THE UNIVERSITY OF SASKATCHEWAN

PHYSICAL ASPECTS OF NON-RUMINANT NUTRITION

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by

NICK HUSSAR

SASKATOON, SASKATCHEWAN

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UNIVERSITY OF SASKATCHEWAN

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CERTIFICATION OF THESIS WORK

We, the undersigned, certify that Nick Hussar, B.Sc., M.Sc., (Alberta)

candidate for the Degree of Doctor of Philosophy

has presented his thesis on the subject, Physical Aspects of Non-Ruminant Nutrition

that the thesis is acceptable in form and content, and that the student demonstrated a satisfactory knowledge of the field covered by his thesis in an oral examination held on April 28, 1965

External Examiner

Professor of

Internal Examiners

ABSTRACT

Nutritionally adequate diets fed to pigs can be expected to yield varied responses due to physical attribute differences, feeding and processing methods, ingredient selection and other factors. Independent and interrelated effects of such dietary characteristics are of special interest where feed intake control in self-fed pigs is of prime economic importance. Evidence is provided in this thesis that rate of gain, feed conversion and carcass quality can be influenced by nature and texture of fibrous ration ingredients, pelleting, antibiotic supplementation and pig sex.

A 3 x 2^5 factorially arranged swine feeding experiment was conducted with finishing rations to assess the effects of: three fibrous diluents (cellulose, wheat bran, oat hulls), two or three daily feedings, two fiber moduli, pelleting, antibiotic supplementation and sex (gilt vs. barrow) comparisons. Response criteria included weight gains, feed intake and conversion, energy and protein digestibility coefficients, carcass traits, gastrointestinal weights, and chemical and physical measurements upon the ingesta from selected gastrointestinal segments. Ingesta assessment included specific gravity, Klasson lignin, proximate principle components, and ingestal fluid physical characteristics.

Treatments increasing daily feed intake included oat hulls, three daily feedings, fine moduli, pelleting or barrows. Growth rate increased only in barrows or pellet-fed groups. Cellulose or antibiotic supplementation improved feed

conversion, whereas oat hulls impaired it.

Oat hulls depressed digestible energy coefficients but increased protein digestibility. Both energy and protein digestibility coefficients were improved by antibiotic supplementation; however, both bulk type and moduli exerted an influence on this response.

Module effects were many and varied; the finer module generally increased feed intakes and conversion. It was noteworthy that fine wheat bran failed to exhibit many characteristic responses of wheat bran. This effect was attributed to destruction of the physical form in bran, namely "flakiness".

Carcass quality paralleled nutrient digestibility and feed intake alterations. The degree of finish, as influenced by fibrous diluent type, feeding frequency or sex, was associated with carcass yield. It was postulated that fluid retention differences in the gut, primarily between fibrous diluent sources, influenced the relative degree of tissue hydration and thereby affected carcass yield. Changes in carcass yield were associated with visceral weight differences observed on fibrous diluent or antibiotic comparisons.

Gastric density characteristics reflected attributes of dry feed. Pelleted, fine module or antibiotic-fortified feed increased gastric density but this effect became dissipated in the intestinal regions. It is possible that appetite-inducing effects of these treatments were manifested in terms

of stomach filling capacity. Ingesta differences attributable to fibrous diluent sources were maintained throughout the tract. The most voluminous ingesta source was wheat bran and the least, oat hulls. In terms of dry matter percentage, oat hull ingesta was the highest and wheat bran the lowest. Larger quantities of ingesta occurred in the rectal segment of oat-hull fed animals. It was postulated that this affect reflected ingesta volume differences upon lumen distention and defecation initiation.

Although dry matter and ingestal fluid physical measurement differences prevailed, these were difficult to correlate with animal performance and ration utilization. Increased fat levels were present in rectal samples from animals fed wheat bran. Antibiotic supplementation increased ingestal fluid pH and viscosity, but tended to reduce surface tension.

The large number of significant high order interactions rendered specific interpretation difficult, but such findings emphasize the important role that physical characteristics of the diet play in determining growth and development of animals fed nutritionally balanced rations.

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PHYSICAL ASPECTS OF NON-RUMINANT NUTRITION

INTRODUCTION

The use of known chemical values in formulating rations to meet recognized nutritional standards may result in varied animal response. Such a situation reflects our still imperfect knowledge of nutrition and inability to describe an ideal diet in adequate terms. Based on the implication that if the animal body is provided with an appropriate assortment of chemical constituents it can perform the functions expected of it, considerable effort has been expended equating nutrient needs to chemically assessable elements. Possessing adequate information on the specific nutrient requirements of a living organism, and on the digestive availability of the nutrient source material, the major problems surrounding nutrition are usually surmounted. However in certain instances ingredient selection for ration make-up is such that inconsistencies occur between expectations and performance. Research has disclosed that, in addition to the chemical constituents, certain physical attributes of some ingredients and subsequently of the ration itself, may be the causative agents for the observed divergences.

Nutritive quality and quantity control, chiefly by caloric manipulation has been a long established practise in the production of desirable carcass characteristics in domestic animals destined for slaughter. A ration with a reduced caloric density, yet adequate in other essential components, reduces growth rate and adipose tissue production. Self-feeding practises in swine raising and the production of lean carcasses may be made compatible through the selective use of fibrous feedstuffs for purposes of controlling caloric intakes. The growth in-

hibitory effects of dietary fibrous feedstuffs, utilized for caloric dilution by virtue of their indigestibility and bulk contributing attributes, have been shown to be dependent not only upon their level but also on the origin of these constituents.

The use of fibrous or bulky feeds has implications other than the reduced digestible energy per unit weight of food. Apart from their nutrient contributions, the behaviour of these feedstuffs in the digestive tract may modify enzymatic and absorptive processes, passage rates and intestinal microflora. Alterations of feed consumption by animals receiving such rations may result from an attempt to fulfill appetite. There is a suggestion that in an effort to increase feed processing capabilities an adaptive change in the digestive tract capacity may occur within the animal.

The study reported herein was instigated to observe performance of finishing market pigs on rations similar in protein and energy, but differing through the use of three dietary fibrous diluents. In order to elucidate the behaviourial differences of these, additional treatments involving feeding frequency, modulus of fineness, ration pelleting, antibiotic supplementation and pig sex comparisons were superimposed. It was expected by using such treatments that ration density, digestibility and other factors could be evaluated. The measures adopted to assess the results included ration utilization, animal productivity, ingesta characteristics and changes in alimentary tract weight.

LITERATURE REVIEW

The developing animal is in a sense a product of its nutritional environment. Expression of the inherent growth potential and direction is dependent on the establishment of adequate nutrition. This in turn is contingent upon appetite, access to food and the contribution the diet can make to the developing organism. For the purposes of classifying the relevant literature, the aforementioned factors have been grouped into either appetite, its origin, abatement and related factors or into growth, its definition and control.

Appetite and its control

Body needs for energy and nutrition are met by food intake, and subsequent anabolic and catabolic processes within the organism. The implications of a balanced intake are obvious in influencing the magnitude of weight losses or gains. It has been interpreted from studying caloric intake patterns in fistulated dogs (Janowitz and Hollander, 1955), that there are two appetite regulatory mechanisms, namely: a homeostatic metabolic device to insure adequate caloric intake under varying caloric need; and a neural mechanism tending to maintain the ingestion act regardless of caloric need.

Neural

The resulting obesity from Frolich's syndrome, due to a tumor of the hypophysis, has long been observed. In addition, it has been shown that injury to the hypothalamus, in the region of the hypophysis, perpetrated a similar condition (Best and Taylor, 1962). An indication of elevated activity in particular areas of the hypothalamus in hungry animals

has been demonstrated by detecting increased levels of high energy phosphate compounds during this state (Larsson, 1954). Bilateral lesions in the ventromedial nucleus of the hypothalamus creates obesity (Khairy et al., 1963). Injuries to the hypothalamic nuclei, just lateral to those involved in obesity, cause the animal to stop eating (Best and Taylor, 1962). It has been demonstrated that even in those animals with hypothalamic lesions excessive food intakes stopped when the animals became obese (Khairy et al., 1963). The effect of drugs that control obesity can be destroyed in animals with hypothalamic lesions (Kennedy and Metra, 1963). Such data have been reviewed by Holder (1963), and present day concepts are that the neural aspects of appetite control are localized in the hypothalamic centers. The locale for appetite has been established as being in the lateral hypothalamic region, and that for satiety in the ventro-medial hypothalamus.

Brobeck (1957) suggested the hypothalamic centers control food intake by facilitating or inhibiting the reflex mechanisms involved in food acquisition and ingestion, which he calls "feeding reflexes". Of these, sensory, olfactory, auditory, tactile, gustatory and enteroceptive (intestinal) reflexes are the sensory mechanisms arousing the reflexes of attention, approach, examination, incorporation and rejection. The hypothalamic centers therefore control food intake indirectly by varying the response of the lower brain centers to stimuli and subsequent control of food acquisition, consumption and assimilation.

Metabolic

Starvation or food absence initiates hunger and excites the feeding centers, subsequent food consumption induces satiety and stimulates

impulses inhibitory to feeding. Gastro-intestinal mechanisms, mainly physical, acting on sensory nerve endings, and metabolic agents, chiefly chemical substances detected by a hypothetical sensory device in the central nervous system, are postulated as acting on the appetite control centers. Hunger contractions of the stomach and small intestine have been linked with blood sugar level (Sparchez et al., 1957; Best and Taylor, 1962), others (Quigley, 1955) deny any link with this. Best and Taylor (1962) state that severance of nerve supplies merely removes the hunger sensation but not the state in man.

Brobeck (1957) has outlined a schematic diagram of the balance between appetite and satiety:

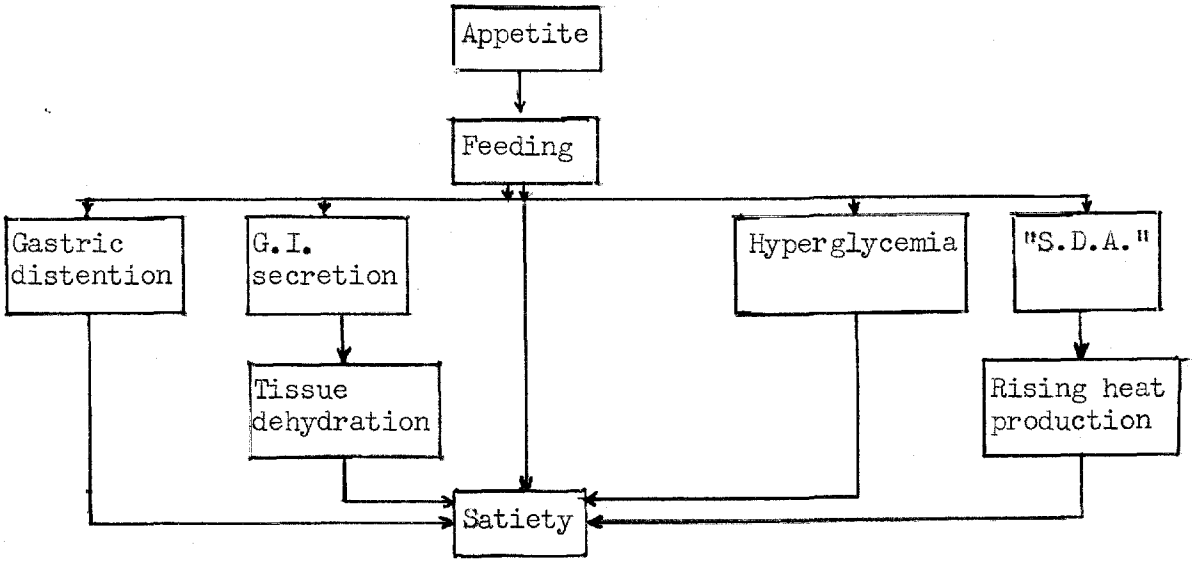


Figure 1 - Factors involved in appetite and satiety (Brobeck, 1957)

Holder (1963) cited literature indicating that the postulated stimulators of the hypothalamic centers are S.D.A. of feed eaten, osmotic effect of the diet, sensory impulses from the tract and concentration of metabolites in the blood. In monogastric animals the utilization of

glucose by hypothalamic centers had been implicated, however Holder found that in the sheep neither glucose nor acetate level of the blood served to regulate appetite. Nasset et al. (1963) proposed that chemoreceptors in the intestinal mucosa may serve to regulate food intake even before possible changes in the chemical composition of the blood could initiate regulatory changes in the central nervous system.

Nutritionists tend to consider food intake regulation in terms of caloric requirements. According to Best and Taylor (1962) a theory exists that total energy stores, predetermined by a balance between hunger and satiety, are maintained at a set level. Animals consuming adequate amounts of all dietary components, except calories, can be expected to exhibit a tendency toward caloric regulation of dietary food intake (Rice et al., 1957). Others (Winchenden et al., 1957; Wilger, 1957, Yoshida et al., 1957) suggest that when dietary energy levels are at or near maintenance, body weight changes are correlated with protein intake. The investigations of Sibbald et al. (1956, 1957) led them to conclude that in the rat there was an optimal digestible energy level for nitrogen retention within each caloric density. Singsen (1957) suggested that growth rate and feed efficiency were more closely correlated to total energy than calorie: protein ratio. It was his concept that the calorie:protein ratio was modified by the total protein in the diet and the proportion of calories derived from fat. The work of Bowland et al. (1958) would tend to confirm the beneficial effect of added fat on nitrogen digestibility and retention. Clawson et al. (1962) have concluded that energy utilization in swine was not influenced by the calorie:protein ratio, however, daily feed intake was. Variations in protein intake have been demonstrated to affect carbon

and energy retention in swine (Cunningham et al., 1962).

Intestinal fill

Food consumption has been related to passage rates (Miller and Kriss, 1934; Castle and Castle, 1957). The effector mechanism appeared to be related to intestinal tract pressures exerted by the amount of fill (Miller and Kriss, 1934; Cooper and Tyler, 1959). In administering food via gastric fistula to dogs, Share et al. (1952) observed that a bulky inert substance in the stomach only exerted an influence on appetite if given just prior to a meal. Holzel (1947), Janowitz and Grossman (1949) and Janowitz and Hollander (1955) all indicated that stomach distention via inert substances, balloons or fistula feeding decreased hunger. From observations following removal of the influence after vagotomy, Paintal (1954, 1954a) concluded that stretch receptors in the stomach are responsible factors in hunger sensation. Share et al. (1952) felt that gastric distention although a factor in hunger, was accompanied by a systemic factor, and neither method alone was totally effective.

James (1957) considered "food factors" such as quantity, physical and chemical nature, osmotic strength, temperature and bacterial content capable of influencing the effluent emerging from the stomach and the subsequent characteristics in the intestinal tract. Sellers et al. (1961), suggested that motor activities of the forestomach of cattle were dependent on ingesta characteristics.

In general, it would appear that rather than serving in the longterm regulation of energy input and output blance, gastric factors are more important in determing the relative size of an individual meal.

Gastric filling and evacuation

Best and Taylor (1962) state that food first eaten passes to the fundic region of the stomach to lie against the greatest curvature. Successive portions consumed are nearer the lesser curvature and as the organ is filled the final portions remain in the cardiac region. Liquids tend to flow near the lesser curvature towards the pylorus. Larger volumes of liquid may even flow around the entire food mass and pass on into the duodenum. In the stomach the main energy of contraction is directed towards mechanical movements rather than expulsion of food. The rate of stomach emptying is determined by numerous factors including total volume of the gastric contents and its consistency, chemical composition, pH, and osmolar concentration. The rate of emptying has been described as an exponential function (Hunt and Macdonald, 1954; Beccari, 1957; James, 1957; Rosenthal and Nasset, 1958; Hunt, 1959; Best and Taylor, 1962). Rogers et al. (1960) found the pattern varied from nearly exponential to nearly linear. They attributed this to animal differences, completeness of the diet, level of dietary protein, the type of carbohydrate and amount of diet fed. The amounts of nitrogen received from the stomach and small intestine in the first hour were always less than fed. Cannon (1911) stated that undigested solids do not pass the pyloric sphincter but remain in the stomach until they are reduced to a fluid or semi-fluid consistency. Cannon further noted that the retention times of foods (in man) in order of increasing time were carbohydrate, proteins and fats.

Hunt (1956) showed that in humans adding salt to water to a concentration of 100 meq./l. hastened emptying of water from the stomach,

above 150 meq./l. the effect was delaying. He concluded that gastric contents made either hypertonic or hypotonic with respect to blood caused variations in stomach emptying. Castle and Castle (1957) noted increased water consumption accelerated intestinal passage rates. There are reports that there is an increase in apparent absorbability when the watering interval is lengthened, this effect is most apparent on crude fiber digestion (Konish and McCay, 1960). However these authors cite references that the gastric content of rats were maintained at a constant moisture percentage regardless of water intake. A significant effect of water on feed consumption in swine and rats has been demonstrated (Smith et al., 1959; Barber et al., 1963). Injections of increasing volumes of water into the stomach, prior to feeding, inhibited the post-feeding water intake to some extent in rats, but even twice the previous voluntary consumption did not prevent it completely (Moyer and Bunnel, 1962).

James (1957) states that there are individual variabilities for gastric emptying rates. Others have noted similar variations in gastrointestinal passage rates (Teague and Hanson, 1954; Reynel et al., 1956; Rogers et al., 1960). The actual control of stomach emptying is still being debated (Best and Taylor, 1962), however it is usually conceeded that the sphincter muscle and the gastric motor reflexes are the controlling mechanisms. Factors such as gastric fluidity cause the initial flow to begin into the intestine in man, flow regulation begins when material in the intestine reaches the point where one of the controlling stimuli has reached threshold value. Regulation depends on the chemical and to some extent volume characteristics of the chyme.

Hunt (1959) and Rosenthal and Nasset (1958) indicated the de-

pendence of gastric emptying on chemical characteristics of the ingesta. However, Hunt felt that the rate was dependent on caloric rather than osmotic effects. The conclusion was that the greater the gastric volume, the greater the outflow. Hunt stated that the volume of the intestine, the"recepticle capacity", set a resistance to stomach outflow. Gastric emptying has been observed even in the absence of peristalsis. Ritter (1956) failed to detect evidence of intestinal tract swelling behaviour in response to application of small pressures. However the duodenum and colonic portions displayed elastic hysteresis. Loops of duodenum and small intestine expanded rapidly under applied pressure and the colon retracted. It has been demonstrated that stomach emptying responded to the action of sensory receptors receiving impulses from osmotic conditions in the duodenum and small intestine (Hunt, 1960; Hunt and Pathak, 1960). Best and Taylor (1962) state that in the chyme the chemical stimuli in order of inhibitory potency on gastric emptying are fats, fatty acids, proteoses, peptones, amino acids, sugars and other starch degradation products, pH, osmotically active substances and non-specific irritants. The effect is to reduce stomach tone and subsequent pressure against the pyloris. Powerful inhibitors, i.e. fat (Loukes et al., 1961) may actually reverse the pressure and result in regurgitation back into the stomach. The enterogastric reflex is exerted through the vagus nerve, or via enterogastrone, a hormone acting in the blood stream, either or both of these can cause inhibition. Other factors such as hormonal components of HCl, protein digestion products, pyloric sphincters control and other unknowns may be implicated in ways as yet unknown.

Alimentary canal filling and evacuation

Current theories involving motivating factors for alimentary canal movements are merely descriptive and often contradictory. The following is a summary derived mostly from Best and Taylor (1962). Movements in the small intestine are confined to segmented contractions occurring along short segments and so called pendular movements, which many consider the same as segmented movements. The frequency of these movements lessen as the distance from the pylorus increases (Hasselbrack and Thomas, 1961; Best and Taylor, 1962). Many feel that the control of these contractions arises from excitation centers in regions above the contraction site. Such movements aggitate, increase subdivision and change fluid contact of the ingesta with intestinal walls to facilitate nutrient absorption. Peristaltic waves originate at irregular intervals and may travel a few inches to several feet. Irritants, such as cathartics, frequently produce contractions that may sweep through the entire small intestinal tract. The control of these waves may be local or central reflex centers, by hormones, circulating metabolites, or actual muscle history - i.e. fatigue, etc. Hasselbrack and Thomas (1961) considered their experiment supported the pacemaker concept in control of the intact intestine.

The intestine has been observed to have peristaltic waves traveling in one direction only. Bayliss and Starling cited by Best and Taylor (1962) derived their "Law of the Intestine" in 1899 and 1911. This law states that the response of the small intestine to local stimuli is a contraction of the smooth muscle above the stimuli and relaxation below it. The stimuli site is propagated as the stimulant moves, this induces

new contraction and relaxation sites and thereby propells the ingesta through the tract. Best and Taylor (1962) also refer to a second theory to explain intestinal functioning. Alvarez in 1940 proposed a "gradient" theory, suggesting a mechanism in the intestine comparable to the pacemaker of the heart. This concept has its adherants, among them Hasselbrack and Thomas (1961) and others. Diament et al. (1961) studying the isolated guinea pig ileum concluded that if any sensory neurons existed they were located in the basal layer of the intestinal wall and not the layer containing the villi.

During absorption the villi, under neural and (or) hormonal control become active, as indicated by apparent lashing, shortening and lengthening movements. Ivanov (1958) using ganglionic blocking agents inhibited glucose absorption in rats. This inhibition of such an absorption process may be indicative of neural mechanisms acting on the villi. Razin et al. (1961) indicated existance of a hormonal link not only involving lymphatic flow but intestinal motility. Secretin was used to initiate greater lymphatic flow through the secretory flow from the thoracic duct, this flow persisted after pancreatomy, but was abolished after excision of the small intestine including the duodenum. They suggested that a substance other than secretin caused some of these effects.

The ileo-colic valve controls flow from the small intestine via its unique form, a constricture composed of circular muscle fibers. This "valve" yields to low pressure from the small intestine but only to high pressures in the cecum. The colon receives the residues after they have transversed the intestine. Water is extracted in this region and the indigestible residues constitute the fecal mass. The colon has two functions,

absorption and propulsion. Colonic contents are aggitated and mixed by various contractions. Trautman and Asher (1940) detected a definite series of movements in the pig associated with anatomical arrangement. In the proximal portion, oscillating, bending and tonic movements were noted and then peristaltic waves of varying intensity. In the terminal region only peristaltic movements were noted. Yasukawa and Otsubo (1954, 1954a) noted that such movements were initiated in the cecum when food was sighted, inhibition of oral and mucosal senses prevented this. Strengthened contractions and vasodilation during feeding were interpreted as increasing the "motility" of the pacemaker. Espe and Cannon (1940) noted that stomach filling caused colonic movement and often defecation in calves. Best and Taylor (1962) state that the mere sensing or sight of food or its ingestion can instigate colonic movements, others indicated a positive correlation of frequency of cecal movements and quantity of food taken (Yasukawa and Otsubo, 1954). Colonic peristalisis may propel the ingesta analward, into the rectal area, wherein defecation reflexes are instigated. Neural centers for the eliminatory act have been localized in the hypothalamus, in the spinal cord, and in the ganglionic plexus of the gut. During evacuation the anal sphincters are relaxed, and both reflex and voluntary action ensues. Swine exhibit patterns of elimination, influenced by feed and water locations (Hafez, 1962). Peristaltic waves, producing pressures of 40 - 50 mm Hg in the dog (Karlan et al., 1959) and reported as high as 200 mm Hg (Best and Taylor, 1962), evacuate fecal material from as far as the distal colon. The defecation reflex is normally initiated by passage of feces into the rectum (Best and Taylor, 1962), others (Cooper and Tyler, 1959) have suggested that it may

also be due to pressures prevalent in upper regions of the tract.

Nutrient absorption

Transport

Wilson (1962) indicates that transport of absorbed nutrients is accomplished in the lymphatic and blood flow systems. Absorbed triglycerides containing long chain fatty acids, cholesterol, absorbed protein, the latter in some instances unaltered i.e. colostrum, egg albumin, etc. can be detected in the lymph. Up to 500 to 1,000 times lymphatic levels of carbohydrate and protein derivatives are found in the blood stream. Wilson (1962) suggests that the practically complete absorption of protein and carbohydrate by blood is not due to selective resorption but chiefly attributable to volume flow differences between blood and lymphatic fluids circulating through the intestinal walls.

Mechanisms

The actual mechanisms of intestinal absorption have been partially elucidated, however only passing reference can be made to the voluminous data on this subject. Wilson (1962) has presented a comprehensive review on the subject and only selected portions of his treatment will be reported here. Permeability phenomena can be subdivided into passive diffusion, and special forms such as active diffusion, facilitated diffusion and pinocytosis. Although the latter mechanisms are responsible for the absorption of most nutrients, simple diffusion is important for water soluble vitamins, nucleic acids and lipid soluble substances. Diffusion is proportional to the concentration gradient, the membrane thickness and area of membrane. Sugars such as sorbose, xylose (Small *et al.*, 1959) and fructose, have been shown to pass through by such a pathway. The evidence that

these sugars are absorbed by such a mechanism was inferred from behaviour over a wide range of concentrations. They were not absorbed against a concentration gradient, were dependent upon initial concentration for rate, other sugars did not compete with them and metabolic inhibitors did not affect their diffusion rate. Some starch compounds with molecular weights of 200 to 400 can also penatrate the cell membranes by the simple diffusion process. Many drugs and other substances which are lipid soluble may pass through by dissolving in the lipid cellular membrane. Cells, intestinal epithelium among them, are known to be more readily permeable to the undissociated rather than the dissociated molecule. The rate of penetration of weak acids and bases may be increased by altering the pH of the environment in the direction of the pK of the compound.

In spite of such apparent unselective mechanisms as mentioned above the intestinal barrier is considered a relatively impermeable and selective membrane. There are exceptions, Juhlin (1959) stated that there were indications of particulate passage through the wall, however, he showed that spheres ranging in size from 0.1 to 0.2 microns failed to be absorbed. Wilson (1962) states that bacteria, starch grains and hydrocarbon emulsions are rejected. Evidence of particulate absorption, frequently thought of as being restricted to the newborn, has been shown to occur in adults. The intestinal epitheium serves as an effective barrier for a variety of substances, among them are compounds that are charged or those of higher molecular weights. The cathartic action of substances like phenol red, an example of a charged molecule of moderate molecular weight, are attributable to their non-absorption.

In some instances bulk flow of water may occur. This is a

process differing from osmosis. Water can flow to regions of differing solute concentration through cell membrane pores. The flow may be capable of dragging along smaller solute molecules, and if of sufficient magnitude produce electric potentials. Such a mass fluid movement, induced by hydrostatic pressure, has been demonstrated to inhibit intestinal glucose transport (Wilson, 1962).

For many substances, membrane traversing by simple diffusion is too slow, and in instances where this movement is against an electrochemical gradient energy is required. To overcome such obstacles to membrane movement, the living cell has developed an active transport mechanism. Such an active process facilitates the movement of glucose, amino acids, fats and NaCl. The latter is also followed by an osmotic movement of H_2O. (Fridhandler and Quastel, 1956, 1956a; Jervis and Smith, 1959; Small et al., 1959; Lin et al., 1961; Wilson, 1962). With the exception of B_{12}, active transport mechanisms are responsible for little if any movement of water-soluble vitamins. The absorptive mechanisms of the fat-soluble vitamins is currently unknown. Non-electrolytes, such as glucose, once transported across the cell membrane, are removed from possible interference by conversion into other associated compounds, such as phosphorylated derivatives. The altered derivatives are prevented from diffusing back into the lumen by differential cell permeability.

To explain the active transport mechanism a membrane carrier has been postulated. Substances approaching the outer cell membrane combine with it and form a substance-carrier complex which then moves across the permeability barrier, to the inner membrane surface where the compound is released. Carrier mediated diffusion, known as facilitated diffusion, can be accomplished without energy expenditure, where there is no electrical gradient

established. James (1962) states that D-xylose in the intestine is believed to move this way. Pinocytosis is a primative mechanism, the food particle being actually engulfed or dissolved by a process of vesiculation. Protein and particulate absorption in infants is believed to occur this way. Dye, particle, and according to recent evidence, lipid absorption, has been demonstrated to occur via this mechanism in older animals, as well as in the young.

Sites

Sugars and degradation products of the more complex carbohydrates are acted upon by the hydrolytic enzymes in the small intestine. The upper portion of the small intestine, particularly the duodenum, absorbs sugars, while the stomach and colon absorb little if any. However, Reynel and Spray (1956) indicated evidence of glucose absorption in the stomach. Unhydrolized disaccharides passing into the colon are subjected to bacterial hydrolysis and fermentation. A patient lacking invertase may pass large amounts of fatty acids in the stools following sucrose ingestion, but not on a sucrose-free diet. In young children in certain instances diarrhea and weight losses have been traced to the inability of the gut to split disaccharides with consequent excretion of the unabsorbed sugar with an osmotic equivalent of fluid. Sugar absorption, dependent on its form, is chiefly through active absorption mechanisms, however, as mentioned for certain sugars some of the other mechanisms are also implicated (Wilson, 1962).

Protein absorption is unique in that it is diluted several fold by endogenous protein originating mainly from the enzymatic secretions and also from such sources as mucoids and desquamated cells (Ju and Nasset, 1959; Nasset and Ju, 1961; Wilson, 1962; Nasset et al., 1963 and others).

Rosenthal and Nasset (1958) estimated that protein recovery in the rat varied from 31 to 1400%, Twombly and Meyer (1961) were more conservative in their estimates and reported that a dilution of 175% may occur in the small intestine, Wilson (1962) indicated a three fold dilution as a reasonable representation, Nasset et al. (1963) considered the mixing of exogenous and endogenous protein in the gut as a homeostatic mechanism to prevent large changes of free amino acids. The feeding of imbalanced proteins over a prolonged period of time may result in a breakdown of this mechanism. The dilution varies with differing conditions in different animals, however, it is an important factor in protein digestion and absorption. The importance of pinocytosis in protein absorption is chiefly thought of as a feature of the newborn, it may be of minor importance in adults. Wilson (1962) has indicated that the pinocytosis phenomenon shows predilection for the lower segments of the small intestine.

Peptides as such are poorly absorbed, and chiefly amino acids are present in the portal blood following digestion. It has been demonstrated that active transport, associated with a considerable specificity, moves the amino acids across the epithelial barriers (Lin et al., 1961; Wilson, 1962). The specific carriers are thought to be selective for carboxyl and amino groups and for hydrogen, however the side chain does not appear to influence the selection. The site of amino acid absorption is the small intestine, the entire region being similar in importance, however neutral amino acids are absorbed more in the mid region. There is some question about amino acid absorption in the colon.

One of the major functions of the intestine is the ingestion, secretion and regulation of electrolytes (Grim et al., 1955; Wilson, 1962).

As an example, man ingests an average of 1.5 liters of fluid daily, however coupled with intestinal secretions a total load of over 7 liters is imposed on this system. Of this fluid, about 150 ml. are lost in the feces indicating that over 8 liters are reabsorbed. The stomach, although a site for water flux, does not serve as an absorption site for fluids and electrolytes. One of the functions of the duodenum is the equilibration of intestinal lumen and blood contents. The major site of fluid resorption in man is the upper region of the small intestine (Grim et al., 1955; Wilson, 1962). Considering the jejunum as the "upper" segment, Wilson (1962) indicates that most electrolytes are absorbed in the upper and mid regions of the small intestine, although there are absorption processes occurring in the lower region. The colon is indicated as a site for Na^+ and H^+ absorption and HCO_3^- and K^+ secretion. Other electrolytes such as Ca^{++}, Fe^{++}, SO_4^-, Sr^{++} and Cl^- may possibly be absorbed or secreted in the colon as well, however their primary route is in the small intestine.

Fat and triglyceride absorption have been indicated as occurring in the small intestine, however opinion varies as to the exact location. Best and Taylor (1962) and Wilson (1962) consider the more distal sections as the probable sites. There is a suggestion of triglyceride absorption in the colon. Recent work has established the absorption of volatile fatty acids (VFA) in the cecum and colon of swine (Friend et al., 1962, 1963). Small amounts of fat hydrolysis have been reported to occur in the stomach. Wilson (1962) states that all animals excrete fat in the feces. The origin of fecal fat is the subject of controversy, however it is postulated that it originates from unabsorbed food fat, from bacterial synthesis, or according to recent views, from desquamated intestinal epithelium (Burr et al.,

1960; Linazasoro and Diaz, 1960; Wilson, 1962). The actual mechanism of fat absorption is thought to be active transport, however particulate absorption, dependent on particle size, pinocytosis and the lipid solubility diffusion hypothesis have all been advanced as possible absorption mechanisms.

Information concerning the absorption of vitamins is very sparse, however Wilson (1962) feels that many of the water soluble vitamins are probably absorbed by simple diffusion. There is a suggestion of an active transport mechanism for choline. Vitamin B_{12} is unique in that it requires a larger protein molecule than itself for its absorption. The vitamin B_{12} is referred to as the "extrinsic factor" and the protein compliment as the "intrinsic factor". The latter is produced by the chief cells in the fundic region of the stomach. There is evidence that the intrinsic factor and the absorption site are species specific. In many species the ileum is implicated as the absorption site and recently there has been a suggestion that pinocytosis is the mechanism for membrane transport of the vitamin B_{12} - intrinsic factor complex (Wilson, 1962). Fat soluble vitamins are known to require bile for their absorption. Wilson (1962) feels that the probable mechanism for membrane diffusion is by the lipid solubility mechanism. Carotene is unique in that it is absorbed into the intestinal epithelium where it is converted to vitamin A. In some species following the injection of carotene it was shown that this conversion could occur elsewhere (in the rat), however in other animals (in calves) there was no conversion following removal of the small intestine.

In the absorption of drugs, factors such as pH, lipid solubility and others affect their uptake. The absorption can occur as early as the

stomach or be delayed until lower regions are reached. There is sparse information concerning antibiotic absorption, however some of the above mentioned factors undoubtedly play a role. Some antibiotics, being highly charged, such as streptomycin and bacitracin, are poorly absorbed. Others, such as erythromycin and carbomycin, being weak bases are readily absorbed in the ileum where favourable pH ranges exist for these compounds to be in the undissociated form.

Based on the behaviour of mecamylamine, a drug used in relieving hypertension, Wilson (1962) infers that many drugs may recirculate through the intestine. This drug is "secreted" into the stomach and is resorbed in the small intestine. Certain endogenous compounds are also known to be recirculated through the intestine, secretion of substances into the bile and their subsequent resorption in the small intestine is a well known example. Iodine is another example, it is secreted in the saliva and is re-absorbed in the stomach or the small intestine (Wilson, 1962). It is very probable that some glandular secretions may possess similar recirculatory patterns.

Growth

Definition and forms

Growth has been defined as "a correlated increase in the mass of the body in definite intervals of time, in a way characteristic of the species", (Schloss, 1911). The individual animal cell represents the ultimate unit of growth. Cellular growth is accomplished by hyperplasia - an increase in cell numbers, and by hypertrophy - an increase in cell size. Unlike embryonic growth, where both cellular hyperplasia and hypertrophy occur, in the adult three forms of cells exist. These forms are the permanent cells, such as nerve cells which cease division in early prenatal

life and become fixed in number; the stable cells, such as most of the organs, which divide for a variable but major portion of the growth cycle and become fixed in adulthood; and the labile cells, such as epithelial and epidermal cells, dividing throughout life, with the exception that in the adult the process becomes limited to cellular replacements. Cells of all three groupings undergo hypertrophy during growth, some such as muscular development, may be increased with physiological demands, others such as adipose tissue may be influenced to an extent by the nutritional environment.

Development

In the developing animal there must be complete and co-ordinated growth of all its parts, thereby involving a multitude of interrelated processes. Growth conforms to the "law of developmental direction", as evidenced by the existence of a well defined anterior-posterior gradient from earlier to later developing regions (McMeekan, 1941). The classical work of Hammond (1932) indicated that this involves an increase in structural tissues such as bone and muscle, next the organs, and lastly an increasing tendency for fat deposition. Subject to individual and species variability, maximal size and development rate are attributable to heredity; however, as Mendel and Hubbell (1935) observed, planes of nutrition can exert a profound influence on these growth characteristics and the ability of the organism to attain its hereditary possibilities. Such observations have been repeatedly confirmed by numerous research workers as well as being common knowledge to both laymen and scientists.

