	1.24	1.22	1.23
	Low	1.25	1.29	1.27
Cellulose	High	1.19	1.42	1.30
	Medium	1.38	1.30	1.34
	Low	1.55	1.35	1.45
Corn cobs	High	1.24	1.39	1.31
	Medium	1.40	1.18	1.29
	Low	1.49	1.37	1.43
		DT: 0.26		DT: 0.18
		DL: 0.22		DL: 0.16
		DP: 0.19		
		(T P)		(T)
Oat hulls		1.32	1.33	1.33
Alfalfa		1.27	1.35	1.31
Wheat bran		1.21	1.23	1.22
Cellulose		1.37	1.36	1.36
Corn cobs		1.37	1.31	1.34
		DT: 0.15		DT: 0.11
		DP: 0.11		
		(L P)		(L)
	High	1.19	1.33	1.26
	Medium	1.32	1.27	1.29
	Low	1.42	1.35	1.39
		DL: 0.12		DL: 0.07
		DP: 0.08		
		(P)		Mean
		1.31	1.32	1.31
		DP: 0.05		

Table 21.- Per Cent of Ham in Male Swine.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	25.0	24.2	24.6
	Medium	25.4	25.1	25.3
	Low	24.5	25.1	24.8
Alfalfa	High	25.2	25.0	25.1
	Medium	25.2	25.4	25.3
	Low	26.4	23.6	25.0
Wheat bran	High	26.0	24.5	25.3
	Medium	24.0	25.2	24.6
	Low	24.7	24.4	24.5
Cellulose	High	24.9	24.4	24.6
	Medium	23.7	24.0	23.8
	Low	24.0	24.1	24.1
Corn cobs	High	24.8	25.8	25.3
	Medium	24.0	24.6	24.3
	Low	24.7	24.6	24.7
		DT: 2.6		DT: 1.8
		DL: 2.2		DL: 1.5
		DP: 1.8		
		(T P)		(T)
Oat hulls		25.0	24.8	24.9
Alfalfa		25.6	24.7	25.1
Wheat bran		24.9	24.7	24.8
Cellulose		24.2	24.2	24.2
Corn cobs		24.5	25.0	24.7
		DT: 1.5		DT: 1.0
		DP: 1.1		
		(L P)		(L)
	High	25.2	24.8	25.0
	Medium	24.4	24.8	24.6
	Low	24.9	24.3	24.6
		DL: 1.0		DL: 0.7
		DP: 0.8		
		(P)		Mean
		24.8	24.7	24.7
		DP: 0.5		

Table 22.- Per Cent of Shoulder in Male Swine.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	28.6	27.3	27.9
	Medium	26.2	26.9	26.5
	Low	27.2	27.2	27.2
Alfalfa	High	27.4	27.0	27.2
	Medium	28.8	27.2	28.0
	Low	26.9	27.3	27.1
Wheat bran	High	28.8	27.5	28.1
	Medium	27.0	27.2	27.1
	Low	27.1	27.1	27.1
Cellulose	High	27.3	27.7	27.5
	Medium	26.4	27.4	26.9
	Low	25.8	26.5	26.1
Corn cobs	High	27.2	25.8	26.5
	Medium	27.8	28.3	28.1
	Low	26.7	26.6	26.7
		DT: 2.4		DT: 1.7
		DL: 2.0		DL: 1.4
		DP: 1.7		
		(T P)		(T)
Oat hulls		27.3	27.1	27.2
Alfalfa		27.7	27.1	27.4
Wheat bran		27.6	27.3	27.4
Cellulose		26.5	27.2	26.8
Corn cobs		27.2	26.9	27.1
		DT: 1.4		DT: 1.0
		DP: 1.0		
		(L P)		(L)
	High	27.8	27.0	27.4
	Medium	27.2	27.4	27.3
	Low	26.7	26.9	26.8
		DL: 0.9		DL: 0.6
		DP: 0.8		
		(P)		Mean
		27.3	27.1	27.2
		DP: 0.4		

