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To the Graduate Council:

I am submitting herewith a thesis written by Charles T. Gamble entitled "A Study of Some of the Factors Affecting the Formation of Esophagogastric Ulcers in Swine." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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A STUDY OF SOME OF THE FACTORS AFFECTING THE FORMATION OF ESOPHAGOGASTRIC ULCERS IN SWINE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Charles T. Gamble

June 1966

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TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	LITERATURE REVIEW	3
	Prevalence	3
	Clinical Signs	4
	Pathologic Characterization	6
	Effect of Physical Form of Feed	7
	Effects of Age	9
	Energy Source Variation	9
	Vitamins	11
	Antibiotics	11
	Minerals	12
	Tranquilizers	12
	Amino Acids	13
	Unknown Factors	13
	Enzymes	13
	Histamines	14
	Additional Factors Influencing Ulcer Development	14
III.	EXPERIMENTAL PROCEDURE	16
	Rations	16
	Pelleting Procedure	16
	Facilities	18

CHAPTER PAGE

Classification 18
Mean Ulcer Score 18
Data and Statistical Analysis 18
Experiment I 20
Experiment II 20
Experiment III 21
Experiment IV 21
Experiment V 22
Experiment VI 22
Experiment VII 23
IV. RESULTS AND DISCUSSION 25
Experiment I 25
Experiment II 29
Experiment III 29
Experiment IV 33
Experiment V 33
Summer phase 33
Winter phase 39
Experiment VI 41
Summer phase 41
Winter phase 45
Experiment VII 47
V. SUMMARY 53
LITERATURE CITED 55

CHAPTER PAGE

APPENDIXES 59

A. Average Daily Gain 60

B. Feed Efficiency 64

LIST OF TABLES

TABLE		PAGE
I.	Composition of Rations	17
II.	Scale for Classifying the Severity of Keratinization or Ulceration in the Esophageal Area of Swine Stomachs . . .	19
III.	Composition of Rations	24
IV.	Effect of Feed Form on the Performance and Incidence of Ulcers in Swine Fed in Confinement, Summer 1963	27
V.	Effect of Feed Form and the Addition of Vitamin A on the Performance and Incidence of Ulcers in Swine Fed in Confinement, Winter 1963-64	31
VI.	Effect of Feed Form on Incidence of Ulcers and Performance of Swine Fed in Confinement from a Starting Weight of 165 Pounds to a Final Weight of 220 Pounds, Spring 1964 .	34
VII.	Effect of Creep and Grower-Finisher Ration Form on the Incidence of Ulcers and Performance of Swine Fed in Confinement, Summer 1964	37
VIII.	Effect of Creep and Grower-Finisher Ration Form on the Incidence of Ulcers and Performance of Swine Fed in Confinement, Winter 1964-65	40
IX.	Effect of Creep and Grower-Finisher Ration Form on the Incidence of Ulcers and Performance of Swine Fed in Confinement or on Pasture, Summer 1964	

TABLE PAGE

X. Effect of Creep and Grower-Finisher Ration Form on the Incidence of Ulcers and Performance of Swine Fed in Confinement or on Pasture, Winter 1964-65 46

XI. Effect of Feed Additives on the Incidence of Ulcers and Performance of Swine Fed in Confinement, Summer 1965 . . . 51

LIST OF FIGURES

FIGURE PAGE

1. Ulcer Classification and Distribution by Ration for Experiment I, Summer 1963 26
2. Ulcer Classification and Distribution by Ration for Experiment III, Winter 1963-64 30
3. Ulcer Classification and Distribution by Ration for Experiment V, Summer 1964 and Winter 1964-65 35
4. Ulcer Classification and Distribution by Ration for Experiment VI, Summer 1964 and Winter 1964-65 42
5. Ulcer Classification and Distribution by Ration for Experiment VII, Summer 1965 49

CHAPTER I

INTRODUCTION

In 1963 the 82 million swine slaughtered in the United States grossed 3 billion dollars, or 7.25 per cent of the gross farm income. Although per capita consumption varied only 0.1 of a pound between 1960 and 1964 (65.2 and 65.3, respectively), it is known that an increasing population demands more total pounds of pork products each year. For example, in 1964 the consumption of pork products was 165 million pounds greater than in 1963.

In Tennessee, farmers grossed 49,981,000 dollars from the sale of swine in 1963. This represented 8 to 9 per cent of the gross farm income, placing Tennessee thirteenth in the United States in swine production.

Esophagogastric ulcers have been diagnosed in swine of all age groups, and death losses due to ulcerated conditions have been reported at all intervening ages. These deaths, however, have not usually occurred in large numbers. To maintain and improve present efficiencies in swine production, attention needs to be given to the problem before it becomes more extensive. With this in mind the objectives of this study were:

1. To determine the effect of feed processing on the incidence of gastrointestinal disturbances in growing-finishing swine.

2. To determine the age that introduction and/or omission of an ulcer-inducing ration affects the degree of ulceration observed.
3. To determine the relative value of different rationing for prevention of ulcers in growing-finishing swine on pasture and/or in confinement.

CHAPTER II

LITERATURE REVIEW

Prevalence

The occurrence of stomach ulcers in swine has been considered rare and unimportant as recently as 1953 (Illingworth).

Ivy et al. (1930) examined 1,000 swine stomachs, finding neither erosions nor ulcers. Jensen and Frederick (1939) found that only 5 per cent of 20,000 stomachs examined were affected with ulcers. Kernkamp (1945) necropsied 754 pigs because of obvious illness and found an ulcer incidence of 2.38 per cent. The swine examined ranged in age from birth to 5 years, but all pigs affected were from 4 weeks to 1 year of age.

Bullard (1951) made the first specific reference to the esophagogastric ulcer. Since this time research leading toward establishing the cause of the ulcerated condition of the esophageal area in swine has increased rapidly.

In 1957, at the University of Wisconsin, enough swine were dying from bleeding gastric ulcers that an experimental project to determine basic causes was initiated. Several surveys since then have been conducted to estimate the incidence of gastric ulcers in swine, and from these reports it now appears that the condition is widespread.

Hoekstra (1962) reported that 22.6 per cent of a sample swine population (857 examined during a 1-year period) had stomach ulcers. Griffing (1963) reported that 13.5 per cent of the pigs which had

received pelleted feed had stomach ulcers, while there was only a 4.4 per cent incidence in pigs fed a meal ration. Curtin, Goetsch and Hollandbeck (1963) examined 443 pigs raised at the Indiana Swine Evaluation Station and reported a 19.64 per cent incidence; they also found a 25 per cent incidence in 164 pigs slaughtered from the Indiana Experiment Station. Perry et al. (1963) found approximately a 50 per cent prevalence of ulcers from pigs fed gelatinized corn and soybean oil meal. Muggenburg et al. (1964) reported a general prevalence of 16 per cent gastric ulcers, erosions, and scars.

Reports of foreign workers indicate similar problems. Dodd (1960) reported that of 747 pigs examined, 30 per cent had ulcers in the glandular regions. Hannan and Nyham (1962) examined 377 swine stomachs and found 53 per cent of the pigs affected with gastric ulcers in the esophageal area. Thoonen and Hoorens (1961) reported that 4.83 per cent of the 600 pigs examined had ulcers in the esophageal area. In 1963, a second report indicated an incidence of 4.69 per cent of 1,322 swine stomachs examined.

Clinical Signs

When discussing clinical signs, one must keep in mind that in the majority of cases of stomach ulcers, outward signs are not apparent. Kowalczyk et al. (1960) reported that during the early stages of the stomach ulcer when only the epithelial layer was affected pigs appeared healthy, vigorous, and gained at apparently normal rates. As the ulcer progressed and the deeper layers of the mucosa were destroyed, there was

gastrointestinal bleeding. Generally, a return to normal was observed in 1 to 2 days. No anemia was observed in these cases. In the more advanced cases with profuse bleeding, feces were tar-like and of a semi-liquid consistency. For 3 to 4 days, anemia was obvious and was accompanied by rapid, shallow breathing, loss of appetite and interruption of weight gains. Occasionally, severe stomach bleeding was manifested by vomiting quantities of blood and early death of pigs.

Curtin, Goetsch and Hollandbeck (1963) reported that common clinical signs were subnormal temperatures and occasional passing of bloody feces. As ulcers neared the terminal state, the affected swine were inactive and frequent grinding of teeth suggested pain. No great decrease in gains was noted except during more severe cases, at which time the pigs failed to eat except when disturbed by the attendant.

Jubb and Kennedy (1963) indicated that among the pigs observed passing bloody feces, a very high death loss resulted. Some cases survived long enough or bled slowly enough to allow digestion and removal of the intragastric clots; the cause in these deaths may be overlooked at autopsy unless the possibility of ulceration is kept in mind. They observed in some cases pigs which recovered from the acute phase later died for no apparent reason.

Observations reported by Rothenbacher, Nelson and Ellis (1963) indicate that a common clinical sign is sudden onset of unthriftiness a day or two before death in the acute cases and that mild or chronic cases are usually clinically undiagnosed and may be without symptoms.

Pathologic Characterization

The surface of the stomach mucosa is normally white, smooth and glistening (Reese, 1965). Lesions are confined to the non-glandular stratified squamous epithelium surrounding the esophageal orifice (Curtin, Goetsch and Hollandbeck, 1963; Rothenbacher, Nelson and Ellis, 1963; Jubb and Kennedy, 1963); and Kowalczyk et al., 1960).

When describing the chronic ulcer (an ulcer which contains sufficient connective tissue to indicate that it has existed for some time), Kowalczyk et al. (1960) stated that in the early stages, there was a proliferation of stratified squamous epithelium arranged in small spots over a wide area and resembling small warts. This change has also been described as keratinization (Barrow and O'Brien, 1963), parakeratotic proliferation and degeneration (Rothenbacher, Nelson and Ellis, 1963) and cornification (Curtin, Goetsch and Hollandbeck, 1963). As the ulcer progressed, the proliferations sloughed leaving small erosions underneath. Later, these small erosions blended to form erosions of varying sizes and shapes, most often along the junction of the squamous epithelium and the glandular epithelium of the cardiac or pyloric regions. As this process progressed, large U-shaped or circular ulcers, which at times covered the major part of the esophageal area, were formed. As these ulcers increased in area, they also increased in depth so that they eventually reached the submucosa, muscularis mucosae, muscularis propria and subserosa. During these stages, hemorrhages occurred due to the erosions of the branches of the gastric artery. There appeared to be a marked thickened or elevated brim hanging over the edges of the

ulcers which gave a crater appearance. Occasionally, healed ulcers were found in the form of a scar. Curtin, Goetsch and Hollandbeck (1963) reported that histologic evidence of scar formation was not evident across the healed ulcer.

In the early stages of acute stomach ulcer formation, there was focal proliferation of the stratified squamous epithelium with subsequent death of the tissues of the mucosa. This death was superficial or extended into the submucosa. When the necrotic process had progressed and the ulcer had deepened, the walls of capillaries and small vessels were destroyed, causing an oozing of blood into the stomach. When the process of necrosis subsided, infiltration with lymphocytes and eosenophils and the fibriolast was prominent. If fatal hemorrhage did not occur, distinct fibrosis, especially of the base of the ulcer became more evident (Kowalczyk et al., 1960).

Chamberlain et al. (1966) suggested a scale which classifies the degree of keratinization or ulceration.

Effect of Physical Form of Feed

Forms of feeds which have been used and reported are: (1) meal, (2) pellet, (3) heat treated (gelatinized) and (4) pellet reground. In general these reports are in agreement.

Chamberlain, Merriman and Lidvall (1964), on the other hand, reported that the pelleting of a ration resulted in a significant ($P<.01$) increase in the number of ulcer-affected pigs. A higher incidence of ulcers was found when the ration was fed as a pellet or when the pellet

was reground and fed as a meal as compared to an unpelleted meal ration.

Perry et al. (1963) reported an incidence of 55 per cent in the treatments receiving heat-treated corn, while finding no ulcers in the lots fed raw corn. These differences were highly significant. Within the first 7 weeks from the start of the initial experiment, a 39 per cent mortality occurred in lots receiving heat-treated corn; upon necropsy, it was found that these pigs died of acute esophagogastric ulcers. In the second experiment, the per cent incidence agreed very closely with that in the first experiment (53 per cent), but per cent mortality dropped to 8.3.