During development of an individual there will be a preferential growth of parts at a given time. Nutrient intake will of course be capable

of influencing this development rate and during the growth cycle the quantitative and qualitative aspects of the diet can create conditions that influence subsequent growth phases, especially adipose tissue deposition. When growth is directed towards adipose tissue formation, increasing increments of growth are attained at an ever increasing cost in terms of feed increments per unit gain. Crampton (1956), quoting calculations of Kriss, estimated that in cattle, "double the calories deposited as body fat would be required in the ration in excess of maintenance energy". Dole (1959) considered fat as both structural and mechanical, serving the animal as an insulator, a cushioning agent and an energy store. Fat, averaging 88% carbon and hydrogen is a highly efficient form of energy storage, however, it is then evident that it must also be costly to form. Fat serves as a throttle to body energy flow by adjusting to cellular needs and responding to hormones, the latter being the regulators of body processes. Substantial portions of the dietary sugars, starches and even excess protein may be channeled into adipose tissue, where it is available for cellular use should the occasion arise. Fat was once considered solely as a consequence of intakes of food in excess of quantities utilized or excreted. Dole (1959) considers that fat should be considered in terms of body needs, as imposed by production and activity demands, when considering means of control over its deposition.

Bacon-type hogs in this country are marketed at about 200 lb. liveweight and well under a year of age. Hammond (1932) noted that during the final stage, as the animals are approaching market weight, body depth changes and fat deposition tend to be maximal in the bacon-type hog. Examination of performance data would suggest that the point of inflection

on the growth curve, mentioned by Crampton and Lloyd (1959) as the point where maximal growth rate and efficiency of feed utilization is prevalent, has been reached and passed by the time the bacon hog is marketed. At the time of market one of the measures of productivity is carcass quality, serving as a basis for financial remuneration when equated with carcass weight. Although the carcass may be partially separable into the three major components of bone, lean and fat, consumer demands and the grading system specifications (Anonymous, 1954) lay considerable emphasis on the proper distribution and quantity of lean and fat. In spite of the producers' desire to obtain maximum economic returns, overfinish has been cited as the chief reason why many 200 lb. bacon pigs fail to attain top grades. This excess fat has been produced not only at the expense of increased feed costs but reduced market returns as well.

Growth restriction

Growth in animals must of necessity be correlated to feed quality and intake. Waters (1908, 1910) and Mendel and Hubbell (1935), reported the effects of dietary interrelationships on growth. The control of daily weight gain and of carcass quality in swine was demonstrated by the classical work of McMeekan (1941). Employing various high-low combination planes of nutrition McMeekan showed that by feeding a high plane of nutrition during the phase of maximal bone and muscle development (the grower stage), and employing a low plane of nutrition during the phase of declining growth rate where fat deposition predominates (the finisher stage), a desirable swine carcass was produced. Such work of course reflects on the calorie: protein ratios (Sibbald et al., 1956, 1957; Rice et al., 1957; Wilger, 1957 and others) mentioned previously. Recently it has been indicated that a

narrow ratio which gave a rapid gain at earlier stages of growth in swine, failed to do so as the finishing stage was approached (Clawson et al., 1962). These authors indicated that the ratios used by them, although influencing feed consumption and growth rate, failed to significantly affect gross energy intake. These authors, however, achieved variation of calorie:protein ratios through the use of high energy fats and carbohydrates, therefore it may not be reflective of conditions encountered during energy dilution via fibrous bulks.

Restriction methods

Variations in the nutritional plane can be achieved through hand feeding to produce a leaner carcass (Hanson, 1958); however, according to Troelsen (1960) even in these instances one may readily note usage of ingredients suggestive of reduced caloric density as the finishing period is approached. The self feeding method of swine raising has become well established in America (Hanson, 1958), to control feeding on such a system it is necessary to either restrict supplies, control feeding time (Barber et al., 1957; Bowland and Berg, 1958) or to use ration dilution (Crampton, 1956 and others). Currently there is resurgent interest on this topic and recent reports on the subject (Passbach et al., 1964; Wallace et al., 1964) serve to reconfirm rate of gain and backfat reductions on restricted feeding.

Basing his views on the restriction methods in existence at the time, Crampton (1956) felt that actual feed restriction was impractical; however, the recent development of mechanical feed restricting systems has once again revitalized this approach to the problem. Experience at this institution (personal communication) on mechanical swine feeders, and

Crampton's (1956) views that over-glutinous or timid individuals may alter their expected feed intakes during competition for restricted feed due to their social behaviour, indicate that mechanical restriction may not be as practical as originally anticipated. The added equipment and operational costs of such methods must be considered as well when making comparisons with self feeding. Yet another factor to consider is the data of Cunningham et al. (1962a) indicating that severe feed restriction (50% of ad lib consumption) may adversely affect nitrogen retention in swine.

To self feed at the finishing stage, and at the same time limit caloric intake, ration dilution with fibrous feedstuffs offers another alternative. Fibrous feedstuffs serve to adequately dilute ration caloric density and still satisfy the animals appetite through their bulk effect (Castle and Castle, 1957; Crampton and Lloyd, 1954, 1959). Troelsen (1960) cited numerous references where fibrous materials were utilized to restrict energy intakes in mice, poultry and swine. Hoelzel (1947) demonstrated the use of non-nutritive substances to dispel appetite in man and found cellulosic bulk formers the most suitable.

High level of dietary fibers were demonstrated to be inhibitory on growth rate in growing-finishing swine by Vestal (1921) and Robinson (1928), and more recently by others (Teague and Hanson, 1951; Whatley et al., 1951; Axelsson and Erikson, 1953; Coey and Robinson, 1954; Bohman et al., 1955; Scott and Noland, 1959; Larson and Oldfield, 1961; Pond et al., 1962; Siegl, 1962). It has been pointed out that the source of this fiber is important in creating this effect (Bohstedt and Fargo, 1933; Forbes and Hamilton, 1952; Bell, 1960; Troelsen, 1960; Troelsen and Bell, 1962).

As mentioned previously, and on observations of others (Crampton, 1956; Crampton et al., 1954; Bohman et al., 1955; Merkel et al., 1958a, Hochstetler et al., 1958, 1959; Troelsen and Bell, 1962; Cunningham et al., 1962), such growth retardation results in the production of a leaner hog carcass.

Daily feed intake, growth rate and feed conversion have been shown to vary with the type and level of fiber used. Cunningham et al.(1962) found that the levels of crude fiber digestibility varied from 0 to over 90%. The work of Bell (1960) demonstrated that the overall efficiency of feed conversion was dependent upon a multitude of factors, amongst them fiber type. On the basis of such work it can be inferred that on diluted rations growth rate reductions and feed intake increases may be expected, in addition carcass quality modification shall vary with fiber type and extent of caloric restriction. Troelsen and Bell (1962) indicated that statistical adjustment of carcass criteria for differences in energy intake removed most of the carcass criteria variation. These workers observed a reduced dressing percentage as the level of bulk in the ration rose. Selecting from their trials the diluents of interest in this project, it is noted that oat hulls produced the highest, solka-floc the medial, and wheat bran the lowest dressing percentages, however the R.O.P. scores were slightly lower on solka-floc rations than on either wheat bran or oat hulls.

Fiber influences

It has been indicated that fibrous feedstuffs assessment on the basis of digestible energy content is inadequate (Bell, 1960; Larsen and Oldfield, 1961; Troelsen and Bell, 1962 and others). In addition to considering the fiber's nutrient quality and content, influences of the enzymatic or microbial action and adaptation in the digestive tract, as well

as physiological changes influencing ingesta passage rates and tract modifications should be taken into account.

Passage rate

It has been reported that ingesta transit time variations prevail not only between species but amongst individuals (Holzel, 1930). This may be partial support of a report suggesting slight differences in "organic matter" and crude protein digestibility between individual pigs (Ziolecka, 1960), however, in this instance one must bear in mind that the report was based on only four animals. Reduced feed intakes and increasing age of the animal increases transit time (Cunningham et al., 1962a). Feed passage patterns in fattening swine were shown to follow a sigmoid curve, with the 5% excretion being 21 hours, mean retention 34 hours, and the 95% point was reached at 53 hours (Castle and Castle, 1956). In sows mean retention times were found to be increased to 51 hours. With the exception of some slight variations in time, others have obtained similar results in swine (Brandt and Thacker, 1958; Horszczaruk, 1962). Complete assurance of meal passage from the tract of swine for purposes of digestibility trials in swine has been set at four days (Moore and Tyler, 1955).

In man (Rose, 1932; Morgan, 1934), and in swine (Cooper and Tyler, 1959) the use of wheat bran or fibrous cellulose, and in poultry "fibrous" feeds (Saito and Kibe, 1956) accelerated passage rates. However, Horszczaruk (1962), employing fifteen 7 month old pigs, six with cecal fistula, observed an initial particle excretion at 12 - 18 hours on 4% crude fiber. When the fiber level was increased to 11%, initial emergencies rose to 18 - 24 hours. The final elimination range of 84 to 90 hours for the 4% crude fiber ration was increased by an additional 18 hours in animals on the higher fiber diet.

Differences in passage rates in rabbits, attributable to crude fiber, were not observed (Mangold and Behn, 1956), and others (Kruger and Meyer, 1958) felt that in pigs transit time was less dependent on feed type (bran vs "ground cereal") than on feeding time. Partial explanation for some of these observations may be the report that if cellulose passes through the tract quickly it retains water, if it goes through slowly it looses water (Cooper and Tyler, 1959, 1959a, 1959b). These workers demonstrated that powdered cellulose had no laxative effect and fibrous cellulose more closely resembled bran in action. Such results may suggest that differing feeds may possess similar passage rate patterns in the intestine.

The initial impression would be that intestinal passage rate and absorption are related. Wilson (1962) refutes the idea that accelerated intestinal motility is always associated with reduced absorption. An instance is cited concerning methantheline, (a parasympathetic blocking agent useful for its relaxant effect on smooth muscle, such as found in the G.I. tract, as well as for its antisecretory properties), induced motility reduction coupled with a reduced Na^+ absorption. Such work however should be viewed with caution, since it has been indicated that ganglionic blocking agents have reduced glucose uptake in rats. (Ivanov, 1958). The work of Castle and Castle (1957) has further demonstrated that one should be cautious from over emphasizing passage rates, they demonstrated that small variations in passage rates had little effect on ration digestibility. The indications are that fecal dry matter ratios are influenced by rates of passage (Cooper and Tyler, 1959). Rates of passage are in turn affected more by levels of fibrous feeds than water intakes (Cooper and Tyler, 1959b). The retention time and passage rate and moisture level of

morning fed meals has been demonstrated to be higher than evening feedings (Castle and Castle, 1956, 1957; Kruger and Meyer, 1958; Cooper and Tyler, 1959a).

Mitchel (1942) indicated that fecal protein was of dietary and body origin. This latter factor, the metabolic fecal nitrogen (MFN) was related to dry matter consumption, and Mitchel found that in monogastric animals this equalled 0.20 to 0.25 gm. MFN per 100 gm. dry matter consumed. On reduced feed intakes fiber digestion rises, however with higher levels of fiber MFN increases (Cunningham et al., 1962). Generally with increasing levels of fiber, depression of protein, energy, crude fiber digestibilities tend to occur (Shehata, 1956; Scott and Noland, 1959; Bell, 1960; Horszczaruk, 1962; Troelsen and Bell, 1962 and others).

The relative importance of pH in the digestive tract, particularly on the dissociation and subsequent absorption of weak acid and bases, was indicated by Wilson (1962). Food type and stomach pH relationships have been demonstrated in dogs (Rumjaneeva, 1962). Wiseman et al. (1956) found no correlation between food type and intestinal pH in poultry fed either a corn or molasses based diet. Maner et al. (1962) reported associative effects or gastric pH and passage rates. They studied the behaviour of isolated soybean protein and casein in young pigs. The soybean protein, through a buffering action, produced a pH value higher than casein. Passage rates of soybean meal were approximately half that of casein. As the pigs reached 8 weeks the in vivo pH differences between the two diets became negligible. An initially greater gastric secretion, instigated by the consumption of bulky feeds, was detected in swine equipped with Pavlov pouches (Gridin, 1956). Gridin concluded that the relative composition rather than

feed bulkiness was an influential factor on secretory activity.

Tract development

Crampton and Lloyd (1959) felt that animals attempting to satisfy energy needs on low caloric density diets might reach a limiting point in feed ingestion brought on by limitations of the animals digestive capacity. Reports of influences of fibrous feedstuffs on the digestive tract are contradictory. Increased tract weight in pigs attributable to fibrous feeds (Bohman et al., 1955; Horst, 1956) and in poultry (Hallsworth and Coates, 1962) were reported. Bohman et al (1955) felt that swine adapted to high levels of bulk (alfalfa) by enlarging the tract where limited transitory feed storage occurs, viz. stomach and large intestine. Such enlargement however wasn't accomplished by increasing tract length as the literature citations by Halsworth and Coates (1962) concerning poultry would suggest. The histological studies of Halsworth and Coates (1962) revealed that in poultry high levels of fiber caused detectable tissue abrasions, some irregularities in glandular structures, and increases in the intestinal musculature. Antibiotic supplementation tended to mitigate these effects somewhat. Mucosal hyperplasia of the mouse cecum has been associated with dietary influences of sugars (Fournier and Guillam, 1960). Moinudden and Lee (1958) reported similar influences in rats, in this instance cellibiose particularly resulted in increased weights. Cellibiose is a degradation product of cellulose and could be present in the gut during digestion. Others report the absence of gastric size modifications in response to dietary regimes involving fibrous feeds (Handgrodinger, 1955; Brownlee, 1959; Pres and Nowicki, 1959).

Site of decomposition

The site of fiber digestion varies with the species, in the pig the cecum and colon are implicated (Crampton and Lloyd, 1959). The degree of fiber digestibility varies within species and individuals as mentioned above. Part of the digestibility variation is due to the fluctuations of the number and type of intestinal microflora in response to the gastric environment. Crampton and Lloyd (1959) assigned a value of 3 - 25% crude fiber digestion in accord with the usual diet consumed by swine, however, Cunningham et al. (1962) indicated fiber digestibilities ranged from 0 to 90% for this species. In swine the chief site of microbial activity and VFA production is the cecum and particularly the colon (Friend et al., 1962). Lower fatty acids, gases and products such as reducing sugars were found and shown to be absorbed from these regions (Crampton and Lloyd, 1959; Cools and Jeuniaux, 1961; Friend et al., 1962, 1963). Cecectomy in pigs, although producing no ill effects, depressed dry matter, crude protein, crude fiber and NFE digestibilities (Lloyd et al., 1958). Vitamin synthesis, notably B_{12} has been demonstrated in this area (Michel, 1961). This author suggested that intestinal microflora were capable of producing losses of food energy and pass toxic substances such as NH_3 into the portal circulation. The proximal region of the colon in swine has been cited as containing larger amounts of organic acids, up to twice the levels present in cattle were found (Friend et al., 1962). These levels were depressed by some diets (cellulose) and in vitro studies indicated a depression due to antibiotic additions as well. In vivo antibiotics may contribute further effects by depressing peristalisis (Reber, 1955; Halsworth and Coates, 1962) and by their influences on intestinal microflora types and population levels (Freerksen, 1955).

Cellulose

Cellulose is one of the supporting components of plant tissue according to Cantarow and Shepartz (1962). There may be over 3,000 glucose residues per molecule, as exemplified by the emperical formula $(C_6H_{10}O_5)_x$, yielding molecular weights of a half a million. Cellulose can exist as the crystaline form, know as α cellulose, an orderly arrangement of molecular units, or exist as the amorphous or β cellulose form. Ballmilling has been shown to destroy the crystalinity of native cellulose (Wiseman, 1959), it has also been indicated that processing methods can affect its recrystalization and structual characteristics (Tarakow, 1950). This is similar to other fibers, where cyrstalinity can be reduced or destroyed by stretching, rolling or other processes causing distortions. It would appear that the source and method of preparation is important in affecting cellulose degradation. Baker (1959) felt that this wasn't solely attributable to the particle size or average mass of the glucose side chains. The degree of swelling and incorporation of water was greater following crystalinity alteration (Jakubovic, 1959). Jakubovic also indicated that intramicellular capillaries, larger aliphatic side chains, and nitrogen contents all played a role in the degree of swelling in cellulose. It has been shown that grinding or swelling increased "accessibility", a factor related to not only crystalinity, but to the capillary networks between the fibers and their nature (Whitaker, 1957). Unlike crystaline cellulose, the binding site availability as well as "accessibility" of amorphous cellulose renders it capable of absorbing water up to 2 or 3 times its dry weight (Stamm, 1950). There are 3 hydroxyl groups in the cellulose monomer that can bind water, however crystalites are impermeable to water whereas in

amorphorus regions these sites are "accessible". In addition to varying with the carboxyl content and degree of hydration of cellulose, those that swelled in solution were capable of retaining 2 or 3 times the enzyme activity when used as an absorbant in enzyme purification techniques (Mitz and Summaria, 1961). The amorphous form of cellulose has been indicated to be more susceptible to enzymic degradation (Walseth, 1952). Bayley and Rose (1960) stated that alpha cellulose exhibited poorer cation binding properties. These authors felt that native cellulose had other substances such as pectins and lignins that would increase their binding capacities.

Natural celluloses are encrusted with other structural elements (Norman and Jenkins, 1933; Armstrong et al., 1950), the proportions of some of these structural components, such as lignins, increase with maturity and vary with the plant source (Crampton, 1956; Crampton and Lloyd, 1959). Tomlin and Davis (1959) failed to correlate cellulose digestibility with its crystalinity. Lyford et al (1963) noted similar results, in addition no influence of the pentosan component was detected. Such divergencies indicate that other factors apart from cellulose crystalinity may be involved in affecting digestibility (Tomlin and Davis, 1959). Dehority et al. (1962) indicated that associated structures such as pectins and hemi-cellulose were more resistant to decomposition, probably as a result of lignin encrustation.

Hvidsten and Homb (1948) indicated cellulose digestibility to be low when fed to swine. Neither fermentation nor NaOH treatments influenced digestibility and a dependence on age and individual variation amongst animals was revealed. (NaOH has been utilized as a solvent for alpha cellulose by Lyford et al., 1963). The literature review presented by Cunningham et al. (1962a) would tend to contradict these results since it was indicated that

processing caused increases in cellulose digestibility. Cunningham et al. (1962a) concluded that the pig expended more energy in utilizing cellulose than it derived from it. As mentioned previously they pointed out that there appeared to be no adaptability to cellulose with time. Feeding level of fiber level intake and age of pig were important factors. Johnson et al. (1960) force-fed a 31% suspension of C^{14}-labelled cellulose to rats. Of this 31% was metabolized, 1% excreted in the urine and 6% retained in the body, the remainder was expired in the respiratory gases. Oxytetracycline markedly suppressed the metabolizing of C^{14}-labelled cellulose in these trials, this being in accord with earlier observations concerning cellulose digestibility (Forbes and Hamilton, 1952). Franz (1959) had indicated that even at levels of 60% rats failed to exhibit cecal enlargement, although at the 40% level animals could not eat enough food to satisfy their needs. Feed utilization at the 20% level of dilution was equivalent to the control groups. It has been pointed out that while "normal" levels of celluloses contribute to proper intestinal motility excessive amounts are irritating to mucous membranes and may even produce constipation (Crampton and Lloyd, 1959; Cantarow and Schepartz, 1962).

Wheat bran

Wheat bran consists of the coarse outer coatings, the aleurone layer and about half of the germ of the wheat kernel. This by-product possesses about 16% crude protein, 10% fiber and has approximately 0.2% of a per cent of phosphorus and slightly less calcium. The cellulose and lignin levels for bran have been reported to be 17% cellulose and 8% lignin (Crampton and Lloyd, 1959). Bran is palatable to livestock, but its chief use lies in its laxative properties. The bulky nature of bran is particularly

adaptable in the dilution of swine rations. Sheely, cited by Gorrill (1960), suggested that the flaky nature of bran tended to make the ingesta susceptible to enzymatic action. Part of the laxative effects were attributed to its water-holding and gas-trapping abilities.

Cooper and Tyler (1959) have noted that bran fed to pigs increased fecal moisture, an effect reproducable with fibrous cellulose. Fecal dry matter as well as water output rose, and colonic distention due to gas formation was noted. It has been shown that gas production was higher on vegetable-origin and high crude fiber diets (Hedin, 1962; Hedin and Adachi, 1962). Of the gases produced, CO_2, CH_4, H_2, O_2 and N_2, only N_2 tended to remain in solution in the intestine, the others tended to be taken up by the circulatory fluids. The proportion of CH_4 rose with decreased motility in the intestinal tract. Bran rations, with their laxative effect would certainly not be in such a category.

Gorrill et al. (1960) noted that the effect of bran on energy digestibility was small relative to its enhancing effect on protein digestibility in growing pigs; this effect was particularly predominant when fed as meal or in conjunction with plant protein. This latter observation confirmed the earlier reported associative effects of wheat bran and all plant protein rations (Norfeldt et al., 1954). Troelsen and Bell (1962) fed rations containing various bulk diluents to swine. Of those of concern in this thesis, wheat bran produced the lowest dressing percentages and average backfat. These authors reported that per unit addition of bulk, wheat bran resulted in the lowest daily DE intake decrease. Selecting the three bulks utilized in this trial from the ones used by Bell (1960), wheat bran exhibited the largest volume of feces and oat hulls the least on rations permitting

60% of 'normal' gains. This is a reflection of earlier reports (Olmsted et al., 1936) that fiber content per se, although contributing materially to it, is not a true indicator of total stool bulk.

References in the literature were cited by Bell (1960) to indicate increased fecal moisture and fatty acid levels in feces originating from bran rations. It was inferred that this was evidence of increased microbial action in the lower gut. However there have been reports of labelled plasma fat being recirculated into the intestinal tract through the intestinal wall (Burr et al., 1960; Linazasoro and Diaz, 1960) and bran rations could conceivably affect this recycling mechanism. Friend et al. (1962) have demonstrated quantitative and qualitative differences in organic acids present in the feces dependent on diet. Bran and whey rations produced more fecal valeric, propionic and acetic acids than cellulose. Further work (Friend et al., 1963) tended to confirm these trends and quantitative and qualitative differences in levels of VFA in the tract, dependent upon the diet, were evident. Lactic acid was found less often on bran supplemented rations, however there was a high proportion of acetic acid. Quantitatively, cellulose and wheat bran produced similar amounts of VFA in the tract.

Oat hulls

Oat hulls are the fibrous outer coverings of the oat grain, having not quite 4% protein, 32% fiber and 0.2% calcium and half as much phosphorus.. Oat hulls have an average of 51% cellulose (NRC Pub. 585, 1958) and two values for lignin: 14.2% (NRC Pub. 585, 1958) and 21% (Bryner et al., 1936) have been reported. Therefore, in comparison to wheat bran on a dry matter basis, oat hulls provide higher levels of both cellulose and lignin.

On the basis of a TDN comparison the 27% value of oat hulls for swine is slightly less than half of that in wheat bran.

Possibly one of the first tests conducted using this by-product was Buckley et al. (1912) who, after feeding a Jersey bull, a mule and a seventy-five pound pig, observed that while the former two fared well, the latter lost twenty-one pounds in six weeks! Oat hulls have been frequently considered as a diluent in finisher rations fed to swine. Gorrill (1960) cited literature references indicating that for small pigs oat hulls were costive. There was a suggestion that oat hulls did not absorb water as freely as bran (Bell, 1960; Gorrill, 1960).

Digestibility coefficients for energy were reported by Bell (1960) as 40, 10 and 0% for wheat bran, oat hulls and cellulose in mice. Indications were that these bulk sources exerted varying effects on the animals' ability or desire to ingest feed. While growth, adjusted for feed intake difference, was reduced in oat hulls at a lower level of ration dilution than that of wheat bran, it was considerably higher than that achieved using cellulose.

Crampton and Bell (1946) have indicated a beneficial effect on fine grinding of oat hulls fed to pigs. Earlier reports have indicated that oat hulls entailed a lower loss of MFN than cellulose (Whiting and Bezeau, 1957). Others indicate that on the basis of equal crude fiber intake this effect was removed (Cunningham et al., 1962). Jensen et al. (1959) concluded that due to a TDN dilution, graded levels of oat hulls depressed growth rate in swine. As levels of oat hulls were increased, gains, feed intake and conversion declined. The addition of dried rumen bacteria failed to exert any effect on the performance. Troelsen and Bell (1962) reported

that oat hull-diluted swine rations, in spite of a lower TDN, promoted faster gains than either wheat bran or cellulose. Dressing percentage was highest on oat hull rations.

Feeding frequency

Both literature and husbandry practices abound with various feeding regimes for swine. Animals may have access to feeds at all times under ad lib feeding systems, or they may be restricted as to time and duration, feed quantity or number of feedings per day. Such restrictions can be imposed by manual or mechanical methods. For the purposes of this report consideration shall be given to work analagous to the system employed in this trial; that is, a restriction chiefly to number of feedings but not quantity, although a control over time and duration was practised.

Braude et al. (1963) compared pigs fed once or twice daily and noted that the only variable factor among growth rate, feed conversion, carcass length, grade and 'kill-out' percentage was the latter, due chiefly to the amount of fill at the time of kill.

Berg and Bowland (1958) compared three systems where pigs were allowed to self feed once or twice daily for one hour periods or fed ad lib. Daily feed intake and gain increased with access to feed, however, feed utilization was reduced on ad lib feeding. Restricted feeding resulted in improved carcasses, and ad lib produced the poorer quality carcasses in these trials. The authors felt that due to labor costs and general quality of pigs used, feed restriction was not warranted. Pig Industry Development Authority (1962) reported in comparisons involving animals fed twice a day with some full fed, that the latter exhibited poorer feed conversion, higher kill out percentage, greater backfat, shorter carcasses, less lean

and poorer grades.

Satter and Baumgard (1962) reported that on 2, 4 or 8 times a day feeding the bovine exhibited fewer fluctuations of VFA, NH_3 and pH on more frequent feedings. Feegenbaum et al. (1962) noted that in comparison to restricted chickens, those full fed had, with the exception of the small intestine, larger digestive organs; however, fat and water retention was higher in restricted groups. The pertinence of data derived from so widely diverse species to swine is debatable, however the possibilities for similar effects exist.

Modulus of fineness

Stevens, cited by Dyer (1963), defines modulus of fineness as the indication of sieve mesh size through which ingredients will pass. Food remaining on screens 4 to 8 (U.S.B.S. sieve No.) was designated coarse, 16 to 30 medium, and that on 50 to 100 as fine. It is a fundamental concept that the finer a material the greater will be the actual surface area exposed. Bulky fibrous components that are processed into reduced particle size will be reduced in apparent volume and will become a denser product.

Observations of Whitaker (1957), Dehority (1961), and Dehority et al. (1962) indicate that reduction in particle size provides increased accessibility of cellulose to enzymatic and bacterial degradation. Crampton and Bell (1946) had demonstrated the beneficial results of fine grinding oat grains and oat hulls in the rations of growing pigs. Clawson (1962) had demonstrated an increased feed consumption by swine of fine ground corn in comparison to a coarser product.

Charlet-Lery and Leroy (1955) demonstrated that bran ground by pressure and ultrasonic forces exhibited increased feeding value, feed in-

take and crude protein digestibility in pigs. Frumin and Beesonev (1958) subjected wheat bran to autoclaving and grinding treatments and observed that its fiber digestibility by rats was improved as a result of the grinding process. King and Moore (1957) have indicated that at a density of 1.2 gm./cm. a plastic pellet was excreted more readily than a lighter one. However these authors indicated reservations about the concept, when they stated that the excretion of Cr_2O_3 marker from the digestive tract was more rapid than expected from its density characteristics.

In man, undigested solids are usually expelled from the stomach only when converted to a relatively fluid consistency (Best and Taylor, 1962). It is probable that finer module feeds are capable of being rendered sooner to the necessary state of fluidity conducive to gastric expulsion.

Calder et al. (1959) observed a reduced dressing percentage in swine on coarse ground oats when compared to the finely ground rations.

Pelleting

Pelleting of feeds has resulted in increased growth rates, feed consumption and utilization in poultry, ruminants, and swine (Davidson, 1957; Aldred et al., 1957, 1957a; Black et al., 1958; Hoefer et al., 1958; Dinusson et al., 1960; Gorrill and Bell, 1960; Hussar and Robblee, 1962; Seerley et al., 1962, 1962a; Troelsen and Bell, 1962; Lindahl and Terrill, 1963 and others).

The compaction of bulky feeds, and subsequent increase in density has made pelleted feeds more palatable to swine (Hoefer et al., 1958). The re-grinding of pellets has been generally shown to maintain at least part, if not all the beneficial results in poultry rations (Hussar and Robblee, 1962). Chickens have been shown to be more tolerant of higher

levels of crude fiber and to perform better on pelleted rations (Black et al., 1959).

Aldred et al. (1957, 1957a) suggested that in pelleted chick rations certain chemical or physical changes may have developed as a result of heat and pressure. Hussar and Robblee (1962) reported temperatures rising to 72°C on a small pelleting mill, (temperature obtained in commercial operations may exceed this due to the use of live steam and higher pressures during mill operations). These authors pointed out though that the actual temperature attained on the outside of the pellets may have exceeded that of the inner core. They further demonstrated that lysine, an amino acid particularly susceptible to heat damage, was unaffected by pelleting. Lindahl and Reynolds (1959) observed increased ether extract and decreased crude fiber in pelleted alfalfa meal fed to sheep. Wright et al. (1963) noted no differences in ether extract or crude fiber digestibility but considered in vitro digestion of cellulose greater on pelleted hays.

In growing swine, pelleted rations were found superior only on plant origin protein supplements and in the absence of bran or antibiotic by Gorrill and Bell (1960). Johnson et al. (1964) noted that the response to pelleting in ruminants was also contingent upon ration make up.

Increased dry matter and energy digestibility, but without apparent benefit to digestibility of nitrogen, have been attributed to pelleting swine rations (Gorrill and Bell, 1960; Troelsen and Bell, 1962; Seerley et al., 1962, 1962a). Reddy et al. (1962) noted similar increases in productive energy in pelleted poultry feeds. Hussar and Robblee (1962) considered the slight changes in dry matter digestion, nitrogen and energy retention on

pelleted feeds fed to chicks insignificant.

Some authors indicate pelleting as such does not affect carcass quality (Cameron, 1960; Troelsen and Bell, 1962), however Bowland (1956) indicated that pigs fed a pelleted oat ration ate more and produced a fatter carcass. The apparent descrepancy in these reports may hinge around differences in the digestible energy contents of the test rations, which ranged widely among the three investigations.

Antibiotics

Mode of action

Jukes (1955) and Goldberg (1959) presented comprehensive reviews on the possible modes of antibiotic action. Luckey, who wrote the chapter on "Antibiotics in Nutrition" in Goldberg's book, has summarized these modes of action and the following outline is excerpted from his write-up.

"Proposed Modes of Action of Antibiotic Growth Stimulation

A. Indirect action:

1. Via intestinal microflora:

I. Increase numbers of "good" microorganisms:

a) Vitamin synthesizers
b) Over populate (potential) pathogenic organisms

II. Decrease numbers of "bad" microorganisms:

a) Vitamin users
b) Toxin producers
c) Pathogens or potential pathogens

III. Change organisms present:

a) Produce (resistant) strains which are less harmful
b) Change metabolism of those present
c) Alter energy requirements in the rumen
d) Decrease invasiveness of normal flora
e) Increase susceptibility to phagocytosis

IV. Relocate organisms into their usual habitat (prevent rising of lower gut organisms).

2. Reduce infectious diseases:

I. "Sub-clinical" infection
II. Help body defenses generally
III. Decrease frank infectious disease

3. External (or intestinal) mileux reaction:

I. Detoxication (chelation)
II. Remove inhibitor (metabolic waste product)
III. Chelation-activator
IV. Reduce surface tension
V. Reduce pH of intestinal mileux

B. Direct action:

1. Cells:

I. Permeability of cell wall
II. Biological stabilizer against stress
III. Protoplasmic stimulant
IV. Activate anabolic regulator
V. Mutagenic agent (microorganisms)
VI. Mitotic stimulant
VII. Stimulate production of cell wall material
VIII. Adaptation expeditor.

2. Tissues:

I. Intestinal wall length, weight and thickness made more efficient
II. Increased absorption rate
III. Increased apparent utilization of metabolites
IV. Decreased energy expenditure

3. Organism:

I. Hormone synergism
II. Increased growth or thyroid hormone
III. Increase palatability
IV. Over reaction to stimulant
V. Increase food utilization
VI. Increase adaptibility to a poor environment
VII. Decrease sensibility to poor environment
VIII. Biological stabilizer to stress
IX. Adrenal cortex reaction

4. Metabolic reactions:

I. Decrease vitamin requirement
II. Increase vitamin synthesis by tissues
III. Act as a metabolite
IV. Stimulate specific reactions:

a) Photosynthesis
b) Sucrose synthesis
c) Vitamin A from carotene

V. Produce less (toxic) side products
VI. Increase enzyme synthesis

C. Combination of several of the above

D. Non-specific activation giving general mobilization of metabolic enzymatic potential abilities."

Effects

The response of swine to antibiotic has been a general growth improvement of about 15%. This will vary depending on the type and quality of the food, a greater response being exerted on poorer quality rations. Appetite and feed efficiency improvements are more pronounced under stress conditions such as sanitation and feed restriction to name but a few. Response has been reported to be greater in young animals. High-level feeding, levels of from 50 to 1000 ppm., are usually fed under disease conditions.

Antibiotics generally improve nitrogen and energy digestibility and are frequently implicated in vitamin sparing.

Bowland and Berg (1957) indicated the controversial ideas present regarding the effects of antibiotic supplementation on hog carcass quality. The results are reported to vary with the strains of animals used and the feeding conditions. Luckey, writing in Goldberg's book, suggested that carcasses usually grade higher. Clausen (1957) and Jukes (1955) suggested that in swine, due to the accelerated growth and feed intake, antibiotic supplementation is frequently accompanied by an increased backfat

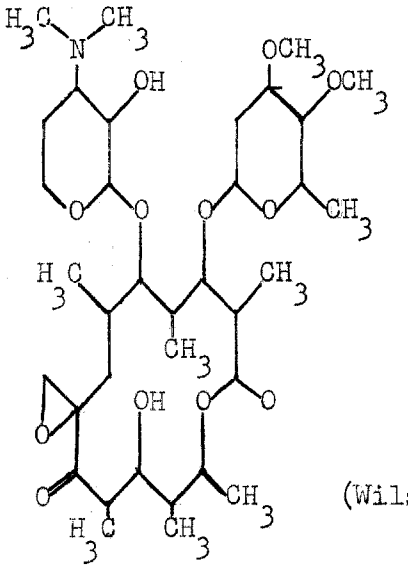
deposition. Under restricted feeding carcasses are not affected, however it would appear that on lower levels of protein and under ad lib feeding of swine, fat deposition will be increased (Goldberg, 1959). Comparisons of swine carcasses indicated that moisture, lipid and protein levels were relatively similar on either supplemented or unsupplemented feeds (Goldberg, 1959). Hall et al. (1963) did not detect any large differences in either palatability or cooking losses in pork derived from antibiotic supplemented animals. Similar conclusions were drawn regarding fat and collagenous tissues, and fiber size in raw and cooked rib eye. Some nutritionists believe that during the finishing period antibiotics should not be fed to pigs (Bowland and Berg, 1957).

Chlortetracycline (Aureomycin), zinc bacitracin and oleandomycin were combined in equal proportions and used as a supplement in these trials. The following is a brief review of their properties, use and overall behaviour in nutritional studies. As a matter of general interest their emperical and structural formulas are indicated in Figure 2.

Chlortetracycline (Aureomycin)

At levels of 12 to 15 grams per ton this antibiotic has been reported as a growth stimulant. It is a broad spectrum antibiotic, primarily bacteriostatic but bacteriocidal at high levels (Goldberg, 1959). It forms stable chelates with most metals and there is a suggestion that its antibiotic properties depend on these properties. Aureomycin is readily absorbed from the intestine and is chiefly excreted through the urine.