Table 23.- Per Cent of Middle in Male Swine.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	46.4	48.6	47.5
	Medium	48.4	48.1	48.3
	Low	48.5	47.8	48.2
Alfalfa	High	47.5	48.1	47.8
	Medium	46.1	47.5	46.8
	Low	46.8	49.2	48.0
Wheat bran	High	45.3	48.0	46.7
	Medium	49.1	47.6	48.4
	Low	48.2	48.6	48.4
Cellulose	High	47.9	48.0	48.0
	Medium	49.8	48.6	49.2
	Low	50.2	49.4	49.8
Corn cobs	High	48.1	48.4	48.3
	Medium	48.2	47.2	47.7
	Low	48.6	48.8	48.7
		DT: 2.6		DT: 1.9
		DL: 2.2		DL: 1.6
		DP: 1.9		
		(T P)		(T)
Oat hulls		47.8	48.2	48.0
Alfalfa		46.8	48.3	47.5
Wheat bran		47.5	48.1	47.8
Cellulose		49.3	48.7	49.0
Corn cobs		48.3	48.1	48.2
		DT: 1.5		DT: 1.1
		DP: 1.1		
		(L P)		(L)
	High	47.0	48.2	47.7
	Medium	48.3	47.8	48.1
	Low	48.5	48.8	48.6
		DL: 1.0		DL: 0.7
		DP: 0.8		
		(P)		Mean
		47.9	48.3	48.1
		DP: 0.5		

Table 24.- Area of Loin(1) in Male Swine.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	3.92	3.74	3.83
	Medium	4.30	4.05	4.17
	Low	3.76	3.49	3.62
Alfalfa	High	4.30	3.76	4.03
	Medium	3.94	3.92	3.93
	Low	3.80	3.86	3.83
Wheat bran	High	4.67	3.88	4.27
	Medium	3.80	4.42	4.11
	Low	4.19	3.46	3.82
Cellulose	High	3.91	3.82	3.87
	Medium	3.69	4.37	4.03
	Low	3.51	3.82	3.67
Corn cobs	High	3.28	4.08	3.68
	Medium	4.00	3.86	3.93
	Low	3.53	3.47	3.50
		DT: 1.31		DT: 0.92
		DL: 1.12		DL: 0.79
		DP: 0.93		
		(T P)		(T)
Oat hulls		3.99	3.76	3.87
Alfalfa		4.01	3.85	3.93
Wheat bran		4.22	3.92	4.07
Cellulose		3.70	4.00	3.85
Corn cobs		3.60	3.80	3.70
		DT: 0.76		DT: 0.53
		DP: 0.54		
		(L P)		(L)
	High	4.01	3.85	3.93
	Medium	3.94	4.12	4.03
	Low	3.76	3.62	3.69
		DL: 0.50		DL: 0.35
		DP: 0.42		
		(P)		Mean
		3.91	3.86	3.88
		DP: 0.24		

(1) The exact area in square inches of the cross-section of the main back muscle.

Table 25.- Average Length of Sides in Inches of Male Swine.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	31.2	32.0	31.6
	Medium	30.7	30.2	30.4
	Low	31.3	31.8	31.5
Alfalfa	High	30.9	31.7	31.3
	Medium	31.6	30.7	31.1
	Low	31.2	31.3	31.2
Wheat bran	High	30.9	31.1	31.0
	Medium	31.9	29.9	30.9
	Low	30.5	31.2	30.8
Cellulose	High	31.0	31.2	31.1
	Medium	32.1	30.5	31.3
	Low	30.8	31.5	31.1
Corn cobs	High	31.4	31.4	31.4
	Medium	30.8	31.0	30.9
	Low	30.7	30.7	30.7
		DT: 1.4		DT: 1.0
		DL: 1.2		DL: 0.9
		DP: 1.0		
		(T P)		(T)
Oat hulls		31.0	31.3	31.2
Alfalfa		31.2	31.2	31.2
Wheat bran		31.1	30.7	30.9
Cellulose		31.3	31.0	31.2
Corn cobs		30.9	31.0	31.0
		DT: 0.8		DT: 0.6
		DP: 0.6		
		(L P)		(L)
	High	31.0	31.5	31.2
	Medium	31.4	30.4	30.9
	Low	30.9	31.3	31.1
		DL: 0.5		DL: 0.4
		DP: 0.5		
		(P)		Mean
		31.1	31.1	31.1
		DP: 0.3		