According to results from nutritional studies conducted with swine by Griffing (1963), ulcers were found to occur in 13.8 per cent of the swine fed pellets and in 4.4 per cent of those fed a meal-type ration.

In a comparison of heat-treated and raw corn as a creep feed for young pigs, Shively (1963) reported that there was a highly significant difference in the number of ulcers, with the pigs on the heat-treated corn having the highest percentage of gastric disorders. He also reported that pigs on the treatments receiving heat-expanded corn were less efficient than those receiving raw corn. Average daily gains were essentially the same (expanded corn, 0.63 lb., and raw corn, 0.65 lb.).

Muggenburg (1965) reported a very extensive study in which the gelatinized corn and soybean oil meal rations produced no measurable effects on the incidence of ulcers when compared to a meal ration. Also, no effect was observed when a pelleted ration was fed.

Chamberlain, Merriman and Lidvall (1964) concluded that the pelleting of a ration significantly reduced the amount of feed required per 100 pounds of gain when fed as a pellet or reground and fed as a meal. They reported that feeding a pelleted ration significantly increased average daily gains for pigs from weaning to market weights as compared to gains when a ration composed of the same ingredients was fed as a meal or a reground pellet.

Effects of Age

Kernkamp (1945) made a survey of 754 pigs that were necropsied because of obvious illness. The ages varied from stillborn to 5 years of age, but in the 18 instances in which gastric ulcers were found, the ages ranged from 4 weeks to 1 year. This lower age is in close agreement with work reported by Curtin, Goetsch and Hollandbeck (1963) in which gastric ulcers were observed in pigs as young as 2 weeks.

In case reports by Kowalczyk et al. (1960) deaths were shown to occur most frequently in swine ranging in age from 3 to 5 months, but the death of an 8-month-old boar was attributed to an acute esophago-gastric ulcer.

Energy Source Variation

Corn has been used as the major energy source in most rations fed in ulcer studies, but Muggenburg (1965) reported results of tests using oats and wheat as the major energy sources. In the first experiment, a 90 per cent wheat ration and an 85 per cent oat ration were compared to a 76 per cent corn ration. Pigs on the wheat or oat ration had

significantly fewer ulcers than did the pigs on the corn ration. Because oats in this experiment provided a more complete protection than wheat, the next experiment concentrated on the inclusion of oats and oat products in the ration. Treatments consisted of: (1) 76 per cent corn ration, (2) 85 per cent oats, (3) corn with oat hulls added in amounts to equal the oat hulls in the 85 per cent oat ration, (4) ground oat groats, and (5) corn and oat flour. None of the pigs fed whole ground oats or corn with oat hulls had stomach ulcers. Pigs fed corn, ground oat groats, and corn and oat flour had a higher incidence of ulcers, erosions or epithelial changes than did pigs on the other treatments. Later work to study the effect of particle size of the oat hulls indicated that the pigs that had been fed the coarsely ground hulls had fewer ulcers; however, differences were so small that no conclusions were drawn. Muggenburg, in summarizing the three experiments, concluded that either oat hulls had an alleviating effect or corn had an ulcer-causing effect.

Beeson (1963), in a summary of work conducted at various experiment stations, reported that the addition of 15 per cent soybean oil appeared to have no alleviating effect on the formation of ulcers.

In a study where oats were fed as the major energy source, Muggenburg (1965) found that 4.40 pounds of feed were required to produce a pound of gain as compared to 3.73 pounds of feed required per pound of gain for a basal corn ration. Average daily gain was significantly reduced when either oats were used as the major energy source or when oat hulls (amounts contained in a whole oat ration) were added to a

basal corn ration. These rations were compared to a corn basal ration.

Vitamins

A report by Muggenburg (1965) indicated no effect on the incidence of gastric ulcers when thiamine, riboflavin, pyridoxine, pantothenate, niacin, vitamin B_{12}, ascorbic acid, vitamin A, palmitate, vitamin D_2, tocopherol and menadione were added to a basal ration. Nuwer et al. (1965) conducted tests studying the effect of additions of vitamin A, alpha tocopherol, alpha tocopherol acetate and vitamin K to diets that were hypothesized to be ulcerogenic in nature. Results agree with those of Muggenburg (1965) in that no alleviating effects were noted.

Chamberlain, Merriman and Lidvall (1964) found no beneficial effects from the addition of 1,000 International Units (I.U.) of vitamin A/pound of reground pellet ration.

Shively (1963) reported no reduction in the number of ulcers observed with the addition of 1.5 mg. thiamine or 50 mcg. of vitamin B_{12}/ pound of a basal heat-treated corn and soybean oil meal diet.

Antibiotics

In a report by Hoekstra (1962), it was noted that there was no reduction in the number of ulcers when a ration containing aureomycin (20 mg./lb. of feed) was compared to the same ration without aureomycin. In discussing results of studies at Wisconsin, Beeson (1963) indicated that the feeding of aureomycin and a combination of aureomycin, bacitracin and arsanilic acid did not appear to either cause or prevent the formation of gastric ulcers.

Reports by Nuwer et al. (1965) indicated that no significant difference in the number of ulcers was found when an antibiotic (oxytetracycline, 20 gm./ton) was fed as a control, or when this antibiotic was fed in combination with 100 parts per million of copper sulfate or 2,000 I.U. of vitamin A/pound of ration.

Muggenburg (1965) tested several antibiotics and found they had no effect on the number of pigs having ulcers. Antibiotics tested were: several levels of chlortetracycline, streptomycin, and the combination of chlortetracycline, arsanilic acid and bacitracin. The addition of these antibiotics was compared with a control ration.

Minerals

Hoekstra (1962) reported that feeding high levels of calcium or feeding zinc or copper supplements appeared to neither cause nor prevent the formation of stomach ulcers in swine. Dietary supplements of zinc, copper and cadmium did not appear to have any effect on the formation of ulcers (Kowalczyk et al., 1960).

Tranquilizers

Nuwer et al. (1965) tested the use of a tranquilizer (Librium Hydro-Chloride) that is frequently employed to reduce the effects of stress. They reported that the formation of ulcers was not prevented with the addition of this tranquilizer to a gelatinized corn and soybean oil meal diet.

Muggenburg (1965) reported that the percentage of swine having stomach ulcers was not different in a comparison of pigs raised in

crowded vs. non-crowded conditions. Ulcers observed were more severe in the crowded group.

Amino Acids

No reduction in number of gastric ulcers due to incorporation of 0.5 per cent lysine to a heat-treated corn diet was observed by Shively (1963). Nuwer et al. (1965) reported that the addition of 0.3 per cent methionine was not effective in preventing esophagogastric ulcers.

Unknown Factors

Rasmussen (1962) reported that gastric ulcers were not encountered when rations contained a source of unidentified growth factors. To evaluate this conclusion, Nuwer et al. (1965) added 5 per cent corn distillers dried solubles to a basal diet. Upon examination of the swine stomachs, no ulcers were found. However, finding 100 per cent cornification and erosions occurring in 66 per cent of the stomachs was interpreted as an inadequacy on the part of distillers dried solubles to prevent conditions leading to the esophagogastric ulcers.

Enzymes

Nuwer et al. (1965) added an amylolytic-proteolytic enzyme to a gelatinized corn diet to test for the presence of an enzyme inhibitor. Results indicated no difference in the number of ulcers formed when this treatment was compared to a control gelatinized corn diet.

Histamines

The addition of a histamine has been recognized as one way to experimentally produce ulcers in a variety of animals, but Nuwer et al. (1965) found no difference in the number of ulcers formed in the pig stomach when a ration of gelatinized corn plus an antihistamine (chlorphenisamine) was compared to a control diet of gelatinized corn.

Additional Factors Influencing Ulcer Development

Baker and Cadman (1963) reported that the fungus Candida albicans was isolated from several pigs in northwestern Wisconsin. They stated that the organisms seemed to have a preference for the esophageal region. It was thought that the increased incidence of Candidasia in pigs may be due to the extensive use of antibiotics, among other conditions. Ovin (1952) reported that infection of the esophagogastric region of the stomach of pigs with Candida albicans produced erosions. Griffing (1963) stated that "Candida albicans was isolated from 47.3% of the gastric ulcers and Candida species from 33.3%." However, no comparison was made to the prevalence of these fungus in normal stomachs. Curtin, Goetsch and Hollandbeck (1963) isolated Candida albicans from the surface of the ulcer crater and found these fungus in superficial tissues of the crater or in adjacent squamous epithelium in some cases.

In contrast, Rothenbacher, Nelson and Ellis (1963), examined lesions, organs and intestines of pigs and found no consistent pattern for infectious agents. McErlean (1962) reported finding no infectious agent involved in the development of ulcers in swine.

Kowalczyk et al. (1960) were unable to produce stomach ulcers in two weanling pigs by intravenous injection of microorganisms isolated from the base and edges of naturally developed swine ulcers.

Various theories as to the causes and/or factors leading to the formation of gastric ulcers in swine have been suggested by various workers. For example, Dunbarry (1958) suggested that inheritance was important in the development of gastric ulcers in swine. Kowalczyk et al. (1960) suggested the following conditions as being possibly involved in the development of gastric ulcers: infectious, toxic, traumatic, hormonal, nutritional and psychosomatic. However, experimental data to support these theories is lacking.

CHAPTER III

EXPERIMENTAL PROCEDURE

Rations

A ration formula meeting National Research Council (NRC) standards was used throughout the experiments reported in this study (Table I). Specific changes in the ration are given in the procedures of the appropriate experiments. All commercially produced rations used in these studies were manufactured by the same feed mill located near the Knoxville Experiment Station.

Pelleting Procedure

In the pelleting procedure the meal was passed through a steam jacket 10 feet long. Live steam under 120 pounds pressure per square inch was injected into the feed for the first 2.5 feet. Steam was then injected into the jacket for the remaining 7.5 feet to maintain the elevated feed temperature. It required 1.75 minutes for the feed to pass through the 10-foot jacket. Temperature ranged from 87.8 to 110.0° C. The steam-heated meal was then passed through a 2.5-inch pellet plate containing 0.2-inch-diameter holes in a standard California pellet mill. Temperature of the meal or pellets on both sides of the die was approximately 85.0° C. This temperature remained high for 1.5 to 2 minutes as the pellets were elevated for delivery into a cooler where they remained for another 1.5 to 2 minutes before being passed into the feed line for sacking.

TABLE I

COMPOSITION OF RATIONS

Approximate Protein	16%	14%
Yellow corn, ground	1,501	1,622
Soybean meal (44%)	300	200
Meat scrap	100	80
Dehydrated alfalfa meal (17%)	60	60
Defluorinated rock phosphate	20	20
Salt	10	10
Trace mineral premix[a]	2	1
Vitamin mix[b]	4	4
Antibiotic[c]	2	2
Antioxidant	1	1

[a]Provides an addition to the ration of 100 p.p.m. manganese, 3 p.p.m. iodine, 1 p.p.m. cobalt, 100 p.p.m. iron, 10 p.p.m. copper and 100 p.p.m. zinc.

[b]Provides an addition to the ration of 2 gm. riboflavin, 4 gm. pantothenic acid, 9 gm. niacin, 10 gm. choline, 10 mg. B_{12}, 500,000 I.U. vitamin A and 250,000 I.U. vitamin D.

[c]Provides 20 gm. chlortetracycline.

Facilities

Confined pigs were fed in 5 x 20 feet pens on concrete, one-half of which was under roof. Pasture pigs were fed in one-half acre lots with portable houses. Each lot or pen contained an automatic waterer and a self feeder. Summer pastures consisted primarily of orchardgrass and Ladino clover with small amounts of alfalfa. Winter pastures were composed of crimson clover, oats or barley and rye grass. They were clipped as needed through the experimental periods.

Classification

All stomachs were classified according to the scale given in Table II, which is based on the degree of keratinization or ulceration.

Mean Ulcer Score

The mean ulcer score values were calculated by taking an average of the classification values (Table II).

Data and Statistical Analysis

Data for average daily gain, feed efficiency, and mean ulcer scale were analyzed using the analysis of variance. When differences were found, Duncan's Multiple Range was used for mean separation (as presented in Appendixes A and B). Chi-square analysis was used when analyzing the differences in numbers of suspect to severe ulcers per treatment.