Many reports have attributed increased rates of gain, feed intake and feed conversion due to the feeding of this antibiotic to swine (Bohman et al., 1955; Beacom, 1959; Conrad and Beeson, 1960; Gorrill et al., 1960

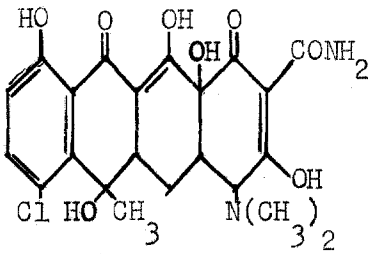


Oleandomycin

$(C_{35}H_{61}NO_{12})$

Mol. Wt. = 679

(Wilson and Gisvold, 1962)



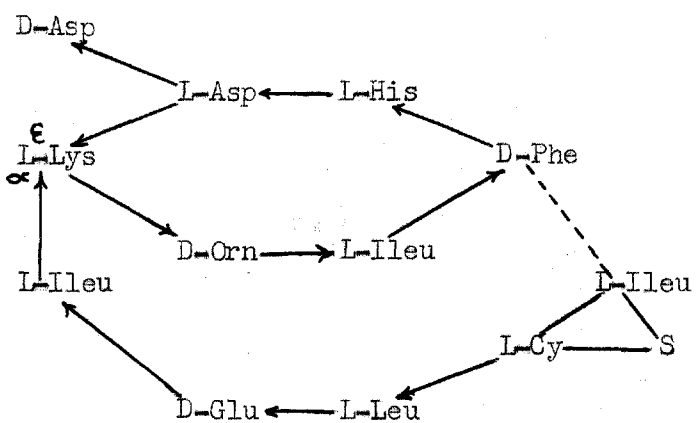
Chlortetracycline

$(C_{22}H_{23}ClN_2O_8)$

Mol. Wt. = 479

(Merck, 1960)

C—N bond indicated by →



Bacitracin A

$(C_{65}H_{103}N_{16}O_{17}S)$

Mol. Wt. = 1470

(Goldberg, 1958)

FIGURE 2 - EMPIRICAL AND STRUCTURAL FORMULAS OF OLEANDOMYCIN, CHLORTETRACYCLINE AND BACITRACIN A

and others). The antibiotic was usually fed at the feeding levels indicated above, however Conrad and Beeson (1960) found that improvement was independent of levels as high as 250 gms. per ton. Beacom (1960) noted that the beneficial effects of aureomycin were particularly evident on medium and low protein rations. Marked responses to this antibiotic have been reported in the presence of an all vegetable source protein ration and in rations formulated without bran (Gorrill et al., 1960).

Gorrill et al. (1960) observed an increase in energy digestibility but not in protein when aureomycin was supplied to growing pigs. Beacom (1959a) indicated that although carcass quality as a whole was unaffected by this antibiotic, an increased backfat deposition was noted, this is in agreement with other reports (Clausen, 1955; Bowland and Berg, 1957).

There are reports that antibiotic feeding does not affect intestinal tract weights in swine (Pres and Nowicki, 1950), Klaus and Fewson (1955) obtained similar results following the use of aureomycin. Total small intestinal and cecal weight and dry mucosal weight reductions were obtained by Vonk et al. (1957b) when young pigs were fed aureomycin. Taylor and Harrington (1955) have noted decreased small intestine and spleenic weight on aureomycin supplemented pigs.

Aureomycin supplementation increased both the level and activity of intestinal and pancreatic cellulase, amylase and protease in young pigs, and did not exhibit an in vivo inhibition on the activity of these enzymes, (Vonk et al., 1957, 1957a, 1957b). Malek et al. (1959) contradicted these results by demonstrating an inhibitory effect of this antibiotic on pancreatic enzymes, they suggested that a similar action was

manifested in the gut. By the demonstration of an *in vitro* inhibition of sugar breakdown by bacteria in a solution containing chlortetracycline, Michel (1961) suggested that a similar *in vivo* action might enhance glucose absorption. An increased phosphatase output following aureomycin supplementation in fistulated pigs has been reported (Cajkina, 1963). Chlortetracycline has been shown to depress plasma cholesterol levels (Howe and Bosshard, 1960). Destruction of the antibiotic activity by heating still perpetrated this effect and the authors felt that the effect was due to an interference with the absorptive processes involving cholesterol or cholic acid from the gut rather than an effect on the bacterial flora in the tract.

A speed-up of barium meal passage rate on aureomycin supplemented diets was observed in rats (Kimbel *et al.*, 1956). Combs (1955) has reported the occurrence of similar effects in other species and with other antibiotics. Reber (1955) indicated that *in vitro* motility of rabbit and pig intestinal muscle was decreased in the presence of aureomycin.

Braham *et al.* (1959) have indicated that raw soybean meal fed to chicks was rendered less toxic by the inclusion of antibiotics in the feed, Among the antibiotics they used were chlortetracycline and zinc bacitracin. These authors noted that this effect was most marked when dietary methionine was marginal, they concluded that perhaps the antibiotics exerted a "sparing action" on this amino acid.

Fuller *et al.* (1960) have demonstrated the development of antibiotic resistant fecal microflora, however the numbers and types of populations were not changed. Johansson (1955) reported that workers have observed an increase in the number of filamentous fungi in the feces of

aureomycin supplemented pigs. There were further reports indicating that protozoa disappeared and glucose fermentors were reduced in numbers.

Bacitracin

Bacitracin has been reported as a growth factor for pigs. Its action is both bacteriostatic and bacteriocidal. At least six fractions of this antibiotic, designated as A, B, C, D, E, and F exist. The A fraction is the most potent the others, particularly the F fraction, are regarded as degradation products. The stability of the drug varies with temperature, moisture and heavy metal contaminants. Zinc metal, through a chelation process, imparts a high stability to bacitracin A and also serves as a dietary supplement for this element (T.D.S. No. 6, 1958). Bacitracin exerts a synergic action on many other antibiotics (Bacitracin, 1952). Weinberg (1959) stated a specific influence of metalic ion on bacitracin. He postulated that bacitracin's antibiotic activity may be exerted through the control of diffusion and assimilation of metalic ions at the cell wall site. The action of this antibiotic has been reported to be restricted to growing microorganisms (Jukes, 1955).

Jukes (1955) indicated that in chicks bacitracin is effective when administered orally, and is poorly absorbed, if at all, from the intestine. Costain and Lloyd (1962) showed that bacitracin fed at levels up to 100 gm. per ton was not absorbed by growing pigs.

Holme and Robinson (1963) fed bacitracin to pigs being raised to market. At feeding levels of 10 gm. per ton a small but favourable response was obtained to the 100 lb. stage. On the premises that they were utilizing responses to penicillin and oleandomycin had become non-existant. There has been a report that weanling pigs exhibited increased gains and feed efficiency

performance coupled with an apparent rise in crude protein, energy and dry matter digestibilities. The greatest response to this antibiotic was on rations where an all vegetable protein was fed (Costain and Lloyd, 1962).

As mentioned previously, Braham et al. (1959) demonstrated that zinc bacitracin was as effective as aureomycin in exerting an apparent "methionine" sparing effect on rations containing raw soybean meal. Augmented glucose and amino acid absorption in poultry occurred on zinc bacitracin supplemented rations (Aramaki and Weiss, 1962). These authors observed a faster intestinal passage rate in young but not older birds supplemented with this antibiotic. Reber (1955) reported that the in vitro motility of rabbit or swine intestinal muscle was unaffected by bacitracin.

Oleandomycin

Oral administration of oleandomycin produces a very low serum concentration and urinary excretion is very low as a result of its poor absorption (Colville et al., 1959).

Sherman et al. (1958) reported that the development of resistant strains to this antibiotic was low, however Holme and Robinson (1963) have reported a lack of response to oleandomycin on their particular premises. Sherman et al. (1958) reported that this antibiotic is effective against certain strains of organisms not affected by conventional antibiotics in agricultural use. They observed a two or three fold response to that of penicillin when supplemented rations were fed to poultry. Oleandomycin levels were fed up to 400 gm. per ton and favourable reactions were detectable at levels as low as 4 gm. per ton, there was no particular advantage derived by feeding the higher levels. Margruder et al. (1958) compared oleandomycin and tetracycline in swine, they found that tetracycline was

more effective in promoting growth. In comparison to the control groups, oleandomycin gave growth improvements in both baby and growing-finishing pigs. Vernon and Mescer (1962) noted similar results in heavy pigs, although they compared oxytetracycline at 10 gm. per ton and oleandomycin at 2.5 gm. per ton. The results in these trials indicated that the responses were better on premises where antibiotic feeding practises had not been previously practised. It has been indicated from the feeding of graded levels of oleandomycin up to 10 gm. per ton to young pigs that the highest level gave the best results, (Hawbaker et al., 1960). Lloyd et al. (1961) fed oleandomycin to young pigs at 10 gm. per ton, two levels of protein and graded levels of calcium. No adverse effects, protein sparing, or Ca interaction developed over the duration of their four week trial. A significant increase in gross energy, protein and ether extract digestibility occurred, however the carbohydrate fraction digestibility was not affected.

After surveying the literature Smith et al. (1963) noted that dietary levels of oleandomycin ranged from 2 to 50 gm. per ton, they selected 12.5 and 25 gm. per ton for comparative purposes. The selected animals were fed to 200 lb. and prior to selection at 50 lb. some had received an oxytetracycline containing creep feed. These authors noted no effect of oleandomycin on feed intake, gains, visceral weight or on associative effects with previous antibiotic supplementation.

Antibiotic combinations

According to Jawetz and Gunnison, cited by Welch et al. (1958), mixtures of primarily bactericidal antibiotics frequently act synergistically and never antagonistically. Mixtures of primarily bacteriostatic

antibiotics are simply additive in their effects and never synergistic or antagonistic. Welch et al. (1958) observed all types of action in their mixtures. Combinations of oleandomycin with other antibiotics exhibited summation 51% of the time, synergism 21% and antagonism only 3% of the time. The tetracyclines and bacitracin were the prominent mixture yielding synergism with oleandomycin. Oswald and Welch (1958) reconfirmed the relative absence of antagonism in oleandomycin-tetracycline mixtures and the presence of synergism. Hanson (1958) has referred to the use of antibiotic combinations involving bacitracin and penicillin in swine feeding but makes no comment on their advantages, if any. Many antibiotic combinations may be found in the Feedstuffs Feed Additive Compendium (1964), indicating that commercially marketed mixtures are available.

Sex

Troelsen and Bell (1962) reiterated published reports indicating greater feed consumption and faster rates of gain in barrows when compared to gilts. Others (Bruner et al., 1958; Bowland and Berg, 1959; Plank and Berg, 1963) have observed similar results. Lucas and Calder (1956), as well as Plank and Berg (1963), have reported instances where feedlot performances of the sexes were contradictory to such observations and gilts out-gained barrows. Under conditions of individual feeding (Hafez, 1962), and on equally limited feeding (Plank and Berg, 1963), gilts have been shown to gain faster than barrows; however, Plank and Berg (1963) found that under ad lib feeding barrows ate more and grew faster.

Wilger (1957) suggested a greater sensitivity to calorie:protein ratio in males when fat deposition was the assessment criteria of poultry carcasses. Berg and Bowland (1959) indicated that during their trials on

three energy to protein levels there were no significant sex x ration interactions occurring on carcass quality. It is common knowledge of course that due to lower B.M.R.'s human females require lower caloric intakes (Best and Taylor, 1962).

Troelsen and Bell (1962) have reported a slight change indicating a poorer (non-significant) energy utilization in barrows. Others (Plank and Berg, 1963) found a slight suggestion of increased dry matter digestibility in males. Makela (1956) indicated that bovine males retain dry matter longer than females and commented further that factors such as a gravid uterus or abdominal fat may have restricted digestive tract capacities in females. Poorer feed conversion ratios have been reported in barrows (Bowland and Berg, 1959; Troelsen and Bell, 1962), however, Plank and Berg (1963) demonstrated equal conversions in both sexes on ad lib feeding.

Thicker backfat (Troelsen and Bell, 1962) and fatter carcasses (Bowland and Berg, 1959; Fletcher et al., 1963) have been reported in barrows. Plank and Berg (1963) observed that the differences between gilts and barrows became further magnified on their "equal limited feeding" regimen (both sexes received 75% of feed requirements). Fletcher et al. (1963) noted that as liveweight increased carcass dressing percentage went up. They noted that up to 180 lb. barrows had a larger visceral weight; in the 210 and 240 lb. category the situation was reversed. However these authors failed to mention the possible influence of female reproductive tract development. These authors indicated that gilts produced a greater weight of loin, overall edible portion of cuts and an increased bone percentage. Acheson et al. (1959) demonstrated that when skeletal development

rather than weight was the measure, female rats ranging in age from 17 to 40 days were more mature than males. Judge (1964) reported the area of longissimus dorsi and percentage of ham significantly greater in gilts, others (Bowland and Berg, 1959; Troelsen and Bell, 1962; Plank and Berg, 1963) have suggested this but found no statistical significance. Salemela et al. (1963) made the general conclusion that gilts produced superior carcasses to barrows on all attributes of carcass leanness. Judge (1964) has posed a possible explanation for some of these contradictive data when he observed that data on gilts tended to be much more varied than on barrows.

An excerpt from Plank and Berg (1963) is appropriate to describe the situation:

"Sex differences in carcass quality probably arise from metabolic differences which influence the relative proportion of fat and lean tissue. .....carcass differences attributable to sex result from differential utilization of these nutrients after digestion rather than from their differential digestion."

The effects of androgenic and estrogenic compounds on the nature of the animals' anabolic and catabolic functions cannot be overlooked, particularly when comparing normal females to castrate males. Sex hormones govern fat distribution; emaciated men and women appear similar in outline (Dole, 1959). Adrenal steriods may be implicated in obesity and the nature of thyroid hormone in accelerating metabolism is knownto occur. Dole (1959) suggests that possibly hormones may act on adipose tissue sites by potentiation mechanisms which sensitize these tissues to the effects of insulin or adrenalin. Lyon's (1961) hypothesis suggesting that a female may be a

genetical mosaic may be yet another factor. According to this, a possibility exists at an early embryonic stage, prior to the inactivation of one of the X chromosomes of the XX compliment, for the expression of either one or both of the ancestral traits borne on these chromosomes to be expressed. Another interesting avenue for speculation has been the observation of Edwards (1962) indicating that in strains of mice, selected on the basis of equal growth rates, pituitary size and activity were greater in females. Hunt (1959) has noted that in the gastric region, the parietal cells of females had about two thirds the secretion of males. Further clarification of the hormonal actions, the implications of Lyon's hypothesis, and perhaps explanation of the other observations will undoubtedly provide useful tools in the elucidation of sex differences pertinent to feedlot performance.

Résumé

The preceding literature review has presented a discussion of the pertinent background material to this thesis. References to past work have been selected so as to elucidate some of the underlying mechanisms concerned with appetite, nutrient assimilation, growth and proposed experimental treatments. These parts have been generally considered separately; however it will soon become evident from the experimental design utilized in this trial, to be described in the succeeding section, that the selected treatments will be superimposed on each other.

An attempt shall be made to restrict one of the predisposing conditions to overfinish in market hogs, namely nutrient excess. It is expected that subjecting the animals to these experimental treatments will be countered by an attempt to overcome this restriction, either by modifying feed intakes, or by alterations in feed utilization. Either of these methods will be con-

tingent on other elements such as feed availability; acceptability; bulkiness; digestibility and other characteristics mentioned in the literature review.

Reflecting back on the literature review will certainly bring to mind many possibilities of synergistic, additive, independent or opposing (antagonistic) combinations of treatments or responses that will fall within the treatments encompassed by this experiment. The literature review has also served to uncover or redisclose previous observations that justify reconfirmation should they fall within the realms of the present trial.

EXPERIMENTAL

OBJECTIVES

As indicated in the previous section there are many factors that influence the amount of food dry matter that an animal may consume. Included among these factors are the source and nature of the fibrous or bulk component, particle size or modulus, pelleting of the ration, frequency of feeding, the inclusion of antibiotics in the formula and usually the sex of the animal involved. Therefore, as a major objective, it was decided to incorporate all of these factors into a single experiment in order to assess the relative importance of each as it influenced feed intake. In addition it was decided to examine effects of the dietary variables on digestibility of energy and protein, on numerous chemical and physical characteristics of ingesta, on gastro-intestinal tract adaptation and on carcass characteristics.

MATERIALS AND METHODS

Allotment and experimental design

Forty eight barrows and an equal number of gilts of purebred Yorkshire breeding were obtained from the University swine herd. Using a 3 x 2 x 2 x 2 x 2 x 2 factorial type of design, allotment consisted of 32 animals on each bulk diluent and 48 animals on all other main treatments as indicated in Table 1.

Prior to selection, the pigs had received the usual management techniques employed at the University Farm, including indoor housing, and at the time of selection were receiving standard grower[1] rations. The

1 The terms "Grower" and "Finisher" rations are used to designate dietary formulations that comply with the NRC recommendations (1959) for bacon-type pigs.

TABLE 1 - EXPERIMENTAL DESIGN

No. times fed per day	Anti-biotic fed	Sex	Solka-floc (cellulose)				Wheat bran				Oat hulls			
			Fine		Coarse		Fine		Coarse		Fine		Coarse	
			Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet
2	Nil	M	*											
		F												
	Add	M												
		F												
3	Nil	M												
		F												
	Add	M												
		F												

* One animal allotted to each treatment. Third and higher order interactions used as statistical error variance.

animals were allotted to the experimental finisher rations indicated in Table 1 upon reaching 100 ± 5 lbs. liveweight.

The trial was commenced May 8, 1961, allotment continuing as the pigs became available. Feeding and sample collection was completed December 14, 1961 when the final test hog was marketed.

Formulation and preparations of experimental rations

Ration formulations used in the trial are listed in Table 2. Referring to the experimental design, Table 1, it is noted that the bulk diluents were fed either as "coarse" or "fine" modulus. The "coarse" designation was applied to wheat bran and oat hulls as purchased locally. The "fine" modulus was prepared by grinding both feedstuffs four times in a burr type mill. If the temperature of the feed rose appreciably during grinding it was allowed to cool before regrinding. Table 3 presents data on screening analysis and bulk density measurements obtained from the "coarse" and "fine" module wheat bran and oat hull diluents. Samples were screened through a series of U.S. standard sieves, arranged in order of decreasing pore size, and set on a mechanical shaker timed to run 15 minutes. Residues on each screen were weighed and expressed as a percentage of the original air dry sample. Bulk density measurements were calculated using a standard Imperial pint brass cylinder in which, after being poured into the cylinder from a uniform height, the samples were weighed to the nearest gram.

TABLE 2 - FORMULAS AND ESTIMATED COMPOSITION OF SWINE FINISHER RATIONS

Component	Solka-floc	Wheat bran	Oat hulls
	lb.	lb.	lb.
Cellulose (coarse or fine)	10.0		
Wheat bran		30.0	
Oat hulls			20.0
Wheat	22.0	4.0	38.0
Barley	50.5	57.8	23.4
Fat (stabilized)	3.0	--	5.0
Molasses (cane)	--	1.0	--
Meat meal	6.3	4.7	7.5
Linseed oil meal	6.7	1.0	4.6
Salt (iodized)	0.5	0.5	0.5
Dicalcium phosphate	1.0	--	1.0
Ground limestone	--	1.0	--
Vitamin-mineral mix[1]	add	add	add
Antibiotic supplement[2]	as required	as required	as required
	%	%	%
Crude protein (calculated)	15.0	15.0	15.0
T.D.N. "	67.0	67.0	67.0
Ca "	0.81	0.85	0.94
P "	0.70	0.80	0.70
Ash "	5.9	6.9	5.4
Crude fiber "	13.0	6.4	9.3

1 Vitamin-mineral mixture/1000 lb. of ration:
$ZnSO_4.7H_2O$ 50 gm.
riboflavin 8 gm.
calcium-pantothenate 5 gm.
vitamin A & D premix 74 gm. (to supply 1500 I.U. A/lb. feed and 150 I.U. D/lb. feed).

2 Antibiotic premix/1000 lbs. as required:
oleandomycin 33.3 gm. (Chas. Pfizer & Co. Inc., Brookly 6, N.Y.)
zinc bacitracin 33.3 gm. (Commercial Solvents Corp., New York 16, N.Y.)
aureomycin 33.3 gm. (Trade name for Chlortetracycline, Cyanamid of Canada Ltd., Agricultural Prod. Dept., Montreal, P.Q.)

Cellulose, in the form of "Alpha-floc"[1], a purified wood cellulose of high alpha content and at least 99.5% cellulose, was purchased in two grades, BNB 40 and BNB 100. Existing stocks of a third -BW 40- were used up in the ratio of 1 part by weight BW 40 with 3 parts BNB 40 to make up the form designated as "coarse" modulus. Physical characteristics of these grades of cellulose are listed in Table 4 as quoted from supplier's specifications[1].

Vitamin, trace mineral and antibiotic supplements were proportioned as required and added to the rations at time of mixing.

It was found that to secure better mixing and to facilitate handling, the fat or molasses portions of the usual 1000 lb. batch mixes were best mixed with 150 - 200 lb. of ground grain, preferably wheat, in a conical type of mixer[2] equipped with a central stirring auger. Grain grinding and final batch mixing was completed at the University Livestock Farm plant. Feed was bagged into approximately 70 - 80 lb. portions following completion of mixing. To maintain freshness, rations were prepared frequently in small batches, and stored in the piggery until time of use.

Pelleted feeds were made from the mixed feeds using a Superior-Templewood Pellet Mill[3] with a 3/16 inch pelleting die. Occasionally, in order to obtain satisfactory pellets, it was necessary to raise the moisture content of the feeds being pelleted by the addition of tap water

1. Trade mark for a purified wood cellulose derivative of Brown Forest Products Ltd., Boston 14, Mass.,U.S.A. Referred to formerly, and in this thesis as "Solka-floc".
2. Mixall mixer. Mfg. by Gordon Johnson Equipment Co., Kansas City 8, Mo., U.S.A.
3. Northland Machinery Supply Co. Limited, Fort William, Ontario.

TABLE 3 - PHYSICAL CHARACTERISTICS OF WHEAT BRAN AND OAT HULLS

U.S.S. sieve	Opening	Wheat bran		Oat hulls	
		Fine	Coarse	Fine	Coarse
No.	microns	%	%	%	%
10	2000	0	7	0	0
20	840	3	58	0	1
30	590	25	13	1	8
40	420	45	10	19	33
50	297	18	6	41	28
60	250	6	4	30	13
Balance	250	3	2	9	17
Bulk cc/gm. (approx. 7% moisture)		3.3	6.2	2.3	2.9

TABLE 4 - PHYSICAL CHARACTERISTICS OF ALPHA-FLOC BY GRADE, COLOR AND MODULUS

Characteristic	BW 40 white coarse	BNB 40 brown coarse	BNB 100 brown fine
Approx. ave. particle size - microns	90	100	55
Approx. screen analysis			
% retained by 100 mesh (149 micron)	35	32	2
% retained by 200 mesh (74 micron)	60	61	20
Bulk cc/gm. (approx. 7% moisture)	4.0	3.9	2.3

from a spray nozzle. Water was added to the feed mixture entering the die until firmly bound pellets were produced. In order to obtain a suitable pellet, prevent moulding and minimize drying time, moisture levels approximating 10% were found to be most suitable. Following processing pelleted rations were sacked and stored as previously indicated.

Following allotment, animals were fed their assigned rations until they reached market weight. During digestibility trials feeds containing chromic sesquioxide, mixed as indicated in the Appendix, were fed in place of the regular diet.

Management and feeding

The feeding trials were conducted in the experimental piggery where a constant environment of 70°F was maintained by the use of forced air heating and ventilation. Animals were confined in groups of four in pens with concrete floors, steel and wood partitions, automatic watering bowls, and a raised sleeping platform. By manually raising guillotine-type gates, pigs were admitted at feeding time to their individual feeding stalls where they ate from hopper-type, galvanized metal self-feeders.

Feeding practices

In accord with one of the treatments under study, animals were fed either two or three times daily. Those on twice a day feeding were confined to their individual feeding stalls for one hour periods from 7 to 8 a.m. and 4 to 5 p.m. Animals on the three times a day feeding regimen were allowed an additional feeding period from 12 noon to 1 p.m.

Wasted feed was either screened and returned to the hoppers or deducted from the consumption records. Individual feed records were

compiled at bi-weekly weighing intervals for the animals.

Management

The rations were selected randomly, however, both pens and animals were utilized as they became available. Pen grouping was restricted to animals on identical feeding frequencies. Hogs were marked with a methylcellulose silver nitrate paste (Appendix A) so as to be readily identifiable during feeding time. The resultant reddish-brown silver nitrate stain proved to be very satisfactory.

Large intestinal roundworm (Ascaris lumbricoides) control was achieved through the use of piperazine[1]. The vermifuge was mixed with the dry meal in the feeder troughs using a well rounded teaspoonful (approximately 10 gms.) per animal or, in those groups receiving pelleted rations, made up as an aqueous solution and sprinkled on the pellets in the feeder trough. Treatment was given soon after animals were placed on the test rations and reapplied at the 160 to 165 lb. stage following completion of the Cr_2O_3 indicator method digestibility trials. Upon reaching 190 lb. liveweight the animals were marketed at a local abattoir[2].

Weight and feed records

All test pigs were placed on trial in the 100 $\pm$ 5 lb. weight range and weighed thereafter at bi-weekly intervals, usually in the late morning. At each weighing, feed consumption for each individual was recorded by weighing the feeders and accounting for any additional feed additions made during the lapsed period.

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1. Dowzene DHC is the trade name for a piperazine dihydrochloride derivative. Dow Chemical Corp., Don Mills, Ontario.

2. Empire Meat Co. Ltd., Saskatoon, Sask.

Protein and energy digestibility determination

As the animals in the experiment reached the 150 lb. weight range, ration digestibility was determined utilizing the Cr_2O_3 indicator method (Appendix B).

Chromic sesquioxide determinations

The chromic sesquioxide assay used was a modification of the Bolin et al. (1952) perchronic acid method as reported by Gorrill (1960) and adopted at this institution (Appendix B).

Crude protein determinations

The procedure used for crude protein analysis was a slight modification of the official method (A.O.A.C., 1960) incorporating the use of a commercially prepared catalyst[1]. A small paper portion cup containing the oven dried fecal sample (Appendix B) was inserted into a 500 ml. Kjeldahl flask, digested and distilled. The receiving acid used was a 4% solution of Boric acid and 60 ml. per liter of a mixed indicator, prepared according to Sher (1955), containing bromcresol green, new coccine and p-nitrophenol. Following collection of ammonia the solution was titrated with 0.1 N HCl. Crude protein was calculated based on the formula:

$$\% \text{ CP} = \frac{0.014 \times \text{ml. HCl} \times \text{Normality}}{\text{wt. of sample}} \times 6.25$$

Results were reported on an oven dry, Cr_2O_3 free basis.

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1. Kjelpak No. 1 (9.9 gm. K_2SO_4, 0.41 gm. HgO and 0.08 gm. $CuSO_4$ in a polythene packet). Mfg. by Harshaw Chemical Co., Cleveland 6, Ohio, U.S.A.

Energy determinations

Calorimetric determinations were carried out using a Parr Oxygen Bomb Calorimeter[1] equipped with a Brown Electronic Recorder[2] for automatic temperature plotting. Dried homogenized samples (Appendix B) were removed from the portion cups and pelleted in a Parr Pellet press[1] prior to ignition in the oxygen bomb. Caloric content of samples were reported on an oven dry, Cr_2O_3 free basis.

Slaughtering and carcass data

Upon reaching 190 lb. liveweight the test hogs were marketed and slaughtered on the nearest hog-kill day at the abbatoir. The majority of hog kills were started at the commencement of the afternoon workshift - i.e. 1 p.m. Pigs were fed as usual, and animals in the group fed three times daily had had the opportunity to eat before being shipped. Liveweights were obtained on the animals prior to loading into the trucking vehicle. At the plant the animals were rendered senseless by being either shot with a captive bolt pistol and hung, or electrically shocked. Bleeding was accomplished by severing the juglar vein. Following processing, hot carcass weights were obtained, and after suitable cooling, the carcasses were assessed according to the Advanced Registry (A.R.) Specifications (1954) by local Officers of the Production and Marketing Branch of the Canada Department of Agriculture.

Gastrointestinal tract sampling

After being bled, the carcasses were vat scalded, mechanically dehaired, hung from a packing house rack trolley for processing, singed

1. Parr Instrument Co. Inc., Moline, Ill., U.S.A.

2. Minneapolis-Honeywell Regulator Co., Brown Instruments Div. Philadelphia, Pa., U.S.A.

and "trimmed of offal." The average post-killing time lapse for the carcasses to reach the evisceration site was 20 minutes. The gastrointestinal tracts, severed at the esophagus anterior to the cardia, were removed and conveyed to the inspection table. Following veterinary scrutiny, the tracts were collected into galvanized tubs. The containers were covered with jute bags and brought to the laboratory for dissection.

Dissection divisions of the tract employed for sample selection are indicated in Table 5.

TABLE 5 - SAMPLING SITES OF INTESTINAL TRACT AND CONTENTS

Organ	Pigs examined and sampled
Stomach	All
Small intestine	All[1]
Large intestine	All on meal
Cecum	All on pellets
Colon	All on pellets
Rectum	All

1. Ingesta and tract weights for portions posterior to the stomach obtained on females only.

Adhering adipose, mesenteric and extraneous tissues were trimmed from the digestive tracts. The stomach was excised, weighed, split longitudinally and the ingesta removed. The empty organ was rinsed with tap water, the excess water squeezed off, following weighing the organ was discarded. Gastric contents were collected in a plastic receptacle, mixed and sampled into a 2 lb. polyethylene plastic bag. Air was expressed and the bags tied with string, labelled as to site and origin, and quick frozen by immersion into a widemouth stainless steel thermos container filled with a methanol-dry ice mixture. Following rapid freezing samples were stored at -15 $\pm$ 2°C for further analysis. Samples from the remaining

tract segments were manually expressed from the longer lengths and the empty organs weighed as indicated in Table 5. In some animals there were insufficient residues in the rectal segment for sample procurement.

Due to processing and transportation factors, an average of one hour elapsed before sampling could be commenced. Since a maximum of 4 - 5 digestive tracts could be dissected and prepared in an hour, on larger kills this time lapse may have extended to 3 hours before the final animal was processed. The question of autolysis arose, and in an effort to reduce the time involved in obtaining representative samples from the chosen sites, tract and content weights, with the exception of the readily accessible stomach, were obtained only in female pigs, although all sites were samples in both barrows and gilts as indicated (Table 5). Initially cecal samples were combined with the large intestine samples, however, following observations during subsequent dissections on the differences in sample fluidity, particularly in respect to the distal colonic region, it was decided to collect cecal samples separately. Since pellet fed animals were placed on trial later, and the combined cecal-large intestine collection method had been in progress on meal fed animals, collections on the meal fed group were continued as initiated, while sample separation into cecal site and that of large intestine was adopted in the pellet fed group.

Analysis of ingesta

The scheme that was used for analyses of the ingesta samples is presented in Figure 3.

Specific gravity

The bagged frozen ingesta samples were weighed in air to the

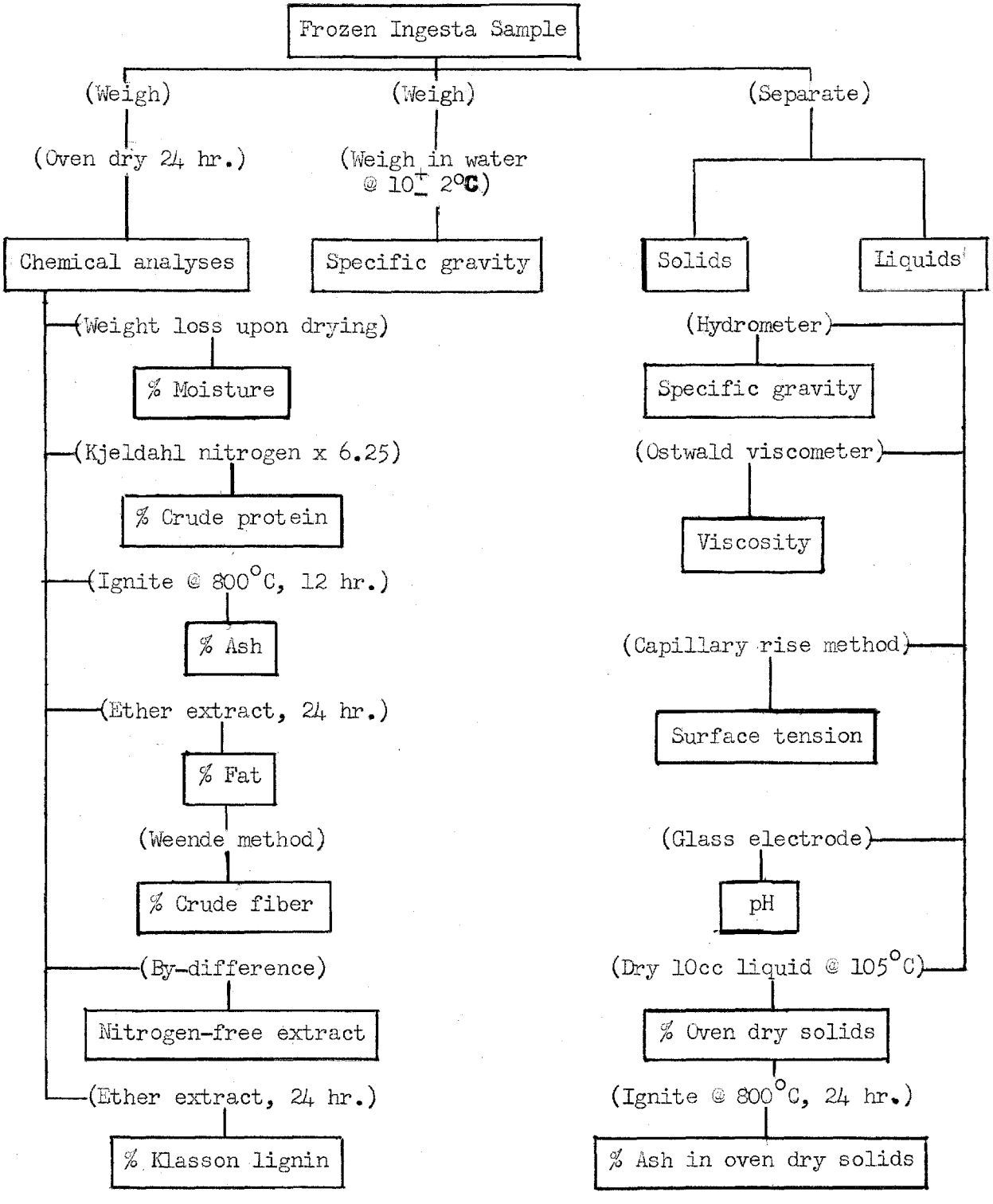

FIGURE 3 - ANALYSIS SCHEME FOR INGESTA SAMPLES

nearest tenth of a gram. A lead sinker was attached to the sample using a rubber band and a water displacement weight was obtained by weighing on a Hydrostatic balance. A large plastic container filled with cool tap water ($10 \pm 2^{\circ}C$) was utilized as a water container.

To obtain ingesta specific gravity the following weights were obtained and calculations employed as listed below.

Let:

W_a = mass weight in air

W_w = mass weight in water

W_s = sinker weight in water

$W_a + W_s$ = mass weight in air + sinker weight in water,

then the change in weight following immersion is:

$$(W_a + W_s) \pm W_w$$

Since specific gravity is the ratio of weight or mass of a given volume of substance to an equal volume of another substance, water being the reference liquid then:

$$\text{specific gravity} = \frac{W_a}{((W_a + W_a) - W_w)}$$

Using standard physical tables and the observed water temperature "T" corrections were made to $4^{\circ}C$ where the density of water is unity, i.e.:

density of water at $10^{\circ}C = 0.99973$

weight loss by immersion $= (W_a + W_s) \pm W_w$

$$\text{to correct to } 4^{\circ}C = \frac{(W_a + W_s) \pm W_w}{0.99973}$$

(specific gravity values corrected to $4^{\circ}C$ are comparable to density values).