Table 26.- Grams of Dry Feed Consumed by Mice During a 14 Day Period.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	50.8	46.9	48.9
	Medium	47.5	48.3	47.9
	Low	43.8	46.0	44.9
Alfalfa	High	36.5	37.3	36.9
	Medium	42.5	37.2	39.9
	Low	40.2	41.1	40.6
Wheat bran	High	41.0	35.3	38.1
	Medium	42.4	41.3	41.8
	Low	47.5	44.2	45.9
Cellulose	High	45.8	48.3	47.0
	Medium	44.1	41.9	43.0
	Low	44.7	45.0	44.8
Corn cobs	High	45.3	44.1	44.7
	Medium	44.6	45.0	44.8
	Low	43.1	43.4	43.2
		DT: 8.4		DT: 6.0
		DL: 7.2		DL: 5.1
		DP: 6.0		
		(T P)		(T)
Oat hulls		47.4	47.1	47.2
Alfalfa		39.7	38.5	39.1
Wheat bran		43.6	40.3	41.9
Cellulose		44.9	45.1	45.0
Corn cobs		44.3	44.2	44.2
		DT: 4.9		DT: 3.4
		DP: 3.5		
		(L P)		(L)
	High	43.9	42.4	43.1
	Medium	44.2	42.7	43.5
	Low	43.9	43.9	43.9
		DL: 3.8		DL: 2.3
		DP: 2.7		
		(P)		Mean
		44.0	43.0	43.5
		DP: 1.6		

Table 27.- Grams of Gain in Body Weight by Mice During a 14 Day Period.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	12.3	11.8	12.0
	Medium	12.9	13.5	13.2
	Low	12.4	13.1	12.8
Alfalfa	High	10.4	10.9	10.6
	Medium	12.3	10.6	11.4
	Low	10.7	11.5	11.1
Wheat bran	High	9.8	8.1	8.9
	Medium	12.5	12.6	12.5
	Low	14.6	13.2	13.9
Cellulose	High	12.7	14.3	13.5
	Medium	12.7	11.8	12.2
	Low	13.8	13.2	13.5
Corn cobs	High	13.0	11.0	12.1
	Medium	12.6	12.3	12.5
	Low	13.3	13.2	13.3
		DT: 3.4		DT: 2.4
		DL: 2.9		DL: 2.0
		DP: 2.4		
		(T P)		(T)
Oat hulls		12.6	12.8	12.7
Alfalfa		11.1	11.0	11.0
Wheat bran		12.3	11.3	11.8
Cellulose		13.1	13.1	13.1
Corn cobs		13.0	12.2	12.6
		DT: 1.9		DT: 1.4
		DP: 1.4		
		(L P)		(L)
	High	11.6	11.2	11.4
	Medium	12.6	12.2	12.4
	Low	13.0	12.8	12.9
		DL: 1.5		DL: 0.9
		DP: 1.1		
		(P)		Mean
		12.4	12.1	12.2
		DP: 0.6		

Table 28.- Grams of Dry Feed Consumed Per Gram of Gain in Body Weight by Mice.

Bulk Type	Bulk Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	4.1	4.1	4.1
	Medium	3.6	3.6	3.6
	Low	3.6	3.5	3.5
Alfalfa	High	3.5	3.4	3.5
	Medium	3.5	3.6	3.6
	Low	3.8	3.7	3.8
Wheat bran	High	4.5	4.7	4.7
	Medium	3.4	3.3	3.4
	Low	3.3	3.4	3.4
Cellulose	High	3.6	3.4	3.5
	Medium	3.5	3.6	3.6
	Low	3.2	3.4	3.3
Corn cobs	High	3.5	4.1	3.8
	Medium	3.6	3.7	3.7
	Low	3.3	3.3	3.3
		DT: 0.9		DT: 0.6
		DL: 0.7		DL: 0.5
		DP: 0.6		
		(T P)		(T)
Oat hulls		3.8	3.7	3.8
Alfalfa		3.6	3.6	3.6
Wheat bran		3.7	3.8	3.8
Cellulose		3.4	3.5	3.5
Corn cobs		3.5	3.7	3.6
		DT: 0.5		DT: 0.4
		DP: 0.4		
		(L P)		(L)
	High	3.9	3.9	3.9
	Medium	3.5	3.6	3.6
	Low	3.4	3.5	3.5
		DL: 0.4		DL: 0.2
		DP: 0.3		
		(P)		Mean
		3.6	3.7	3.7
		DP: 0.2		

Table 29.- Dry Matter Digestibility of the Rations Fed to Mice (Figures in Per Cent).