TABLE II

SCALE FOR CLASSIFYING THE SEVERITY OF KERATINIZATION OR ULCERATION IN THE ESOPHAGEAL AREA OF SWINE STOMACHS

Condition	Scale Rating	Description
Normal	0	Smooth or wrinkled, glistening white or yellowed; no lesions or keratinization.
Keratinized	1	Slight keratinization covering less than 1/8 of the esophageal area.
	2	Medium keratinization covering 1/8 to 1/2 of the esophageal area.
	3	Heavy keratinization covering more than 1/2 of the esophageal area.
Suspect	4	Stomachs which could not be classified definitely as having ulcers, but which showed evidence of an abnormal esophageal mucosa.
Ulcer	5	Slight ulcer, usually relatively narrow, not over 2 or 3 cm. long, covering 1/8 or less of the esophageal area.
	6	Medium ulcer, covering 1/8 to 1/2 of the esophageal area.
	7	Heavy ulcer, covering more than 1/2 of the esophageal area.

Experiment I

Thirty-two weanling Duroc and Hampshire pigs were allotted to eight lots of four pigs each on the basis of age, breed, sex and weight. One lot of each breed was randomly allotted to each of the following treatments: (I) meal, mixed at the Knoxville Experiment Station; (II) commercially mixed meal with formulation identical to treatment I; (III) identical to treatment II except that the ration was pelleted; (IV) the pellet reground and fed as a meal.

Pigs were started on test at an average weight of 44 pounds and continued on test until the average pig weight reached 200 pounds. When the pigs were removed from test, they were held 24 hours without feed but were given free access to water before being taken to a commercial packing plant for slaughter. At slaughter, stomachs from all pigs were recovered, identified and returned to the University Laboratory for inspection. Color photographs were made of each stomach for detailed study. After the photographs were studied, a scale was developed to classify the stomachs as to the degree of keratinization or ulceration (Table II, page 19).

Experiment II

Twenty-four market weight pigs, which had been fed a meal ration and had received similar management in confinement on concrete during the growing-finishing period, were randomly allotted into two groups. Twelve of the pigs were sent to slaughter with a 24-hour fast. The other 12 were trucked directly to the packing plant for slaughter

without a fasting period. All 24 stomachs were recovered, identified, examined and classified.

In addition, 37 stomachs of pigs were taken at random from a local slaughter line. They were divided into two groups: empty or full, to compare to the 24 pigs from this experiment.

Experiment III

Duroc barrows averaging 54 pounds were allotted to 12 lots of four pigs each on the basis of age, weight and breeding. Three lots were randomly allotted to each of the following treatments: (I) meal; (II) pellet; (III) reground pellet; (IV) reground pellet plus 2,000,000 I.U. of vitamin A per ton of ration. The same formula (Table I, page 17) was used by a commercial manufacturer to produce all rations. Pigs were continued on these rations until the average pig weight reached 200 pounds. At this time, they were removed from test and trucked directly to a commercial packing plant where they were slaughtered within 3 to 6 hours. Stomachs were identified, recovered, examined and classified.

Experiment IV

Ten pigs, averaging 165 pounds, that had been on a meal ration were allotted into two uniform lots. One of these lots was allotted to a meal ration and one to a pellet ration of the same formulation (Table I, page 17). Pigs were fed to an approximate average weight of 220 pounds. They were taken directly to a commercial packing plant where they were slaughtered within 3 to 6 hours. Stomachs were identified, recovered, examined and classified.

Experiment V

Pigs used in this experiment were started on creep feed of the same formulation at 2 weeks of age. The creep feed varied only in that one-half was fed as a meal and the other half was fed as pellets. Litters were paired as to breed and number in the litter, and then randomly assigned to either the meal or pellet creep. They continued on this type of feed until weaning.

Forty-eight pigs were used in both the summer and winter phase. They were selected (24 of which had been on meal creep and 24 on pellet creep feed) and divided uniformly into groups of four. Treatments were: (I) meal creep--meal during the growing-finishing period; (II) meal creep--pellets during the growing-finishing period; (III) pellet creep--meal during the growing-finishing period; (IV) pellet creep--pellet during the growing-finishing period. Pigs were continued on these growing-finishing rations until the average pig weight reached 200 pounds. At this time, they were removed from test and taken directly to a commercial packing plant where they were slaughtered within 3 to 6 hours. Stomachs were identified, recovered, examined and classified.

Experiment VI

Forty-four pigs were used in this experiment. They had received a pelleted creep ration to weaning at about 8 weeks of age. A two by two factorial design was used using pasture and confinement feeding as one variable, and meal and pellets as the other variable. Pigs were lotted into groups of four for confinement feeding and uniform groups of

five for the pasture phase and randomly assigned to a meal or pellet grower-finisher. Treatments were: confinement (I) meal; (II) pellet; pasture (I) meal; (II) pellet. Three replications were used in confinement and two on pasture.

When the average pig weight reached 200 pounds, they were removed from test and trucked directly to a commercial packing plant where they were slaughtered within 3 to 6 hours. Stomachs were identified, recovered, examined and classified.

Experiment VII

Seventy-two Duroc and Hampshire pigs averaging 44 pounds were used in this study. They were allotted into 18 uniform lots on the basis of sex, age, weight and breeding. Three of these groups were then randomly assigned to each of the following treatments: (I) control meal; (II) control pellet; (III) pellet with the addition of 1 per cent bicarbonate of soda; (IV) pellet with the addition of 3 per cent bicarbonate of soda; (V) pellet with the addition of 3 per cent dehydrated alfalfa leaf meal to raise the total level to 6 per cent; (VI) pellet containing 20 per cent whole oats, which replaced an equivalent amount of corn and soybean meal (Table III). Complete ration formulation is given in Table III. Pigs were continued on test until the average pig weight reached 200 pounds, at which time they were removed from test and trucked directly to a commercial packing house for slaughter within 3 to 6 hours. Stomachs were identified, recovered, examined and classified.

TABLE III

COMPOSITION OF RATIONS

Ration Form	Meal	Pellet	Pellet	Pellet	Pellet	Pellet
			Approximate Protein 16%			
Oats	--	--	--	--	--	400
Yellow corn, ground	1,501	1,501	1,481	1,441	1,441	1,131
Soybean meal (44%)	300	300	300	300	300	270
Meal scrap	100	100	100	100	100	100
Dehydrated alfalfa (17%)	60	60	60	60	120	60
Dicalcium phosphate	20	20	20	20	20	20
Salt	10	10	10	10	10	10
Trace mineral premix[a]	2	2	2	2	2	2
Vitamin premix[b]	4	4	4	4	4	4
Antibiotic[c]	2	2	2	2	2	2
Antioxidant	1	1	1	1	1	1
Sodium bicarbonate	--	--	20	60	--	--
Total	2,000	2,000	2,000	2,000	2,000	2,000
			Approximate Protein 14%			
Oats	--	--	--	--	--	400
Yellow corn, ground	1,621	1,621	1,601	1,546	1,561	1,251
Soybean meal (44%)	200	200	200	215	200	170
Meal scrap	80	80	80	80	80	80
Dehydrated alfalfa (17%)	60	60	60	60	120	60
Dicalcium phosphate	20	20	20	20	20	20
Salt	10	10	10	10	10	10
Trace mineral premix[a]	2	2	2	2	2	2
Vitamin premix[b]	4	4	4	4	4	4
Antibiotic[c]	2	2	2	2	2	2
Antioxidant	1	1	1	1	1	1
Sodium bicarbonate	--	--	20	60	--	--
Total	2,000	2,000	2,000	2,000	2,000	2,000

[a]Provides an addition to the ration of 100 p.p.m. manganese, 2.4 p.p.m. iodine, 2 p.p.m. cobalt, 40 p.p.m. iron, 10 p.p.m. copper and 80 p.p.m. zinc.

[b]Provides an addition to the ration of 2 gm. riboflavin, 4 gm. pantothenic acid, 9 gm. niacin, 10 gm. choline, 10 mg. B_{12}, 500,000 I.U. vitamin A and 250,000 I.U. vitamin D.

[c]Provides 20 gm. chlortetracycline.

CHAPTER IV

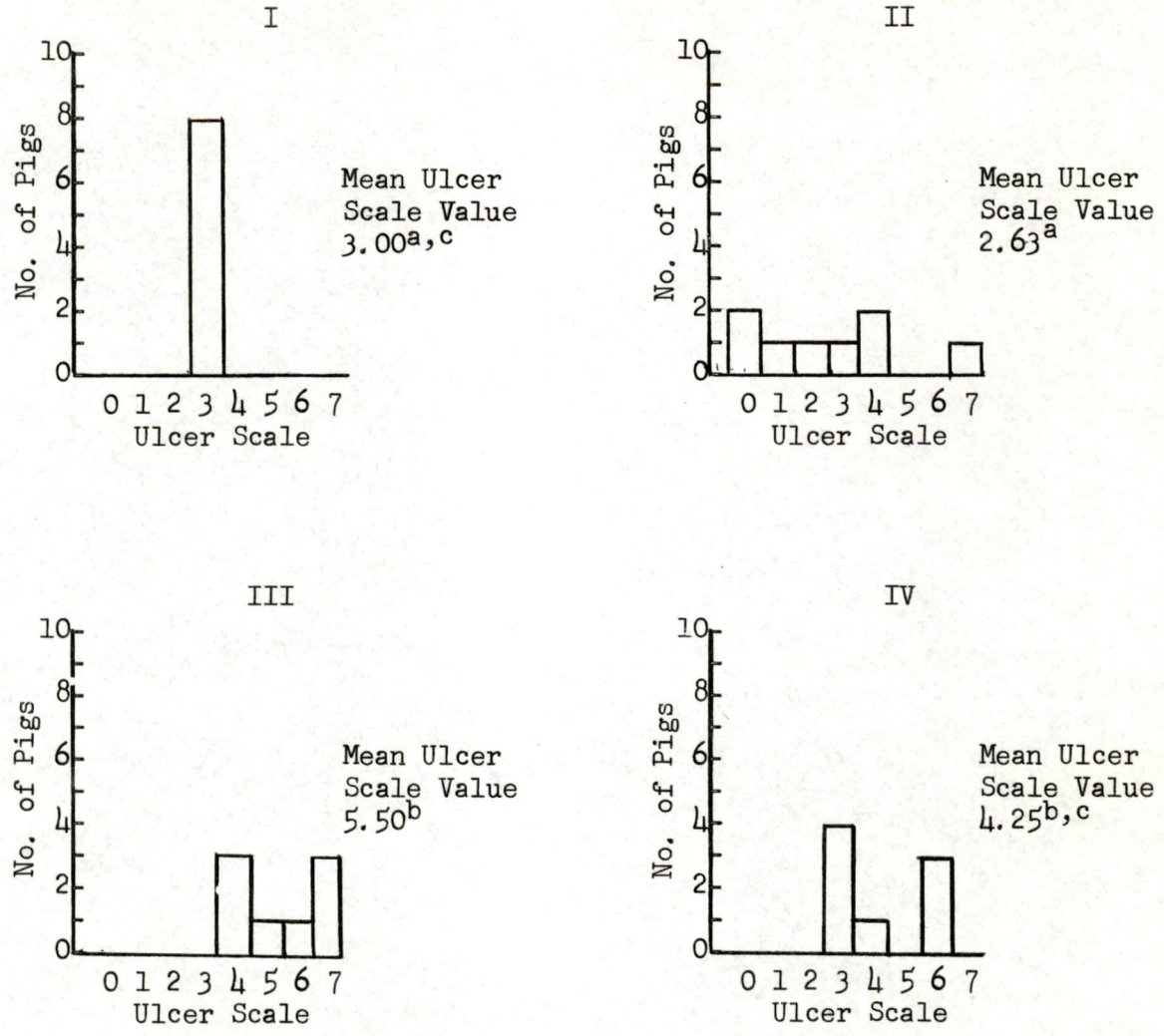
RESULTS AND DISCUSSION

Experiment I

Effects of the various rations on incidence of ulcers and performance of the swine are shown in Figure 1 and Table IV. Only one ulcer was diagnosed in the 16 stomachs from pigs on the two unpelleted meal rations. Two stomachs from these groups showed "suspect" lesions. However, of the 16 stomachs from the combined groups receiving pellets or reground pellets, there were eight ulcers and four keratinized esophageal areas. The incidence of ulcers found in this experiment is in general agreement with the findings of Perry, Jimenez and Shively (1963).