Determination of proximate principles

In reference to Figure 3, it may be noted that the frozen ingesta samples were split longitudinaly, and wherever possible approximately half of the original sample was retained for liquid phase analyses. One of the split segments was dried for moisture determination, ground through a 30 mesh sieve and crude protein, ash, ether extract (fat), crude fiber and N.F.E. levels were determined according to the standard A.O.A.C. (1960) methods with the noted exceptions.

Moisture. Approximately one half of the original sample was stripped of adhering polyethylthene, placed into a tared shallow pan, weighed and dried at 110°C in a forced draft oven. After a few hours of drying the mass in the pans was broken up with a spatula and drying was continued for at least 24 hours. The oven was shut off and the oven and samples were allowed to cool. The sample weight was re-determined and the loss during drying was reported as per cent moisture. The dried samples were ground through a 30-mesh sieve in a Wiley mill and bagged in labelled polyethylthene bags. Subsequent analyses were reported on an oven dry basis.

Crude protein. Duplicate samples of the dried and ground samples were analyzed for crude protein using the standard A.O.A.C. method with the modifications previously noted on page 66.

Ash. Per cent ash in the dried and ground ingesta samples was determined in accordance with the A.O.A.C. (1960) methods.

Fat. Fat or "ether extract" was determined by placing a 10 gm. oven dried sample of ingesta into a thimble prepared from an 18.5 cm. Reeve Angel No. 230 creped surface filter paper. Fifteen to twenty thimbles were placed into a stainless steel bucket, connected to a syphoning and distil-

lation component. Cyclical extraction was attained by automatic syphoning off of the Skelly F solvent, (a petroleum ether derivative, boiling point range 40 - 60°C), and continued redistillation into the sample bucket. The extraction was continued for at least 24 hours. Following extraction, the weight loss of the dried and ground ingesta was obtained by drying the sample to drive off residual solvent. The extracted samples were transferred to screw-top glass containers to await further analysis.

Crude fiber. The Weende method, according to the A.O.A.C. method (1960), was utilized in assaying for crude fiber. Duplicate 2 gm. fat-free samples obtained from the Skelly F extraction, were boiled in 0.255 N. H_2SO_4. Excess acid and solubles were filtered off through "handkerchief linen". Following a hot water wash to rid the residual acid, the residues were boiled in 0.312 N NaOH. Excess base and solubles were decanted through an ignited gooch crucible having an acid-base washed, re-ignited, medium-fiber asbestos mat. The residue was quantitatively transferred to the gooch, washed with portions of hot water and rinsed with a small quantity of ethanol. In cases where necessary, n-octyl alcohol was used to prevent excessive foaming during alkaline boiling. The weight loss of the resulting residue, following ignition was reported as crude fiber:

$$\% \text{ Crude Fiber} = \frac{\text{O.D. sample weight} - \text{Wt. of ignited residues}}{\text{O.D. sample weight}} \times 100$$

The values were adjusted accordingly to obtain a fat-corrected value.

Nitrogen free extract (N.F.E.). The usual method of determination, namely that of: % NFE = 100 - (% H_2O + % Crude protein + % Ash + % Fat + % Crude fiber) was used to determine N.F.E. In this thesis N.F.E. was usually reported on a dry matter basis.

Klasson lignin

A fat free sample, obtained following completion of the fat determination, was subjected to a 2N HCl hydrolysis to remove interfering nitrogenous substances. The solubles were separated by filtration and the residue treated by the method of Jayme et al. (1958) to obtain Klasson lignin. (See Appendix B). (Lignin chemists term Klasson lignin the fraction of organic plant residues insoluble in 72% H_2SO_4).

Ingesta liquid-phase analyses

Preparation of ingesta liquid-phase

The samples retained for these tests (Figure 3) were placed in beakers, covered with watch glasses and left to thaw overnight. Most samples exuded a sufficient quantity of liquid for processing. When exudates were insufficient, particularly in gastric samples originating from wheat bran rations where the solid phase tended to hold the liquid, the ingesta was squeezed in several layers of cheesecloth so as to exude the fluids. In some of the samples obtained from the rectum, centrifugation 10 minutes at 6000 rpm. in a Lourdes Model L Centrifuge[1] was necessary to obtain a "liquid phase". When the liquid samples separated from the solid phase liquid was decanted and filtered through several layers of cheesecloth into stoppered erlenmyer flasks for subsequent measurements. The solid phase of the ingesta was discarded.

Prior to the commencement of physical measurements, ingesta liquids were brought to room temperature, 24 $\pm$ 2°C, using a water bath. To maintain uniform temperature during viscosity and surface tension measurements the measuring devices were inserted into a larger container

1. Lourdes Instrument Corp., Brooklyn 32, N.Y., U.S.A.

to form an air-jacket type of insulator. Glassware was washed with a detergent solution immediately following use, rinsed with distilled water, drained, and dried with acetone.

Specific gravity

Direct readings of liquid specific gravity were obtained using a Squibb Urinometer Float No. A-274/F hydrometer[1]. Use of this type of hydrometer permitted measurements of liquid volumes as small as 10-15 cc.

Viscosity

A standard Ostwald Viscometer was used to determine the fluid viscosity using the formula:

$$\frac{N_1}{N_2} = \frac{d_1 t_1}{d_2 t_2}$$

Where N = viscosity
d = density
t = time in seconds

Consistency of ingesta fluid volume in the viscometer was maintained by filling the lower sample reservoir to the top of bulb. To measure viscosity the fluid was drawn, by the use of gentle suction, into the upper bulb, past the top constriction and etch mark. The time interval that the meniscus took to flow from the upper to the lower etch mark was noted. Liquid density values were calculated from previous specific gravities. Distilled water was used as the reference fluid.

Surface tension

A graduated capillary tube and a thermometer, were inserted through a two holed rubber stopper and placed into a 200 x 25 mm side arm type test tube containing ingesta fluid. Negative or positive air pressure, applied through the test tube side arm as desired, was employed to raise or lower fluid levels in the capillary tube. Following removal of

1. Clay Adams Inc., New York, U.S.A.

pressure the capillary rise was allowed to stabilize and using the scale on the graduated capillary tube a reading of the actual capillary height above the main body of fluid was taken. The formula:

$$\frac{V_1}{V_2} = \frac{h_1 d_1}{h_2 d_2}$$

where V = viscosity
h = height or reading of actual capillary column
d = density of the liquid

was used to arrive at liquid surface tension. The reference liquid was distilled water.

pH

Ingesta liquid was placed into a small beaker and pH determined using a Beckman Zeromatic pH Meter[1].

Oven dry solids

10 cc. of ingesta fluid was pipetted into a previously ignited and weighed glazed porcelain crucible. Samples were weighed on a Sitoptic Analytical Rapid Balance[2] and oven dried at 105°C for at least 12 hours. The weight of the resulting residue was obtained after cooling in a desiccator and the per cent oven dry solids calculated on the basis of the original wet sample weight.

Ash in oven dry solids

The sample of oven dried residue from the 10 cc. liquid, mentioned above, was ashed in a muffle furnace overnight at 800°C. The per cent ash in the oven dry solids was determined on the basis of the incombustible residue.

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1. Beckman Instruments Inc., Fullerton, Calif., U.S.A.

2. "Becker Sons", N.Y., Brummen, Holland.

Statistical analyses

The data were subjected to an analysis of variance according to the method of Snedecor (1956). Treatment means were evaluated by employing the Multiple Range Test (LSR) of Duncan (1955). In calculating the minimum (min.) and maximum (max.) ranges for the LSR comparisons the 5% probability level was accepted.

Experimental data obtained from animal performance and response measurements shall be presented and considered within the following general divisions:

General animal performance.

Carcass characteristics.

Ration digestibility and usage.

Intestinal tract and ingesta measures.

Each of these respective divisions shall be further categorized as to measures employed in their assessment. For example, in the first division, headed "General animal performance", the measurement categories were: average daily feed intake; average daily gain; and feed efficiency. Categorizations of the other divisions are listed in the table of contents. In order to assess the various treatment aspects, further subdivision of such categories shall be made as to: bulk type; feeding frequency; bulk modulus; pelleting; antibiotic supplementation; sex differences; and the respective interactions of those treatment combinations that have been proven to be statistically significant following analysis of variance.

For conciseness, reference to treatments shall be made by referring to the particular variation component, i.e. "wheat bran" shall, unless otherwise indicated, refer to the ration wherein this feedstuff was the diluent employed. In the division involving intestinal tract and ingesta measures statistical analyses were conducted only on samples originating from the stomach. Consequently unless reference is made to statistical significance, observations in this division shall be based on the comparisons of averages only.

Following presentation and sectional summarization of data under

the aforementioned divisions, the usual interpretation of the results shall be presented in the succeeding thesis section entitled "DISCUSSION".

General animal performance

Average daily feed intake

TABLE 6 - THE EFFECTS OF BULK MODULUS AND ANTIBIOTIC ON THE AVERAGE DAILY FEED INTAKE (ADF) RESPONSES TO BULK TYPE

Treatment[1]	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
	lb.	lb.	lb.		
Bulk mean*	5.38	5.38	5.80	0.21	0.22
Bulk modulus**					
Fine	5.65	5.25	5.98	0.30	0.31
Coarse	5.11	5.51	5.62		
Antibiotic					
Nil	5.28	5.43	5.71	0.30	0.31
Add	5.49	5.33	5.89		
Bulk modulus x Antibiotic*					
Fine nil	5.70	5.21	5.99	0.43	0.45
add	5.61	5.29	5.96		
Coarse nil	4.86	5.65	5.42		
add	5.37	5.38	5.82		

1. Significance found upon analysis of variance denoted by: $P < 0.05^{*}$, $P < 0.01^{**}$.

The general effect indicated in Table 6 reveals that in comparison to the other two bulk diluents, average daily feed consumption was significantly greater on oat hull based rations. Interaction effects disclosed that feed intakes on fine modulus wheat bran rations were below those for other bulks. Coarse modulus resulted in decreased solka-floc consumption, but this effect appeared to be offset by antibiotic supplementation. ADF on coarse modulus wheat bran was increased notably in the absence of anti-

biotic supplements. Of particular note is the low ADF of 4.86 lbs. on coarse modulus unsupplemented solka-floc; a response that undoubtedly reduced the general mean for solka-floc. The highest intakes of ADF occurred on fine moduli oat hulls.

In summary, fine modulus and antibiotic supplementation tended to increase feed intake on solka-floc and oat hull rations, the opposite occurred on wheat bran rations.

TABLE 7 - THE EFFECTS OF BULK MODULUS, PELLETING AND ANTIBIOTIC ON THE AVERAGE DAILY FEED INTAKE (ADF) RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		lb.	lb.	
Frequency mean**		5.34	5.70	0.17
Bulk modulus				
Fine		5.44	5.81	0.25
Coarse		5.24	5.59	
Pelleting				
Meal		5.20	5.58	0.25
Pellets		5.48	5.83	
Antibiotic				
Nil		5.27	5.68	0.25
Add		5.41	5.73	
Bulk modulus x Pelleting*				
Fine	meal	5.44	5.66	0.35
	pellets	5.44	6.02	
Coarse	meal	4.96	5.54	
	pellets	5.52	5.65	
Bulk modulus x Antibiotic*				
Fine	nil	5.33	5.94	0.35
	add	5.55	5.69	
Coarse	nil	5.20	5.42	
	add	5.27	5.77	

The results in Table 7 reveal that a significant increase of 0.36 lb. ADF occurred on three times a day feeding ($P < 0.01$). This trend persisted throughout the first order interactions but became less consistent statistically in the second order ones. The feeding of fine modulus, in the form of meal, or with the addition of antibiotic, tended to reduce the mean difference below statistical significance between two or three times a day feeding. Coarse modulus ADF intake, unlike that of fine, when fed as meal or with antibiotic was higher on three times a day feeding.

In summary, increased feed intake on three times a day feeding occurred. This influence was modified by the dependency of the bulk modulus response on pelleting or antibiotic treatments.

The overall response indicated in Table 8 reveals that ADF on fine bulk modulus significantly exceeded that of coarse modulus by 0.22 lb. It appeared that coarse modulus depressed intakes on solka-floc and oat hull rations but increased that of wheat bran ($P < 0.05$) and the addition of antibiotic tended to nullify these effects on all three bulks. Twice-a-day feeding of meal-type rations tended to depress intake on coarse modulus, however, other treatments of pelleting or consideration of antibiotic supplementation on this feeding frequency failed to effect ADF difference between the moduli. Three times a day feeding of meal type or antibiotic supplemented rations appeared to equalize ADF on the two moduli.

It is apparent that feed intakes generally were higher when fine modulus rations were fed but there were exceptions effected by each of the other experimental ration variables. Modulus had no such effect with bran rations. The inclusion of antibiotics improved intakes on coarse moduli solka-floc and oat hull rations about as effectively as did finer grinding

TABLE 8 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, PELLETING AND ANTIBIOTIC ON THE AVERAGE DAILY FEED INTAKE (ADF) RESPONSES TO BULK MODULUS

Treatment		Bulk modulus		LSR
		Fine	Coarse	
		lb.	lb.	
Modulus mean*		5.63	5.41	0.17
Bulk type**				
Solka-floc		5.65	5.11	0.30
Wheat bran		5.25	5.51	
Oat hulls		5.98	5.62	
Feeding frequency				
2/day		5.44	5.24	0.25
3/day		5.81	5.59	
Pelleting				
Meal		5.52	5.25	0.25
Pellets		5.73	5.58	
Antibiotic				
Nil		5.63	5.31	0.25
Add		5.62	5.52	
Bulk type x Antibiotic*				
Solka-floc	nil	5.70	4.86	0.43
	add	5.61	5.37	
Wheat bran	nil	5.21	5.65	
	add	5.29	5.38	
Oat hulls	nil	5.99	5.42	
	add	5.96	5.82	
Feeding frequency x Pelleting*				
2/day	meal	5.44	4.96	0.35
	pellets	5.44	5.52	
3/day	meal	5.61	5.54	
	pellets	6.02	5.65	
Feeding frequency x Antibiotic*				
2/day	nil	5.33	5.20	0.35
	add	5.55	5.27	
3/day	nil	5.94	5.42	
	add	5.69	5.77	

but there appeared to be no additive effect of finer grinding and antibiotic supplementation. Fine modulus gave no advantage with pigs fed three times daily unless the rations were pelleted and for pigs fed twice daily, no response was obtained with pelleted feeds.

TABLE 9 - THE EFFECTS OF FEEDING FREQUENCY, ANTIBIOTIC AND SEX ON THE AVERAGE DAILY FEED INTAKE (ADF) RESPONSES TO PELLETING

Treatment	Pelleting		LSR
	Meal	Pellets	
	lb.	lb.	
Pelleting mean**	5.39	5.65	0.17
Feeding frequency			
2/day	5.20	5.48	0.25
3/day	5.58	5.83	
Bulk modulus			
Fine	5.52	5.73	0.25
Coarse	5.25	5.58	
Antibiotic**			
Nil	5.46	5.48	0.25
Add	5.31	5.83	
Sex*			
Barrows	5.70	6.19	0.25
Gilts	5.08	5.11	
Feeding frequency x Bulk modulus*			
2/day fine	5.44	5.44	0.35
coarse	4.96	5.52	
3/day fine	5.61	6.02	
coarse	5.54	5.65	

Results in Table 9 indicate a significant ($P < 0.01$) increase in the average daily feed intake of pelleted rations in comparison to meal type. This increase was particularly significant on antibiotic supplemented

rations and on barrow groups. Twice a day fine or three times a day coarse moduli feeds failed to respond to the pelleting influence on ADF.

The data in Table 10 reveal that antibiotic supplementation failed to increase average daily feed intake, except with pelleted rations as previously noted. Coarse moduli solka-floc rations had a significantly reduced ADF in the absence of antibiotic, and coarse moduli oat hulls appeared to increase significantly in daily consumption when antibiotic was present. The results indicate that the significance noted in the interaction involving feeding frequency and bulk moduli was due to causes other than antibiotic supplementation.

Although antibiotic addition did not directly influence ADF, pelleting antibiotic supplemented rations resulted in higher daily feed intakes. The incorporation of antibiotic supplements in coarse moduli solka-floc or oat hull rations appeared to maintain or increase average feed intake. It is of interest to note however, that wheat bran ration responses were opposite to these trends.

As indicated in Table 11, barrows consumed significantly more feed than gilts. The sex difference was significantly different on the pelleting interaction and while certainly evident on meal type rations, was particularly pronounced on pelleted rations. The significant interaction effect appears to be entirely a matter of degree of response rather than opposing effects.

Average daily feed intake appears to be influenced by an interplay of the various factors in this trial. It was evident that bulk type response was governed by bulk modulus, and to a lesser degree by antibiotic influence. Fine bulk modulus, which on the whole tended to in-

TABLE 10 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS AND PELLETING ON THE AVERAGE DAILY FEED INTAKE (ADF) RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		lb.	lb.	
Antibiotic mean		5.47	5.57	0.17
Pelleting**				
Meal		5.46	5.31	0.25
Pellets		5.48	5.83	
Bulk type x Bulk modulus*				
Solka-floc	fine	5.70	5.61	0.43
	coarse	4.86	5.37	
Wheat bran	fine	5.21	5.29	
	coarse	5.65	5.38	
Oat hulls	fine	5.99	5.96	
	coarse	5.42	5.82	
Feeding frequency x Bulk modulus*				
2/day	fine	5.33	5.55	0.35
	coarse	5.20	5.27	
3/day	fine	5.94	5.69	
	coarse	5.42	5.77	

TABLE 11 - THE EFFECTS OF PELLETING ON THE AVERAGE DAILY FEED INTAKE (ADF) RESPONSES TO SEX

Treatment	Sex Barrows	Sex Gilts	LSR
	lb.	lb.	
Sex mean**	5.95	5.10	0.17
Pelleting mean*			
Meal	5.70	5.08	0.25
Pellets	6.19	5.11	

crease feed intake caused a depression on wheat bran. The antibiotic supplementation of coarse bulks, except wheat bran, appeared to result in increased feed intake. Pelleting and three times a day feeding were conducive to increased feed intake as mentioned previously. Male animals, particularly those on pelleted rations, consumed more feed than females.

Factors that reduce bulkiness, accessibility to feed and sex differences seemed to play significant roles in determining feed intake in this trial.

Average daily gain

TABLE 12 - THE EFFECTS OF FEEDING FREQUENCY AND BULK MODULUS ON THE AVERAGE DAILY GAIN (ADG) RESPONSES TO BULK TYPE

Treatment	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
	lb.	lb.	lb.		
Bulk mean	1.52	1.45	1.53	0.08	0.08
Feeding frequency*					
2/day	1.54	1.39	1.47	0.03	0.03
3/day	1.49	1.51	1.59		
Bulk modulus*					
Fine	1.58	1.41	1.57	0.03	0.03
Coarse	1.45	1.50	1.49		

The general response indicated that wheat bran rations produced a lower ADG than either solka-floc or oat hulls. It is apparent from interaction effects that the greatest reduction of ADG on wheat bran feeds occurred upon twice a day feeding, and to a slightly lesser extent on fine bulk modulus. Daily gains were highest on oat hull rations fed three times a day and coarse modulus appeared to depress solka-floc gains significantly.

Data in Table 13 reveal an increase in ADG on lots fed three

times daily. In contrast to solka-floc rations, which had significantly higher ADG on twice a day feeding, wheat bran and oat hull rations produced higher gains on three times a day feeding. To sum, it appeared that greater ADG was evident on increased feeding, except on solka-floc rations.

The general response in Table 14 reveals the similarity of ADG on groups fed either fine or coarse moduli bulks. Bulk modulus interaction with bulk type tends to indicate that while solka-floc and oat hull group gains were improved on fine modulus, there was a depression of ADG on wheat bran rations as a result of fine modulus feeding.

Gilts fed meal, and barrows fed pellets, performed better on fine modulus, but barrows fed meal and gilts fed pellets reacted more favourably on coarse modulus. It would appear that the two extremes in ADG were achieved by barrow groups on fine bulk moduli pellets (1.76 lb.) and gilt groups on coarse moduli meals (1.34 lb.).

Fine modulus was conducive to higher gains in solka-floc and oat hull rations, but reduced ADG on wheat bran. Interactions with pelleting seemed to vary with sex differences.

Results in Table 15 indicate that ADG was significantly increased ($P < 0.01$) on pelleted rations. Barrow groups fed pellets, on either moduli rations, outgained meal-fed counterparts, and it would appear that gilt groups fed coarse moduli meals achieved the lowest rate of ADG. In summary, barrows fed pellets, particularly fine moduli bulk, had the highest rate of gain, while gilts fed meals, especially coarse modulus, gained the slowest.

The analysis of variance on the data related to antibiotic supple-

TABLE 13 - THE EFFECTS OF BULK TYPE ON THE AVERAGE DAILY GAIN (ADG) RESPONSES TO FEEDING FREQUENCY

Treatment	Feeding frequency 2/day	Feeding frequency 3/day	LSR
	lb.	lb.	
Frequency mean	1.47	1.53	0.06
Bulk type*			
Solka-floc	1.54	1.49	0.03
Wheat bran	1.39	1.51	
Oat hulls	1.47	1.59	

TABLE 14 - THE EFFECTS OF BULK TYPE, PELLETING AND SEX ON THE AVERAGE DAILY GAIN (ADG) RESPONSES TO BULK MODULUS

Treatment		Bulk modulus Fine	Bulk modulus Coarse	LSR
		lb.	lb.	
Modulus mean		1.52	1.48	0.06
Bulk type*				
Solka-floc		1.58	1.45	0.03
Wheat bran		1.41	1.50	
Oat hulls		1.57	1.49	
Pelleting				
Meal		1.46	1.44	0.03
Pellets		1.59	1.52	
Sex				
Barrows		1.63	1.57	0.03
Gilts		1.42	1.39	
Pelleting x Sex*				
Meal	barrows	1.49	1.54	0.04
	gilts	1.42	1.34	
Pellets	barrows	1.76	1.60	
	gilts	1.41	1.45	

TABLE 15 - THE EFFECTS OF BULK MODULUS AND SEX ON THE AVERAGE DAILY GAIN (ADG) RESPONSES TO PELLETING

Treatment		Pelleting		LSR
		Meal	Pellets	
		lb.	lb.	
Pelleting mean**		1.45	1.56	0.06
Bulk modulus				
Fine		1.46	1.59	0.09
Coarse		1.44	1.52	
Sex				
Barrows		1.51	1.68	0.09
Gilts		1.38	1.43	
Bulk modulus x Sex*				
Fine	barrows	1.49	1.76	0.04
	gilts	1.42	1.41	
Coarse	barrows	1.54	1.60	
	gilts	1.34	1.45	

TABLE 16 - THE EFFECTS OF BULK MODULUS AND PELLETING ON THE AVERAGE DAILY GAIN (ADG) RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
		lb.	lb.	
Sex mean**		1.60	1.40	0.06
Bulk modulus				
Fine		1.63	1.42	0.09
Coarse		1.57	1.39	
Pelleting				
Meal		1.51	1.38	0.09
Pellets		1.68	1.43	
Bulk modulus x Pelleting*				
Fine	meal	1.49	1.42	0.04
	pellets	1.76	1.41	
Coarse	meal	1.54	1.34	
	pellets	1.60	1.45	

mentation revealed that the average daily gains of 1.44 lb. in the unsupplemented groups were significantly less ($P < 0.01$) than the 1.57 lb. attained in the supplemented groups. No other factors in combination with antibiotic effect produced significant mean deviations.

The barrow groups had a significantly higher ADG than gilt groups ($P < 0.01$) as indicated in Table 16. The strength of this influence is also evident in the interactions.

In summarizing the factors found to influence the rate of average daily gain in these trials it becomes evident that the variations in responses to bulk type were influenced by feeding frequency and bulk modulus. Feeding three times daily increased rate of gain except on solka-floc. Fine moduli bulks, with the exception of wheat bran, were conducive to improved gains. There appeared to be a definite increase of ADG in response to pelleting, however part of this may be attributed to the high response of barrows to pelleting, particularly on fine moduli bulks. Antibiotic supplementation of rations resulted in a significant increase in daily gain.

Feed efficiency

The general response indicated a significant improvement in feed efficiency in groups fed solka-floc rations (Table 17). On twice-a-day feeding, feed efficiency on solka-floc was significantly better than on oat hull and wheat bran rations, but not so on three times a day feeding. The inclusion of antibiotic improved feed efficiencies in every case. Efficiency on three times a day feeding was inferior on all bulk types. Antibiotic supplementation improved this situation, but oat hull rations were improved less than wheat bran or solka-floc rations.

It appeared that solka-floc rations tended to respond more favourably to antibiotic supplementation and twice a day feeding than the other two bulks. Three times a day feeding reduced feed utilization on all bulks in the absence of antibiotic.

While on the whole, twice a day feeding frequency fell short of significantly improving feed efficiency ($P<0.05$), it tended to be more efficient in feed conversion than three times a day feeding. Solka-floc rations responded favourably to twice-a-day feeding, a response that was evident on both unsupplemented and antibiotic supplemented rations, but proved to be significant only with antibiotic inclusion. The generally lowered utilization on three times-a-day fed unsupplemented bulks was reflected in solka-floc and wheat bran rations, however, oat hull rations yielded poorer efficiency figures on both feeding frequencies.

Antibiotic supplementation, as indicated in Table 19, significantly ($P < 0.01$) improved feed utilization. The favourable efficiency response prevailed on all bulk types and on three times a day feeding, but was less marked on twice a day feeding. Wheat bran rations particularly failed to respond to antibiotic on twice-a-day feeding nor was the response of solka-floc fed groups as marked as that of oat hulls fed twice daily.

As a rule antibiotic incorporation improved feed utilization, particularly on three times a day feeding, however, on twice-a-day feeding this effect was less pronounced on wheat bran based rations.

In summary the significant effect of bulk type was attributed to the tendency of solka-floc rations to respond more readily to the favourable influences of both twice-a-day feeding and antibiotic inclusion. In the absence of antibiotic supplementation twice-a-day feeding tended to

TABLE 17 - THE EFFECTS OF FEEDING FREQUENCY AND ANTIBIOTIC ON FEED EFFICIENCY RESPONSES TO BULK TYPE

Treatment	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
Bulk mean*	3.57[1]	3.72	3.81	0.13	0.14
Feeding frequency					
2/day	3.43	3.72	3.78	0.20	0.20
3/day	3.70	3.71	3.84		
Antibiotic					
Nil	3.70	3.83	3.93	0.20	0.20
Add	3.43	3.62	3.69		
Feeding frequency x Antibiotic*					
2/day nil	3.50	3.70	3.93	0.28	0.29
add	3.36	3.77	3.63		
3/day nil	3.91	3.95	3.92		
add	3.50	3.46	3.76		

1. Pounds of feed per pound of gain.

TABLE 18 - THE EFFECTS OF BULK TYPE AND ANTIBIOTIC ON FEED EFFICIENCY RESPONSES TO FEEDING FREQUENCY

Treatment	Feeding frequency		LSR
	2/day	3/day	
Frequency mean	3.65	3.75	0.11
Bulk types			
Solka-floc	3.43	3.70	0.20
Wheat bran	3.72	3.71	
Oat hulls	3.78	3.84	
Antibiotic*			
Nil	3.71	3.93	0.16
Add	3.59	3.57	
Bulk type x Antibiotic*			
Solka-floc nil	3.50	3.91	0.28
add	3.36	3.50	
Wheat bran nil	3.70	3.95	
add	3.72	3.46	
Oat hulls nil	3.93	3.92	
add	3.63	3.76	

TABLE 19 - THE EFFECTS OF BULK TYPE AND FEEDING FREQUENCY ON FEED EFFICIENCY RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
Antibiotic mean*		3.82	3.58	0.11
Bulk types				
Solka-floc		3.70	3.43	0.20
Wheat bran		3.83	3.62	
Oat hulls		3.93	3.69	
Feeding frequency*				
2/day		3.71	3.59	0.16
3/day		3.93	3.57	
Bulk type x Feeding frequency*				
Solka-floc	2/day	3.50	3.36	0.28
	3/day	3.91	3.50	
Wheat bran	2/day	3.70	3.77	
	3/day	3.95	3.46	
Oat hulls	2/day	3.93	3.63	
	3/day	3.92	3.76	

improve feed utilization. Antibiotic supplementation, particularly on three times a day feeding, improved feed utilization.

Summary

Animal performance was measured by deriving the ratio:

$$\text{Feed efficiency} = \frac{\text{units of feed}}{\text{units of gain}}$$

therefore, it is possible for animals to have equal feed conversion ratios yet possess differing daily gain and feed intakes. Within a similar performance group there could be low or high gaining groups as indicated by feeding frequency, pelleting and sex comparisons. The lack of a significant correlation between feed intake and feed conversion has been reported (Siegl, 1960); however others suggest that animals which eat more tend to

be less efficient (Magee, 1962). Such contradictions may be explained by the demonstration of a positive correlation of dietary feed intake and gain (Siegl, 1960; Magee, 1962) and of body fat and gain (Lassiter et al., 1960, using mice). The extent to which body growth was due to adipose tissue deposition could result in an apparent change in feed conversion due to the energetics involved in fat assimilation.

In these trials differences existed between the feed conversion ratios on the three bulk types, solka-floc produced the most efficient gains. Although daily gains on oat hull rations were equivalent to those on solka-floc, they were attained at the expense of increased feed consumption. Feeding frequency, bulk modulus, and antibiotic treatments interacted with the bulk types on both ADG and ADF measures and influenced conversion ratios. Solka-floc responses to twice-a-day feeding and to antibiotic inclusion were greater than for the other bulks. Fine modulus depressed performance on wheat bran rations. Increased feed intakes were evident on three times a day feeding, on pelleted or fine modulus rations and in barrow groups, nevertheless overall feed efficiency ratios remained similar. Generally though, bulk modulus response was dependent on bulk type, pelleting and antibiotic treatments. The response of wheat bran was, unlike the other two bulks, more favourable on coarse modulus. Antibiotic incorporation increased rates of gain and since this occurred on relatively similar feed intakes, an improved feed conversion ratio is indicated. This latter influence was particularly evident on increased feeding of solka-floc and oat hull rations. Barrow groups gained and ate more than gilts and showed no important differences in feed conversion. Fine modulus and pelleted rations, factors conducive towards increased intake without altered

feed conversion, were the particular treatments where the differences between the sexes were indicated.

Carcass characteristics

Loin area

TABLE 20 - THE EFFECTS OF BULK MODULUS AND ANTIBIOTIC ON LOIN AREA RESPONSES TO BULK TYPE

Treatment		Bulk type			Min.	Max.
		Solka-floc	Wheat bran	Oat hulls		
		$cm.^2$	$cm.^2$	$cm.^2$		
Bulk mean		3.57	3.76	3.57	0.18	0.19
Bulk modulus**						
Fine		3.45	3.93	3.57	0.25	0.26
Coarse		3.69	3.59	3.57		
Antibiotic						
Nil		3.49	3.75	3.50	0.25	0.26
Add		3.64	3.78	3.64		
Bulk modulus x Antibiotic*						
Fine	nil	3.48	3.76	3.50	0.36	0.37
	add	3.41	4.11	3.64		
Coarse	nil	3.50	3.74	3.49		
	add	3.88	3.44	3.64		

The overall response indicated a significant increase in loin area in animals fed wheat bran rations, this influence appeared to be particularly prevalent on the fine bulk modulus (Table 20). It is indicated that antibiotic supplementation of fine modulus wheat bran resulted in a significant increase in loin area. A similar tendency of antibiotic supplementation on coarse modulus solka-floc was evident when compared to the reduced loin area on coarse modulus supplemented wheat bran.

The apparent increase of loin area on wheat bran rations appeared to be attributable to the effects of fine modulus, particularly in the

presence of antibiotic.

In Table 21 the general response indicated lack of significant difference of loin area between groups fed twice and three times a day. Meal form rations supplemented with antibiotic or fed to gilts resulted in increased loin area on three times a day feeding, while pellets fed to gilts decreased loin area on three times a day feeding.

Data in Table 22 reveal the apparent similarity of loin area produced on fine and coarse bulk moduli. Significantly larger loin areas were produced when coarse modulus solka-floc and fine modulus wheat bran rations were supplemented with antibiotic. Fine moduli pellets fed twice a day created a significant increase in loin area. The loin area of 4.11 $cm.^2$ on the aforementioned wheat bran ration was notably larger than other groups.

The magnitude and direction of bulk modulus influence on loin area was dependent on the bulk type antibiotic interaction, and also on twice a day feeding of pelleted feeds.

The differences in loin area between meal and pellet type rations (Table 23) were non-significant, however barrows fed pellets and gilts fed meals had significantly increased loin areas. Further significant increases in loin area on pelleted rations occurred on twice a day fed fine moduli or antibiotic supplemented rations and barrows fed three times a day. Loin area on pelleted rations was less on those rations that were fed three times a day with antibiotic inclusion, or fed to gilt groups.

With regard to the effects of ration pelleting, gilts and barrows responded differently in terms of loin area development. Pelleting resulted in increased loin area in barrow carcasses, especially under three times a

TABLE 21 - THE EFFECTS OF BULK MODULUS, ANTIBIOTIC, PELLETING AND SEX ON LOIN AREA RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		$cm.^2$	$cm.^2$	
Frequency mean		3.60	3.66	0.15
Bulk modulus x Pelleting*				
Fine	meal	3.49	3.72	0.29
	pellets	3.83	3.56	
Coarse	meal	3.57	3.67	
	pellets	3.51	3.70	
Bulk modulus x Antibiotic*				
Fine	nil	3.70	3.46	0.29
	add	3.62	3.81	
Coarse	nil	3.46	3.69	
	add	3.63	3.68	
Pelleting x Antibiotic**				
Meal	nil	3.58	3.49	0.29
	add	3.48	3.90	
Pellets	nil	3.58	3.67	
	add	3.77	3.59	
Pelleting x Sex**				
Meal	barrows	3.39	3.25	0.29
	gilts	3.68	4.14	
Pellets	barrows	3.50	3.71	
	gilts	3.85	3.51	

TABLE 22 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, PELLETING AND ANTIBIOTIC ON LOIN AREA RESPONSES TO BULK MODULUS

Treatment		Bulk modulus: Fine	Bulk modulus: Coarse	LSR
		$cm.^2$	$cm.^2$	
Modulus mean		3.65	3.61	0.15
Bulk type*				
Solka-floc		3.45	3.59	0.25
Wheat bran		3.93	3.59	
Oat hulls		3.57	3.57	
Bulk type x Antibiotic*				
Solka-floc	nil	3.48	3.50	0.36
	add	3.41	3.88	
Wheat bran	nil	3.76	3.74	
	add	4.11	3.44	
Oat hulls	nil	3.50	3.49	
	add	3.64	3.64	
Feeding frequency x Pelleting*				
2/day	meal	3.49	3.57	0.29
	pellets	3.83	3.51	
3/day	meal	3.72	3.67	
	pellets	3.56	3.70	
Feeding frequency x Antibiotic*				
2/day	nil	3.70	3.46	0.29
	add	3.62	3.63	
3/day	nil	3.46	3.69	
	add	3.81	3.68	

day feeding. Gilts showed no significant increase when fed twice daily and when fed three times daily, there was a marked decrease in loin area.

Antibiotic supplementation as such (Table 24) had no influence on loin area. However in two instances, increases in loin area occurred on supplemented rations fed three times daily, either as fine modulus or

meal type.