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	61.0	62.6	61.8
	Medium	68.6	69.6	69.1
	Low	75.1	74.8	75.8
Alfalfa	High	69.1	70.6	69.8
	Medium	72.5	72.2	72.4
	Low	76.4	76.7	76.6
Wheat bran	High	56.8	59.3	58.3
	Medium	64.6	66.0	65.3
	Low	73.8	72.1	72.9
Cellulose	High	67.4	67.0	67.2
	Medium	72.1	72.1	72.1
	Low	76.7	76.7	76.7
Corn cobs	High	67.7	66.5	67.1
	Medium	71.0	71.0	71.0
	Low	76.3	76.9	76.6
		DT: 2.8		DT: 2.0
		DL: 2.4		DL: 1.7
		DP: 2.0		
		(T P)		(T)
Oat hulls		68.2	69.0	68.6
Alfalfa		72.7	73.2	72.9
Wheat bran		65.0	65.8	65.4
Cellulose		72.0	71.9	72.0
Corn cobs		71.7	71.5	71.6
		DT: 1.6		DT: 1.1
		DP: 1.1		
		(L P)		(L)
	High	64.4	65.2	64.8
	Medium	69.8	70.2	70.0
	Low	75.6	75.4	75.5
		DL: 1.1		DL: 0.8
		DP: 0.9		
		(P)		Mean
		69.9	70.3	70.1
		DP: 0.5		

Table 30.- Digestibility of Energy in the Rations Fed to Mice (Figures in Per Cent).

Type	Bulk Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	62.9	64.5	63.7
	Medium	70.2	71.2	70.7
	Low	76.8	76.6	76.7
Alfalfa	High	70.7	71.7	71.2
	Medium	73.8	73.3	73.5
	Low	77.7	78.1	77.9
Wheat bran	High	57.9	60.0	58.9
	Medium	66.6	67.4	67.0
	Low	75.7	73.7	74.7
Cellulose	High	70.2	69.0	69.6
	Medium	74.6	73.8	74.2
	Low	78.2	78.8	78.5
Corn cobs	High	69.5	67.6	68.5
	Medium	72.9	73.2	73.0
	Low	78.1	79.1	78.6
		DT: 2.6		DT: 1.9
		DL: 2.3		DL: 1.6
		DP: 1.9		
		(T P)		(T)
Oat hulls		70.0	70.8	70.4
Alfalfa		74.0	74.3	74.2
Wheat bran		66.7	67.0	66.9
Cellulose		74.3	73.9	74.1
Corn cobs		73.5	73.3	73.4
		DT: 1.5		DT: 1.1
		DP: 1.1		
		(L P)		(L)
	High	66.2	66.6	66.4
	Medium	71.6	71.8	71.7
	Low	77.3	77.2	77.3
		DL: 1.2		DL: 0.7
		DP: 0.8		
		(P)		Mean
		71.7	71.8	71.8
		DP: 0.5		

Table 31.- Apparent Digestibility of Protein in the Rations Fed to Mice (Figures in Per Cent).

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	58.7	56.1	57.4
	Medium	64.2	66.6	65.4
	Low	67.9	68.2	68.1
Alfalfa	High	63.8	66.2	65.0
	Medium	66.2	66.4	66.3
	Low	67.0	67.4	67.2
Wheat bran	High	54.2	62.9	58.6
	Medium	59.6	64.6	62.1
	Low	70.0	65.4	67.7
Cellulose	High	65.8	69.3	67.5
	Medium	67.9	70.7	69.3
	Low	71.9	67.9	69.9
Corn cobs	High	62.2	64.6	62.5
	Medium	65.5	67.6	66.5
	Low	65.1	70.2	67.6
		DT: 3.2		DT: 2.2
		DL: 2.7		DL: 1.9
		DP: 2.2		
		(T P)		(T)
Oat hulls		63.6	63.6	63.6
Alfalfa		65.7	66.7	66.2
Wheat bran		61.1	64.3	62.8
Cellulose		68.5	69.3	68.9
Corn cobs		64.3	67.4	65.9
		DT: 1.8		DT: 1.3
		DP: 1.3		
		(L P)		(L)
	High	60.9	63.8	62.4
	Medium	64.7	67.2	65.9
	Low	68.4	67.8	68.1
		DL: 1.2		DL: 0.9
		DP: 1.0		
		(P)		Mean
		64.7	66.3	65.5
		DP: 0.6		