The statistical analysis showed no differences in feed required per 100 pounds gain between the two unpelleted meal feeds nor between the pellets and the reground pellets. There was a significant difference ($P<.05$) between the average feed efficiencies for swine fed the two unpelleted meal feeds (3.23 pounds/pound gain) and average feed efficiencies for swine eating pellets and reground pellets (2.99 pounds/pound gain). The group receiving pellets had a significantly higher average daily gain than did the other three groups (meal, meal or reground pellets).

There was no difference in mean ulcer score between swine on the two unpelleted meal rations nor between swine on the pellets and



I. Meal U. T. Exp. Sta. Farm
II. Meal commercially mixed
III. Pellets
IV. Reground pellets

a,b,cMeans in the same row followed by the same letter(s) are not significantly different (P>.05)--those followed by different letters are significantly different (P<.05).

Figure 1. Ulcer classification and distribution by ration for Experiment I, summer 1963.

TABLE IV

EFFECT OF FEED FORM ON THE PERFORMANCE AND INCIDENCE OF ULCERS IN SWINE FED IN CONFINEMENT, SUMMER 1963

Ration Form	Meal	Meal	Pellet	Reground Pellet
Ration Source	U. T. Blount Farm	Comm.	Comm.	Comm.
No. lots/treatment	2	2	2	2
No. pigs/lot	4	4	4	4
Av. wt. and gain, lb.				
Initial	44	44	44	44
Final	202	199	211	200
Daily gain	1.44[a]	1.50[a]	1.69[b]	1.52[a]
Av. age, days				
Initial	73	71	70	70
Final	182	174	169	172
Av. daily feed, lb.	4.71	4.81	4.87	4.76
Feed/cwt. gain, lb.	325[a]	320[a,c]	291[b]	306[b,c]
Mean ulcer score value	3.00[a,c]	2.63[a]	5.50[b]	4.25[b,c]
No. of suspect to severe ulcers/treatment	0/8[a]	3/8[b]	8/8[c]	4/8[b]

[a,b,c]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

reground pellets. The difference between average mean ulcer scores for stomachs of swine from the two unpelleted meal groups (2.86) and for those of swine from the pellet and the reground pellet group (4.88) was highly significant ($P<.01$). This would indicate that the ulcerogenic effect was due to the pelleting process and not to the form in which the ration was fed.

No statistical differences in performance of the pigs or mean ulcer values were found between swine fed the meal ration produced at the Knoxville Experiment Station or the commercially-produced meal feed.

Differences due to breed were not significant which agrees with findings of Curtin, Goetsch and Hollandbeck (1963); Muggenburg et al. (1964). The former found esophagogastric ulcers in eight breeds of swine: Yorkshire, Hampshire, Landrace, Berkshire, Spotted Poland China, Poland China, Tamworth and Duroc. The latter reported no significant difference in the incidence of esophagogastric ulcers between Poland China, Chester White and Hampshire breeds and no difference between Yorkshire and Duroc breeds.

In this experiment, incidence of ulcers was not affected by sex of the pig. However, this is different from the results of Curtin, Goetsch and Hollandbeck (1963) and Muggenburg et al. (1964) who reported an incidence ration of 1.5 for barrows to 1.0 for gilts.

These data indicate that pelleting results in a significant increase in the incidence of ulcers and an improvement in feed efficiency when compared to an unpelleted meal ration. Pigs receiving pellets gained significantly faster than those receiving meal or reground pellets.

Experiment II

In Experiment I, it was noted that 53 per cent of the stomachs had varying degrees of apparent keratinization of the esophageal area. This tissue, when scraped with a thumbnail, was readily removed, exposing a normal esophageal area. It was hypothesized that the fasting period just prior to slaughter had some effect on this keratinization. Experiment II tested this hypothesis.

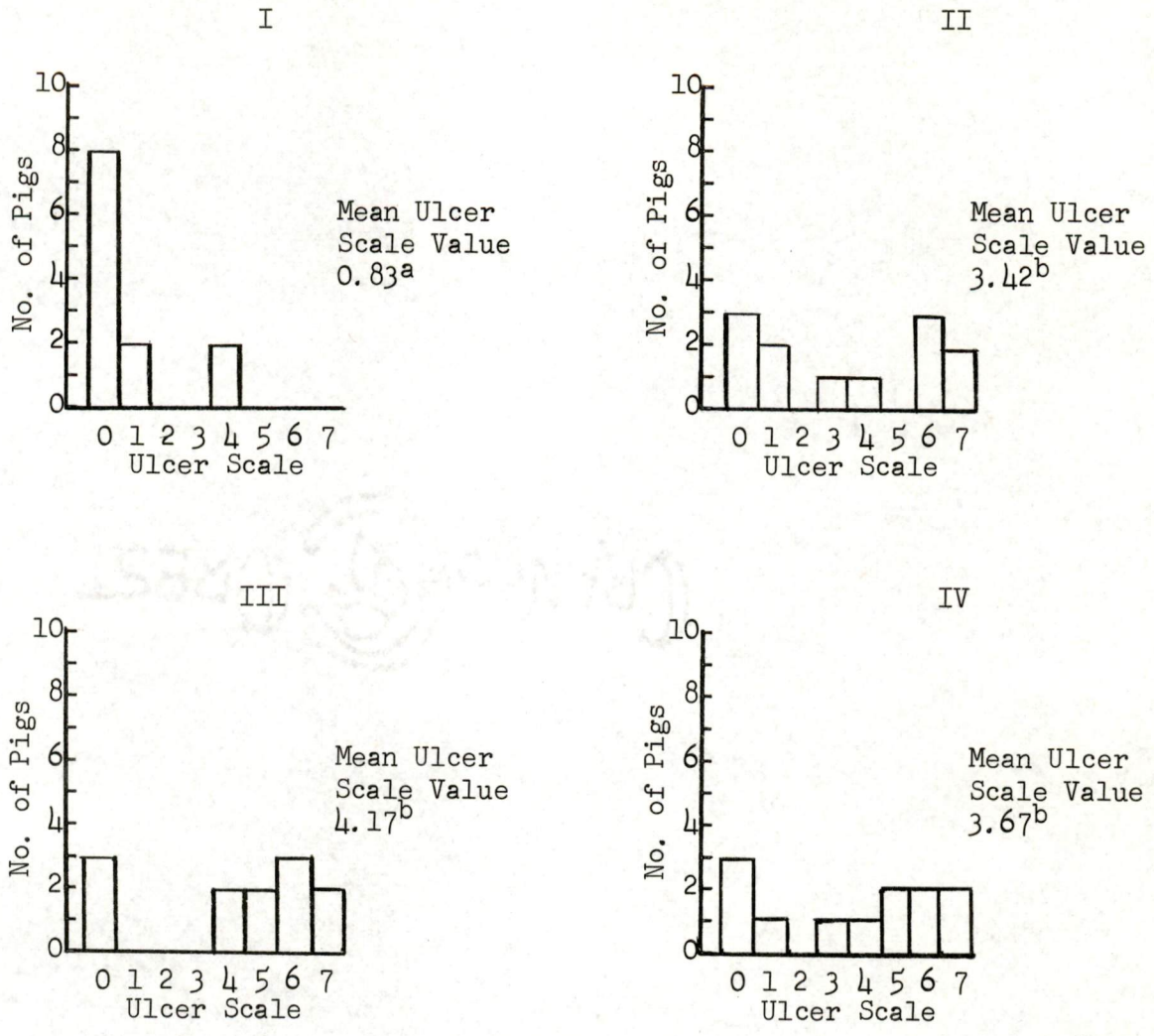
Nine of the 12 stomachs from pigs fasted for 24 hours showed varying degrees of apparent keratinization, while only 2 of the 12 stomachs from pigs kept on feed until taken to slaughter showed any evidence of apparent keratinization. This difference was highly significant.

Of the stomachs taken at random from the slaughter line, 42 per cent of the full group showed varying degrees of apparent keratinization. Of those in the empty group, 76 per cent exhibited varying degrees of apparent keratinization. This difference was highly significant.

It was concluded from these results that fasting significantly affected the degree of apparent keratinization, and it was decided that pigs from future experiments would go directly to slaughter without a fasting period.

Experiment III

Effects of the various rations on incidence of ulcers and performance of the swine are shown in Figure 2 and Table V. Of the 12 stomachs from swine consuming an unpelleted meal ration, there were no



I. Meal commercially mixed
II. Pellets
III. Reground pellets
IV. Reground pellets plus vit. A

[a,b]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

Figure 2. Ulcer classification and distribution by ration for Experiment III, winter 1963-64.

TABLE V

EFFECT OF FEED FORM AND THE ADDITION OF VITAMIN A ON THE PERFORMANCE AND INCIDENCE OF ULCERS IN SWINE FED IN CONFINEMENT, WINTER 1963-64

Ration Form	Meal	Pellet	Reground Pellet	Reground Pellet
Ration Source	Comm.	Comm.	Comm.	Comm.
Additives	--	--	--	Vitamin A
No. lots/treatment	3	3	3	3
No. pigs/lot	4	4	4	4
Av. wt. and gain, lb.				
Initial	53	54	54	54
Final	201	212	208	206
Daily gain	1.72	1.83	1.74	1.76
Av. age, days				
Initial	74	75	73	72
Final	160	161	161	157
Av. daily feed, lb.	6.28	5.66	5.46	5.69
Feed/cwt. gain, lb.	340[a]	308[b]	312[b]	318[b]
Mean ulcer score value	0.83[a]	3.42[b]	4.17[b]	3.67[b]
No. of suspect to severe ulcers/treatment	2/12[a]	6/12[c]	7/12[c]	7/12[c]

[a,b,c]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

definite ulcers, 2 "suspect" lesions and 2 keratinized esophageal areas. When examining stomachs from swine consuming pellets, 5 definite ulcers, 1 "suspect" lesion and 3 keratinized esophageal areas were noted and from swine consuming reground pellets, 7 definite ulcers and 2 "suspect" lesions were observed. Six definite ulcers, 1 "suspect" lesion and 2 keratinized esophageal areas were noted in the 12 stomachs from swine consuming reground pellets with additional vitamin A. Thus, additional vitamin A did not appear to reduce the incidence of ulcers compared to the pelleted or reground pelleted ration fed as a meal.

There were no significant differences in pig performance nor in the incidence of ulcers when pigs fed the pellets were compared with those consuming reground pellets. Addition of vitamin A to the reground pellet did not affect pig performance or incidence of ulcers. This agrees with work by Nuwer et al. (1965). The pigs receiving the unpelleted meal ration required significantly more feed per 100 pound gain and had a significantly lower mean ulcer scale value than did those pigs receiving the pellets, reground pellets or reground pellets with additional vitamin A.

Pig performance and incidence of ulcers were not effected by season.

When studying Figures 1 and 2, pages 26 and 30, it should be noted that the pigs in Experiment I had a 24-hour fast period to slaughter, while those in Experiment III were not fasted.

Experiment IV

Results of Experiments I and III indicated that the pelleting of a ration significantly affected the incidence of ulcers and pig performance in growing-finishing swine when compared to a meal ration. Curtin, Goetsch and Hollandbeck (1963) had observed ulcers in pigs as young as 2 weeks of age. However, they were observed most frequently in pigs weighing 30 to 120 pounds. This experiment was designed to test the effect of introducing a ration hypothesized to be ulcerogenic in nature at weights heavier than these.

Table VI summarizes the results of this experiment. Upon examination, 2 definite ulcers and 1 keratinized esophageal area were found in stomachs from pigs receiving pellets, while no ulcers nor keratinized esophageal areas were found in pigs receiving meal. Difference in number of ulcers per treatment and mean ulcer score was significantly greater in those receiving pellets.

Experiment V

Summer phase. Shively (1963) reported that digestive disturbances were evident in young pigs fed a creep ration considered to be ulcerogenic in nature. He did not indicate whether these disturbances were due to ulcers. This experiment was conducted to test the affect of the age of the pig at the time of introduction of pellets on ulcer incidence.