TABLE 23 - THE EFFECTS OF FEEDING FREQUENCY, BULK MODULUS, ANTIBIOTIC AND SEX ON LOIN AREA RESPONSES TO PELLETING

Treatment		Pelleting		LSR
		Meal	Pellets	
		$cm.^2$	$cm.^2$	
Pelleting mean		3.61	3.65	0.15
Feeding frequency				
2/day		3.53	3.67	0.21
3/day		3.69	3.63	
Sex effect**				
Barrows		3.32	3.60	0.21
Gilts		3.91	3.70	
Feeding frequency x Bulk modulus*				
2/day	fine	3.49	3.83	0.29
	coarse	3.57	3.51	
3/day	fine	3.72	3.56	
	coarse	3.67	3.70	
Feeding frequency x Antibiotic**				
2/day	nil	3.58	3.58	0.29
	add	3.48	3.77	
3/day	nil	3.49	3.67	
	add	3.90	3.59	
Feeding frequency x Sex**				
2/day	barrows	3.39	3.50	0.29
	gilts	3.68	3.85	
3/day	barrows	3.25	3.71	
	gilts	4.14	3.54	

The data in Table 25 reveal that gilts had significantly larger areas of loin than barrows. This trend was evident on both feeding frequencies and proved to be statistically significant on meal type rations. Barrow groups performed as well as gilts on pelleted rations, this effect was nullified by twice a day feeding but was re-established on three times

a day feeding.

TABLE 24 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS AND PELLETING ON LOIN AREA RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		cm.^{2}	cm.^{2}	
Antibiotic mean		3.58	3.69	0.15
Bulk type x Bulk modulus*				
Solka-floc	fine	3.48	3.41	0.36
	coarse	3.50	3.88	
Wheat bran	fine	3.76	4.11	
	coarse	3.74	3.44	
Oat hulls	fine	3.50	3.64	
	coarse	3.49	3.64	
Feeding frequency x Bulk modulus*				
2/day	fine	3.70	3.62	0.29
	coarse	3.46	3.63	
3/day	fine	3.46	3.81	
	coarse	3.69	3.68	
Feeding frequency x Pelleting**				
2/day	meal	3.58	3.48	0.29
	pellets	3.58	3.77	
3/day	meal	3.49	3.90	
	pellets	3.67	3.59	

Gilts yielded significantly larger areas of loin except when compared to barrow groups fed pellets, particularly on the increased feeding frequency.

In summary, wheat bran rations, depending somewhat on the influence of modulus and antibiotic inclusion, increased loin area. Loin area was greater in gilt groups, however, this effect was nullified by pelleted rations, particularly on increased feeding, to the point that loin area differences become non-significant between sexes.

TABLE 25 - THE EFFECTS OF FEEDING FREQUENCY AND PELLETING ON LOIN AREA RESPONSES TO SEX

Treatment	Sex		LSR
	Barrows	Gilts	
	$cm.^2$	$cm.^2$	
Sex mean**	3.46	3.80	0.15
Feeding frequency			
2/day	3.44	3.76	0.21
3/day	3.48	3.84	
Pelleting**			
Meal	3.32	3.91	0.21
Pellets	3.60	3.70	
Feeding frequency x Pelleting**			
2/day meal	3.39	3.68	0.29
pellets	3.50	3.85	
3/day meal	3.25	4.14	
pellets	3.71	3.54	

Dressing percentage

The data in Table 26 disclose that significant dressing percentage differences existed between all bulks, lowest yields were realized on wheat bran rations and highest on oat hulls.

On twice a day feeding yields were significantly larger only on oat hull rations, while on three times a day feeding the increased yields on solka-floc and oat hulls resulted in a significantly larger dressing percentage than on wheat bran rations. Twice a day feeding of antibiotic supplemented rations increased carcass yield on wheat bran rations to the level of oat hulls, however, in barrow groups the oat hull ration carcasses outdressed both bulks. Three times a day feeding, irrespective of antibiotic or sex, produced the lowest carcass recoveries on wheat bran rations.

TABLE 26 - THE EFFECTS OF FEEDING FREQUENCY, BULK MODULUS, PELLETING, ANTIBIOTIC AND SEX ON DRESSING PERCENTAGE[1] RESPONSES TO BULK TYPE

Treatment		Bulk type: Solka-floc	Wheat bran	Oat hulls	Min.	Max.
		%	%	%		
Bulk mean**		75.00	73.92	75.96	0.62	0.62
Feeding frequency**						
2/day		73.97	74.36	75.71	0.87	0.92
3/day		76.04	73.47	76.21		
Bulk modulus						
Fine		74.89	73.65	76.11	0.87	0.92
Coarse		75.12	74.19	75.81		
Pelleting						
Meal		74.72	73.91	76.30	0.87	0.92
Pellets		75.28	73.93	75.62		
Antibiotic						
Nil		74.90	73.60	75.53	0.87	0.92
Add		75.11	74.24	76.38		
Sex						
Barrows		74.53	73.94	75.18	0.87	0.92
Gilts		75.48	73.90	76.74		
Feeding frequency x Antibiotic*						
2/day	nil	73.64	73.60	75.76	1.23	1.30
	add	74.30	75.12	75.66		
3/day	nil	76.15	73.61	75.31		
	add	75.93	73.35	77.10		
Feeding frequency x Sex**						
2/day	barrows	73.04	74.70	74.78	1.23	1.30
	gilts	74.90	74.03	76.64		
3/day	barrows	76.02	73.19	75.58		
	gilts	76.06	73.76	76.83		
Bulk modulus x Antibiotic**						
Fine	nil	75.25	72.98	75.96	1.23	1.30
	add	74.52	74.37	76.26		
Coarse	nil	74.54	74.23	75.11		
	add	75.71	74.15	76.50		
Pelleting x Antibiotic**						
Meal	nil	74.96	73.87	75.15	1.23	1.30
	add	74.50	73.96	77.45		
Pellets	nil	74.83	73.34	75.92		
	add	75.73	74.51	75.32		

1 Hot carcass weight per 100 lb. liveweight.

The incorporation of antibiotic supplementation resulted in significant interactions involving feeding frequency, bulk modulus, and pelleting with bulk type. In the absence of antibiotic, wheat bran yielded lowest dressing percentages on both feeding frequencies, fine modulus and on both pelleting treatments. The solka-floc interaction with antibiotic was similar to wheat bran on twice a day feeding but on pellets it performed medial to the other bulks. In other instances where significant differences involving solka-floc existed it equalled dressing percentage yields on oat hulls. Antibiotic inclusion removed yield differences except on twice-a-day feeding where solka-floc yielded lower than oat hulls, on both moduli where wheat bran yielded lower than oat hulls, and on meal-type rations where oat hulls significantly out performed the other bulks and produced a higher dressing percentage.

Generally wheat bran rations produced lowest carcass yields, solka-floc was medial and pigs on oat hulls dressed the highest. However it appeared that twice-daily feeding depressed solka-floc yields and antibiotic inclusion tended to moderate yield differences due to bulk type.

The data in Table 27 reveal that a significant difference in dressing percentage, favouring three times a day feeding was evident. Interactions reveal that there was a complex and varied effect of the other factors in these trials, mostly favouring three times a day feeding. Significantly increased dressing percentage on three times a day feeding was evident on solka-floc feeds. There were indications of increased dressing percentages on fine modulus and pelleted rations, and in barrow groups. Contrastingly a significant reduction in the dressing percentage of wheat bran fed groups occured on the higher feeding frequency.

Three times a day feeding produced a significantly increased dressing percentage on solka-floc rations, irrespective of antibiotic or sex treatments. Oat hull rations supplemented with antibiotic increased carcass yield on three times a day feeding. Wheat bran rations produced a significantly higher carcass yield on twice a day feeding when antibiotic was incorporated in the ration.

Groups fed three times a day exhibited higher dressing percentages on fine moduli meals, pellets of coarse moduli bulks or fed to barrows, and barrows not receiving antibiotic supplementation. Other treatment differences proved non-significant ($P > 0.05$).

In summary, carcass yields were higher on three times a day feeding. As previously noted, dressing percentage was lowest on wheat bran rations and highest on oat hulls. The response to feeding frequency of the various bulk types indicated that wheat bran rations usually reacted in an opposite pattern to those of the other bulks. Interaction results were suggestive that factors other than feeding frequency may also have been responsible for some of the significant differences.

On the whole, modulus of the bulk component did not influence carcass yield (Table 28). However a reduced yield did occur with pigs fed fine modulus wheat bran in the absence of an antibiotic supplement, and there was evidence that an additional daily feeding of meal type rations influenced the responses obtained to different moduli.

As evident from a study of Table 29 pelleting of the rations had little if any effect upon dressing percentages. It can be concluded therefore that statistically significant interactions involving pelleting, and shown in this table, must be explained on the basis of other variables

TABLE 27 - THE EFFECTS OF BULK TYPE, BULK MODULUS, PELLETING, ANTIBIOTIC AND SEX ON DRESSING PERCENTAGE RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		%	%	
Frequency mean*		74.68	75.24	0.50
Bulk type**				
Solka-floc		73.97	76.04	0.87
Wheat bran		74.36	73.47	
Oat hulls		75.71	76.21	
Sex				
Barrows		74.17	74.93	0.71
Gilts		75.19	75.55	
Bulk type x Antibiotic*				
Solka-floc	nil	73.64	76.15	1.23
	add	74.30	75.93	
Wheat bran	nil	73.60	73.61	
	add	75.12	73.35	
Oat hulls	nil	75.76	75.31	
	add	75.66	77.10	
Bulk type x Sex*				
Solka-floc	barrows	73.04	76.02	1.23
	gilts	74.90	76.06	
Wheat bran	barrows	74.70	73.19	
	gilts	74.03	73.76	
Oat hulls	barrows	74.78	75.58	
	gilts	76.64	76.83	

continued .....

TABLE 27 (continued) - THE EFFECTS OF BULK TYPE, BULK MODULUS, PELLETING, ANTIBIOTIC AND SEX ON DRESSING PERCENTAGE RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		%	%	
Bulk modulus				
Fine		74.44	75.32	0.71
Coarse		74.92	75.16	
Pelleting				
Meal		74.78	75.17	0.71
Pellets		74.58	75.31	
Bulk modulus x Pelleting**				
Fine	meal	74.29	75.85	1.00
	pellets	74.59	74.80	
Coarse	meal	75.28	74.50	
	pellets	74.56	75.82	
Pelleting x Sex*				
Meal	barrows	74.32	74.69	1.00
	gilts	75.25	75.65	
Pellets	barrows	74.02	75.17	
	gilts	75.13	75.45	
Antibiotic x Sex*				
Nil	barrows	73.71	74.93	1.00
	gilts	74.96	75.11	
Add	barrows	74.63	74.93	
	gilts	75.43	75.99	

contained in the interactions. These effects are discussed elsewhere.

Antibiotic supplementation improved dressing percentage in the majority of experimental conditions involved in this experiment (Table 30). The improvement was especially marked with oat hull rations fed three times daily where the increase was from 75.31 to 77.10%, and with oat hull rations fed as meal an even greater increase was obtained. The highest carcass yields

TABLE 28 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, PELLETING, ANTIBIOTIC AND SEX ON DRESSING PERCENTAGE RESPONSES TO BULK MODULUS

Treatment		Bulk modulus		LSR
		Fine	Coarse	
		%	%	
Modulus mean		74.88	75.04	0.50
Sex				
Barrows		74.74	74.36	0.71
Gilts		75.03	75.71	
Bulk type x Antibiotic**				
Solka-floc	nil	75.25	74.54	1.23
	add	74.52	75.71	
Wheat bran	nil	72.98	74.23	
	add	74.37	74.15	
Oat hulls	nil	75.96	75.11	
	add	76.26	76.50	
Feeding frequency x Pelleting**				
2/day	meal	74.29	75.28	1.00
	pellets	74.59	74.56	
3/day	meal	75.85	74.50	
	pellets	74.80	75.82	

in the experiment were produced with oat hull rations containing antibiotics, fed three times daily in the meal form.

Some effects were observed with bran rations where, in relation to the general mean, it might be concluded that the absence of antibiotics resulted in a decreased dressing percentage under twice daily feeding and with fine modulus.

TABLE 29 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS, ANTIBIOTIC AND SEX ON DRESSING PERCENTAGE RESPONSES TO PELLETING

Treatment		Pelleting: Meal	Pelleting: Pellets	LSR
		%	%	
Pelleting mean		74.98	74.94	0.50
Sex				
Barrows		74.50	74.70	0.71
Gilts		75.45	75.19	
Bulk type x Antibiotic**				
Solka-floc	nil	74.96	74.83	1.23
	add	74.50	75.73	
Wheat bran	nil	73.87	73.34	
	add	73.96	74.51	
Oat hulls	nil	75.15	75.92	
	add	77.45	75.32	
Feeding frequency x Bulk modulus**				
2/day	fine	74.29	74.59	1.00
	coarse	75.28	74.56	
3/day	fine	75.85	74.80	
	coarse	74.50	75.82	
Feeding frequency x Sex*				
2/day	barrows	74.32	74.02	1.00
	gilts	75.25	75.13	
3/day	barrows	74.69	75.17	
	gilts	75.65	75.45	

TABLE 30 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS, PELLETING AND SEX ON DRESSING PERCENTAGE RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		%	%	
Antibiotic mean**		74.68	75.24	0.50
Bulk modulus				
Fine		74.73	75.03	0.71
Coarse		74.62	75.45	
Sex				
Barrows		74.32	75.03	0.71
Gilts		74.78	75.71	
Bulk type x Feeding frequency*				
Solka-floc	2/day	73.64	74.30	1.23
	3/day	76.15	75.93	
Wheat bran	2/day	73.60	75.12	
	3/day	73.61	73.35	
Oat hulls	2/day	75.76	75.66	
	3/day	75.31	77.10	
Bulk type x Bulk modulus**				
Solka-floc	fine	75.25	74.52	1.23
	coarse	74.54	75.71	
Wheat bran	fine	72.98	74.37	
	coarse	74.23	74.15	
Oat hulls	fine	75.96	76.26	
	coarse	75.11	76.50	
Bulk type x Pelleting**				
Solka-floc	meal	74.96	74.50	1.23
	pellets	74.83	75.73	
Wheat bran	meal	73.87	73.96	
	pellets	73.34	74.51	
Oat hulls	meal	75.15	77.45	
	pellets	75.92	75.32	
Feeding frequency x Sex**				
2/day	barrows	73.71	74.63	1.00
	gilts	74.96	75.43	
3/day	barrows	74.93	74.93	
	gilts	75.11	75.99	

TABLE 31 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS, PELLETING AND ANTIBIOTIC ON DRESSING PERCENTAGE RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
		%	%	
Sex mean**		74.55	75.37	0.50
Bulk type				
Solka-floc		74.53	75.48	0.87
Wheat bran		73.94	73.90	
Oat hulls		75.18	76.74	
Feeding frequency				
2/day		74.17	75.19	0.71
3/day		74.93	75.55	
Bulk modulus*				
Fine		74.74	75.03	0.71
Coarse		74.36	75.71	
Pelleting				
Meal		74.50	75.45	0.71
Pellets		74.70	75.19	
Antibiotic				
Nil		74.32	75.03	0.71
Add		74.78	75.71	
Bulk type x Feeding frequency**				
Solka-floc	2/day	73.04	74.90	1.23
	3/day	76.02	76.06	
Wheat bran	2/day	74.70	74.03	
	3/day	73.19	73.76	
Oat hulls	2/day	74.78	76.64	
	3/day	75.58	76.83	
Feeding frequency x Pelleting*				
2/day	meal	74.32	75.25	1.00
	pellets	74.02	75.13	
3/day	meal	74.69	75.65	
	pellets	75.17	75.45	
Feeding frequency x Antibiotic*				
2/day	nil	73.71	74.96	1.00
	add	74.63	75.43	
3/day	nil	74.93	75.11	
	add	74.93	75.99	

Results in Table 31 reveal that gilt groups yielded significantly higher dressing percentages than barrows. First order interactions tend to bear out this effect; however only in the case of bulk modulus comparisons were the differences statistically significant.

In the second order interactions listed, gilt groups fed twice daily yielded significantly higher dressing percentages, with the exception of those receiving wheat bran, meal type or antibiotic supplemented rations. Gilts fed three times daily produced carcass yields similar to barrows, except those receiving oat hull or antibiotic supplemented rations.

In general, gilts yielded a higher dressing percentage than barrows. This was evident on either bulk modulus. It would appear that carcass yields favouring gilts were substantially reduced by a feeding frequency of three times a day. Of the bulks, wheat bran suppressed the sex effect on dressing percentage, however oat hulls appeared to maintain it.

Carcass yield was significantly influenced by bulk type, yields were highest on oat hulls and lowest on wheat bran. Interaction results suggested bulk type response was influenced by feeding frequency and antibiotic inclusion. Increased feeding frequency, antibiotic addition and gilt goups appeared to yield higher dressing percentages.

Average backfat

The data in Table 32 indicate a significant difference between average backfat due to bulk types, with wheat bran yielding the lowest and oat hulls the highest values. Reduced average backfat prevailed when wheat bran was combined with three times a day feeding, fine modulus, either

TABLE 32 - THE EFFECTS OF FEEDING FREQUENCY, BULK MODULUS, ANTIBIOTIC AND SEX ON AVERAGE BACKFAT[1] RESPONSES TO BULK TYPE

Treatment		Bulk type			LSR	
		Solka-floc	Wheat bran	Oat hulls	Min.	Max.
		in.	in.	in.		
Bulk mean**		1.21	1.14	1.27	0.06	0.06
Feeding frequency						
2/day		1.12	1.11	1.24	0.08	0.08
3/day		1.30	1.18	1.30		
Bulk modulus*						
Fine		1.26	1.08	1.31	0.08	0.08
Coarse		1.16	1.20	1.23		
Antibiotic						
Nil		1.18	1.14	1.23	0.08	0.08
Add		1.24	1.14	1.31		
Sex						
Barrows		1.27	1.22	1.38	0.08	0.08
Gilts		1.15	1.07	1.16		
Feeding frequency x Bulk modulus*						
2/day	fine	1.19	1.04	1.35	0.11	0.12
	coarse	1.06	1.17	1.13		
3/day	fine	1.33	1.12	1.27		
	coarse	1.26	1.24	1.33		
Bulk modulus x Antibiotic*						
Fine	nil	1.27	1.04	1.30	0.11	0.12
	add	1.25	1.12	1.32		
Coarse	nil	1.10	1.24	1.16		
	add	1.23	1.17	1.30		
Bulk modulus x Sex*						
Fine	barrows	1.33	1.11	1.44	0.11	0.12
	gilts	1.19	1.05	1.18		
Coarse	barrows	1.22	1.33	1.31		
	gilts	1.10	1.08	1.14		

1 Mean of shoulder, minimum back and loin measurements.

antibiotic treatment and in gilts. However, only in the case of fine modulus was the effect statistically significant.

Feeding fine modulus wheat bran rations reduced average backfat on either feeding frequency, in the presence or absence of antibiotic and in both sex groups. In comparison to coarse moduli oat hulls a significant backfat reduction on wheat bran occurred on antibiotic supplemented rations. Fine moduli oat hulls yielded significantly greater average backfat levels on twice a day feeding and in barrow groups. The principal effects appearing to reduce average backfat on solka-floc rations when compared to oat hulls appeared to be fine moduli fed either twice a day or to barrow groups.

Where significant differences existed, wheat bran produced the least backfat and oat hulls the highest, and solka-floc, while tending to be medial, occasionally produced results varying toward either extreme. Fine bulk modulus appeared to depress backfat production on wheat bran, while the results on solka-floc and oat hulls appeared to be opposite to this and backfat was greater.

The general response indicated that twice-a-day feeding significantly depressed average backfat deposition. This effect was prevalent on solka-floc, coarse modulus and antibiotic free rations, but proved to be statistically significant only on coarse modulus rations. The data in Table 33 further indicate that animals fed twice daily exhibited significant average backfat reductions on fine moduli bulks when these were fed as solka-floc or without antibiotic. Coarse moduli bulks produced lower average backfat on solka-floc or oat hull rations irrespective of antibiotic treatment.

TABLE 33 - THE EFFECTS OF BULK TYPE, BULK MODULUS AND ANTIBIOTIC ON AVERAGE BACKFAT RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	3/day	LSR
		in.	in.	
Frequency mean**		1.16	1.26	0.05
Bulk type				
Solka-floc		1.12	1.30	0.08
Wheat bran		1.11	1.18	
Oat hulls		1.24	1.30	
Bulk modulus*				
Fine		1.19	1.24	0.07
Coarse		1.12	1.28	
Antibiotic				
Nil		1.10	1.26	0.07
Add		1.20	1.26	
Bulk type x Modulus*				
Solka-floc	fine	1.19	1.33	0.11
	coarse	1.06	1.26	
Wheat bran	fine	1.04	1.12	
	coarse	1.17	1.24	
Oat hulls	fine	1.35	1.27	
	coarse	1.13	1.33	
Bulk modulus x Antibiotic*				
Fine	nil	1.12	1.28	0.09
	add	1.26	1.20	
Coarse	nil	1.10	1.23	
	add	1.14	1.32	

The effects of feeding frequency on backfat deposition were appreciable when solka-floc rations (either fine or coarse) and oat hulls (coarse) were involved. In these cases more frequent feeding led to marked increases in fat thickness.

Bulk modulus (Table 34) effects proved to be influenced in one way or another with every one of the other experimental variables. The

TABLE 34 - THE EFFECT OF BULK TYPE, FEEDING FREQUENCY, PELLETING, ANTIBIOTIC AND SEX ON AVERAGE BACKFAT RESPONSES TO BULK MODULUS

Treatment		Bulk modulus Fine	Bulk modulus Coarse	LSR
		in.	in.	
Modulus mean		1.22	1.20	0.05
Bulk type**				
Solka-floc		1.26	1.16	0.08
Wheat bran		1.08	1.20	
Oat hulls		1.31	1.23	
Feeding frequency*				
2/day		1.19	1.12	0.07
3/day		1.24	1.28	
Pelleting*				
Meal		1.23	1.16	0.07
Pellets		1.21	1.26	
Bulk type x Feeding frequency*				
Solka-floc	2/day	1.19	1.06	0.11
	3/day	1.33	1.26	
Wheat bran	2/day	1.04	1.17	
	3/day	1.12	1.24	
Oat hulls	2/day	1.35	1.13	
	3/day	1.27	1.33	
Bulk type x Antibiotic*				
Solka-floc	nil	1.27	1.10	0.11
	add	1.25	1.23	
Wheat bran	nil	1.04	1.24	
	add	1.12	1.17	
Oat hulls	nil	1.30	1.16	
	add	1.32	1.30	
Bulk type x Sex*				
Solka-floc	barrows	1.33	1.22	0.11
	gilts	1.19	1.10	
Wheat bran	barrows	1.11	1.33	
	gilts	1.05	1.08	
Oat hulls	barrows	1.44	1.31	
	gilts	1.18	1.14	
Feeding frequency x Antibiotic*				
2/day	nil	1.12	1.10	0.09
	add	1.26	1.14	
3/day	nil	1.28	1.23	
	add	1.20	1.32	

different types of bulk responded differently to modulus effects. Backfat deposition was significantly depressed on coarse module feeds when either solka-floc or oat hulls were fed twice daily, without antibiotic or to barrows. Conversely under identical feeding frequency, antibiotic and sex treatments, average backfat depth was increased in animals fed coarse wheat bran.

Modulus effects were also modified by antibiotic supplementation and feeding frequency interactions. With twice daily feeding of antibiotic-supplemented rations the fine modulus resulted in more backfat, but on three times daily feeding the reverse occurred. Coarse moduli meals fed twice daily produced animals that exhibited decreased backfat thickness.

While bulk modulus as such did not influence average backfat depth, it was implicated in the nature of the bulk type response. Fine moduli increased backfat production on solka-floc and oat hull rations, but decreased it on wheat bran based rations. Subject to a modifying influence of antibiotic inclusion, backfat was less on coarse modulus fed either twice daily or in the meal form.

TABLE 35 - THE EFFECTS OF BULK MODULUS ON AVERAGE BACKFAT RESPONSES TO PELLETING

Treatment	Pelleting		LSR
	Meal	Pellets	
	in.	in.	
Pelleting mean	1.20	1.22	0.05
Bulk modulus**			
Fine	1.23	1.21	0.07
Coarse	1.16	1.26	

The general response indicated that pelleting exerted no effect on average backfat; however, on coarse modulus feeds pelleting produced a significant increase in backfat in contrast to the absence of such an effect on fine modulus. It is of interest to note that bulk moduli effects (Table 34) were influential on meal type rations only in this comparison, this may, in conjunction with the above effects, indicate that ration bulkiness may have been influential on factors affecting backfat deposition.

Although the effect was statistically non-significant, antibiotic supplementation of rations increased average backfat (Table 36). Interaction effects disclosed that this tendency of antibiotic was statistically significant on solka-floc, oat hull or three times a day rations fed as the coarse bulk moduli. The use of antibiotic on twice-a-day feeding of fine moduli bulks also resulted in significant increases in average backfat. It would appear that antibiotic supplementation potentiated other factors towards the production of increased backfat levels.

Barrow groups, as indicated in Table 37, had significantly more average backfat than gilts, an effect prevalent on all bulk type and moduli interactions except fine wheat bran fed lots.

Average backfat depth was lowest on wheat bran and highest on oat hull rations, however this effect was apparently mitigated by bulk modulus. The response of wheat bran to modulus, was in a manner opposite to that produced in the other two bulks. Twice-a-day feeding produced less backfat, however this effect was also associated to some degree with bulk modulus. Pelleting coarse moduli bulks increased backfat. Inclusion of antibiotic tended to increase average backfat, however this response was contingent upon bulk type and modulus. As a group barrows yielded more backfat than gilts.

TABLE 36 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY AND BULK MODULUS ON AVERAGE BACKFAT RESPONSES ON ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		in.	in.	
Antibiotic mean		1.18	1.23	0.05
Bulk types				
Solka-floc		1.18	1.24	0.08
Wheat bran		1.14	1.14	
Oat hulls		1.23	1.31	
Feeding frequency				
2/day		1.10	1.20	0.07
3/day		1.26	1.26	
Bulk modulus				
Fine		1.20	1.23	0.07
Coarse		1.16	1.26	
Bulk type x Bulk modulus*				
Solka-floc	fine	1.27	1.25	0.11
	coarse	1.10	1.23	
Wheat bran	fine	1.04	1.12	
	coarse	1.24	1.17	
Oat hulls	fine	1.30	1.32	
	coarse	1.16	1.30	
Feeding frequency x Bulk modulus*				
2/day	fine	1.12	1.26	0.09
	coarse	1.10	1.14	
3/day	fine	1.28	1.20	
	coarse	1.23	1.32	

TABLE 37 - THE EFFECTS OF BULK TYPE AND MODULUS ON AVERAGE BACKFAT RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
		in.	in.	
Sex mean*		1.29	1.14	0.05
Bulk type				
Solka-floc		1.27	1.15	0.08
Wheat bran		1.22	1.07	
Oat hulls		1.38	1.16	
Bulk modulus				
Fine		1.29	1.14	0.07
Coarse		1.29	1.11	
Bulk type x Bulk modulus*				
Solka-floc	fine	1.33	1.19	0.11
	coarse	1.22	1.10	
Wheat bran	fine	1.11	1.05	
	coarse	1.33	1.08	
Oat hulls	fine	1.44	1.18	
	coarse	1.31	1.14	

Carcass grades

Carcass grades were not subjected to a statistical analysis, however a summary of this data is presented in Table 38. The data would indicate that percentage-wise deviations in carcass grades in comparison to the test average are indicated in bulk type, feeding frequency and sex treatments, and possibly on pelleting. Wheat bran rations, twice daily feeding and particularly gilt groups produced a higher percentage of "A's" than occurred on the test as a whole. There was a slight indication that a higher percentage of "A" carcasses were also evident in those groups receiving pelleted feed, although these differences are probably too small to be real.

TABLE 38 - SUMMARY OF CARCASS GRADES

Treatment	Carcass grade A		B	
	Number	%	Number	%
Bulk type				
Solka-floc	21	67	11	33
Wheat bran	25	78	7	22
Oat hulls	18	53	14	47
Feeding frequency				
2/day	36	75	12	25
3/day	27	56	21	44
Bulk modulus				
Fine	31	65	17	35
Coarse	33	69	15	31
Pelleting				
Meal	30	63	18	37
Pelleting	34	71	14	29
Antibiotic				
Nil	33	69	15	31
Add	30	63	18	37
Sex				
Barrows	22	46	26	54
Gilts	41	85	7	15
Test average	64	67	32	33

The complete data on carcass grades are presented in the appendix (Table C). It is evident that factors such as oat hulls and barrows proved to be additive, i.e. only 25% A carcasses were produced on this treatment combination.

Summary

Meatiness has been positively correlated with loin area and negatively with backfat and carcass weights (Bowman et al., 1962; Carpenter et

al., 1962). In the trial being considered currently, animals were slaughtered within relatively similar weight ranges therefore dressing percentage would reflect yield differences between carcasses in this instances. It has been indicated that higher dressing percentages are accompanied by a greater degree of fatness (Plank and Berg, 1963).

Wheat bran rations produced the lowest carcass dressing percentage and average backfat as well as the largest loin area and highest percentage of "A" carcasses. Oat hull rations were the opposite and produced animals having the highest dressing percentage and average backfat and the smallest loin area and percentage of "A" carcasses. The inference made from these results is that wheat bran produced the "meatiest" carcasses and oat hulls the "fattest". The situation proved to be somewhat analagous when making sex comparisons, differences between dressing percentage, average backfat, loin area and carcass grades were evident. Gilt groups produced a significantly larger loin area and dressing percentage and acquired less backfat than barrows, these differences were also reflected in the higher percentage of "A" carcasses in gilts. Whether or not the yield of carcass was attributable to degree of adiposity, amount of fill or trim is not particularly evident at this time.

The summary of grade comparisons would indicate that feeding frequency was an influential factor in achieving the particular distribution of A's and B's. Statistical analysis revealed that dressing percentage and average backfat, but not loin area, was reduced on twice a day feeding. Antibiotic supplementation increased both dressing percentage and average backfat, however indications were that neither loin area nor carcass grades were altered by this treatment. Dressing percentage, average backfat, loin

area and the apparent distribution of A and B carcass grades appeared to be independent of either bulk modulus or pelleting treatments.

Interaction effects on loin area implied that bulk type response was associated with modulus and antibiotic treatments, particularly on wheat bran rations. Similar trends were evident upon dressing percentage and average backfat, although the degree and direction of response varied with the bulk type. Wheat bran rations usually responded in an opposing manner to the other two bulk diluents. The influences of pelleting rations was indicated in the responses elicited by coarse bulk modulus and three times a day feeding in that average backfat deposition was increased. A further interaction between pelleting and sex resulted in a significant increase in loin area of barrow groups.

Ration digestibility and performance

Energy digestibility

The general effect indicated in Table 39 shows a significant reduction of energy digestibility on oat hull rations. Similar depressions on oat hull rations occurred on coarse modulus, meal type and antibiotic supplemented rations. It was indicated that oat hull ration energy digestibility was significantly greater on unsupplemented fine moduli than other bulks, however on coarse moduli neither presence nor absence of antibiotic affected energy digestibility in oat hulls. The addition of antibiotic to fine moduli solka-floc and coarse moduli wheat bran resulted in significantly higher energy digestibility percentages.

In oat hull rations energy digestibility percentages were usually the lowest and subject to the greatest variation. The response of wheat

TABLE 39 - THE EFFECTS OF BULK MODULUS, PELLETING AND ANTIBIOTIC ON ENERGY DIGESTIBILITY RESPONSES TO BULK TYPE

Treatment	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Max.	Min.
	%	%	%		
Bulk mean*	68.5	68.8	67.0	1.5	1.6
Bulk modulus**					
Fine	68.7	67.3	69.3	2.2	2.3
Coarse	68.2	70.3	64.5		
Pelleting*					
Meal	70.0	68.2	66.4	2.2	2.3
Pellets	67.3	69.4	67.5		
Antibiotic*					
Nil	67.9	68.5	68.4	2.2	2.3
Add	69.0	69.1	65.6		
Bulk modulus x Antibiotic*					
Fine nil	66.9	67.4	71.9	3.1	3.3
add	70.5	67.2	66.9		
Coarse nil	68.8	69.7	64.8		
add	67.7	71.0	64.2		

bran to moduli differed in that it responded more favourably when coarse, whereas the other bulks responded to fine moduli, the degree of response being dependent on antibiotic treatment.

On the whole, bulk modulus had no significant influence on energy digestibility (Table 40), however fine modulus depressed energy digestibility in wheat bran and increased it in oat hull rations ($P < 0.05$). The second order interaction indicated that in wheat bran this effect appeared to be linked with not only the effects of modulus but with the antibiotic effect upon coarse modulus, and in the case of oat hulls this was apparently a factor attributable to fine modulus and the absence of anti-

biotic.

Bulk moduli, while not influencing energy digestibility directly, appeared to influence the response of wheat bran and oat hulls. Wheat bran rations responded to coarse moduli favourably in the presence of antibiotic, while oat hulls responded to fine moduli in the absence of antibiotic.

TABLE 40 - THE EFFECTS OF BULK TYPE AND ANTIBIOTIC ON ENERGY DIGESTIBILITY RESPONSES TO BULK MODULUS

Treatment		Bulk modulus Fine	Coarse	LSR
		%	%	
Modulus mean		68.5	67.7	1.3
Bulk type**				
Solka-floc		68.7	68.2	2.2
Wheat bran		67.3	70.3	
Oat hulls		69.3	64.5	
Bulk type x Antibiotic*				
Solka-floc	nil	66.9	68.8	3.1
	add	70.5	67.6	
Wheat bran	nil	67.4	69.7	
	add	67.2	71.0	
Oat hulls	nil	71.9	64.8	
	add	66.9	64.2	

The main treatment effect of pelleting indicated in Table 41 did not create a change in energy digestibility, however on solka-floc rations a significant increase in energy digestibility occurred on meal type rations. In reference to Table 39, it appears that one of the factors causing significant differences between bulk types on meal rations was the nature and magnitude of solka-floc ration response to pelleting. The significantly different responses of energy digestibility to pelleting

seemed to be dependent on antibiotic. On meals antibiotic-free rations fed to gilts yielded an increased energy digestibility, this effect was reversed in the presence of antibiotic.

It would appear that while pelleting failed to influence percent of digestible energy, these values were decreased on pelleted solka-floc rations. The magnitude and direction of digestible energy variations to pelleting in gilts may have been in response to other factors.

TABLE 41 - THE EFFECTS OF BULK TYPE, ANTIBIOTIC AND SEX ON ENERGY DIGESTIBILITY RESPONSES TO PELLETING

Treatment	Pelleting		LSR
	Meal	Pellets	
	%	%	
Pelleting mean	68.1	68.0	1.3
Bulk type*			
Solka-floc	70.0	67.3	2.2
Wheat bran	68.2	69.4	
Oat hulls	66.4	67.5	
Antibiotic x Sex**			
Nil barrows	67.0	68.7	2.5
gilts	70.0	67.4	
Add barrows	68.6	67.5	
gilts	66.9	68.5	

The results in Table 42 indicate the lack of significant differences in energy digestibility between rations varying in antibiotic treatment. The addition of antibiotic to fine modulus increased energy digestibility in solka-floc rations and decreased energy digestibility in oat hull rations. The latter difference was significant on oat hull rations and, although evident, it was short of significance on solka-floc, probably due to the smaller influence of antibiotic on fine solka-floc. Gilts on meal rations reacted unfavourably to antibiotic addition in that energy digesti-

bility declined from 70.0. to 66.9%.

It appeared that antibiotic supplementation of rations failed to directly affect digestible energy percentages. The response to antibiotic inclusion varied from an increased energy digestibility on fine moduli solka-floc to a decrease on fine moduli oat hulls and meal fed gilts.

TABLE 42 - THE EFFECTS OF BULK TYPE, BULK MODULUS, PELLETING AND SEX ON ENERGY. DIGESTIBILITY RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		%	%	
Antibiotic mean		68.2	67.9	1.3
Bulk type*				
Solka-floc		67.9	69.0	2.2
Wheat bran		68.5	69.1	
Oat hulls		68.4	65.6	
Bulk type x Bulk modulus*				
Solka-floc	fine	66.9	70.5	3.1
	coarse	68.8	67.6	
Wheat bran	fine	67.4	67.2	
	coarse	69.7	71.0	
Oat hulls	fine	71.9	66.9	
	coarse	64.8	64.2	
Pelleting x Sex**				
Meal	barrows	67.0	68.6	2.5
	gilts	70.0	66.9	
Pellets	barrows	68.7	67.6	
	gilts	67.4	68.5	

While on the whole, differences in sex failed to affect digestible energy (Table 43) there was one treatment, that of unsupplemented meals fed to gilt groups, that produced a significantly higher digestible energy percentage.