Table 32.- Consumption of Digestible Calories
During a 14 Day Period by Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	135.9	129.0	132.4
	Medium	142.7	146.9	144.8
	Low	144.5	151.5	148.0
Alfalfa	High	112.3	116.3	114.3
	Medium	136.3	118.4	127.4
	Low	135.0	139.1	137.1
Wheat bran	High	103.5	92.4	98.0
	Medium	123.6	121.4	122.5
	Low	155.1	140.8	148.0
Cellulose	High	137.5	142.4	140.0
	Medium	141.7	133.0	137.4
	Low	149.8	152.1	151.0
Corn cobs	High	131.3	127.4	129.4
	Medium	141.4	143.0	142.2
	Low	145.1	147.9	146.5
		DT: 25.3		DT: 17.9
		DL: 21.6		DL: 15.3
		DP: 18.0		
		(T P)		(T)
Oat hulls		141.0	142.4	141.7
Alfalfa		127.9	124.6	126.2
Wheat bran		127.4	118.2	122.8
Cellulose		143.0	142.5	142.8
Corn cobs		139.3	139.4	139.3
		DT: 14.6		DT: 10.3
		DP: 10.4		
		(L P)		(L)
	High	124.1	121.5	122.8
	Medium	137.1	132.5	134.8
	Low	145.9	146.3	146.1
		DL: 9.7		DL: 6.8
		DP: 8.1		
		(P)		Mean
		135.7	133.4	134.6
		DP: 4.7		

Table 33.- Digestible Calories Consumed Per Gram of Gain in Body Weight by Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	11.1	11.1	11.1
	Medium	11.0	10.9	11.0
	Low	11.7	11.6	11.7
Alfalfa	High	10.9	10.7	10.8
	Medium	11.2	11.5	11.4
	Low	12.6	12.4	12.5
Wheat bran	High	11.3	11.9	11.6
	Medium	9.9	9.7	9.8
	Low	10.9	10.7	10.8
Cellulose	High	10.9	9.9	10.4
	Medium	11.2	11.5	11.3
	Low	10.8	11.6	11.2
Corn cobs	High	10.2	11.3	10.7
	Medium	11.3	11.7	11.5
	Low	10.9	11.3	11.1
		DT: 2.3		DT: 1.6
		DL: 2.0		DL: 1.4
		DP: 1.6		
		(T P)		(T)
Oat hulls		11.3	11.2	11.3
Alfalfa		11.5	11.5	11.5
Wheat bran		10.7	10.8	10.8
Cellulose		11.0	11.0	11.0
Corn cobs		10.8	11.5	11.1
		DT: 1.3		DT: 0.9
		DP: 0.9		
		(L P)		(L)
	High	10.9	11.0	11.0
	Medium	10.9	11.1	11.0
	Low	11.4	11.5	11.5
		DL: 0.9		DL: 0.6
		DP: 0.7		
		(P)		Mean
		11.0	11.2	11.1
		DP: 0.4		

Table 34.- Per Cent of Fat in Carcasses of Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	6.25	5.14	5.69
	Medium	6.19	5.78	5.98
	Low	6.57	5.75	6.15
Alfalfa	High	4.81	4.82	4.81
	Medium	5.88	5.85	5.87
	Low	5.93	5.64	5.79
Wheat bran	High	4.58	4.11	4.34
	Medium	5.51	5.28	5.39
	Low	6.01	6.18	6.09
Cellulose	High	6.72	6.11	6.41
	Medium	6.75	5.50	6.12
	Low	6.29	6.78	6.53
Corn cobs	High	6.06	5.92	5.99
	Medium	6.18	5.55	5.87
	Low	6.07	5.60	5.84
		DT: 1.81		DT: 1.28
		DL: 1.55		DL: 1.09
		DP: 1.29		
		(T P)		(T)
Oat hulls		6.34	5.55	5.94
Alfalfa		5.54	5.44	5.49
Wheat bran		5.36	5.19	5.28
Cellulose		6.58	6.13	6.36
Corn cobs		6.10	5.69	5.90
		DT: 1.05		DT: 0.74
		DP: 0.74		
		(L P)		(L)
	High	5.68	5.22	5.45
	Medium	6.10	5.59	5.85
	Low	6.17	5.99	6.08
		DL: 0.69		DL: 0.49
		DP: 0.58		
		(P)		Mean
		5.99	5.60	5.79
		DP: 0.33		