Effects of various rations on incidence of ulcers and performance of swine are shown in Figure 3 and Table VII. Of the 12 stomachs from pigs consuming meal feed throughout the entire period, only 1 "suspect"

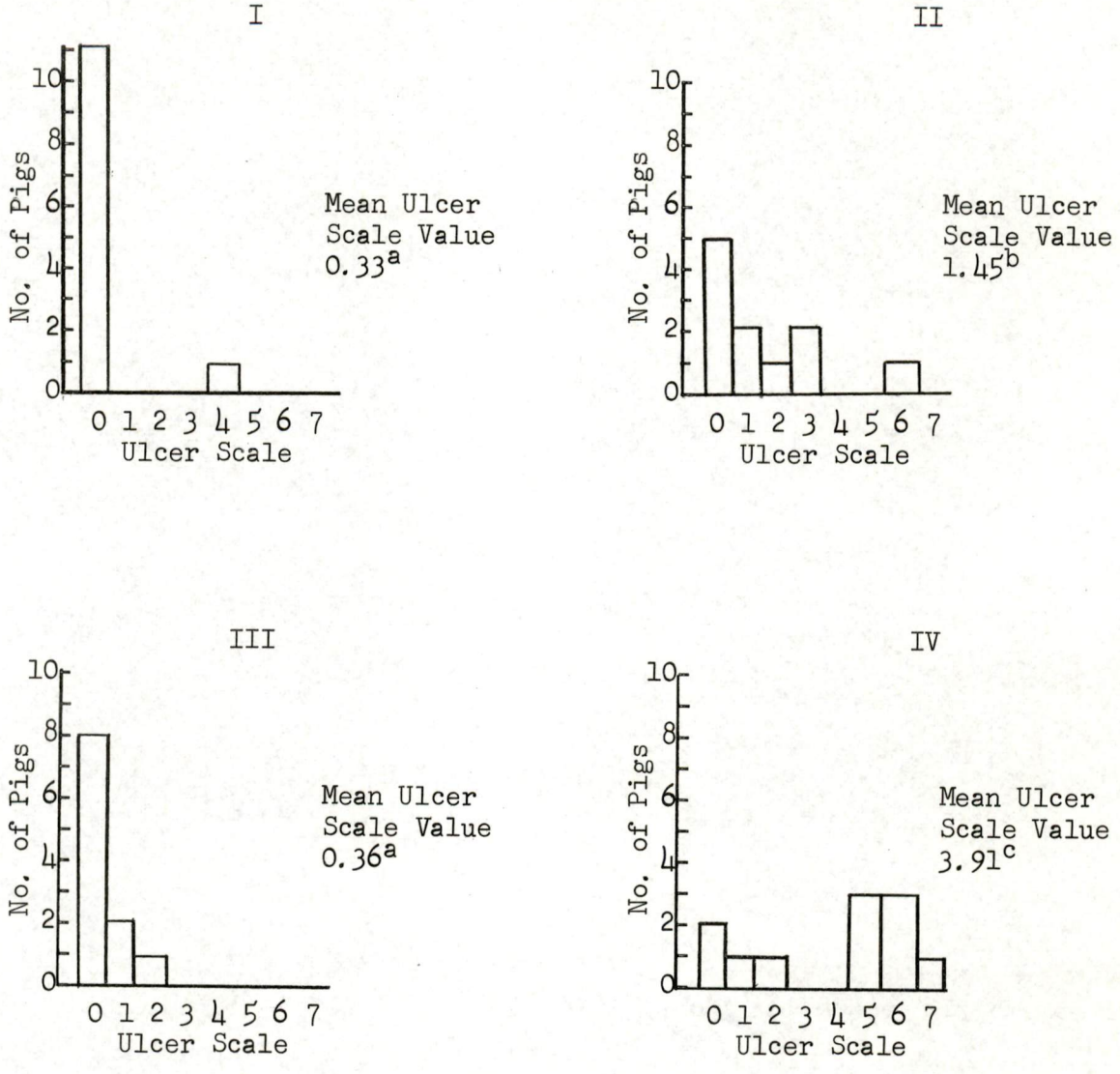
TABLE VI

EFFECT OF FEED FORM ON INCIDENCE OF ULCERS AND PERFORMANCE OF SWINE FED IN CONFINEMENT FROM A STARTING WEIGHT OF 165 POUNDS TO A FINAL WEIGHT OF 220 POUNDS, SPRING 1964

Ration Form	Pellet	Meal
Ration Source	Comm.	Comm.
No. lots/treatment	1	1
No. pigs/lot	5	5
Av. wt. and gain, lb.		
Initial	168	169
Final	222	216
Daily gain	1.93	1.68
Av. age, days		
Initial	135	135
Final	163	163
Av. daily feed, lb.	7.10	6.52
Feed/cwt. gain, lb.	366	388
Mean ulcer score value	2.40[a]	0.00[b]
No. of suspect to severe ulcers/treatment	2/5[a]	0/5[b]

[a,b]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

Summer 1964



I. Meal creep, meal grower-finisher

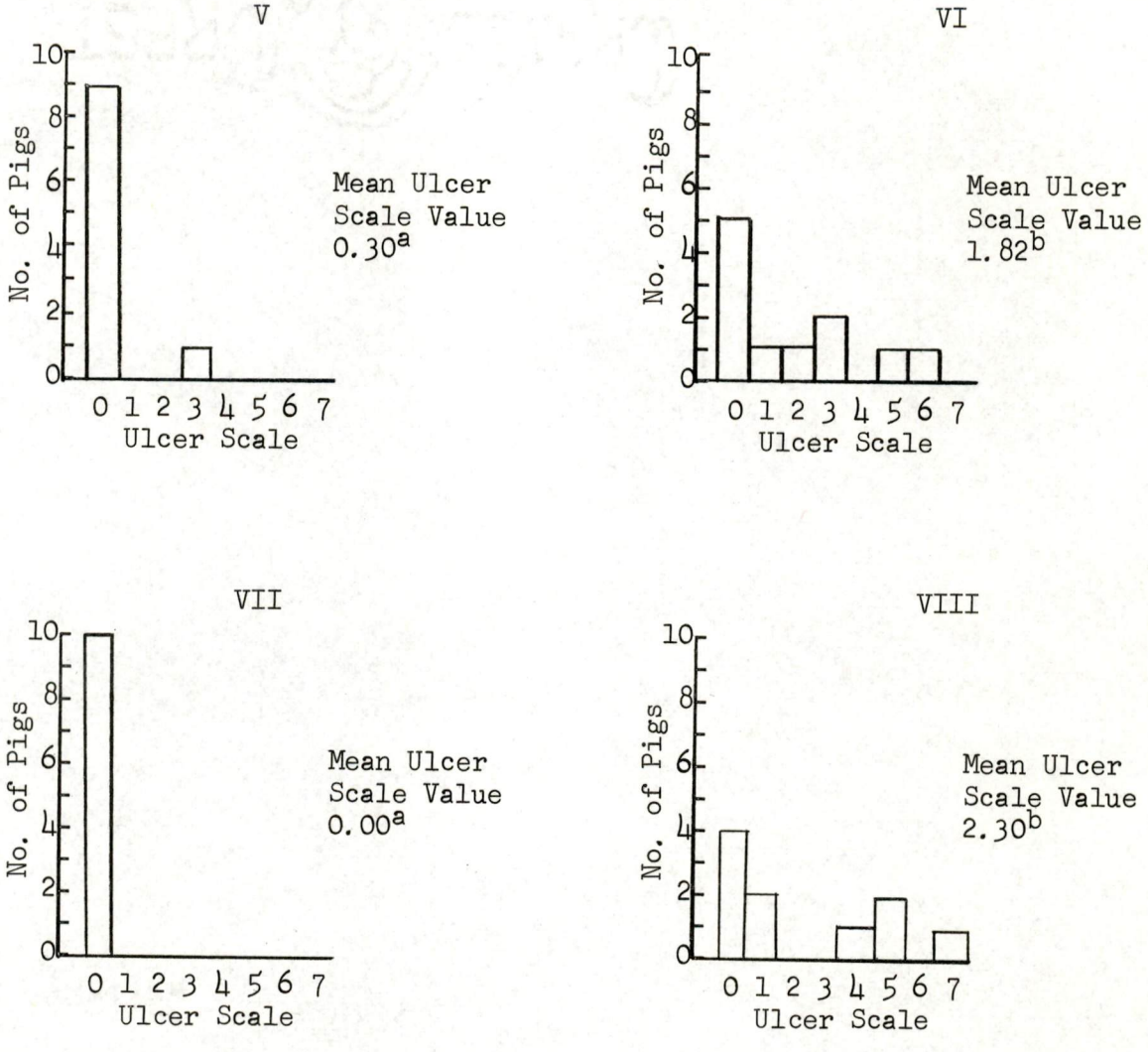
II. Meal creep, pellets grower-finisher

III. Pellets creep, meal grower-finisher

IV. Pellets creep, pellet grower-finisher

Figure 3. Ulcer classification and distribution by ration for Experiment V, summer 1964 and winter 1964-65.

Winter 1964-65



V. Meal creep, meal grower-finisher

VI. Meal creep, pellets grower-finisher

VII. Pellets creep, meal grower-finisher

VIII. Pellets creep, pellet grower-finisher

[a,b,c]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

Figure 3 (continued)

TABLE VII

EFFECT OF CREEP AND GROWER-FINISHER RATION FORM ON THE INCIDENCE OF ULCERS AND PERFORMANCE OF SWINE FED IN CONFINEMENT, SUMMER 1964

Creep Ration Form	Meal	Meal	Pellets	Pellets
Growing-finishing Ration Form	Meal	Pellets	Meal	Pellets
Ration Source	Comm.	Comm.	Comm.	Comm.
No. lots/treatment	3	3	3	3
No. pigs/lot	4	4	4	4[1]
Av. wt. and gain, lb.				
Initial	50	50	43	43
Finial	204	207	204	204
Daily gain	1.54	1.72	1.50	1.63
Av. age, days				
Initial	71	72	68	69
Final	171	163	175	167
Av. daily feed, lb.	4.92	5.31	4.80	4.80
Feed/cwt. gain, lb.	318[a]	309[a,c]	322[a]	295[b,c]
Mean ulcer score value	0.33[a]	1.45[b]	0.36[a]	3.91[c]
No. of suspect to severe ulcers/treatment/no. of stomachs examined	1/12[2b]	1/11[2b]	0/11[2a]	7/11[2c]

[1]Pig removed because of illness.

[2]Stomach lost during the slaughter process.

[a,b,c]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

lesion was found. In contrast, 2 keratinized esophageal areas and 7 definite ulcers were found in the stomachs of pigs consuming pellets from birth to market. One definite ulcer and 5 keratinized esophageal areas were found on examination of the stomachs from pigs receiving a meal creep feed to weaning, followed by pellets during the growing-finishing period. Three keratinized esophageal areas were found on examination of the stomachs from pigs receiving a pellet feed to weaning followed by a meal ration during the growing-finishing period.

An analysis considering only the "suspect" to severe ulcers per treatment showed that pigs receiving pellets from birth to market had significantly more ulcers than did pigs on the other three treatments. When comparing the pigs receiving the meal ration from birth to market with the pigs receiving meal followed by the pelleted ration, there were no significant differences in the number of ulcers. Significantly more ulcers were observed when pigs from either of these treatments were compared with pigs receiving pellets followed by meal.

Testing the mean ulcer scores (average classification value) produced statistical differences that were somewhat different from the ones received, using only the number of suspect to severe ulcers per stomach examined. There was a significant difference in the mean ulcer score for the pigs receiving both creep and growing-finishing rations of pellets (3.91) compared to pigs receiving the meal ration from birth to market (0.33) with the one receiving a pellet creep followed by a meal ration during the growing-finishing period (0.36), there were no significant differences in mean ulcer score.

Ration did not significantly affect average daily gain. However, the difference between daily gains for the pigs receiving the meal ration from birth to market (1.54 lbs./day) and the ones receiving a meal creep followed by pellets during the growing-finishing period (1.72 lbs./day) did approach significance ($P<.10$).