TABLE 43 - THE EFFECTS OF PELLETING AND ANTIBIOTIC ON ENERGY DIGESTIBILITY RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
		%	%	
Sex mean		68.0	68.2	1.3
Pelleting x Antibiotic**				
Meal	nil	67.0	70.0	2.5
	add	68.6	66.9	
Pellets	nil	68.7	67.4	
	add	67.6	68.5	

Bulk type influenced the digestible energy levels in that oat hulls yielded the lowest level of energy digestibility. These responses were influenced by interactions with bulk modulus, antibiotic and pelleting treatments. Coarse modulus, while increasing digestible energy in wheat bran, depressed it in oat hulls. The addition of antibiotic to fine modulus solka-floc increased digestible energy but depressed it in oat hulls on the same treatment. Pelleting depressed digestible energy in solka-floc rations.

Protein digestibility

The general response indicated that oat hull rations had a significantly higher protein digestibility than either solka-floc or wheat bran rations. The superiority of oat hulls in respect to protein digestibility was evident on both pelleting and antibiotic treatments. When wheat bran was the ration diluent it was apparent that protein digestibility was significantly depressed on pelleted rations and on those rations fed without antibiotic supplementation.

It appeared that the protein digestibility of oat hull rations

TABLE 44 - THE EFFECTS OF PELLETING AND ANTIBIOTIC ON PROTEIN DIGESTIBILITY RESPONSES TO BULK TYPE

Treatment	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
	%	%	%		
Bulk mean**	78.2	76.8	81.5	1.6	1.6
Pelleting*					
Meal	79.4	78.0	80.6	2.2	2.3
Pellets	77.0	75.6	82.5		
Antibiotic*					
Nil	77.0	74.2	81.0	2.2	2.3
Add	79.5	79.3	82.1		

TABLE 45 - THE EFFECTS OF PELLETING ON PROTEIN DIGESTIBILITY RESPONSES TO FEEDING FREQUENCY

Treatment	Feeding frequency		LSR
	2/day	3/day	
	%	%	
Frequency mean	79.1	78.5	1.3
Pelleting*			
Meal	80.3	78.4	1.8
Pellets	78.0	78.7	

increased significantly above the other bulks. Protein digestibility of wheat bran rations was particularly affected by either pelleting or antibiotic supplementation.

Results in Table 45, while indicating a slightly higher protein digestibility on twice daily feeding proved to be non-significant, however meal rations fed twice daily exhibited a significant increase in digestibility of protein.

TABLE 46 - THE EFFECTS OF BULK TYPE AND FEEDING FREQUENCY ON PROTEIN DIGESTIBILITY RESPONSES TO PELLETING

Treatment	Pelleting		LSR
	Meal	Pellets	
	%	%	
Pelleting mean	79.3	78.3	1.3
Bulk type*			
Solka-floc	79.4	77.0	2.2
Wheat bran	78.0	75.6	
Oat hulls	80.6	82.5	
Feeding frequency*			
2/day	80.3	78.0	1.9
3/day	78.4	78.7	

TABLE 47 - THE EFFECTS OF BULK TYPE ON PROTEIN DIGESTIBILITY RESPONSES TO ANTIBIOTIC

Treatment	Antibiotic		LSR
	Nil	Add	
	%	%	
Antibiotic mean**	77.4	80.3	1.3
Bulk type*			
Solka-floc	77.0	79.5	2.2
Wheat bran	74.2	79.3	
Oat hulls	81.0	82.1	

The general response to pelleting (Table 46) failed to constitute a significant change in protein digestibility. Interaction results revealed that pelleting significantly depressed the digestibility of protein in rations containing solka-floc and wheat bran but oat hull rations produced an increased digestibility of protein ($P < 0.05$). Protein digestibility was significantly higher on meal type rations fed

twice-a-day in comparison to pellets.

In summary, it appeared that while pelleting as such did not influence protein digestibility, this treatment in association with bulk type and feeding frequency produced digestibility variations.

The data in Table 47 indicate a significant improvement in protein digestibility levels on antibiotic supplemented rations. Similar significant increases prevailed on solka-floc and wheat bran rations, however the increase with oat hulls proved to be short of significance ($P > 0.05$).

In summarizing the influential factors on apparent digestibility of crude protein in the ration, it was found that bulk type tended to influence the direction and magnitude of variability. Reduced feeding frequency increased the digestibility of protein only on meal rations and pelleting depressed protein digestibility on solka-floc and wheat bran rations. Antibiotic addition tended to create conditions favourable towards increased protein digestibility levels in the ration.

Digestible energy intake

The overall response in Table 48 indicated that mean daily digestible energy (DE) intake was significantly reduced on wheat bran rations. Interaction results revealed that these differences were particularly evident on fine bulk modulus where significant differences between all bulk types existed.

A significant increase in DE intake occurred on three times a day feeding (7.31 Mcal.) in comparison to twice a day feeding (6.95 Mcal., with the LSR being 0.27).

TABLE 48 - THE EFFECT OF BULK MODULUS ON AVERAGE DAILY DE INTAKE RESPONSES TO BULK TYPE

Treatment	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
	Mcal.	Mcal.	Mcal.		
Bulk mean**	7.17	6.80	7.47	0.33	0.35
Bulk modulus**					
Fine	7.47	6.55	7.99	0.47	0.49
Coarse	6.74	7.11	6.96		

TABLE 49 - THE EFFECTS OF BULK TYPE, PELLETING AND SEX ON AVERAGE DAILY DE INTAKE RESPONSES TO BULK MODULUS

Treatment		Bulk modulus		LSR
		Fine	Coarse	
		Mcal.	Mcal.	
Modulus mean**		7.32	6.94	0.27
Bulk type**				
Solka-floc		7.47	6.74	0.47
Wheat bran		6.51	7.11	
Oat hulls		7.99	6.96	
Pelleting				
Meal		7.13	6.79	0.38
Pellets		7.51	7.08	
Sex				
Barrows		7.95	7.34	0.38
Gilts		6.70	6.53	
Pelleting x Sex*				
Meal	barrows	7.48	7.22	0.54
	gilts	6.79	6.36	
Pellets	barrows	8.41	7.47	
	gilts	6.61	6.70	

The data in Table 49 reveal that on fine modulus there was a greater ($P < 0.01$) average daily DE intake. This influence was prevalent on solka-floc and oat hull rations but was reversed on wheat bran. DE intakes on fine modulus were significantly increased in barrow groups fed pellets.

Results presented in Table 50 indicate a significant increase in average daily DE intake on pelleted rations. Similar statistically significant increases were evident on antibiotic supplemented rations as well as fine moduli bulks fed to barrow groups. It would appear that given the opportunity of consuming feeds of higher density barrows increased their intakes accordingly.

TABLE 50 - THE EFFECTS OF BULK MODULUS, ANTIBIOTIC AND SEX ON AVERAGE DAILY DE INTAKE RESPONSES TO SEX

Treatment	Pelleting		LSR
	Meal	Pellets	
	Mcal.	Mcal.	
Pelleting mean*	6.96	7.30	0.27
Bulk modulus			
Fine	7.13	7.51	0.38
Coarse	6.79	7.08	
Antibiotic*			
Nil	7.11	7.13	0.38
Add	6.81	7.46	
Sex			
Barrows	7.35	7.94	0.38
Gilts	6.57	6.66	
Bulk modulus x Sex*			
Fine barrows	7.48	8.41	0.54
gilts	6.79	6.61	
Coarse barrows	7.22	7.47	
gilts	6.36	6.70	

An increased mean daily DE intake occurred on pelleted rations. Similar increases were also evident on antibiotic-supplemented rations and particularly in barrow groups consuming pelleted fine moduli feeds.

TABLE 51 - THE EFFECT OF PELLETING ON AVERAGE DAILY DE INTAKE RESPONSES TO ANTIBIOTIC

Treatment	Antibiotic		LSR
	Nil	Add	
	Mcal.	Mcal.	
Antibiotic mean	7.12	7.14	0.27
Pelleting*			
Meal	7.10	6.81	0.38
Pellets	7.13	7.46	

Antibiotic supplementation as such had no influence upon DE intake. Results in Table 51 further disclose that the existing mean differences due to pelleting interactions proved to be non-significant, and the statistical significance of this interaction was attributable to the influences of pelleting discussed in Table 48.

The results in Table 52 indicate that barrow groups had a significantly higher average daily DE intake than gilts. This effect was evident on both moduli and also on the pelleting comparisons, particularly so on treatments conducive to greater feed intake, namely fine modulus and pelleting. The effects of modulus and pelleting proved to be additive, energy intake was particularly elevated on barrows consuming fine moduli pellets.

Statistical analysis disclosed that barrow groups consumed significantly higher amounts of DE daily than gilt groups.

In summarizing the factors found to influence average daily DE

intake it was found that three times a day feeding, through increasing access to feed, resulted in a higher daily DE intake. Bulk modulus affected daily DE intake, the response of wheat bran was opposite to that of the other two bulks in that fine modulus depressed DE intake. Pelleting increased DE intake, this response was particularly evident on barrow groups consuming fine moduli bulks. Barrows as a group consumed significantly higher intakes of DE.

TABLE 52 - THE EFFECTS OF BULK MODULUS AND PELLETING ON AVERAGE DAILY DE INTAKE RESPONSES TO SEX

Treatment	Sex		LSR
	Barrows	Gilts	
	Mcal.	Mcal.	
Sex mean**	7.64	6.61	0.27
Bulk modulus			
Fine	7.95	6.70	0.38
Coarse	7.34	6.53	
Pelleting			
Meal	7.35	6.57	0.38
Pellets	7.94	6.66	
Bulk modulus x Pelleting*			
Fine meal	7.48	6.79	0.54
Fine pellets	8.41	6.61	
Coarse meal	7.22	6.36	
Coarse pellets	7.47	6.70	

Digestible protein intake

The general response indicated that animals consuming oat hull rations had a significantly higher daily digestible protein (DP) intake than other bulk groups (Table 53). Indications in the bulk modulus interactions disclosed that fine moduli was responsible for this variation,

where differences in digestible protein intake existed between all bulks.

The DP intake response of wheat bran and oat hulls to bulk moduli differed in degree and direction, the former being depressed and the latter increased on fine modulus.

TABLE 53 - THE EFFECT OF BULK MODULUS ON AVERAGE DAILY DP INTAKE RESPONSES TO BULK TYPE

Treatment	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
	gm.	gm.	gm.		
Bulk mean	321	315	350	15	15
Bulk modulus*					
Fine	323	305	375	21	22
Coarse	319	326	325		

Mean daily DP intake on twice a day feeding, being 320 gm., was significantly less ($P < 0.05$, LSR = 12) than the 338 gm. intake on three times a day feeding. This factor was a function of the increased feed intake on three times a day feeding, since protein digestibility had been found to be unaffected by feeding frequency variations.

TABLE 54 - THE EFFECT OF BULK TYPE ON AVERAGE DAILY DP INTAKE RESPONSES TO BULK MODULUS

Treatment	Bulk modulus		LSR
	Fine	Coarse	
	gm.	gm.	
Modulus mean	335	323	12
Bulk type*			
Solka-floc	323	319	14
Wheat bran	305	326	
Oat hulls	375	325	

The results in Table 54 illustrate that daily DP intake tended to be greater on fine bulk moduli rations, however interaction reveals that although this was so on oat hulls the opposite effect, that of decreased DP intake, occurred on wheat bran.

Average daily DP intake on antibiotic-free feeds was 320 gm. This proved to be significantly less ($P < 0.01$, LSR = 12) than the 337 gm. intake in the antibiotic supplemented group.

Barrow groups exhibited an average daily DP intake of 349 gm. which was significantly greater than the 308 gm. intake of gilt groups ($P < 0.01$, LSR = 12).

Factors conducive to increased daily DP intake proved to be three times a day feeding, antibiotic inclusion, as well as intakes of barrow groups. Bulk modulus proved to be influential in that DP intake was increased on oat hulls and depressed on wheat bran rations when these were fed in the fine module form.

TABLE 55 - THE EFFECTS OF BULK MODULUS, PELLETING AND ANTIBIOTIC ON DP:DE[1] RATIO RESPONSES TO BULK TYPE

Treatment		Bulk type			LSR	
		Solka-floc	Wheat bran	Oat hulls	Min.	Max.
		gm./Mcal.	gm./Mcal.	gm./Mcal.		
Bulk type*		45.5	46.3	47.0	0.9	0.9
Bulk modulus**						
Fine		43.4	46.9	47.1	1.2	1.3
Coarse		47.6	45.8	47.0		
Pelleting**						
Meal		45.3	47.5	47.1	1.2	1.3
Pellets		45.6	45.2	46.9		
Antibiotic*						
Nil		45.0	44.9	45.4	1.2	1.3
Add		45.9	47.8	48.6		
Bulk modulus x Antibiotic*						
Fine	nil	43.2	45.4	44.2	1.7	1.8
	add	43.5	48.4	49.9		
Coarse	nil	46.8	44.5	46.6		
	add	48.4	47.1	47.4		
Pelleting x Antibiotic*						
Meal	nil	44.9	45.1	45.0	1.7	1.8
	add	45.8	49.9	49.2		
Pellets	nil	45.1	44.8	45.9		
	add	46.1	45.6	48.0		

1 Grams digestible protein per megacalorie digestible energy.

The general response in Table 55 indicated that solka-floc rations had a significantly lower DP:DE ratio than oat hull rations. The simple interaction effects revealed that in comparison to the other bulks this ratio in solka-floc was depressed by fine modulus, meal type rations and antibiotic containing rations. In comparison to the other bulks, coarse modulus depressed the DP:DE ratio in wheat bran rations. Pelleting appeared

to result in a higher DP:DE ratio in oat hulls than either of the other bulks.

The second order interaction effects suggest that solka-floc rations tended to have a lower ratio on finer moduli on either control or antibiotic treatment and on antibiotic supplemented meals, indicating that moduli and ration form (meal) influenced this bulk type. In the absence of antibiotic, coarse modulus wheat bran produced a lowered protein to energy ratio. Pelleting antibiotic supplemented oat hull rations resulted in this treatment yielding a higher DP:DE ratio.

The DP:DE ratio varied with the bulk type and was the highest on oat hulls. Bulk modulus, pelleting and antibiotic treatments, individually or in combination, influenced the responses of this ratio to the three bulk types.

The data in Table 56 revealed the absence of statistically significant differences in DP:DE ratios attributable to feeding frequency. It is also apparent that the interaction between sex x pelleting x feeding frequency does not affect the general observation that feeding frequency has no effect on the ratio of these two classes of nutrients.

The results in Table 57 revealed that the DP:DE ratio was significantly increased on coarse moduli rations. Solka-floc rations irrespective of antibiotic treatment, and antibiotic-free oat hulls yielded a significantly higher DP:DE ratio on coarse modulus. Wheat bran rations and antibiotic supplemented oat hulls responded in an opposing manner to coarse modulus and a significant reduction in the DP:DE ratio occurred.

It would appear that the DP:DE ratio was significantly higher on coarse bulk moduli, however, interaction results suggest that in wheat

TABLE 56 - THE EFFECTS OF PELLETING AND SEX ON DP:DE RATIO RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		gm./Mcal.	gm./Mcal.	
Frequency mean		46.2	46.4	0.7
Pelleting x Sex*				
Meal	barrows	46.6	46.2	1.4
	gilts	46.3	47.5	
Pellets	barrows	45.2	45.8	
	gilts	46.8	46.0	

TABLE 57 - THE EFFECTS OF BULK TYPE AND ANTIBIOTIC ON DP:DE RATIO RESPONSES TO BULK MODULUS

Treatment		Bulk modulus Fine	Bulk modulus Coarse	LSR
		gm./Mcal.	gm./Mcal.	
Modulus mean*		45.8	46.8	0.7
Bulk type**				
Solka-floc		43.4	47.6	1.0
Wheat bran		46.9	45.8	
Oat hulls		47.1	47.0	
Antibiotic				
Nil		44.3	46.0	1.0
Add		47.2	47.6	
Bulk type x Antibiotic*				
Solka-floc	nil	43.2	46.8	1.7
	add	43.5	48.4	
Wheat bran	nil	45.4	44.5	
	add	48.4	47.1	
Oat hulls	nil	44.2	46.6	
	add	49.9	47.4	

bran and oat hull based rations, unlike solka-floc, moduli may be less influential than, or dependent upon antibiotic inclusion.

TABLE 58 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, ANTIBIOTIC AND SEX ON DP:DE RATIO RESPONSES TO PELLETING

Treatment		Pelleting: Meal	Pelleting: Pellets	LSR
		gm./Mcal.	gm./Mcal.	
Pelleting mean*		46.6	45.9	0.7
Bulk type**				
Solka-floc		45.3	45.6	1.2
Wheat bran		47.5	45.2	
Oat hulls		47.1	46.9	
Feeding frequency				
2/day		46.5	46.0	1.0
3/day		46.8	45.9	
Antibiotic**				
Nil		45.0	45.2	1.0
Add		48.3	46.6	
Sex effect				
Barrows		46.4	45.5	1.0
Gilts		46.9	46.4	
Bulk type x Antibiotic*				
Solka-floc	nil	44.9	45.1	1.7
	add	45.8	46.1	
Wheat bran	nil	45.1	44.8	
	add	49.9	45.6	
Oat hulls	nil	45.0	45.9	
	add	49.2	48.0	
Feeding frequency x Sex*				
2/day	barrows	46.6	45.2	1.4
	gilts	46.3	46.8	
3/day	barrows	46.2	45.8	
	gilts	47.5	46.0	

The general response in the meal versus pelleting comparisons indicated a significantly larger DP:DE ratio in meal type rations (Table 58). The higher ratios produced on wheat bran and antibiotic supplemented feeds were statistically significant. These two effects proved to be additive and were present when meal form wheat bran was antibiotic supplemented. Meals fed three times daily to gilt groups also produced a significant increase in the DP:DE ratio.

While pelleting tended to decrease the DP:DE ratio it appeared that bulk type and antibiotic inclusion affected the magnitude of response.

It was found that the DP:DE ratio was significantly increased on antibiotic supplemented rations (Table 59). With the exception of solka-floc rations, this effect prevailed on the first order interactions involving bulk types, and pelleting comparisons. The interaction effects involving bulk type with bulk modulus or pelleting indicated a similar pattern of ratio increase, with the exception that in addition to solka-floc the DP:DE ratios of coarse modulus oat hulls and pelleted wheat bran were not influenced by antibiotic supplementation.

Antibiotic inclusion raised the DP:DE ratio. The antibiotic response appeared to be influenced by bulk type, the effect being noticeably pronounced on solka-floc rations.

The results in Table 60 indicate a significant increase in the DP:DE ratio in gilt groups. This trend although evident on twice-a-day feeding proved to be statistically significant only on twice-a-day feeding of pellets to gilts.

In summarizing, it appeared that the DP:DE ratio was highest on oat hull rations. This ratio was also increased on meal type or antibiotic

supplemented rations and in gilt groups.

TABLE 59 - THE EFFECT OF BULK TYPE, BULK MODULUS AND PELLETING ON DP:DE RATIO RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		gm. Mcal:	gm. Mcal:	
Antibiotic mean*		45.1	47.4	0.7
Bulk type*				
Solka-floc		45.0	45.9	1.2
Wheat bran		44.9	47.8	
Oat hulls		45.4	48.6	
Bulk modulus				
Fine		44.3	47.2	1.2
Coarse		46.0	47.6	
Pelleting*				
Meal		45.0	48.3	1.2
Pellets		45.2	46.6	
Bulk type x Bulk modulus*				
Solka-floc	fine	43.2	43.5	1.7
	coarse	46.8	48.4	
Wheat bran	fine	45.4	48.4	
	coarse	44.5	47.1	
Oat hulls	fine	44.2	49.9	
	coarse	46.6	47.4	
Bulk type x Pelleting*				
Solka-floc	meal	44.9	45.8	1.7
	pellets	45.1	46.1	
Wheat bran	meal	45.1	49.9	
	pellets	44.8	45.6	
Oat hulls	meal	45.0	49.2	
	pellets	45.9	48.0	

TABLE 60 - THE EFFECTS OF FEEDING FREQUENCY AND PELLETING ON DP:DE RATIO RESPONSES TO SEX

Treatment	Sex		LSR
	Barrows	Gilts	
	gm./Mcal.	gm./Mcal.	
Sex mean*	45.9	46.6	0.7
Feeding frequency			
2/day	45.9	46.9	1.0
3/day	46.0	46.8	
Pelleting			
Meal	46.4	46.9	1.0
Pellets	45.5	46.4	
Feeding frequency x Pelleting*			
2/day meal	46.6	46.3	1.4
pellets	45.2	46.8	
3/day meal	46.2	47.5	
pellets	45.8	46.0	

Efficiency of digestible energy utilization

The only factor that resulted in a significant difference in the efficiency of digestible energy utilization (Mcal. of DE required per lb. gain) occured on comparisons involving antibiotic supplementation. Groups receiving antibiotic required 4.59 Mcal./DE per lb. gain versus 4.98 Mcal. for unsupplemented groups ($P < 0.01$, LSR = 0.18).

Efficiency of digestible protein utilization

The data in Table 61 reveal that on oat hull rations there were significantly higher requirements for DP per unit gain, however wheat bran rations tended to remain fairly uniform in comparison to the variations shown by the other bulks. Significant variation in DP conversion attribut-

able to bulk modulus occurred on solka-floc and oat hulls. On fine moduli bulks the lowest DP requirements for gain were evident on solka-floc rations and the highest on oat hulls. Feeding the fine moduli bulks twice daily caused a significant improvement in solka-floc rations and on three times a day feeding oat hulls had a poorer conversion than the other bulks. Coarse moduli oat hull rations fed twice daily had a significantly poorer DP conversion than solka-floc, but three times a day feeding reversed the trend and solka-floc rations yielded the poorest conversion.

TABLE 61 - THE EFFECTS OF BULK MODULUS AND FEEDING FREQUENCY ON EFFICIENCY OF DIGESTIBLE PROTEIN UTILIZATION RESPONSES TO BULK TYPE

Treatment	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
	gm./lb.	gm./lb.	gm./lb.		
Bulk mean**	213	219	231	9	9
Feeding frequency					
2/day	205	220	232	13	13
3/day	220	217	230		
Bulk modulus**					
Fine	204	218	240	13	13
Coarse	221	219	222		
Feeding frequency x Bulk modulus*					
2/day fine	198	218	229	18	19
coarse	212	222	235		
3/day fine	211	219	250		
coarse	230	216	209		

In summing up it would appear that with the exception of wheat bran the DP requirements for gain tended to vary with bulk type. The bulk modulus x feeding frequency interaction appeared to cause variations in the

magnitude and direction of these influences.

TABLE 62 - THE EFFECTS OF BULK TYPE AND BULK MODULUS ON EFFICIENCY OF DIGESTIBLE PROTEIN UTILIZATION RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		gm./lb.	gm./lb.	
Frequency mean		219	222	7
Bulk type				
Solka-floc		205	220	13
Wheat bran		220	217	
Oat hulls		232	230	
Bulk modulus				
Fine		215	226	10
Coarse		223	218	
Bulk type x Bulk modulus*				
Solka-floc	fine	198	211	18
	coarse	212	230	
Wheat bran	fine	218	219	
	coarse	222	216	
Oat hulls	fine	229	250	
	coarse	235	209	

Feeding frequency as such did not appear to affect the DP requirements for gain (Table 62). Interaction results revealed that coarse modulus solka-floc and fine modulus oat hulls increased DP requirements for gain on three times a day feeding, however on coarse modulus the animals required more DP on twice a day feeding.

Bulk modulus had no significant affect on the DP requirements for gain (Table 63). Interactions disclosed the existance of significant changes in association with bulk type and feeding frequency. Reductions in DP requirements for gain occurred on fine modulus solka-floc, particularly on three times a day feeding, oat hulls, in contrast to this,

TABLE 63 - THE EFFECTS OF BULK TYPE AND FEEDING FREQUENCY ON EFFICIENCY OF DIGESTIBLE PROTEIN UTILIZATION RESPONSES TO BULK MODULUS

Treatment	Bulk modulus		LSR
	Fine	Coarse	
	gm./lb.	gm./lb.	
Modulus mean	221	221	7
Bulk type**			
Solka-floc	204	221	13
Wheat bran	218	219	
Oat hulls	240	222	
Bulk type x Feeding frequency*			
Solka-floc 2/day	198	212	18
3/day	211	230	
Wheat bran 2/day	218	222	
3/day	219	216	
Oat hulls 2/day	229	235	
3/day	250	209	

produced conditions conducive towards increased DP requirements on the same treatments.

In summary it appeared that the DP efficiency responses to bulk modulus were mitigated by bulk type and were particularly evident on the increased feeding frequency.

The consumption of 216 gm. DP per lb. of gain on pelleted rations was significantly less than the DP requirements of 225 gm. (LSR = 7) on meal type rations.

In the overall summary it appeared that the grams of DP per pound of gain varied with bulk type, being usually lowest on solka-floc and highest on oat hull rations. These influences were dependent upon feeding frequency and bulk modulus. Pelleting of the rations significantly reduced the DP levels required for gain.

Summary

The data in Table 64 indicate that of the factors influencing energy and protein digestibility, bulk type was important. The effect of oat hulls was to decrease energy digestibility and increase that of protein, this proved to be an influence that was opposite to that exerted by the other two bulks. These responses were to a degree influenced by other treatments such as bulk modulus, pelleting and antibiotic, the degree and direction being dependent upon the particular bulk type. Antibiotic addition as a whole increased protein digestibility.

Relating energy and protein digestibility to feed intake disclosed that in cases involving feeding frequency, bulk modulus and sex differences, in spite of similar digestibility data, the actual intakes of calories and protein were affected by feed quantity differences. Considering bulk modulus and sex disclosed that the ratio of digestible protein to calories was affected as well. In the case of antibiotic treatments, due to an increased efficiency, digestible protein levels were increased in spite of similar feed intakes. As a consequence of this there was an accompanying effect causing a change in ratio of digestible protein to energy. The antibiotic influence had associative effects with pelleting and sex treatments. Pelleting was unique in that in spite of an increased feed intake on pelleted rations, the actual quantity of DP proved to be similar to that obtained with meal rations. This effect was also accompanied by a change in the DP:DE ratio. Such results would indicate the occurrence of a reduced level of DP, which did in fact occur (79.3 vs. 78.3%), but proved to be non-significant.

Bulk type responses to average daily DE intake and DP intake

TABLE 64 - SUMMARY OF MAIN EFFECTS OF TREATMENTS ON DIGESTIBILITY AND UTILIZATION OF ENERGY AND PROTEIN

Treatment	Digestibility coefficients		Average daily intake		DP:DE ratio	Efficiency of utilization for gain	
	Energy	Protein	Digestible energy	Digestible protein		DE	DP
	%	%	Mcal.	gm.	gm./Mcal.	Mcal./lb.	gm./lb.
General average	68.1	78.7	7.13	3.29	46.3	4.78	221
Bulk type							
Solka-floc	+	-	0	-	-	0	-
Wheat bran	+	---	-	---	0	0	0
Oat hulls	---	++++	+	+++	+	0	+
Feeding frequency							
2/day	0	0	-	-	0	0	0
3/day	0	0	+	+	0	0	0
Bulk modulus							
Fine	0	0	+	+	-	0	0
Coarse	0	0	-	-	+	0	0
Pelleting							
Meal	0	0	-	0	+	0	+
Pellets	0	0	+	0	-	0	-
Antibiotic							
Nil	0	-	0	-	-	-	0
Add	0	+	0	+	+	+	0
Sex							
Barrows	0	0	+	+	-	0	0
Gilts	0	0	-	-	+	0	0

suggested that oat hulls exhibited the highest intakes of both and wheat bran the lowest. Oat hull rations had been consumed in the largest quantities, the intake of the other two bulks being lower but similar to each other. In the bulk comparisons increased daily intakes of oat hulls not only resulted in the highest daily DP intake, but were of sufficient magnitude to produce the highest daily DE intakes despite reductions in oat hull energy digestibility. The lowest daily DE intake occurred on wheat bran rations. Bulk moduli responses affected the bulk type influences, with the nature of the response being dependent upon the bulk type.

Insofar as the utilization of DE for gain was concerned, only antibiotic supplementation caused a significant improvement in this criteria. The utilization of DP for body gain was affected by bulk type and pelleting. Oat hull rations and meals were conducive towards higher DP requirements for gain. The responses of the bulk types were, to a degree, contingent upon feeding frequency and bulk modulus interactions.

Gastro-intestinal tract and ingesta measures

Ingesta weight

The animals fed three times daily, as indicated in Table 67, had considerably more ingesta in the stomach. The interactions reveal that this difference was further accentuated on coarse modulus and on pelleted feeds fed three times daily.

While on the whole modulus appeared to cause no statistical divergence on stomach ingesta mass, a larger weight resulted on coarse modulus fed three times daily (Table 68). The causative agent for this latter effect, may have been due to the effect of increased feeding frequancy noted above.

TABLE 67 - THE EFFECTS OF BULK MODULUS AND PELLETING ON GASTRIC INGESTA WEIGHT RESPONSES TO FEEDING FREQUENCY

Treatment	Feeding frequency 2/day	Feeding frequency 3/day	LSR
	gm.	gm.	
Feeding frequency**	1654	2087	314
Bulk modulus*			
Fine	1804	1855	445
Coarse	1504	2319	
Pelleting*			
Meal	1738	1767	445
Pellets	1570	2406	

TABLE 68 - THE EFFECTS OF FEEDING FREQUENCY ON GASTRIC INGESTA WEIGHT RESPONSES TO BULK MODULUS

Treatment	Bulk modulus Fine	Bulk modulus Coarse	LSR
	gm.	gm.	
Modulus mean	1829	1911	314
Feeding frequency*			
2/day	1804	1504	445
3/day	1855	2319	

TABLE 69 - THE EFFECTS OF FEEDING FREQUENCY AND ANTIBIOTIC ON GASTRIC INGESTA WEIGHT RESPONSES TO PELLETING

Treatment	Pelleting		LSR
	Meal	Pellets	
	gm.	gm.	
Pelleting mean	1752	1989	314
Feeding frequency*			
2/day	1738	1570	445
3/day	1767	2406	
Antibiotic*			
Nil	1589	2148	445
Add	1915	1830	

TABLE 70 - THE EFFECTS OF PELLETING ON GASTRIC INGESTA WEIGHT RESPONSES TO ANTIBIOTIC

Treatment	Antibiotic		LSR
	Nil	Add	
	gm.	gm.	
Antibiotic mean	1868	1873	314
Pelleting*			
Meal	1589	1915	445
Pellets	2148	1830	

Data in Table 69 reveal the absence of direct effects of pelleting on stomach contents, however pelleted rations fed three times daily or without antibiotic supplementation appeared to cause significant increases in the stomach contents. The former effect was more pronounced when considered from the aspect of increased feeding, however the latter effect appears to be a factor related to pelleting.

The results shown in Table 70 reveal the absence of statistically significant aberrations attributable to antibiotic treatment as such, nor were there deviating means upon comparing the statistically significant interaction with pelleting.

The variation between total stomach contents among bulk types proved to be non-significant in spite of increased average feed intake on oat hulls. It was observed that the largest total weight was on solka-floc rations and the lowest on oat hulls. This latter trend changed in progressing down the tract and wheat bran emerged as the ration type present in the largest amount. In the rectal region, based on observations during sampling and the data in Table 71 it appeared as though wheat bran upon reaching this site was more readily expelled, particularly in comparison to oat hull rations. This may indicate that either the consumption of oat hull feeds had dropped or that its passage rate was faster than the other bulks.

Stomach contents were, like average daily feed intake, higher on three times a day feeding, this was particularly evident on coarse moduli and on pelleted rations. Similar effects in the rest of the tract were not as evident, with the exception of probable increase in the small intestinal segment means. This may indicate that the noon meal had started leaving the stomach but had not progressed beyond the small intestine by the time of slaughter.

A statistically significant increase of total stomach contents attributable to bulk moduli occurred on interactions involving the three times a day feeding of coarse moduli feeds. The increase in gastric contents is indicated in Table 71, however on coarse modulus the weights

TABLE 71 - MAIN EFFECT INFLUENCES ON INGESTA WEIGHT

Treatment	Region of gastro-intestinal tract						Tract mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	gm.	gm.	gm.	gm.	gm.	gm.	gm.
Bulk type							
Solka-floc	2070	1636	422	2623	2025	126	1620
Wheat bran	1839	1597	503	3205	2377	84	1670
Oat hulls	1702	1448	411	2639	1791	136	1390
Feeding frequency							
2/day	1654	1454	454	2728	2113	119	1820
3/day	2087	1667	437	2737	2016	111	1980
Bulk modulus							
Fine	1829	1687	445	2561	1954	127	1540
Coarse	1911	1434	445	2903	2174	104	1600
Pelleting							
Meal	1752	1411	---	2963	----	129	1600
Pellets	1989	1709	445	2502	1064	102	1590
Antibiotic							
Nil	1867	1622	489	2929	2133	109	1620
Add	1873	1493	402	2535	1996	121	1520
Sex							
Barrows	1946						
Gilts	1795	1560	445	2732	2064	115	1542
Number of observations	96	48	24	48	24	48	

of the ingesta averaged less in the small intestinal region. In the combined cecal-large intestinal samples and in the large intestine ingesta weight increases were evident. Such results may suggest a retention of ingesta in the lower tract segments when coarse moduli bulks were fed, particularly in view of the larger average intakes of feed on fine moduli feeds.

Pelleting treatment was, as previously mentioned, the treatment wherein the split was instigated between the combined cecum-large intestine samples collected on meals and the separation of these two segments on pelleted rations. Where the data involved weights, the two segments on pellet treatment were added to provide a comparable value to meals.

Total tract contents were higher in the initial segments on pelleted rations in agreement with increased feed intakes. This effect fell short of significance in the stomach, however there were significant increases on pelleted feeds fed three times or without antibiotic. In the small intestine some differences indicating greater weight occurred, however in the succeeding sites this effect was reversed. This may suggest a slower stomach emptying time for pelleted rations, and the possible longer retention of meals in the lower tract segments.

Antibiotic comparisons indicated no difference in stomach contents. The remaining tract segments indicated the possibility of reduced passage rates on antibiotic-free rations, this being particularly evident on similar feed intakes.

Data involving ingesta weight, with the exception of the stomach, were collected on females only. Total stomach contents were significantly higher on barrows, probably a factor related to feed consumption.

Statistical analysis disclosed that the quantity of ingesta was increased on three times a day feeding, this was particularly evident on coarse moduli and pelleted rations. There were suggestions that bulk type, particularly oat hulls had a faster passage rate. Treatments suggestive of longer retention times in the lower tracts were coarse modulus, meal and antibiotic-free rations.

Ingesta moisture

The data in Table 72 indicate that solka-floc rations resulted in significantly more water being present in the stomach than with oat hull rations. Similar trends ($P < 0.05$) existed between these two bulks on twice a day feeding, meal type rations, antibiotic supplementation and barrow groups. The stomach water content differences between solka-floc and oat hull rations become particularly accentuated on antibiotic-supplemented meal-type rations.

In summary it was evident that only in comparison to solka-floc rations was there less water in the stomach on oat hull rations. This effect appeared most pronounced on meal-type antibiotic-supplemented rations.

The general response indicated that there was a significant increase in stomach water content in groups fed three times daily (Table 73). The interaction effects revealed that stomach water content on three daily feedings significantly increased on either coarse module or pelleted rations. Although gastric moisture content did not differ significantly between the two feeding frequencies in comparisons associated with the feeding of the three bulks to the two sexes, there was a trend prevalent indicating reduced gastric fluid on the twice daily feeding of either oat hulls or barrows.