Table 35.- Per Cent of Water in Carcasses of Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	70.6	71.5	71.0
	Medium	70.5	70.6	70.5
	Low	70.1	71.0	70.5
Alfalfa	High	71.9	72.5	72.2
	Medium	71.2	70.4	70.7
	Low	71.0	71.3	71.2
Wheat bran	High	73.1	73.0	73.1
	Medium	71.3	71.6	71.5
	Low	70.7	70.8	70.7
Cellulose	High	70.6	70.5	70.6
	Medium	70.1	71.3	70.7
	Low	70.8	70.0	70.4
Corn cobs	High	70.4	70.9	70.7
	Medium	70.7	71.2	70.9
	Low	70.9	70.7	70.8
		DT: 1.8		DT: 1.3
		DL: 1.6		DL: 1.1
		DP: 1.3		
		(T P)		(T)
Oat hulls		70.4	71.0	70.7
Alfalfa		71.4	71.4	71.4
Wheat bran		71.7	71.8	71.8
Cellulose		70.5	70.6	70.6
Corn cobs		70.7	70.9	70.8
		DT: 1.1		DT: 0.7
		DP: 0.7		
		(L P)		(L)
	High	71.3	71.7	71.5
	Medium	70.8	71.0	70.9
	Low	70.7	70.8	70.7
		DL: 0.7		DL: 0.5
		DP: 0.6		
		(P)		Mean
		70.9	71.1	71.0
		DP: 0.3		

Table 36.- Per Cent of Protein in Carcasses of Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	20.2	20.2	20.2
	Medium	20.3	20.7	20.5
	Low	20.3	20.3	20.3
Alfalfa	High	20.2	19.6	19.9
	Medium	19.9	20.5	20.2
	Low	20.2	19.9	20.0
Wheat bran	High	19.5	19.8	19.6
	Medium	20.4	20.2	20.3
	Low	20.8	20.0	20.4
Cellulose	High	19.7	20.3	20.0
	Medium	20.3	20.2	20.3
	Low	20.1	20.2	20.2
Corn cobs	High	20.5	20.1	20.3
	Medium	20.1	20.2	20.2
	Low	20.0	20.6	20.3
		DT: 1.3		DT: 0.9
		DL: 1.1		DL: 0.8
		DP: 0.9		
		(T P)		(T)
Oat hulls		20.3	20.4	20.4
Alfalfa		20.1	20.0	20.1
Wheat bran		20.2	20.0	20.1
Cellulose		20.0	20.2	20.1
Corn cobs		20.2	20.3	20.3
		DT: 0.7		DT: 0.5
		DP: 0.5		
		(L P)		(L)
	High	20.0	20.0	20.0
	Medium	20.2	20.4	20.3
	Low	20.3	20.2	20.3
		DL: 0.5		DL: 0.3
		DP: 0.4		
		(P)		Mean
		20.1	20.2	20.2
		DP: 0.2		

Table 37.- Per Cent of Ash in Carcasses of Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	3.02	3.18	3.10
	Medium	3.05	2.99	3.02
	Low	3.00	3.01	3.01
Alfalfa	High	3.10	3.05	3.08
	Medium	3.12	3.30	3.21
	Low	2.93	3.17	3.05
Wheat bran	High	2.88	3.12	3.00
	Medium	2.87	2.90	2.88
	Low	2.82	3.07	2.94
Cellulose	High	2.95	3.09	3.02
	Medium	2.88	3.02	2.95
	Low	2.89	3.04	2.97
Corn cobs	High	3.04	3.09	3.06
	Medium	3.04	3.13	3.08
	Low	3.04	3.11	3.08
		DT: 0.32		DT: 0.23
		DL: 0.28		DL: 0.19
		DP: 0.23		
		(T P)		(T)
Oat hulls		3.02	3.06	3.04
Alfalfa		3.05	3.17	3.11
Wheat bran		2.89	3.03	2.94
Cellulose		2.91	3.05	2.98
Corn cobs		3.04	3.11	3.07
		DT: 0.19		DT: 0.13
		DP: 0.13		
		(L P)		(L)
	High	3.00	3.11	3.05
	Medium	2.99	3.07	3.03
	Low	2.94	3.08	3.01
		DL: 0.12		DL: 0.09
		DP: 0.10		
		(P)		Mean
		2.97	3.08	3.03
		DP: 0.06		