Pigs required significantly more feed per pound of gain when receiving either the meal ration throughout (3.18) or a pelleted creep ration followed by the meal (3.22) than did the pigs receiving pellets from birth to market (2.95).

Winter phase. The effect of ration on incidence of ulcers and pig performance in the winter phase is shown in Figure 3, page 35, and Table VIII. Of pigs receiving the meal ration from birth to market, 1 keratinized esophageal area was found upon stomach examination. No keratinized esophageal areas, "suspect" lesions, or definite ulcers were found in stomachs from pigs receiving a pellet creep ration followed by meal during the growing-finishing period. Three definite ulcers, 1 "suspect" lesion and 2 keratinized esophageal areas were found when examining stomachs from pigs receiving pellets from birth to market. Four keratinized esophageal areas and 2 definite ulcers were found in stomachs from pigs receiving a meal creep ration followed by pellets during the growing-finishing period.

No significant difference in number of ulcers was found when comparing (1) the treatment receiving meal from birth to market with the treatment receiving a pellet creep ration followed by meal during the

TABLE VIII

EFFECT OF CREEP AND GROWER-FINISHER RATION FORM ON THE INCIDENCE OF ULCERS AND PERFORMANCE OF SWINE FED IN CONFINEMENT, WINTER 1964-65

Creep Ration Form	Meal	Meal	Pellets	Pellets
Growing-finishing Ration Form	Meal	Pellets	Meal	Pellets
Ration Source	Comm.	Comm.	Comm.	Comm.
No. lots/treatment	3	3	3	3
No. pigs/lot	4	4	4	4
Av. wt. and gain, lb.				
Initial	38	39	37	37
Final	201	207	202	204
Daily gain	1.58	1.67	1.57	1.61
Av. age, days				
Initial	60	61	60	60
Final	164	161	165	163
Av. daily feed, lb.	4.06	4.88	4.98	4.75
Feed/cwt. gain, lb.	325[b]	291[a]	320[b]	295[a]
Mean ulcer score value	0.30[a]	1.82[b]	0.00[a]	2.30[b]
No. of suspect to severe ulcers/treatment/no. of stomachs examined	0/10[1,3a]	2/11[3b]	0/10[1,3a]	4/10[1,3b]

[1]Stomach lost during slaughter process.

[2]Two gilts selected from each pasture lot for the breeding herd.

[3]One gilt selected from each confinement lot for the breeding herd.

[a,b]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

growing-finishing period nor (2) the treatment receiving pellets from birth to market with the one receiving a meal creep and pellets during the growing-finishing period. However, there was a significant increase in the number of ulcers found in pigs receiving pellets from birth to market and from weaning to market compared to those receiving meal from birth to market or from weaning to market. When the total scale was taken into consideration, significant differences were the same for mean ulcer scores as they were for number of suspect to severe ulcers per treatment. Either treatment receiving the pellet ration during the growing-finishing period required significantly less feed per cwt. gain (2.91 and 2.95) than did either treatment receiving the meal ration during the growing-finishing period (3.25 and 3.20). Differences in average daily gains were not significant (1.58 - 1.67 - 1.57 - 1.61).

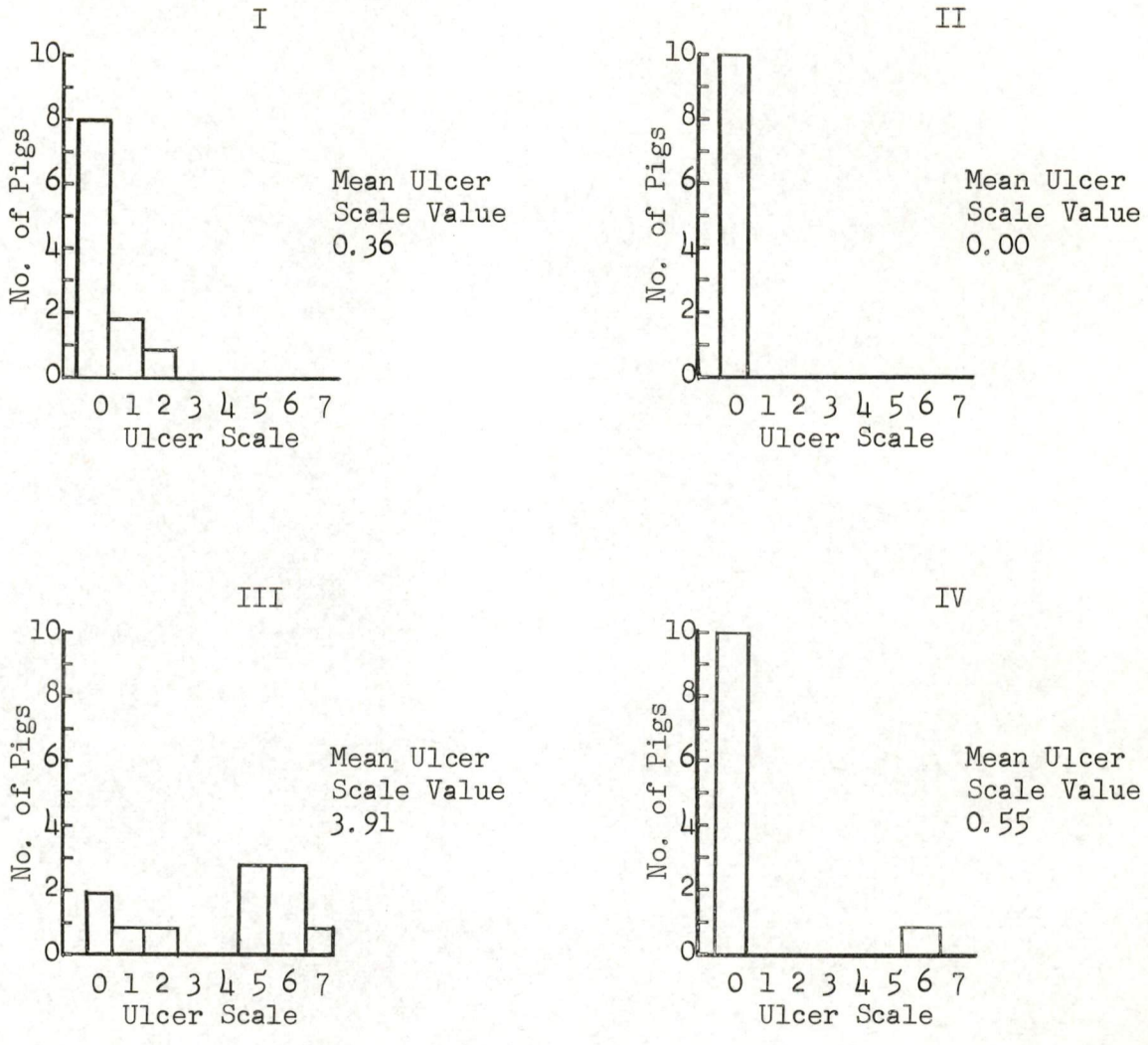
Experiment VI

Summer phase. This experiment was conducted to test the effect of pasture on the incidence of ulcers and on pig performance. The results are summarized in Figure 4 and Table IX. On examination of 12 stomachs from pigs in confinement receiving pellets from birth to market, 2 keratinized esophageal areas and 7 definite ulcers were found; as compared to stomachs from pigs fed on pasture receiving pellets from birth to market, in which only 1 definite ulcer was found out of 10 pigs examined. Two keratinized esophageal areas were found in stomachs from pigs receiving meal in confinement, and all stomachs were normal from the group receiving a meal ration on pasture.

Summer 1964

Confinement

Pasture



I. Pellet creep, meal grower-finisher

II. Pellet creep, meal grower-finisher

III. Pellet creep, pellet grower-finisher

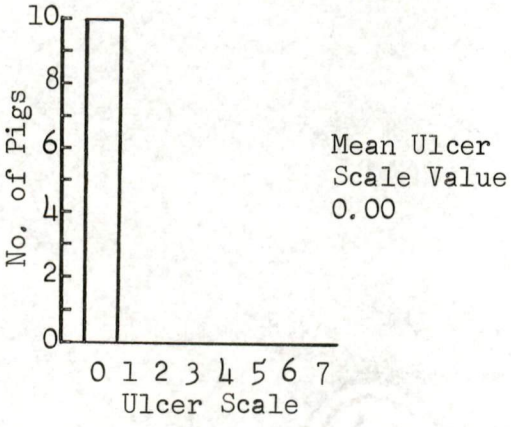
IV. Pellet creep, pellet grower-finisher

Figure 4. Ulcer classification and distribution by ration for Experiment VI, summer 1964 and winter 1964-65.

Winter 1964-65

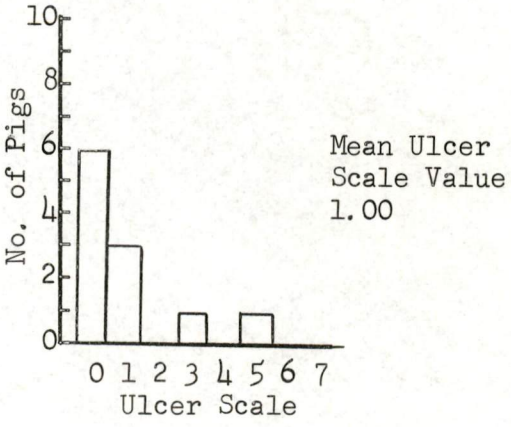
Confinement

V

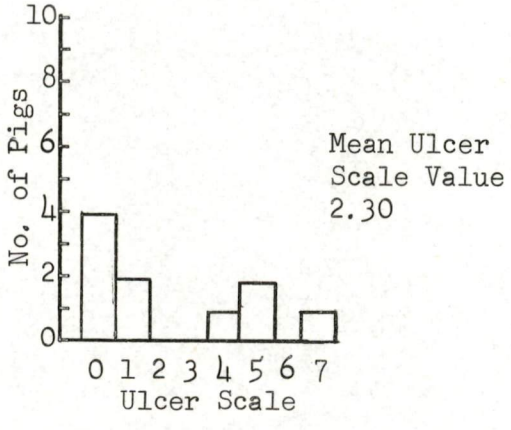


Pasture

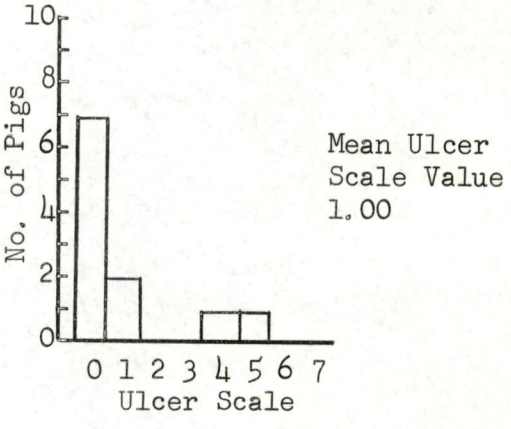
VI



VII



VIII



V. Pellet creep, meal grower-finisher

VI. Pellet creep, meal grower-finisher

VII. Pellets creep, pellet grower-finisher

VIII. Pellets creep, pellet grower-finisher

Figure 4 (continued)

TABLE IX

EFFECT OF CREEP AND GROWER-FINISHER RATION FORM ON THE INCIDENCE OF ULCERS AND PERFORMANCE OF SWINE FED IN CONFINEMENT OR ON PASTURE, SUMMER 1964

	Confinement		Pasture	
Creep Ration Form	Pellets	Pellets	Pellets	Pellets
Growing-finishing Ration Form	Meal	Pellets	Meal	Pellets
Ration Source	Comm.	Comm.	Comm.	Comm.
No. lots/treatment	3	3	2	2
No. pigs/lot	4	4[1]	5	5
Av. wt. and gain, lb.				
Initial	43	43	46	46
Final	204	204	202	204
Daily gain	1.50[a]	1.63[b]	1.54[a]	1.62[b]
Av. age, days				
Initial	68	69	72	72
Final	175	167	173	170
Av. daily feed, lb.	4.80	4.80	4.90	5.05
Feed/cwt. gain, lb.	322	295	319	313
Mean ulcer score value	0.36	3.91	0.00	0.55
No. of suspect to severe ulcers/treatment/no. of stomachs examined	0/11[2a]	7/11[2c]	0/10[a]	1/10[b]

[1]Pig removed because of illness.