TABLE 72 - THE EFFECTS OF FEEDING FREQUENCY, PELLETING, ANTIBIOTIC AND SEX ON GASTRIC INGESTA MOISTURE RESPONSES TO BULK TYPE

Treatment		Bulk type			LSR	
		Solka-floc	Wheat bran	Oat hulls	Min.	Max.
		gm.	gm.	gm.		
Bulk mean*		1490	1373	1154	255	269
Feeding frequency						
2/day		1378	1278	965	361	380
3/day		1601	1469	1344		
Pelleting						
Meal		1525	1209	1039	361	380
Pellets		1454	1538	1269		
Antibiotic						
Nil		1451	1462	1171	361	380
Add		1529	1284	1138		
Sex						
Barrows		1532	1488	1137	361	380
Gilts		1457	1259	1173		
Feeding frequency x Sex*						
2/day	barrows	1280	1320	901	511	538
	gilts	1476	1235	1029		
3/day	barrows	1765	1655	1370		
	gilts	1438	1283	1380		
Pelleting x Antibiotic*						
Meal	nil	1201	1201	1096	511	538
	add	1849	1216	983		
Pellets	nil	1700	1723	1245		
	add	1209	1353	1294		

A significant increase of stomach water content on coarse module or pelleted rations was indicated in groups fed three times a day. feeding.

The data in Table 74 reveal that pelleting as such did not influence stomach water content significantly. Interaction results disclosed

TABLE 73 - THE EFFECT OF BULK TYPE, BULK MODULUS, PELLETING AND SEX ON GASTRIC INGESTA MOISTURE RESPONSES TO FEEDING FREQUENCY

Treatment	Feeding frequency 2/day	3/day	LSR
	gm.	gm.	
Frequency mean*	1207	1471	209
Bulk type			
Solka-floc	1378	1601	361
Wheat bran	1278	1469	
Oat hulls	965	1344	
Bulk modulus*			
Fine	1301	1323	295
Coarse	1103	1619	
Pelleting*			
Meal	1256	1259	295
Pellets	1158	1683	
Sex			
Barrows	1167	1597	295
Gilts	1247	1346	
Bulk type x Sex*			
Solka-floc barrows	1280	1765	511
gilts	1476	1438	
Wheat bran barrows	1320	1655	
gilts	1235	1283	
Oat hulls barrows	901	1370	
gilts	1029	1380	

that there was an increased water content on pelleted rations when fed thrice daily or without antibiotic. With antibiotic-containing solka-floc rations water content was greater on meal-type rations, however in contrast to this the water content of the stomach was increased on pelleted antibiotic-free wheat bran.

The results suggest that the influence of pelleting was to in-

crease the presence of water in the stomach on three-times-a-day feeding and in the absence of antibiotic. It was indicated that these effects tended to vary with bulk type.

TABLE 74 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY AND ANTIBIOTIC ON GASTRIC INGESTA MOISTURE RESPONSES TO PELLETING

Treatment	Pelleting		LSR
	Meal	Pellets	
	gm.	gm.	
Pelleting mean	1258	1420	209
Bulk type			
Solka-floc	1525	1454	361
Wheat bran	1209	1538	
Oat hulls	1039	1269	
Feeding frequency*			
2/day	1256	1158	295
3/day	1259	1683	
Antibiotic*			
Nil	1166	1556	295
Add	1349	1285	
Bulk type x Antibiotic*			
Solka-floc nil	1201	1700	511
add	1849	1209	
Wheat bran nil	1201	1723	
add	1216	1353	
Oat hulls nil	1096	1245	
add	983	1294	

The results in Table 75 reveal that on the whole antibiotic supplementation failed to influence stomach water content. Interaction results disclosed that only in the case of meal-type solka-floc rations was there an increase in stomach liquid on supplemented feeds.

The data in Table 76 reveal the absence of statistically significant differences in stomach water content attributable to sex differences.

TABLE 75 - THE EFFECTS OF BULK TYPE AND PELLETING ON GASTRIC INGESTA MOISTURE RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		gm.	gm.	
Antibiotic mean		1361	1317	209
Pelleting*				
Meal		1116	1349	295
Pellets		1556	1285	
Bulk type x Pelleting*				
Solka-floc	meal	1201	1849	511
	pellets	1700	1209	
Wheat bran	meal	1201	1216	
	pellets	1723	1353	
Oat hulls	meal	1096	983	
	pellets	1245	1294	

TABLE 76 - THE EFFECTS OF BULK TYPE AND FEEDING FREQUENCY ON GASTRIC INGESTA MOISTURE RESPONSES TO SEX

Treatment		Sex Barrows	Sex Gilts	LSR
		gm.	gm.	
Sex mean		1382	1296	209
Bulk type x Feeding frequency*				
Solka-floc	2/day	1280	1476	511
	3/day	1765	1438	
Wheat bran	2/day	1320	1235	
	3/day	1655	1283	
Oat hulls	2/day	901	1029	
	3/day	1370	1380	

Statistical analysis of the total water in the stomach disclosed that oat hull-consuming groups had significantly less liquid present than groups fed solka-floc. Equating the liquid to a percentage basis (Table 77)

TABLE 77 - MAIN EFFECT INFLUENCES ON INGESTA MOISTURE

Treatment	Region of gastro-intestinal tract						Tract mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	71.6	85.3	85.5	79.0	79.0	75.8	78.8
Wheat bran	75.6	85.0	85.2	82.8	80.6	78.5	80.6
Oat hulls	69.9	83.3	81.1	74.6	72.8	69.9	75.0
Feeding frequency							
2/day	73.6	85.2	84.0	78.6	77.4	74.6	78.6
3/day	71.0	83.8	84.2	78.9	78.0	74.8	77.8
Bulk modulus							
Fine	71.7	84.4	84.2	77.8	77.3	74.6	77.9
Coarse	72.9	84.6	84.0	80.2	78.0	74.8	78.5
Pelleting							
Meal	72.7	85.0	----	78.8	----	74.8	77.6
Pellets	72.0	84.0	84.1	----	77.7	74.7	78.0
Antibiotic							
Nil	72.9	84.6	84.3	78.8	77.5	74.4	78.3
Add	71.8	84.4	83.9	78.7	77.9	75.0	78.1
Sex							
Barrows	71.2	84.7	83.6	78.9	77.4	75.1	78.0
Gilts	73.4	84.3	84.5	78.6	78.0	74.3	78.4
Number of observations	96	93	53	40	54	93	

it became evident that the highest proportion of moisture was present in wheat bran, while the lowest was in oat hull rations. In the regions of high moisture, i.e. small intestine and cecum, the magnitude of these differences declined but was re-established in the lower tract segments where moisture levels tended to approach original gastric levels. It was evident that the driest rectal samples were produced on oat hull rations and the most moist on wheat bran.

Water content was higher on three times a day feeding, this was again evident in association with both coarse modulus and pelleted feeds. As a percentage it appeared in comparing means that both stomach and small intestinal samples tended to be somewhat drier on three times a day feeding, other segments seemed to be similar in moisture levels.

Statistical analysis had disclosed that moisture levels in the stomach were similar on either moduli. Equating the moisture levels to a percentage basis indicated that, with the exception of the combined cecum-large intestinal segment, there were only minor fluctuations attributable to moduli differences. In view of these trends it was inferred that the 2.4% increase in moisture of coarse modulus ingesta found in the cecum-large intestinal site was attributable to other causes.

Although pelleting as such failed to cause significant differences in stomach water content, there was an associative effect with increased feeding frequency or antibiotic-free rations. The data pertaining to actual moisture percentages indicates that mean levels within tract segments proved to be similar.

Total water content in the stomach was statistically similar in barrows and gilts. As a percentage moisture levels were slightly higher

in gilts, the continued presence of this pattern in gilts proved to be small and it is doubtful if this difference would be real.

Quantity-wise, water in the stomach was increased on solka-floc rations in comparison to oat hulls, on three times a day feeding and on pelleted rations in conjunction with either antibiotic or increased feeding frequency.

Based on relative proportions of water, wheat bran rations were associated with the highest levels in most of the digestive tract and oat hulls were consistently the lowest. Three-times-a-day feeding resulted in lower percentages of water in the stomach and small intestine but in other regions of the tract the samples were similar.

Ingesta dry matter

The data in Table 78 indicate the absence of an influence of bulk type on stomach dry matter levels. Significant interactions with feeding frequency indicated that only in the comparison of wheat bran rations fed three times a day and oat hulls were there differences, in this instance indicating the presence of more dry matter on oat hull rations.

TABLE 78 - THE EFFECTS OF FEEDING FREQUENCY ON GASTRIC DRY MATTER RESPONSES TO BULK TYPE

	Bulk type			LSR	
Treatment	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
	gm.	gm.	gm.		
Bulk mean	580	466	554	130	136
Feeding frequency*					
2/day	512	453	376	184	193
3/day	648	480	732		

TABLE 79 - THE EFFECTS OF BULK TYPE, BULK MODULUS, PELLETING AND ANTIBIOTIC ON GASTRIC DRY MATTER RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		gm.	gm.	
Frequency mean**		447	620	106
Bulk type*				
Solka-floc		512	648	184
Wheat bran		453	480	
Oat hulls		376	732	
Bulk modulus*				
Fine		493	532	150
Coarse		400	708	
Pelleting**				
Meal		481	508	150
Pellets		413	733	
Antibiotic				
Nil		412	610	150
Add		481	630	
Bulk modulus x Antibiotic*				
Fine	nil	391	434	212
	add	596	367	
Coarse	nil	571	649	
	add	493	768	
Pelleting x Antibiotic*				
Meal	nil	436	409	212
	add	572	606	
Pellets	nil	389	811	
	add	436	654	

The results in Table 79 show that stomach dry matter was significantly ($P < 0.01$) larger on three-times-a-day feeding. Interaction effects disclosed that dry matter contents were significantly increased on three-times-a-day feeding in conjunction with oat hulls, coarse moduli and pelleted rations. The presence of antibiotic in fine moduli rations tended to significantly depress dry matter on three-times-a-day feeding. In contrast, on coarse rations supplemented with antibiotic dry matter content was increased. Pelleted rations, with or without antibiotic, produced increased amounts of dry matter in the stomach on three-times-a-day feeding.

In general it appeared that dry matter content in the stomach was significantly increased on three-times-a-day feeding, particularly so on oat hull rations, pelleted feeds and on coarse moduli feeds.

TABLE 80 - THE EFFECTS OF FEEDING FREQUENCY AND ANTIBIOTIC ON GASTRIC DRY MATTER RESPONSES TO BULK MODULUS

Treatment		Bulk modulus: Fine	Bulk modulus: Coarse	LSR
		gm.	gm.	
Modulus mean		512	554	106
Feeding frequency*				
2/day		493	400	150
3/day		532	708	
Feeding frequency x Antibiotic*				
2/day	nil	391	571	212
	add	596	493	
3/day	nil	434	649	
	add	367	768	

The data in Table 80 reveal that moduli differences did not influence stomach dry matter content and only on three-times-a-day feeding, either with or without antibiotic, were there significant increases of stomach dry matter associated with coarse modulus.

TABLE 81 - THE EFFECTS OF FEEDING FREQUENCY, ANTIBIOTIC AND SEX ON GASTRIC DRY MATTER RESPONSES TO PELLETING

Treatment		Pelleting: Meal	Pelleting: Pellets	LSR
		gm.	gm.	
Pelleting mean		494	372	106
Feeding frequency**				
2/day		481	413	150
3/day		507	733	
Antibiotic				
Nil		422	600	150
Add		566	545	
Feeding frequency x Antibiotic*				
2/day	nil	436	389	210
	add	527	436	
3/day	nil	409	811	
	add	606	654	
Antibiotic x Sex*				
Nil	barrows	522	592	210
	gilts	323	540	
Add	barrows	540	618	
	gilts	660	472	

It appears that although pelleting as such did not create a significant difference in stomach dry matter content there was a higher dry matter content on three-times-a-day feeding of antibiotic-free rations. There was also a significant increase in stomach dry matter in gilt groups consuming antibiotic-free pellets.

Bulk modulus appeared to be unimportant in influencing the quantity of stomach dry matter, except on three-times-a-day feeding associated with coarse modulus.

TABLE 82 - THE EFFECTS OF FEEDING FREQUENCY, BULK MODULUS, PELLETING AND SEX ON GASTRIC DRY MATTER RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		gm.	gm.	
Antibiotic mean		511	556	106
Feeding frequency x Bulk modulus*				
2/day	fine	391	596	212
	coarse	571	493	
3/day	fine	434	367	
	coarse	649	768	
Feeding frequency x Pelleting*				
2/day	meal	436	527	212
	pellets	389	436	
3/day	meal	409	606	
	pellets	811	654	
Pelleting x Sex*				
Meal	barrows	522	323	212
	gilts	592	540	
Pellets	barrows	540	660	
	gilts	618	472	

The data in Table 82 reveal that stomach dry matter content proved to be statistically unaffected by the various treatments involving antibiotics.

Results in Table 83 reveal that stomach dry matter content was not influenced by sex differences nor by the tabulated interactions, although there was a tendency for barrows to have retained larger amounts of dry matter in the stomach.

TABLE 83 - THE EFFECTS OF PELLETING AND ANTIBIOTIC ON GASTRIC DRY MATTER RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
		gm.	gm.	
Sex mean		568	499	106
Pelleting x Antibiotic*				
Meal	nil	522	323	212
	add	592	540	
Pellets	nil	540	660	
	add	618	472	

Dry matter levels are a reflection of moisture levels in that as one component changes so must the other in a compensatory way. Data in Table 84 indicate that oat hull rations had the highest dry matter percentages and wheat bran the lowest. Solka-floc and wheat bran behaved similarly only in the small intestine and cecal segments. As previously mentioned, the driest rectal samples were from oat hulls and the most moist from wheat bran.

It had been previously indicated that three-times-a-day feeding significantly increased dry matter content in the stomach. The average percentages listed in Table 84 indicate that, apart from increased dry matter percentages in the stomach and small intestine, there were no further changes attributable to feeding frequency, or sex differences and pelleting of feeds. Consumption of fine moduli bulks or antibiotic supplemented feeds increased gastric dry matter, however these differences failed to persist in other segments of the intestinal tract.

TABLE 84 - MAIN EFFECT INFLUENCES ON INGESTA DRY MATTER

Treatment	Region of gastro-intestinal tract						Tract mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	28.4	14.7	14.5	21.0	21.0	24.2	21.2
Wheat bran	24.4	15.0	14.8	17.2	19.4	21.5	19.2
Oat hulls	30.1	16.7	18.9	25.4	27.2	30.1	25.0
Feeding frequency							
2/day	26.4	14.8	16.0	21.4	22.6	25.4	21.4
3/day	29.0	16.2	15.8	21.1	22.0	25.2	22.2
Bulk modulus							
Fine	28.3	15.6	15.8	22.2	22.7	25.4	22.1
Coarse	27.1	15.4	16.0	19.8	22.0	25.2	21.5
Pelleting							
Meal	27.3	15.0	----	21.2	----	25.2	22.4
Pellets	28.0	16.0	15.9	----	22.3	25.3	22.0
Antibiotic							
Nil	27.1	15.4	15.7	21.2	22.5	25.6	21.7
Add	28.2	15.6	16.1	21.3	22.1	25.0	21.7
Sex							
Barrows	28.8	15.3	16.4	21.1	22.6	24.9	22.0
Gilts	26.6	15.7	15.5	21.4	22.0	25.7	21.6
Number of observations	96	93	53	40	54	93	

In summary it appeared that total dry matter content in the stomach was higher only on three-times-a-day feeding. This effect proved to have associative effects with coarse modulus and pelleted feeds. Percentage assessment of dry matter indicated that differences between bulk types were probable, with oat hulls yielding the driest ingesta and wheat bran the most moist. The other treatments appeared to cause only slight differences in dry matter levels, in most instances these effects were nullified in the lower regions of the digestive tract.

Ingesta specific gravity

Data in Table 85 reveal that specific gravity of the stomach ingesta was significantly reduced on wheat bran rations. Reduced specific gravity of wheat bran origin ingesta was also evident in the other listed comparisons but proved to be significant only on treatments involving coarse moduli meals.

Animals fed three times daily had a significantly higher stomach ingesta specific gravity of 0.972 in contrast to the 0.955 value for twice-a-day fed groups (LSR = 0.016).

The data in Table 86 reveal that stomach ingesta specific gravity was significantly reduced on coarse module bulks. Decreased specific gravity generally prevailed on the coarse module, but significant differences occurred only in gilts or in those animals receiving meal-type wheat bran or oat hulls. In contrast, a significant increase in the specific gravity of fine module samples occurred on pelleted solka-floc rations.

In general gastric contents had a lower specific gravity on coarse moduli bulks, this response was prevalent in gilt groups and varied in the bulks depending upon pelleting treatment.

TABLE 85 - THE EFFECTS OF BULK MODULUS AND PELLETING ON GASTRIC INGESTA SPECIFIC GRAVITY RESPONSES TO BULK TYPE

Treatment	Bulk type			LSR	
	Solka-floc	Wheat bran	Oat hulls	Min.	Max.
Bulk mean**	0.978	0.933	0.979	0.019	0.020
Bulk modulus					
Fine	0.987	0.960	0.986	0.027	0.029
Coarse	0.970	0.906	0.972		
Pelleting					
Meal	0.973	0.912	0.952	0.027	0.029
Pellets	0.981	0.955	1.006		
Bulk modulus x Pelleting*					
Fine meal	0.972	0.956	0.969	0.039	0.041
pellets	1.000	0.966	1.000		
Coarse meal	0.975	0.867	0.935		
pellets	0.965	0.944	1.010		

The data in Table 87 reveal that there was a significant increase in stomach ingesta specific gravity on pelleted rations ($P < 0.01$). In conjunction with bulk type and modulus these trends prevailed, but only two treatments, wheat bran or oat hulls fed as coarse modulus, proved to be statistically different.

In summary, pelleted rations produced a significantly higher density stomach ingesta, however the significance of this appeared to be associated with bulk type and modulus.

TABLE 86 - THE EFFECTS OF BULK TYPE, PELLETING AND SEX ON GASTRIC INGESTA SPECIFIC GRAVITY RESPONSES TO BULK MODULUS

Treatment		Bulk modulus		LSR
		Fine	Coarse	
Modulus mean**		0.978	0.949	0.016
Bulk type				
Solka-floc		0.987	0.970	0.019
Wheat bran		0.960	0.906	
Oat hulls		0.986	0.972	
Pelleting				
Meal		0.966	0.926	0.022
Pellets		0.990	0.972	
Sex*				
Barrow		0.975	0.981	0.022
Gilts		0.963	0.935	
Bulk type x Pelleting*				
Solka-floc	meal	0.972	0.975	0.039
	pellets	1.000	0.965	
Wheat bran	meal	0.956	0.867	
	pellets	0.966	0.944	
Oat hulls	meal	0.969	0.935	
	pellets	1.000	1.010	

Antibiotic supplementation (0.955) resulted in an increased ($P < 0.01$) specific gravity of stomach contents in comparison to non-supplemented (0.972) rations (LSR = 0.016).

Specific gravity in the gastric region had been significantly reduced on wheat bran rations (Table 85). The similarity of the specific gravity values in the small intestinal segment are evident in Table 88. It would appear from the averages indicated that in the lower tract regions oat hulls produced the highest and wheat bran the lowest specific

TABLE 87 - THE EFFECTS OF BULK TYPE AND BULK MODULUS ON GASTRIC INGESTA SPECIFIC GRAVITY RESPONSES TO PELLETING

Treatment		Pelleting: Meal	Pelleting: Pellets	LSR
Pelleting mean**		0.946	0.981	0.016
Bulk type				
Solka-floc		0.973	0.981	0.027
Wheat bran		0.912	0.955	
Oat hulls		0.952	1.006	
Bulk modulus				
Fine		0.966	0.990	0.022
Coarse		0.926	0.972	
Bulk type x Bulk modulus*				
Solka-floc	fine	0.972	1.000	0.032
	coarse	0.975	0.965	
Wheat bran	fine	0.956	0.966	
	coarse	0.867	0.944	
Oat hulls	fine	0.969	1.000	
	coarse	0.935	1.010	

gravity values.

On the remaining treatments, where previous significant differences had been established in the gastric samples, it appeared that the overall tendency was for these differences to be equalized in the lower intestinal tract regions.

The data in Table 89 indicate that ingesta liquid specific gravity was consistently similar between all treatments. The actual specific gravity differences between inter-segment comparisons appeared to be relatively small.

In general significant differences had been indicated between the behaviour of wheat bran and the other two bulks in the stomach.

TABLE 88 - MAIN EFFECT INFLUENCES ON INGESTA SPECIFIC GRAVITY

Treatment	Region of gastro-intestinal tract					Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	
Bulk type						
Solka-floc	0.978	0.904	0.902	0.956	0.954	0.939
Wheat bran	0.933	0.907	0.914	0.913	0.923	0.919
Oat hulls	0.979	0.910	0.927	0.954	0.970	0.948
Feeding frequency						
2/day	0.955	0.900	0.907	0.941	0.954	0.930
3/day	0.972	0.914	0.919	0.935	0.945	0.939
Bulk modulus						
Fine	0.978	0.909	0.915	0.949	0.953	0.942
Coarse	0.949	0.905	0.911	0.921	0.946	0.927
Pelleting						
Meal	0.946	0.900	---	0.938	---	0.926
Pellets	0.981	0.914	0.913	---	0.949	0.942
Antibiotic						
Nil	0.955	0.910	0.908	0.942	0.949	0.933
Add	0.972	0.903	0.918	0.934	0.950	0.936
Sex						
Barrows	0.969	0.909	0.916	0.944	0.953	0.939
Gilts	0.958	0.904	0.910	0.934	0.945	0.931
Site mean	0.964	0.907	0.913	0.938	0.949	0.935
Number of observations[1]	94	93	49	40	55	(331)

1 Solka-floc samples of coarse moduli meals were collected as separate cecum and large intestine rather than the combined sample.

TABLE 89 - MAIN EFFECT INFLUENCE ON INGESTA LIQUID PHASE SPECIFIC GRAVITY

Treatment	Region of gastro-intestinal tract					Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	
Bulk type						
Solka-floc	1.020	1.028	1.010	1.014	1.014	1.019
Wheat bran	1.018	1.026	1.014	1.016	1.017	1.019
Oat hulls	1.019	1.029	1.012	1.014	1.015	1.019
Feeding frequency						
2/day	1.017	1.027	1.012	1.014	1.015	1.018
3/day	1.018	1.029	1.012	1.016	1.015	1.019
Bulk modulus						
Fine	1.020	1.028	1.011	1.014	1.015	1.019
Coarse	1.018	1.028	1.012	1.016	1.015	1.019
Pelleting						
Meal	1.016	1.027	---	1.015	---	1.020
Pellets	1.022	1.029	1.012	---	1.015	1.021
Antibiotic						
Nil	1.017	1.027	1.012	1.015	1.015	1.018
Add	1.020	1.028	1.011	1.015	1.015	1.019
Sex						
Barrows	1.022	1.028	1.012	1.015	1.015	1.020
Gilts	1.016	1.027	1.011	1.016	1.015	1.018
Site mean	1.019	1.028	1.012	1.015	1.015	1.019
Number of observations	91	89	50	38	53	(321)

These differences appeared to be maintained in the intestinal tract, moreover the inter-bulk specific gravity variations diverged to the point where it appeared that all three bulks differed. Animals fed three times daily or receiving antibiotic exhibited increased specific gravities in the stomach. Groups fed fine moduli feeds or pelleted rations exhibited increased specific gravities also, however these treatments were associated with bulk type interactions. No variation in the liquid phase specific gravity was found on the various treatments and only slight differences existed between the sampling sites.

Gastro-intestinal weight

TABLE 90 - THE EFFECTS OF PELLETING AND SEX ON GASTRIC WEIGHT RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	3/day	LSR
		gm.	gm.	
Feeding frequency		665	682	40
Antibiotic				
Nil		650	706	56
Add		680	659	
Pelleting x Antibiotic*				
Meal	nil	655	786	80
	add	709	681	
Pellets	nil	646	626	
	add	651	637	

The data in Table 90 reveal that feeding frequency as such did not influence stomach weight. Only in one instance, that of antibiotic-free meal-type rations, were the stomach weights significantly heavier in groups fed three times daily.

TABLE 91 - THE EFFECTS OF PELLETING ON STOMACH WEIGHT RESPONSES TO BULK MODULUS

Treatment	Bulk modulus		LSR
	Fine	Coarse	
	gm.	gm.	
Modulus mean	669	678	40
Pelleting*			
Meal	681	734	56
Pellets	658	622	

TABLE 92 - THE EFFECTS OF FEEDING FREQUENCY, BULK MODULUS AND SEX ON STOMACH WEIGHT RESPONSES TO PELLETING

Treatment		Pelleting		LSR
		Meal	Pellets	
		gm.	gm.	
Pelleting mean**		708	640	40
Feeding frequency				
2/day		682	649	56
3/day		734	631	
Bulk modulus*				
Fine		681	658	56
Coarse		734	622	
Antibiotic				
Nil		721	636	56
Add		695	644	
Feeding frequency x Antibiotic*				
2/day	nil	655	646	80
	add	709	651	
3/day	nil	786	626	
	add	681	637	

TABLE 93 - THE EFFECTS OF FEEDING FREQUENCY AND PELLETING ON STOMACH WEIGHT RESPONSES TO ANTIBIOTIC

Treatment	Antibiotic		LSR
	Nil	Add	
	gm.	gm.	
Antibiotic mean	678	669	40
Feeding frequency			
2/day	650	680	56
3/day	706	659	
Pelleting			
Meal	721	695	56
Pellets	636	644	
Feeding frequency x Pelleting*			
2/day meal	655	709	80
pellets	646	651	
3/day meal	786	681	
pellets	626	637	

The data in Table 91 would indicate that neither bulk modulus nor the interaction with pelleting produced significant alterations in the stomach weight.

The feeding of meal-type rations significantly increased stomach weight (Table 92). Similar weight increases prevailed in association with either coarse modulus bulks or antibiotic-free rations fed three times daily.

Only in one instance, that of antibiotic-free meals fed three times daily, did the data indicate significant weight increases (Table 93). The results from this trial would indicate that antibiotic supplementation did not significantly influence stomach weights.

In comparison to gilt groups (702 gm.), barrows had significantly

lighter stomach weights (654 gm., LSR = 40).

Tract weight

Initial comparisons involving the stomach indicated that the weight differences existing between bulk types was non-significant. Average weight relationships prevailing in the remaining tract segments, apart from a small but persistantly higher weight in wheat bran groups, would indicate that tract weights were not influenced to any extent by bulk type variations (Table 94).

Remaining tract segments, in accord with previously observed trends in the stomach, indicated that feeding frequency failed to affect intestinal tract weights.

Bulk modulus had been previously shown to be without direct influence on stomach weights, a somewhat similar situation was indicated in Table 94. There was a 10% weight increase in the large intestinal weight on coarse modulus, this has been derived from a smaller sample, however it may represent an increase of significance.

Stomach weights had been shown to be significantly increased on meal type rations, particularly on coarse modulus fed animals. The remaining tract weights, derived only from females, tended to follow a similar pattern. These weight increases averaged approximately 15%. The absence of significant pelleting x sex interactions on stomach weights would suggest that possibly barrows behaved in a fashion similar to gilts.

Antibiotic inclusion as such failed to influence stomach weights significantly, however the available means in Table 94 would suggest that in other regions of the tract a small but persistant reduction in weight on antibiotic supplemented groups prevailed.

TABLE 94 - MAIN EFFECT INFLUENCES ON INTESTINAL TRACT WEIGHTS

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	gm.	gm.	gm.	gm.	gm.	gm.	gm.
Bulk type							
Solka-floc	688	1434	220	1222	921	455	850
Wheat bran	670	1660	216	1298	1020	559	920
Oat hulls	644	1496	198	1211	941	473	840
Feeding frequency							
2/day	665	1528	218	1231	987	508	870
3/day	682	1533	203	1254	935	483	870
Bulk modulus							
Fine	669	1555	198	1237	915	509	870
Coarse	678	1505	222	1250	1006	482	870
Pelleting							
Meal	708	1507	---	1331	---	568	960
Pellets	640	1554	210	1156	961	423	830
Antibiotic							
Nil	678	1568	219	1309	1013	521	900
Add	669	1493	202	1179	908	470	840
Sex							
Barrows	645	---	---	---	---	---	---
Gilts	702	1530	210	1244	961	495	880
Site mean	674	1530	210	1244	961	495	870
Number of observations	96	48	24	48	24	48	(288)

Statistical analyses had disclosed that stomach weights were significantly heavier in gilt groups, however other treatments had not interacted with this treatment. The remaining tract segments were weighed only in gilts therefore this trend could not be followed through the remaining portions of the tract.

In summary, statistical evidence indicated that stomach weights were increased on meal type rations, and interactions in conjunction with coarse modulus with this treatment, evidence also indicated that gilts had heavier stomachs. Indications were that intestinal tract segments were heavier on coarse moduli bulks. Small but persistant intestinal tract weight decreases were observed on wheat bran rations and on antibiotic supplemented feeds.

Liquid phase pH

The results in Table 95 indicate the absence of statistical differences between gastric liquid pH and bulk type. The interactions with the listed factors indicate the variability of the effects produced in combination with these treatments. Antibiotic-free solka-floc, in conjunction with coarse modulus, yielded the lowest pH. Antibiotic addition to solka-floc increased liquid pH, particularly in barrow groups. Meal type solka-floc, in comparison to wheat bran, produced a significantly lower stomach pH, this ration fed to gilts produced the lowest pH of the three bulks. Either pelleted or antibiotic supplemented wheat bran produced the lowest gastric liquid pH. The influence of the antibiotic treatment on wheat bran was indicated by a similar pH reduction on the coarse modulus, and also when comparing gilts on this ration to oat hulls. Feeding of pelleted wheat bran to gilts produced reduced gastric liquid pH values.

TABLE 95 - THE EFFECTS OF BULK MODULUS, PELLETING, ANTIBIOTIC AND SEX ON GASTRIC LIQUID pH RESPONSES TO BULK TYPE

Treatment		Bulk type			LSR	
		Solka-floc	Wheat bran	Oat hulls	Min.	Max.
Bulk mean		4.46	4.38	4.51	0.17	0.17
Pelleting effects**						
Meal		4.31	4.57	4.46	0.23	0.25
Pellets		4.61	4.19	4.57		
Antibiotic effects*						
Nil		4.22	4.39	4.37	0.23	0.25
Add		4.70	4.37	4.66		
Bulk modulus x Antibiotic*						
Fine	nil	4.46	4.36	4.40	0.33	0.35
	add	4.62	4.53	4.70		
Coarse	nil	3.97	4.42	4.34		
	add	4.78	4.21	4.62		
Pelleting x Sex*						
Meal	barrows	4.61	4.55	4.43	0.33	0.35
	gilts	4.01	4.60	4.49		
Pellets	barrows	4.64	4.44	4.66		
	gilts	4.58	3.93	4.48		
Antibiotic x Sex*						
Nil	barrows	4.35	4.37	4.44	0.33	0.35
	gilts	4.08	4.41	4.30		
Add	barrows	4.98	4.63	4.65		
	gilts	4.43	4.12	4.67		

It would appear that while bulk type as such did not influence stomach pH directly, there was a variation in response to other treatments. Solka-floc and wheat bran, in response to pelleting and antibiotic treatments tended to produce more acidic conditions than oat hull rations.

Stomach liquid pH was significantly higher on three times a day feeding. This trend continued to prevail in most of the interacting

TABLE 96 - THE EFFECTS OF BULK MODULUS, PELLETING, ANTIBIOTIC AND SEX ON GASTRIC LIQUID pH RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
Frequency mean*		4.36	4.54	0.14
Bulk modulus				
Fine		4.41	4.61	0.19
Coarse		4.31	4.47	
Pelleting effects				
Meal		4.36	4.53	0.19
Pellets		4.36	4.55	
Antibiotic effects				
Nil		4.24	4.41	0.19
Add		4.48	4.67	
Sex effects**				
Barrows		4.37	4.77	0.19
Gilts		4.35	4.31	
Bulk modulus x Antibiotic*				
Fine	nil	4.21	4.60	0.27
	add	4.61	4.68	
Coarse	nil	4.26	4.22	
	add	4.36	4.72	
Pelleting x Antibiotic*				
Meal	nil	4.22	4.24	0.27
	add	4.50	4.83	
Pellets	nil	4.25	4.59	
	add	4.47	4.51	

treatments such as fine bulk modulus, pelleted rations and antibiotic supplementation, but was significantly different only in barrow groups. In the absence of antibiotic, either fine modulus or pelleting produced higher pH liquids on three times a day feeding. On antibiotic supplemented feeds coarse moduli or meal type rations also produced increased

TABLE 97 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, ANTIBIOTIC AND SEX ON GASTRIC LIQUID pH RESPONSES TO BULK MODULUS

Treatment		Bulk modulus Fine	Bulk modulus Coarse	LSR
Modulus mean		4.51	4.39	0.14
Sex effect				
Barrows		4.67	4.47	0.19
Gilts		4.36	4.31	
Bulk type x Antibiotic*				
Solka-floc	nil	4.46	3.97	0.33
	add	4.62	4.78	
Wheat bran	nil	4.36	4.42	
	add	4.53	4.21	
Oat hulls	nil	4.40	4.34	
	add	4.70	4.62	
Feeding frequency x Antibiotic*				
2/day	nil	4.21	4.26	0.27
	add	4.61	4.36	
3/day	nil	4.60	4.22	
	add	4.62	4.72	
Antibiotic x Sex*				
Nil	barrows	4.42	4.35	0.27
	gilts	4.39	4.13	
Add	barrows	4.91	4.59	
	gilts	4.33	4.48	

gastric pH values on the three times a day feeding regimen.

Stomach pH was increased on three times a day feeding, particularly in barrow groups. Moduli and pelleting response to feeding frequency varied depending on the antibiotic treatment.

Bulk modulus as such failed to influence stomach pH significantly (Table 97). Interaction results indicated that in the absence of antibiotic, solka-floc rations and rations fed three times a day had significantly

TABLE 98 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, ANTIBIOTIC AND SEX ON GASTRIC LIQUID pH RESPONSES TO PELLETING

Treatment		Pelleting: Meal	Pelleting: Pellets	LSR
Pelleting mean		4.45	4.46	0.14
Bulk type**				
Solka-floc		4.31	4.61	0.23
Wheat bran		4.57	4.19	
Oat hulls		4.46	4.57	
Antibiotic effects*				
Nil		4.23	4.42	0.19
Add		4.66	4.49	
Bulk type x Sex*				
Solka-floc	barrows	4.61	4.64	0.33
	gilts	4.01	4.58	
Wheat bran	barrows	4.55	4.44	
	gilts	4.60	3.93	
Oat hulls	barrows	4.43	4.66	
	gilts	4.49	4.48	
Feeding frequency x Antibiotic*				
2/day	nil	4.22	4.25	0.27
	add	4.50	4.47	
3/day	nil	4.24	4.59	
	add	4.83	4.51	
Antibiotic x Sex**				
Nil	barrows	4.42	4.36	0.27
	gilts	4.04	4.48	
Add	barrows	4.64	4.86	
	gilts	4.69	4.12	

higher pH values on fine moduli rations. On antibiotic-supplemented rations pH increases occurred on twice-a-day feeding and in barrow groups. It would appear from these responses that the increased stomach liquid pH on fine modulus may have been dependent upon the reaction of other factors to antibiotic treatments.

Stomach liquid pH variations resulting from the overall effects of pelleting proved to be non-significant. Data in Table 98 indicate that while pH was significantly increased by pelleted solka-floc or antibiotic-free rations, it was reduced on wheat bran. Gilts fed solka-floc or antibiotic-free rations exhibited higher pH values on pelleted rations, while those receiving wheat bran or antibiotic-supplemented feeds had reduced values. The response of pelleting to three-times-a-day feeding was dependent upon the presence of antibiotic, the addition of this supplement appeared to increase the significantly depressed pH evoked by antibiotic-free meal rations to a value that was significantly above that observed on pellets.

The response of stomach liquid to pelleting appeared to vary with bulk type and antibiotic. Pelleting increased liquid pH on solka-floc rations whereas it was decreased on wheat bran. The increased pH values evident on antibiotic-free pelleted rations were depressed by antibiotic incorporation.