Table 38.- Per Cent Water in Fat-free Carcasses of Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	75.3	75.3	75.3
	Medium	75.1	75.0	75.1
	Low	74.4	75.3	74.8
Alfalfa	High	75.5	76.2	75.8
	Medium	75.5	74.8	75.1
	Low	75.5	75.6	75.6
Wheat bran	High	76.6	76.2	76.4
	Medium	75.4	75.6	75.5
	Low	74.3	75.4	74.8
Cellulose	High	75.7	75.1	75.4
	Medium	75.2	75.4	75.3
	Low	75.5	75.1	75.3
Corn cobs	High	75.0	75.4	75.2
	Medium	75.3	75.3	75.3
	Low	74.9	74.9	74.9
		DT: 1.5		DT: 1.1
		DL: 1.3		DL: 0.9
		DP: 1.1		
		(T P)		(T)
Oat hulls		74.9	75.2	75.0
Alfalfa		75.5	75.5	75.5
Wheat bran		75.4	75.7	75.6
Cellulose		75.5	75.2	75.3
Corn cobs		75.1	75.2	75.1
		DT: 0.9		DT: 0.6
		DP: 0.6		
		(L P)		(L)
	High	75.6	75.6	75.6
	Medium	75.3	75.2	75.3
	Low	74.9	75.3	75.1
		DL: 0.6		DL: 0.4
		DP: 0.5		
		(P)		Mean
		75.3	75.4	75.4
		DP: 0.3		

Table 39.- Per Cent Protein in Fat-free Carcasses of Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	21.5	21.3	21.4
	Medium	21.6	21.9	21.8
	Low	21.7	21.5	21.6
Alfalfa	High	21.2	20.6	20.9
	Medium	21.3	21.8	21.5
	Low	21.4	21.0	21.2
Wheat bran	High	20.4	20.6	20.5
	Medium	21.5	21.3	21.4
	Low	21.9	21.3	21.6
Cellulose	High	21.1	21.6	21.4
	Medium	21.8	21.4	21.6
	Low	21.5	21.6	21.6
Corn cobs	High	21.8	21.3	21.6
	Medium	21.5	21.4	21.4
	Low	21.9	21.8	21.9
		DT: 1.4		DT: 1.0
		DL: 1.2		DL: 0.8
		DP: 1.0		
		(T P)		(T)
Oat hulls		21.6	21.6	21.6
Alfalfa		21.3	21.1	21.2
Wheat bran		21.3	21.1	21.2
Cellulose		21.4	21.5	21.5
Corn cobs		21.7	21.5	21.6
		DT: 0.8		DT: 0.6
		DP: 0.6		
		(L P)		(L)
	High	21.2	21.1	21.1
	Medium	21.5	21.5	21.5
	Low	21.7	21.5	21.6
		DL: 0.5		DL: 0.4
		DP: 0.4		
		(P)		Mean
		21.5	21.4	21.4
		DP: 0.3		

Table 40.- Per Cent Ash in Fat-free Carcasses of Mice.

Bulk Type	Level	Meal	Pellet	
		(T L P)		(T L)
Oat hulls	High	3.22	3.35	3.28
	Medium	3.29	3.17	3.23
	Low	3.21	3.20	3.20
Alfalfa	High	3.26	3.21	3.23
	Medium	3.31	3.50	3.41
	Low	3.11	3.36	3.24
Wheat bran	High	3.02	3.26	3.14
	Medium	3.04	3.05	3.04
	Low	3.00	3.27	3.13
Cellulose	High	3.16	3.28	3.22
	Medium	3.12	3.20	3.16
	Low	3.09	3.26	3.17
Corn cobs	High	3.23	3.30	3.26
	Medium	3.23	3.31	3.27
	Low	3.21	3.29	3.25
		DT: 0.35		DT: 0.24
		DL: 0.30		DL: 0.21
		DP: 0.25		
		(T P)		(T)
Oat hulls		3.24	3.24	3.24
Alfalfa		3.23	3.36	3.29
Wheat bran		3.02	3.19	3.10
Cellulose		3.12	3.25	3.18
Corn cobs		3.22	3.30	3.26
		DT: 0.20		DT: 0.14
		DP: 0.14		
		(L P)		(L)
	High	3.18	3.28	3.23
	Medium	3.20	3.25	3.22
	Low	3.12	3.28	3.20
		DL: 0.13		DL: 0.09
		DP: 0.11		
		(P)		Mean
		3.16	3.28	3.22
		DP: 0.06		