[2]Stomach lost during the slaughter process.

[a,b,c]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

Analysis showed that pigs in confinement receiving pellets from birth to market had significantly more ulcers than did pigs receiving a pellet creep followed by a meal grower-finisher. A similar significant difference was obtained when comparing corresponding treatments fed on pasture.

There were significantly fewer ulcers when the pasture treatments were grouped and compared to the grouped confinement treatments.

Pigs receiving pellets from birth to market required significantly less feed than did the pigs receiving a meal ration from birth to market when comparing treatments fed on both concrete and pasture. No significant differences in feed required per pound of gain were noted between pigs in confinement compared to those on pasture.

Significantly higher gains were obtained for the pigs receiving pellets during the growing-finishing period compared to those receiving meal. Location did not significantly affect average daily gain.

Results of the summer phase of Experiment V indicated that pasture produced some type of an alleviating effect in the number and severity of ulcers for the treatments receiving pellets during the growing-finishing period. However, the incidence of ulcers was approximately the same on pasture or in confinement for the pigs receiving meal during the growing-finishing period.

Winter phase. Results are in close agreement with those of the summer phase of Experiment VI. Figure 4, page 42, and Table X give a summary of the results obtained in this experiment. Examination of

TABLE X

EFFECT OF CREEP AND GROWER-FINISHER RATION FORM ON THE INCIDENCE OF ULCERS AND PERFORMANCE OF SWINE FED IN CONFINEMENT OR ON PASTURE, WINTER 1964-65

	Confinement		Pasture	
Creep Ration Form	Pellets	Pellets	Pellets	Pellets
Growing-finishing Ration Form	Meal	Pellets	Meal	Pellets
Ration Source	Comm.	Comm.	Comm.	Comm.
No. lots/treatment	3	3	3	3
No. pigs/lot	4	4	6	6
Av. wt. and gain, lb.				
Initial	37	37	50	50
Final	202	204	195	201
Daily gain	1.57	1.61	1.59	1.66
Av. age, days				
Initial	60	60	75	75
Final	165	163	166	167
Av. daily feed, lb.	4.98	4.75	4.91	5.18
Feed/cwt. gain, lb.	320	295	308	313
Mean ulcer score value	0.00	2.30	1.00	1.00
No. of suspect to severe ulcers/treatment/no. of stomachs examined	0/10[1,3a]	4/10[1,3b]	1/11[1,2c]	2/11[1,2c]

[1]Stomach lost during slaughter process.

[2]Two gilts selected from each pasture lot for replacement gilts.

[3]One gilt selected from each confinement lot for replacement gilts.

[a,b,c]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

stomachs from pigs in confinement receiving a pellet creep followed by meal during the grower-finisher period revealed no keratinized esophageal areas nor any ulcers. Pigs in confinement receiving pellets from birth to market had 2 keratinized esophageal areas, 1 "suspect" lesion and 3 definite ulcers. Examination of the stomachs of pigs on pasture showed 2 keratinized esophageal areas and 1 definite ulcer in pigs receiving a pellet creep followed by meal during the growing-finishing period, and those pigs on pasture receiving a pellet creep and pellets during the growing-finishing period had 2 pigs with keratinized esophageal areas, 1 with a "suspect" lesion and 1 with a definite ulcer.

Pigs receiving a meal ration during the growing-finishing period had significantly fewer ulcers than did the pigs receiving pellets during the same period but location differences were not significant. A severe winter and a short pasture supply may explain in part the failure to show significance due to location.

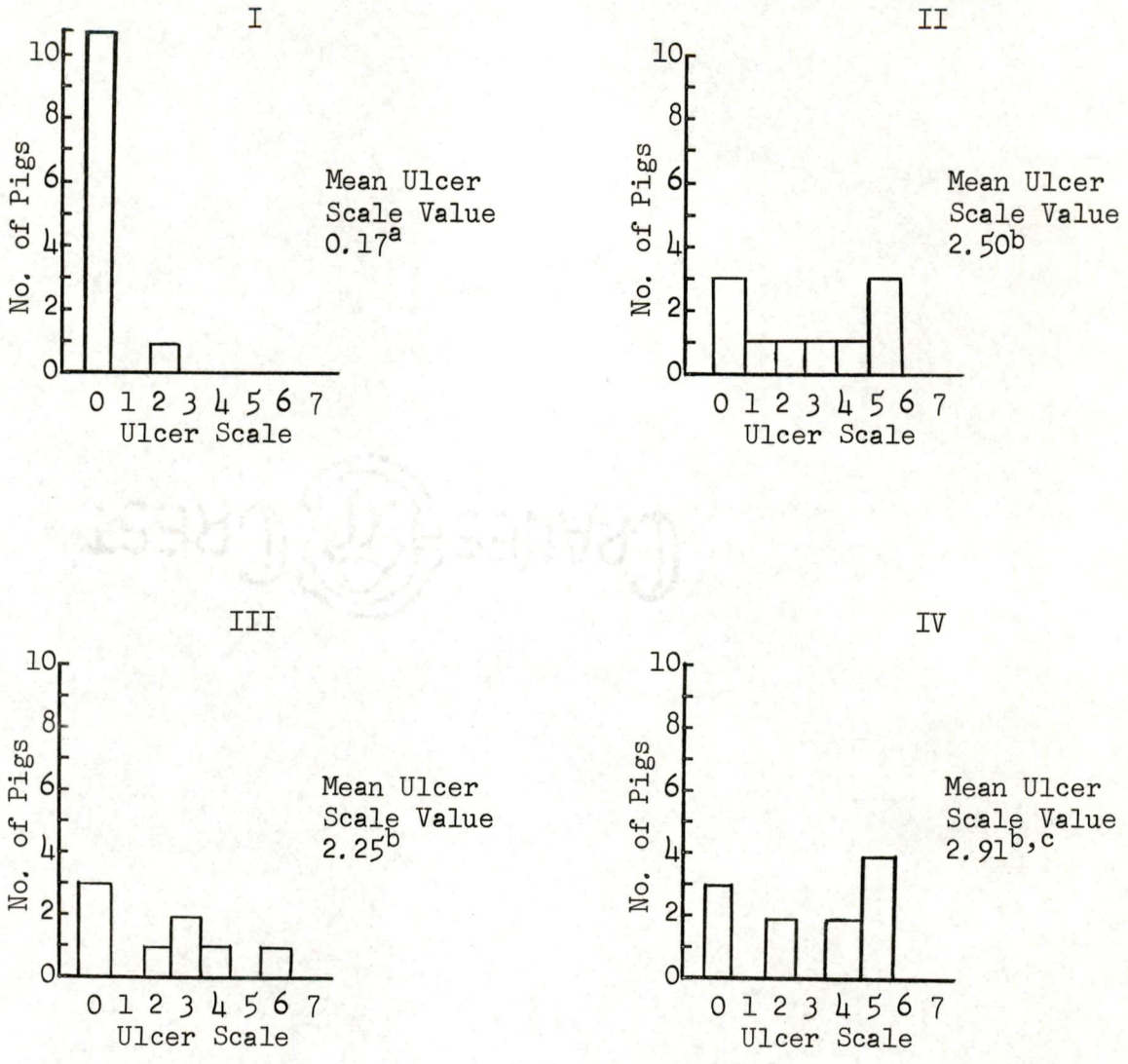
Differences in average daily gains were significant for both treatments and location, with the highest gains on pellets and pasture. Analysis for feed required per 100 pound gain revealed a highly significant treatment by location interaction which prevented testing of treatment and location differences.

Experiment VII

This experiment was designed to test the addition to the ration of certain products which were expected to reduce the amount of free acid in the stomach, and the possible influence of pig performance and incidence of esophagogastric ulcers.

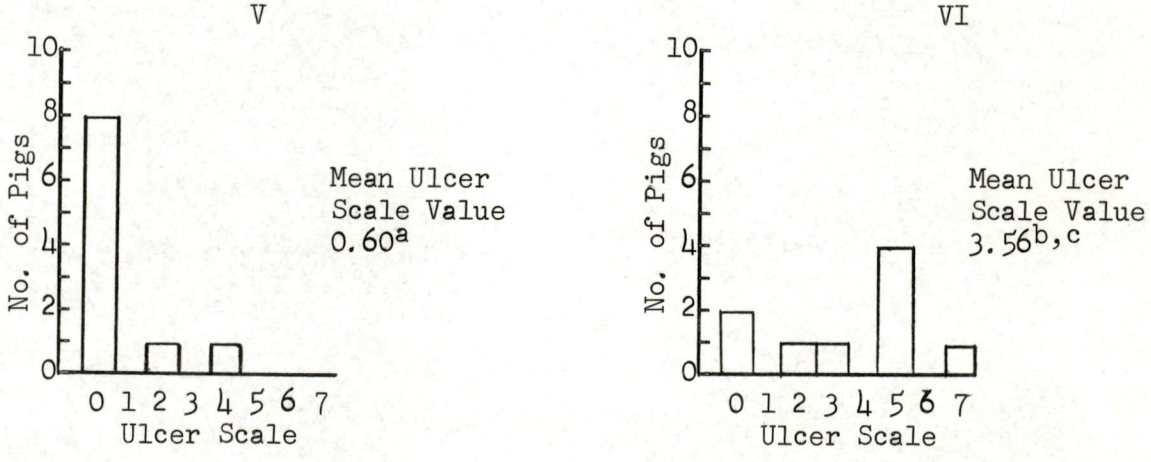
Effects of various rations on incidence of ulcers and performance of swine are shown in Figure 5 and Table XI. Of the pigs receiving the meal ration, only 1 keratinized esophageal area was found; of the pigs receiving pellets with a total of 6 per cent dehydrated alfalfa leaf meal, only 1 keratinized esophageal area and 1 "suspect" lesion were found. On examining stomachs from pigs receiving the pellet control, 3 keratinized esophageal areas, 1 "suspect" lesion and 3 definite ulcers were found; and from pigs receiving pellets containing 20 per cent oats, 2 keratinized esophageal areas and 5 definite ulcers were noted. Three keratinized esophageal areas, 1 "suspect" lesion and 1 definite ulcer were found when examining stomachs from pigs receiving pellets plus 1 per cent bicarbonate; while of those stomachs receiving pellets plus 3 per cent bicarbonate of soda, 2 keratinized esophageal areas, 2 "suspect" lesions and 4 definite ulcers were found.

Pigs receiving the meal ration had significantly fewer ulcers than did pigs on any other ration, but when the complete scale rating was taken into consideration, the treatment receiving pellets with 6 per cent dehydrated alfalfa leaf meal had a comparable mean ulcer score value to that obtained for meal. Pigs receiving pellets plus 1 per cent bicarbonate of soda had significantly fewer ulcers than did the pigs receiving pellets plus 3 per cent bicarbonate of soda, pellets or pellets plus 20 per cent oats. Significantly higher mean ulcer scores were obtained for pigs fed a pelleted 3 per cent bicarbonate of soda ration and pellets containing 20 per cent oats than for pigs receiving pellets or pellets plus 1 per cent bicarbonate of soda.



I. Meal
II. Pellets
III. Pellets plus 1% bic.
IV. Pellet plus 3% bic.

Figure 5. Ulcer classification and distribution by ration for Experiment VII, summer 1965.



V. Pellet plus 3% additional alfalfa

VI. Pellet with 20% oats

^{a,b,c}Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

Figure 5 (continued)

TABLE XI

EFFECT OF FEED ADDITIVES ON THE INCIDENCE OF ULCERS AND PERFORMANCE OF SWINE FED IN CONFINEMENT, SUMMER 1965

Ration Form	Control Meal	Control Pellet	Pellet	Pellet	Pellet	Pellet
Ration Source	Comm.	Comm.	Comm.	Comm.	Comm.	Comm.
Additives	--	--	1% Bic.	3% Bic.	3% Alf.	20% Oats
No. lots/treatment	3	3	3	3	3	3
No. pigs/lot	4	4	4	4	4	4
Av. wt. and gain, lb.						
Initial	44	44	44	44	44	44
Final	203	207	206	206	207	209
Daily gain	1.62	1.69	1.69	1.61	1.66	1.67
Av. age, days						
Initial	61	60	60	60	60	60
Final	159	156	156	160	159	158
Av. daily feed, lb.	5.11	5.28	5.17	5.20	5.18	5.21
Feed/cwt. gain, lb.	316	313	307	324	312	311
Mean ulcer score value	0.16[a]	2.50[b]	2.25[b]	2.91[b,c]	0.60[a]	3.56[b,c]
No. of suspect to severe ulcers/no. examined	0/12[a]	4/10[1c,d]	2/8[1c]	6/11[c,d]	1/10[1b]	5/9[1c,d]

[1]Stomachs lost during the slaughter process.

[a,b,c]Means in the same row followed by the same letter(s) are not significantly different ($P>.05$)--those followed by different letters are significantly different ($P<.05$).

Differences for average daily gain were not significant. Pigs on the treatment of a pelleted 3 per cent bicarbonate of soda ration required significantly more feed per pound of gain than did either the pigs on pellets plus 1 per cent bicarbonate of soda or the pigs on pellets containing 20 per cent oats.

To draw definite conclusions, more work would need to be done, but it appears from these data that the addition of bicarbonate of soda or 20 per cent oats did not significantly effect the incidence of ulcers.

CHAPTER V

SUMMARY

Three hundred and sixty-three pigs were used during a 3-year period to study the effects of: (1) ration form; (2) confinement or pasture feeding; (3) age of the pig at the time of introduction of a ration hypothesized to be ulcerogenic in nature; and (4) feed additives on the incidence of ulcers and pig performance. Three ration forms were tested; unpelleted meal, pellet and a meal from reground pellets. Rations hypothesized to be ulcerogenic in nature were introduced at 2, 8 or 19 weeks of age. A high level of vitamin A, the addition of two levels of a buffer (bicarbonate of soda), additional alfalfa leaf meal and oats were the feed additives or feed sources tested.

Conclusions drawn from the data observed were:

1. The pelleting of a ration under the conditions described significantly increased the incidence of ulcers, average daily gain and feed efficiency.
2. When the ration was reground and fed as a meal average daily gain and feed efficiency were reduced compared to average daily gain and feed efficiency of pigs fed the pelleted ration.
3. Pasture, when in abundant supply, significantly reduced the incidence of ulcers.

4. In this study age of the pigs, when the hypothesized ulcerogenic ration was introduced, did not significantly affect the incidence of ulcers.
5. The addition of 3 per cent bicarbonate of soda did not significantly reduce the incidence of ulcers but the amount of feed required per cwt. gain was significantly increased.
6. Alfalfa leaf meal when fed at the level of 6 per cent of the pelleted ration significantly reduced the incidence of ulcers when compared to a control ration containing 3 per cent alfalfa leaf meal.
7. The incidence of ulcers was not significantly affected when oats were used as 20 per cent of the ration.

In this study the lowest incidence of ulcers was observed when pigs received an unpelleted meal feed or when they received a pelleted ration containing 6 per cent alfalfa leaf meal.

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APPENDIXES

APPENDIX A

AVERAGE DAILY GAIN

Confinement

Summer 1963

	Meal	Meal	Pellet	Reground Pellet
Lot I	1.36	1.47	1.66	1.40
Lot II	1.53	1.54	1.72	1.64
$\bar{X}$	1.45	1.51	1.69	1.52

Winter 1963-64

	Meal	Pellet	Reground Pellet	Reground Pellet + Vit. A
Lot I	1.62	1.76	1.82	1.75
Lot II	1.79	1.97	1.82	1.84
Lot III	1.75	1.76	1.59	1.70
$\bar{X}$	1.72	1.83	1.74	1.76

Summer 1964

	Meal	Meal Pellet	Pellet Meal	Pellet
Lot I	1.61	1.70	1.45	1.65
Lot II	1.38	1.74	1.61	1.66
Lot III	1.64	1.71	1.43	1.57
$\bar{X}$	1.54	1.72	1.50	1.63

Winter 1964-65

	Meal	Meal Pellet	Pellet Meal	Pellet
Lot I	1.64	1.72	1.54	1.60
Lot II	1.70	1.66	1.58	1.60
Lot III	1.35	1.64	1.59	1.63
$\bar{X}$	1.56	1.67	1.57	1.61

Summer 1964

	Confinement		Pasture	
	Pellet	Meal	Pellet	Meal
Lot I	1.65	1.45	1.61	1.54
Lot II	1.66	1.61	1.54	1.44
Lot III	1.57	1.43	1.58[a]	1.49[a]
$\bar{X}$	1.63	1.50	1.58	1.49

[a]Mean values substituted.

Winter 1964-65

	Confinement		Pasture	
	Pellet	Meal	Pellet	Meal
Lot I	1.60	1.54	1.64	1.62
Lot II	1.60	1.58	1.67	1.55
Lot III	1.63	1.59	1.67	1.61
$\bar{X}$	1.61	1.57	1.66	1.59

Summer 1965

	Confinement					
	Meal	Pellet	Pellet + 1% Bic.	Pellet + 3% Bic.	Pellet + 6% Alf.	Pellet + 20% Oats
Lot I	1.69	1.65	1.74	1.47	1.70	1.77
Lot II	1.54	1.70	1.64	1.76	1.56	1.65
Lot III	1.63	1.71	1.68	1.59	1.73	1.60
$\bar{X}$	1.62	1.69	1.69	1.61	1.66	1.67

ANALYSIS FOR AVERAGE DAILY GAIN

Confinement

Summer 1963

Source	d.f.	s.s.	m.s.	f
Total	7	0.1138	-	
Treatment	3	0.0663	0.0221	1.18 N.S.
Error	4	0.0475	0.0188	

Winter 1963-64

Source	d.f.	s.s.	m.s.	f
Total	11	0.1107		
Treatment	3	0.0202	0.0067	< 1 N.S.
Error	8	0.0905	0.0113	

Summer 1964

Source	d.f.	s.s.	m.s.	f
Total	11	0.1501		
Treatment	3	0.0844	0.0281	3.43 N.S.
Error	8	0.0657	0.0082	

Winter 1964-65

Source	d.f.	s.s.	m.s.	f
Total	11	0.0985		
Treatment	3	0.0230	0.0072	<1 N.S.
Error	8	0.0755	0.0094	

Pasture and Confinement

Summer 1964

Source	d. f.	s. s.	m. s.	f
Total	9[a]	0.0709		
Tmt	1	0.0352	0.0352	6.64* (P<.05)
Location	1	0.0025	0.0025	<1 N.S.
TxL	1	0.0014	0.0014	<1 N.S.
Error	6[a]	0.0318	0.0053	

[a]Two d.f. subtracted to compensate for the use of the mean values.

Pasture and Confinement

Winter 1964-65

Source	d. f.	s. s.	m. s.	f
Total	11	0.0186		
Tmt	1	0.0086	0.0086	12.29** (P<.01)
Location	1	0.0040	0.0040	5.71* (P<.05)
TxL	1	0.0005	0.0005	<1 N.S.
Error	8	0.0055	0.0007	

Confinement

Summer 1965

Source	d. f.	s. s.	m. s.	f
Total	17	0.1106		
Treatment	7	0.0178	0.00356	<1 N.S.
Error	12	0.0928	0.0077	

APPENDIX B

FEED EFFICIENCY

Confinement

Summer 1963

	Meal	Meal	Pellet	Reground Pellet
Lot I	3.31	3.24	2.92	3.05
Lot II	3.19	3.17	2.90	3.06
$\overline{X}$	3.25	3.21	2.91	3.06

Winter 1963-64

	Meal	Pellet	Reground Pellet	Reground Pellet + Vit. A
Lot I	3.56	3.23	3.25	3.29
Lot II	3.38	3.04	3.20	3.14
Lot III	3.25	2.96	2.90	3.11
$\overline{X}$	3.40	3.08	3.12	3.18

Summer 1964

	Meal	Meal Pellet	Pellet Meal	Pellet
Lot I	3.04	3.09	3.35	2.97
Lot II	3.24	3.11	3.04	2.92
Lot III	3.28	3.08	3.26	2.95
$\overline{X}$	3.19	3.09	3.22	2.95

Winter 1964-65

	Meal	Meal Pellet	Pellet Meal	Pellet
Lot I	3.36	2.87	3.14	2.91
Lot II	3.14	2.91	3.29	2.93
Lot III	3.25	2.96	3.19	3.01
$\bar{X}$	3.25	2.91	3.21	2.95

Confinement and Pasture

Summer 1964

	Pellet	Meal	Pellet	Meal
Lot I	2.97	3.35	3.09	3.06
Lot II	2.92	3.04	3.18	3.30
Lot III	2.95	3.26	3.13[a]	3.18[a]
$\bar{X}$	2.95	3.22	3.13	3.18

[a]Mean values substituted.

Winter 1964-65

	Pellet	Meal	Pellet	Meal
Lot I	2.91	3.14	3.16	2.98
Lot II	2.93	3.29	3.17	3.12
Lot III	3.01	3.19	3.06	3.15
$\bar{X}$	2.95	3.21	3.13	3.08

Confinement

Summer 1965

	Meal	Pellet	Pellet + 1% Bic.	Pellet + 3% Bic.	Pellet + 6% Alf.	Pellet + 20% Oats
Lot I	3.15	3.31	3.09	3.27	3.18	3.06
Lot II	3.18	3.04	2.98	3.15	3.15	3.21
Lot III	3.14	3.04	3.13	3.30	3.04	3.06
$\bar{X}$	3.16	3.13	3.07	3.24	3.12	3.11

ANALYSIS FOR FEED EFFICIENCY

Confinement

Summer 1963

Source	d.f.	s.s.	m.s.	f
Total	7	0.1530		
Treatment	3	0.1431	0.0477	19.08** (P<.01)
Error	4	0.0099	0.0025	

Mean Separation

$S\bar{x}$ = .0548

r	3.93	4.01	4.02	
R	.215	.220	.220	
	C	D	B	A
	2.91	3.06	3.21	3.25

Winter 1963-64

Source	d.f.	s.s.	m.s.	f
Total	11	0.3602		
Treatment	3	0.1830	0.0610	2.75 N.S.
Error	8	0.1772	0.0222	

Summer 1964

Source	d.f.	s.s.	m.s.	f
Total	11	0.2183		
Treatment	3	0.1326	0.0445	4.16* (P<.05)
Error	8	0.0857	0.0107	

Mean Separation

$S\bar{x}$ = .0598

r	3.26	3.39	3.47	
R	.195	.203	.208	
	D	B	A	C
	2.95	3.09	3.19	3.22

Confinement

Winter 1964-65

Source	d.f.	s.s.	m.s.	f
Total	11	0.3144		
Treatment	3	0.2689	0.0896	15.72** (P<.01)
Error	8	0.0455	0.0057	

Mean Separation

$\bar{Sx}$ = .0435

r	4.74	5.00	5.14	
R	.206	.218	.224	
	B	D	C	A
	2.91	2.95	3.21	3.25

Confinement and Pasture

Summer 1964

Source	d.f.	s.s.	m.s.	f
Total	9[a]	0.2145		
Tmt	1	0.0752	0.0752	5.30* (P<.05)
Location	1	0.0169	0.0169	1.19 N.S.
TxL	1	0.0374	0.0374	2.63 N.S.
Error	6[a]	0.0850	0.0142	

[a]Two d.f. subtracted to compensate for the use of the mean values.

Winter 1964-65

Source	d.f.	s.s.	m.s.	f
Total	11	0.1456		
Tmt	1	0.0331	0.0331	5.43* (P<.05)
Location	1	0.0024	0.0024	<1 N.S.
TxL	1	0.0610	0.0610	10.00** (P<.01)
Error	8	0.0491	0.0061	

Confinement

Summer 1965

Source	d.f.	s.s.	m.s.	f
Total	17	0.1507		
Treatment	5	0.1000	0.0200	4.76* (P<.05)
Error	12	0.0507	0.0042	

Mean Separation

$S\bar{x}$ = .0375

r	3.08	3.23	3.33	3.36	3.40
R	.116	.121	.125	.126	.128

C	F	E	B	A	D
3.07	3.11	3.12	3.13	3.16	3.24