The results in Table 99 indicate a significant stomach liquid pH increase on antibiotic-supplemented rations. A similar trend was indicated on most of the other treatments, however only solka-floc, oat hulls and meal rations produced significant increases in conjunction with antibiotic. The significant liquid pH increase on solka-floc rations was evident on coarse modulus or in either sex, while on oat hulls only gilt groups deviated significantly. Fine modulus increased liquid pH values on twice daily feeding and in barrow groups, whereas coarse modulus did so on meal rations on either feeding frequency and in gilts, however pelleting depressed pH in barrows and increased it in gilts.

TABLE 99 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS, PELLETING AND SEX ON GASTRIC LIQUID pH RESPONSES TO ANTIBIOTIC

Treatment	Antibiotic		LSR
	Nil	Add	
Antibiotic mean**	4.32	4.58	0.14
Bulk type*			
Solka-floc	4.22	4.70	0.23
Wheat bran	4.39	4.37	
Oat hulls	4.37	4.66	
Feeding frequency			
2/day	4.24	4.48	0.19
3/day	4.41	4.67	
Bulk modulus			
Fine	4.41	4.62	0.19
Coarse	4.24	4.54	
Pelleting*			
Meal	4.23	4.66	0.19
Pellets	4.42	4.49	
Sex			
Barrows	4.39	4.75	0.19
Gilts	4.26	4.40	
Bulk type x Bulk modulus*			
Solka-floc fine	4.46	4.62	0.33
coarse	3.97	4.78	
Wheat bran fine	4.36	4.53	
coarse	4.42	4.21	
Oat hulls fine	4.40	4.70	
coarse	4.34	4.62	

continued ....

TABLE 99 continued- THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS, PELLETING AND SEX ON GASTRIC LIQUID pH RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
Bulk type x Sex*				
Solka-floc	barrows	4.35	4.98	0.33
	gilts	4.08	4.43	
Wheat bran	barrows	4.37	4.63	
	gilts	4.41	4.12	
Oat hulls	barrows	4.44	4.65	
	gilts	4.30	4.67	
Feeding frequency x Bulk modulus*				
2/day	fine	4.21	4.61	0.27
	coarse	4.26	4.36	
3/day	fine	4.60	4.62	
	coarse	4.22	4.72	
Feeding frequency x Pelleting*				
2/day	meal	4.22	4.50	0.27
	pellets	4.25	4.47	
3/day	meal	4.24	4.83	
	pellets	4.59	4.51	
Bulk modulus x Sex*				
Fine	barrows	4.42	4.91	0.27
	gilts	4.39	4.33	
Coarse	barrows	4.35	4.59	
	gilts	4.13	4.48	
Pelleting x Sex**				
Meal	barrows	4.42	4.64	0.27
	gilts	4.04	4.69	
Pellets	barrows	4.36	4.86	
	gilts	4.48	4.12	

The groups supplemented with antibiotic had slightly less acidic gastric liquid exudates, particularly so on solka-floc, oat hull or meal type rations. The other treatments were implicated in the interaction effects, and although no consistent pattern prevailed, the significant differences, with one exception, favoured higher pH values on antibiotic treatments.

As indicated in Table 100, barrow groups had a significantly higher stomach liquid pH than gilts. Increased stomach liquid pH values were indicated on most of the other treatments but were significant only on three times-a-day feeding. It was further indicated that of the meals solka-floc and antibiotic-free rations and pelleting either wheat bran or antibiotic supplemented rations produced conditions increasing gastric liquid pH in barrows. Antibiotic supplemented solka-floc, wheat bran, fine moduli or pelleted rations and unsupplemented coarse moduli and meal type rations produced conditions that produced higher pH values in the stomach liquid of barrows.

In summary it would appear that barrows tended to have significantly higher stomach liquid pH values than gilts. The increased gastric liquid pH in barrows was particularly evident on three-times-a-day feeding. Further variations contingent on pelleting and antibiotic responses to sex differences were indicated as well.

While the effects of bulk type on pH were statistically insignificant, interactions indicated that oat hulls tended to produce conditions inducing reduced acidity. The data in Table 101 indicate that wheat bran created conditions suggestive of increased acidity in the lower tract regions and solka-floc behaved somewhat medially to the other two bulks.

TABLE 100 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS, PELLETING AND ANTIBIOTIC ON GASTRIC LIQUID pH RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
Sex mean**		4.57	4.33	0.14
Bulk type				
Solka-floc		4.62	4.29	0.23
Wheat bran		4.50	4.26	
Oat hulls		4.55	4.48	
Feeding frequency**				
2/day		4.37	4.35	0.19
3/day		4.77	4.31	
Bulk modulus				
Fine		4.67	4.36	0.19
Coarse		4.47	4.31	
Pelleting				
Meal		4.53	4.36	0.19
Pellets		4.61	4.30	
Antibiotic				
Nil		4.39	4.26	0.19
Add		4.75	4.40	
Bulk type x Pelleting*				
Solka-floc	meal	4.61	4.01	0.33
	pellets	4.64	4.58	
Wheat bran	meal	4.55	4.60	
	pellets	4.44	3.93	
Oat hulls	meal	4.43	4.49	
	pellets	4.66	4.48	

continued .....

TABLE 100 -continued- THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS, PELLETING AND ANTIBIOTIC ON GASTRIC LIQUID pH RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
Bulk type x Antibiotic*				
Solka-floc	nil	4.35	4.08	0.33
	add	4.98	4.43	
Wheat bran	nil	4.37	4.41	
	add	4.63	4.12	
Oat hulls	nil	4.44	4.30	
	add	4.65	4.67	
Bulk modulus x Antibiotic*				
Fine	nil	4.42	4.39	0.27
	add	4.91	4.33	
Coarse	nil	4.35	4.13	
	add	4.59	4.48	
Pelleting x Antibiotic**				
Meal	nil	4.42	4.04	0.27
	add	4.64	4.69	
Pellets	nil	4.36	4.48	
	add	4.86	4.12	

Three-times-a-day feeding had significantly increased gastric liquid pH values, data in Table 101 indicate that this influence was dissipated in the lower regions of the tract. The addition of antibiotic had increased stomach liquid pH, this effect prevailed as far as the large intestinal sampling site. Sex differences, proving to be of significance in the gastric region appeared to be dissipated in the remaining tract regions.

The overall tendency was for solka-floc and wheat bran rations, in response to pelleting and antibiotic treatments, to produce more acidic

conditions than oat hulls. The consideration of the tract as far as the large intestine suggested that acidity was influenced to some extent by bulk type, with wheat bran creating the lowest pH and oat hulls the highest. Increased feeding frequency, particularly in barrows, increased pH, this effect appeared to be dissipated in lower tract regions. Groups receiving antibiotic had less acidic stomach liquids, a condition that was absent on wheat bran rations. The effect of antibiotic appeared to persist as far as the large intestinal sampling site. Barrows had a significantly higher pH only in the gastric region, this effect was particularly accentuated by other treatments such as feeding frequency, pelleting and antibiotic.

TABLE 101 - MAIN EFFECT INFLUENCES ON INGESTA LIQUID PHASE pH

Treatment	Region of gastro-intestinal tract					Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	
Bulk type						
Solka-floc	4.46	6.61	6.13	6.14	6.01	5.76
Wheat bran	4.38	6.44	5.72	5.96	5.88	5.58
Oat hulls	4.51	6.69	6.05	6.46	6.14	5.84
Feeding frequency						
2/day	4.36	6.57	5.96	6.22	6.03	5.70
3/day	4.54	6.60	6.01	6.18	6.00	5.76
Bulk modulus						
Fine	4.51	6.60	5.99	6.16	5.96	5.74
Coarse	4.39	6.57	5.98	6.27	6.06	5.73
Pelleting						
Meal	4.45	6.70	----	6.20	----	5.68
Pellets	4.46	6.48	5.96	----	6.02	5.61
Antibiotic						
Nil	4.32	6.54	5.90	6.02	6.01	5.65
Add	4.58	6.64	6.07	6.41	6.02	5.82
Sex						
Barrows	4.57	6.61	5.98	6.11	5.97	5.76
Gilts	4.33	6.56	5.99	6.30	6.07	5.71
Site mean	4.45	6.59	5.96	6.20	6.02	5.73
Number of observations	94	89	49	38	52	(322)

Liquid phase viscosity

TABLE 102 - THE EFFECTS OF FEEDING FREQUENCY, BULK MODULUS, ANTIBIOTIC AND SEX ON GASTRIC LIQUID VISCOSITY RESPONSES TO BULK TYPE

Treatment		Bulk type: Solka-floc	Wheat bran	Oat hulls	Min.	Max.
		cp.[1]	cp.	cp.		
Bulk mean**		2.23	1.45	1.86	0.31	0.32
Feeding frequency*						
2/day		2.14	1.46	1.48	0.43	0.45
3/day		2.33	1.45	2.23		
Bulk modulus						
Fine		1.96	1.51	1.78	0.43	0.45
Coarse		2.51	1.40	1.93		
Antibiotic*						
Nil		1.86	1.45	1.87	0.43	0.45
Add		2.61	1.45	1.85		
Sex*						
Barrows		2.66	1.52	1.92	0.43	0.45
Gilts		1.81	1.39	1.79		
Feeding frequency x Bulk modulus*						
2/day	fine	2.23	1.49	1.53	0.61	0.64
	coarse	2.05	1.43	1.43		
3/day	fine	1.69	1.53	2.03		
	coarse	2.98	1.37	2.44		
Bulk modulus x Antibiotic*						
Fine	nil	1.88	1.42	1.82	0.61	0.64
	add	2.04	1.59	1.73		
Coarse	nil	1.85	1.48	1.91		
	add	3.18	1.32	1.96		

1 centipoises

The data in Table 102 indicate that stomach liquid viscosity was significantly increased on solka-floc rations and decreased on wheat bran; oat hull rations being intermediate. Interaction effects indicated that viscosity was significantly increased on solka-floc rations, on twice-a-day feeding, antibiotic supplemented rations and in barrow groups. On twice-a-day feeding this effect prevailed on both moduli but on antibiotic supplemented rations only on coarse modulus. Wheat bran rations yielded the significantly lowest viscosity on three-times-a-day feeding. Three daily feedings of wheat bran also yielded significantly reduced viscosity on either coarse modulus or antibiotic supplemented rations.

In general solka-floc rations produced gastric liquid with the highest viscosity and wheat bran the lowest. Wheat bran rations tended to be influenced less by the other experimental variables than the other bulks appeared to be.

Stomach liquid viscosity was significantly increased on three-times-a-day feeding ($P < 0.05$). Interaction results revealed similar significant viscosity increases on oat hull rations, and on coarse modulus. The data in Table 103 indicate that feeding coarse moduli bulks three-times daily also caused significant viscosity increases on solka-floc or oat hull rations and in conjunction with antibiotic supplementation.

In general it appeared that stomach liquid viscosities were increased on three-times-a-day feeding. Coarse moduli solka-floc and oat hulls tended to produce a more viscous liquid than wheat bran on the higher feeding frequency.

While data in Table 104 indicate that bulk modulus as such failed to influence stomach liquid viscosity significantly, there were significant

TABLE 103 - THE EFFECTS OF BULK TYPE, BULK MODULUS AND ANTIBIOTIC ON GASTRIC LIQUID VISCOSITY RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		cp.	cp.	
Feeding frequency*		1.69	2.00	0.25
Bulk type*				
Solka-floc		2.14	2.33	0.43
Wheat bran		1.46	1.45	
Oat hulls		1.48	2.23	
Bulk modulus*				
Fine		1.75	1.75	0.35
Coarse		1.64	2.26	
Antibiotic				
Nil		1.54	1.92	0.35
Add		1.85	2.09	
Bulk type x Bulk modulus*				
Solka-floc	fine	2.23	1.69	0.61
	coarse	2.05	2.98	
Wheat bran	fine	1.49	1.53	
	coarse	1.43	1.37	
Oat hulls	fine	1.53	2.03	
	coarse	1.43	2.44	
Bulk modulus x Antibiotic*				
Fine	nil	1.48	1.93	0.50
	add	2.02	1.56	
Coarse	nil	1.60	1.90	
	add	1.68	2.63	

interactions associated with it. As reflected by viscosity increases, significantly associated effects with coarse modulus occurred on three-times-a-day feeding, these interactions prevailed on solka-floc fed three times daily and antibiotic supplemented rations. Solka-floc rations supplemented with antibiotic, and meals fed to barrows yielded a more

viscous stomach liquid phase on coarse moduli feeds.

In summary, increases in stomach liquid viscosity, due to coarse moduli feeds were mainly elicited by solka-floc fed three times daily and in barrow groups fed meals.

Data in Table 105 indicate that the pelleting effect failed to increase significantly stomach liquid viscosity, although significant increases were evident on fine moduli feeds when fed to barrows. Gilt groups receiving antibiotic-free meals exhibited a significantly lower gastric fluid viscosity. It would appear though that these effects may be attributable to other factors and pelleting as such was not an influential factor on gastric fluid viscosity.

While indications in Table 106 were that antibiotic inclusion failed to increase significantly stomach liquid viscosity, a significant viscosity increase was indicated on antibiotic supplemented solka-floc. Indications were that production of increased fluid viscosity on antibiotic supplemented feeds were linked with coarse moduli feeds fed either in association with solka-floc, or on the three-times-a-day feeding regimen. Fine moduli bulks fed twice daily and pelleted rations fed to barrows also produced conditions conducive towards increased viscosity on antibiotic supplemented feeds.

In summary, it was indicated that the expression of increased viscosity on antibiotic inclusion was linked to factors involving associative effects of the other treatments, amongst which solka-floc was particularly associated.

TABLE 104 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, PELLETING, ANTIBIOTIC AND SEX ON GASTRIC LIQUID VISCOSITY RESPONSES TO BULK MODULUS

Treatment		Bulk modulus Fine	Bulk modulus Coarse	LSR
Modulus mean		1.75	1.95	0.25
Bulk type				
Solka-floc		1.96	2.51	0.43
Wheat bran		1.51	1.40	
Oat hulls		1.78	1.93	
Feeding frequency*				
2/day		1.75	1.64	0.35
3/day		1.75	2.26	
Pelleting				
Meal		1.54	1.95	0.35
Pellets		1.92	1.98	
Antibiotic				
Nil		1.71	1.79	0.35
Add		1.75	2.15	
Bulk type x Feeding frequency*				
Solka-floc	2/day	2.23	2.05	0.61
	3/day	1.69	2.98	
Wheat bran	2/day	1.49	1.43	
	3/day	1.53	1.37	
Oat hulls	2/day	1.53	1.43	
	3/day	2.03	2.44	
Bulk type x Antibiotic*				
Solka-floc	nil	1.88	1.85	0.61
	add	2.04	3.18	
Wheat bran	nil	1.42	1.48	
	add	1.59	1.32	
Oat hulls	nil	1.82	1.91	
	add	1.73	1.96	

continued....

TABLE 104 -continued- THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, PELLETING, ANTIBIOTIC AND SEX ON GASTRIC LIQUID VISCOSITY RESPONSES TO BULK MODULUS

Treatment		Bulk modulus Fine	Coarse	LSR
Feeding frequency x Antibiotic**				
2/day	nil	1.48	1.60	0.50
	add	2.02	1.68	
3/day	nil	1.93	1.90	
	add	1.56	2.63	
Pelleting x Sex*				
Meal	barrows	1.64	2.21	0.50
	gilts	1.44	1.63	
Pellets	barrows	2.29	1.99	
	gilts	1.61	1.97	

TABLE 105 - THE EFFECTS OF BULK MODULUS, ANTIBIOTIC AND SEX ON GASTRIC LIQUID VISCOSITY RESPONSES TO PELLETING

Treatment		Pelleting Meal	Pellets	LSR
Pelleting mean		1.73	1.97	0.25
Bulk modulus				
Fine		1.54	1.92	0.35
Coarse		1.95	1.98	
Bulk modulus x Sex*				
Fine	barrows	1.64	2.29	0.50
	gilts	1.44	1.61	
Coarse	barrows	2.21	1.99	
	gilts	1.63	1.97	
Antibiotic x Sex*				
Nil	barrows	1.83	1.81	0.50
	gilts	1.37	1.89	
Add	barrows	2.01	2.48	
	gilts	1.70	1.68	

TABLE 106 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS, PELLETING AND SEX ON GASTRIC LIQUID VISCOSITY RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
Antibiotic mean		1.73	1.97	0.25
Bulk type*				
Solka-floc		1.86	2.61	0.43
Wheat bran		1.45	1.45	
Oat hulls		1.87	1.85	
Bulk modulus				
Fine		1.71	1.79	0.35
Coarse		1.75	2.15	
Sex effects				
Barrows		1.82	2.21	0.35
Gilts		1.63	1.69	
Bulk type x Bulk modulus*				
Solka-floc	fine	1.88	2.04	0.61
	coarse	1.85	3.18	
Wheat bran	fine	1.42	1.59	
	coarse	1.48	1.32	
Oat hulls	fine	1.82	1.73	
	coarse	1.91	1.96	
Feeding frequency x Bulk modulus**				
2/day	fine	1.48	2.02	0.50
	coarse	1.93	1.56	
3/day	fine	1.60	1.68	
	coarse	1.90	2.63	
Pelleting x Sex*				
Meal	barrows	1.83	2.01	0.50
	gilts	1.37	1.70	
Pellets	barrows	1.81	2.48	
	gilts	1.89	1.68	

TABLE 107 - THE EFFECTS OF BULK TYPE, BULK MODULUS, PELLETING AND ANTIBIOTIC ON GASTRIC LIQUID VISCOSITY RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
Sex mean*		2.03	1.66	0.25
Bulk type*				
Solka-floc		2.66	1.81	0.43
Wheat bran		1.52	1.39	
Oat hulls		1.92	1.79	
Pelleting				
Meal		1.92	1.54	0.35
Pellets		2.14	1.79	
Antibiotic				
Nil		1.82	1.63	0.35
Add		2.24	1.69	
Bulk modulus x Pelleting*				
Fine	meal	1.64	1.44	0.50
	pellets	2.29	1.61	
Coarse	meal	2.21	1.63	
	pellets	1.99	1.97	
Pelleting x Antibiotic*				
Meal	nil	1.83	1.37	0.50
	add	2.01	1.70	
Pellets	nil	1.81	1.89	
	add	2.48	1.68	

Data in Table 107 reveal that stomach liquid viscosity was higher ($P < 0.05$) in barrow groups and interaction results indicate that this was particularly so on solka-floc type rations. Meal-type rations in the coarse modulus and either fine modulus or antibiotic supplemented rations fed in the pelleted form produced conditions whereby gastric fluid viscosity was significantly greater in barrow groups.

In summary barrow groups had a higher gastric fluid viscosity

than gilt groups. Solka-floc rations, and pelleting treatment, dependent on moduli or antibiotic supplementation produced conditions that tended to increase gastric fluid viscosity in barrows.

Significant viscosity increases attributable to bulk types had been demonstrated in the gastric segment, indications being that solka-floc produced the highest and wheat bran the lowest viscosity. Data in Table 108 indicate that this effect became variable in the remaining segments, the values fluctuated to the point that in the last segment sampled, the large intestine, solka-floc rations yielded the least viscous fluid.

Three-times-a-day feeding increased gastric viscosity, indications were that this effect prevailed in the remaining tract as well. Results were near significance on antibiotic-containing gastric liquid. Data in Table 108 indicate that increased viscosity on antibiotic supplemented feeds became more pronounced in the intestinal tract, particularly in the lower regions. Differences in the gastric region indicating increased viscosity in barrows failed to persist in other sampling sites.

The overall trend indicated that in the gastric region solka-floc induced the highest viscosity and not only did wheat bran yield the lowest viscosities, but it appeared that bran was the least variable. Data in the other tract segments indicated considerable variation, and in the large intestine solka-floc yielded the least viscous fluid. Viscosity increased on three daily feedings, particularly in association with coarse solka-floc and oat hulls in the stomach. The increased viscosity due to three-times-a-day feeding persisted through the other tract segments. Indications were that increased viscosity, induced by antibiotic supplementation, became more pronounced in the lower regions of the intestine.

TABLE 108 - MAIN EFFECT INFLUENCES ON INGESTA LIQUID PHASE VISCOSITY

Treatment	Region of gastro-intestinal tract					Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	
	cp.	cp.	cp.	cp.	cp.	cp.
Bulk type						
Solka-floc	2.23	2.79	1.51	3.25	3.12	2.53
Wheat bran	1.45	2.18	1.61	2.94	3.42	2.16
Oat hulls	1.86	2.70	1.66	3.57	3.41	2.51
Feeding frequency						
2/day	1.69	2.45	1.54	3.19	3.18	2.29
3/day	2.00	2.71	1.66	3.38	3.41	2.53
Bulk modulus						
Fine	1.75	2.51	1.54	3.56	3.24	2.38
Coarse	1.95	2.63	1.65	2.94	3.34	2.43
Pelleting						
Meal	1.73	2.54	----	3.28	----	2.32
Pellets	1.97	2.60	1.60	----	3.29	2.34
Antibiotic						
Nil	1.73	2.41	1.53	2.91	2.93	2.22
Add	1.97	2.74	1.68	3.71	3.62	2.60
Sex						
Barrows	2.03	2.54	1.63	3.30	3.20	2.44
Gilts	1.66	2.60	1.58	3.26	3.38	2.37
Site mean	1.85	2.57	1.60	3.28	3.29	2.41
Number of observations	92	88	49	37	50	(316)

Barrows, either as a group, or in association with other factors, exhibited increased gastric viscosity values, however this trend did not persist in the intestinal tract.

Liquid phase surface tension

TABLE 109 - THE EFFECTS OF ANTIBIOTIC AND SEX ON GASTRIC LIQUID SURFACE TENSION RESPONSES TO BULK TYPE

Treatment		Bulk type			LSR	
		Solka-floc	Wheat bran	Oat hulls	Min.	Max.
		dynes/cm^2	dynes/cm^2	dynes/cm^2		
Bulk mean		47.6	46.5	46.7	1.6	1.6
Antibiotic x Sex**						
Nil	barrows	48.7	47.1	47.1	3.1	3.3
	gilts	48.6	46.0	50.1		
Add	barrows	45.4	45.5	46.4		
	gilts	48.0	47.6	43.4		

The bulk type influence on gastric liquid surface tension proved to be non-significant (Table 109). Gilts receiving antibiotic-free oat hull rations produced a higher surface tension value than those fed wheat bran, while in contrast groups fed antibiotic supplemented oat hulls had the significantly lowest stomach liquid surface tension value of the bulk types.

Feeding frequency, as such, did not create significant variations in stomach liquid surface tension (Table 110). Interaction results revealed that on twice-a-day feeding surface tension was greater on fine bulk modulus and in gilt groups. These results were additive and fine moduli feeds fed to gilt groups twice daily produced a significant increase in surface tension.

TABLE 110 - THE EFFECTS OF BULK MODULUS AND SEX ON GASTRIC LIQUID SURFACE TENSION RESPONSES TO FEEDING FREQUENCY

Treatment		Feeding frequency 2/day	Feeding frequency 3/day	LSR
		dynes/cm^2	dynes/cm^2	
Frequency mean		47.4	46.5	1.3
Bulk modulus*				
Fine		48.5	46.0	1.8
Coarse		46.3	47.1	
Sex*				
Barrows		46.4	47.0	1.8
Gilts		48.4	46.1	
Bulk modulus x Sex*				
Fine	barrows	47.0	47.2	2.6
	gilts	50.1	45.0	
Coarse	barrows	45.8	46.7	
	gilts	46.8	47.4	

TABLE 111 - THE EFFECTS OF FEEDING FREQUENCY AND SEX ON GASTRIC LIQUID SURFACE TENSION RESPONSES TO BULK MODULUS

Treatment		Bulk modulus Fine	Bulk modulus Coarse	LSR
		dynes/cm^2	dynes/cm^2	
Modulus mean		47.3	46.7	1.3
Feeding frequency*				
2/day		48.5	46.3	1.8
3/day		46.0	47.1	
Feeding frequency x Sex*				
2/day	barrows	47.0	45.8	2.6
	gilts	50.1	46.8	
3/day	barrows	47.2	46.7	
	gilts	45.0	47.4	

The results in Table 111 disclose that the bulk modulus did not influence stomach liquid surface tension. Feeding twice daily as well as following this regimen in gilt groups produced significant difference indicating higher surface tension in fine bulk moduli feeds.

Animals fed pellets tended to have a higher ($P < 0.01$) surface tension of 47.8 in comparison to groups fed meals which had a value of 46.1 dynes per cm^2 (LSR = 1.3).

TABLE 112 - THE EFFECTS OF BULK TYPE AND SEX ON GASTRIC LIQUID SURFACE TENSION RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil	Antibiotic Add	LSR
		dynes/cm^2	dynes/cm^2	
Antibiotic mean**		47.9	46.0	1.3
Bulk type				
Solka-floc		48.6	46.6	2.2
Wheat bran		46.6	46.5	
Oat hulls		48.6	44.9	
Sex effects				
Barrows		47.6	45.7	1.8
Gilts		48.2	46.3	
Bulk type x Sex**				
Solka-floc	barrows	48.7	45.4	3.1
	gilts	48.6	48.0	
Wheat bran	barrows	47.1	45.5	
	gilts	46.0	47.6	
Oat hulls	barrows	47.1	46.4	
	gilts	50.1	43.4	

The data in Table 112 reveal that the mean stomach liquid surface tension obtained from animals consuming antibiotic supplemented rations was significantly less than the unsupplemented groups. Interaction results reveal that similar effects were also of significance in

barrow groups consuming solka-floc and gilts consuming oat hull rations.

TABLE 113 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY, BULK MODULUS AND ANTIBIOTIC ON GASTRIC LIQUID SURFACE TENSION RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
		dynes/cm^2	dynes/cm^2	
Sex mean		46.7	47.3	1.3
Bulk type				
Solka-floc		47.6	48.3	2.2
Wheat bran		46.3	46.8	
Oat hulls		46.8	46.7	
Feeding frequency*				
2/day		46.4	48.4	1.8
3/day		47.0	46.1	
Bulk type x Antibiotic**				
Solka-floc	nil	48.7	48.6	3.1
	add	45.4	48.0	
Wheat bran	nil	47.1	46.0	
	add	45.5	47.6	
Oat hulls	nil	47.1	50.1	
	add	46.4	43.4	
Feeding frequency x Bulk modulus*				
2/day	fine	47.0	50.1	2.6
	coarse	45.8	46.2	
3/day	fine	47.2	45.0	
	coarse	46.7	47.4	

While on the whole there were no changes in surface tension attributable to sex difference interaction results revealed a significant rise in surface tension in gilts fed twice daily, the effect persisted on fine but not coarse moduli bulks.

Bulk type did not influence surface tension variations in the gastric site. Data in Table 114 indicate that there was a larger surface

TABLE 114 - MAIN EFFECT INFLUENCES ON INGESTA LIQUID PHASE SURFACE TENSION

Treatment	Region of gastro-intestinal tract					Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	
	dynes/cm^2	dynes/cm^2	dynes/cm^2	dynes/cm^2	dynes/cm^2	dynes/cm^2
Bulk type						
Solka-floc	47.6	32.7	48.1	47.0	46.2	44.7
Wheat bran	46.5	39.6	47.0	44.6	44.8	44.2
Oat hulls	46.7	39.3	48.3	47.8	45.1	44.7
Feeding frequency						
2/day	47.4	39.1	48.2	46.8	45.8	44.9
3/day	46.5	38.5	47.5	46.0	45.2	44.2
Bulk modulus						
Fine	47.3	38.7	47.8	45.9	45.3	44.5
Coarse	46.7	38.9	47.8	47.2	45.7	44.6
Pelleting						
Meal	46.1	37.9	----	46.4	----	42.8
Pellets	47.8	39.6	47.8	----	45.5	44.8
Antibiotic						
Nil	47.9	39.4	47.6	46.6	45.4	45.0
Add	46.0	38.1	48.0	46.2	45.7	44.1
Sex						
Barrows	46.7	38.5	48.3	46.6	45.6	44.5
Gilts	47.3	39.1	47.4	46.2	45.5	44.6
Site mean	47.0	38.8	47.8	46.4	45.5	44.6
Number of observations	92	88	50	38	53	(321)

tension decline in the small intestinal sample on solka-floc rations than on other bulks. The increased surface tension produced in the stomach on pelleted rations prevailed in the small intestine. Surface tension depression in the stomach due to antibiotic in the ration appeared to be dissipated in the intestinal tract and both treatments produced similar values.

In summary, pelleting increased surface tension of the gastric liquid, an effect that persisted in the small intestine. While antibiotic inclusion depressed surface tension in the stomach this effect did not prevail in the other sites. Fine modulus bulks and gilt groups fed three times daily appeared to exhibit decreased surface tension values.

Liquid phase oven dry residue

The data in Table 115 reveal that although the oven dried stomach liquid residues on oat hull rations were less than those of solka-floc and wheat bran rations, the differences were not significant. Interaction effects disclosed that oat hull ration residues were significantly less ($P<0.05$) on twice-a-day feeding, and in comparison to solka-floc, wheat bran produced less residue on antibiotic supplemented rations. On rations with antibiotic there was a significant depression of residue on coarse wheat bran.

Three-times-a-day feeding significantly increased oven-dried residue. The interaction results indicate that these effects were also significantly prominent on oat hull rations and in coarse bulks fed on the increased feeding regimen.

TABLE 115 - THE EFFECTS OF FEEDING FREQUENCY, BULK MODULUS AND ANTIBIOTIC ON OVEN DRY GASTRIC LIQUID RESIDUE RESPONSES TO BULK TYPE

Treatment	Bulk type: Solka-floc	Wheat bran	Oat hulls	Min.	Max.
	% Angles[1]	% Angles	% Angles		
Bulk mean	4.5 (12.2)	4.0 (11.5)	3.8 (11.2)	(1.0)	(1.0)
Feeding frequency*					
2/day	4.1 (11.7)	4.0 (11.5)	3.0 (9.9)	(1.4)	(1.6)
3/day	4.8 (12.6)	4.0 (11.5)	3.8 (12.6		
Antibiotic*					
Nil	5.9 (11.4)	4.5 (12.2)	3.7 (11.1)	(1.4)	(1.6)
Add	5.1 (13.0)	3.5 (10.8)	3.9 (11.4)		
Bulk modulus x Antibiotic*					
Fine nil	3.9 (11.4)	4.1 (11.7)	4.0 (11.5)	(2.0)	(2.4)
add	4.8 (12.6)	4.3 (11.9)	3.6 (10.9)		
Coarse nil	3.8 (11.3)	4.9 (12.8)	4.1 (11.7)		
add	5.4 (13.4)	2.5 (9.0)	4.3 (11.9)		

1 Percentage data transformed to angles for statistical analysis (Johnson, 1950).

TABLE 116 - THE EFFECTS OF BULK TYPE AND BULK MODULUS ON OVEN DRY GASTRIC LIQUID RESIDUE RESPONSES TO FEEDING FREQUENCY

Treatment	Feeding frequency: 2/day	3/day	LSR
	% Angles	% Angles	
Modulus mean	3.6 (11.0)	4.6 (12.3)	(0.8)
Bulk type*			
Solka-floc	4.1 (11.7)	4.8 (12.6)	(1.4)
Wheat bran	4.0 (11.5)	4.0 (11.5)	
Oat hulls	3.0 (9.9)	4.8 (12.6)	
Bulk modulus*			
Fine	4.0 (11.5)	4.2 (11.8)	(1.2)
Coarse	3.4 (10.6)	4.8 (12.7)	

TABLE 117 - THE EFFECTS OF BULK TYPE, FEEDING FREQUENCY AND ANTIBIOTIC ON OVEN DRY GASTRIC LIQUID RESIDUE RESPONSES TO BULK MODULUS

Treatment		Bulk modulus: Fine	Bulk modulus: Coarse	LSR
		% Angles	% Angles	
Modulus mean		4.1 (11.7)	4.0 (11.6)	(0.8)
Feeding frequency*				
2/day		4.0 (11.5)	3.4 (10.6)	(1.2)
3/day		4.2 (11.8)	4.8 (12.7)	
Bulk type x Antibiotic*				
Solka-floc	nil	3.9 (11.4)	3.8 (11.3)	(2.0)
	add	4.8 (12.6)	5.4 (13.4)	
Wheat bran	nil	4.1 (11.7)	4.9 (12.8)	
	add	4.3 (11.9)	2.5 (9.0)	
Oat hulls	nil	4.0 (11.5)	4.1 (11.7)	
	add	3.6 (10.9)	4.3 (11.9)	

The data in Table 117 reveal that bulk modulus did not influence oven-dried residues. Interaction results indicate that only in the case of coarse wheat bran supplemented with antibiotic was there a significant decrease in oven-dried residues.

Data in Table 118 indicate a significant reduction in stomach-liquid oven-dried residues on meal-type rations. Interaction results reveal that significant reductions of oven dry residue on pelleted rations were indicated in gilts fed antibiotic-free rations and barrows receiving antibiotic supplements.

On the whole antibiotic inclusion failed to affect oven-dried residues (Table 119), nevertheless interaction results show that while antibiotic inclusion increased residues on solka-floc rations, the residues were decreased by it on wheat bran rations. Further analysis disclosed

TABLE 118 - THE EFFECTS OF ANTIBIOTIC AND SEX ON OVEN DRY GASTRIC LIQUID RESIDUE RESPONSES TO PELLETING

Treatment	Pelleting		LSR
	Meal	Pellets	
	% Angles	% Angles	
Pelleting mean**	3.4 (10.6)	4.8 (12.6)	(0.8)
Sex			
Barrows	4.0 (11.5)	5.4 (13.4)	(1.2)
Gilts	2.9 (9.8)	4.2 (11.8)	
Antibiotic x Sex**			
Nil barrows	4.2 (11.8)	4.7 (12.5)	(1.6)
gilts	2.6 (9.3)	4.8 (12.7)	
Add barrows	3.8 (11.2)	6.1 (14.3)	
gilts	3.2 (10.3)	3.7 (11.0)	

that only on coarse solka-floc and coarse wheat bran were the aforementioned effects prevalent. On pelleted rations containing antibiotic oven dry residue was significantly increased in barrow groups but was significantly decreased in gilts.

In summary, it appeared that the response to antibiotic supplementation varied with bulk type and also sex response to pelleting. Increased residues were present on solka-floc rations and barrow groups only.

The data in Table 120 indicate a reduction ($P < 0.01$) of oven-dried stomach liquid residues in gilt groups. These conditions prevailed on both pelleting and antibiotic treatments, but were significant only in barrows fed antibiotic-free meals or supplemented pellets.

The data in Table 121 would suggest that apart from the significant ingesta liquid residue differences cited in the stomach samples there appeared to be very little variation present in the remaining intestinal sites.

TABLE 119 - THE EFFECTS OF BULK TYPE, BULK MODULUS, PELLETING AND SEX ON OVEN DRY GASTRIC LIQUID RESIDUE RESPONSES TO ANTIBIOTIC

Treatment		Antibiotic Nil		Antibiotic Add		LSR
		%	Angles	%	Angles	
Antibiotic mean		4.0	(11.6)	4.1	(11.7)	(0.8)
Bulk type*						
Solka-floc		3.9	(11.4)	5.1	(13.0)	(1.4)
Wheat bran		4.5	(12.2)	3.5	(10.8)	
Oat hulls		3.7	(11.1)	3.9	(11.4)	
Bulk type x Bulk modulus*						
Solka-floc	fine	3.9	(11.4)	4.8	(12.6)	(2.0)
	coarse	3.8	(11.3)	5.4	(13.4)	
Wheat bran	fine	4.1	(11.7)	4.3	(11.9)	
	coarse	4.9	(12.8)	2.5	(9.0)	
Oat hulls	fine	4.0	(11.5)	3.6	(10.9)	
	coarse	4.1	(11.7)	4.3	(11.9)	
Pelleting x Sex**						
Meal	barrows	4.2	(11.8)	3.8	(11.2)	(1.6)
	gilts	2.6	(9.3)	3.2	(10.3)	
Pellets	barrows	4.7	(12.5)	6.1	(14.3)	
	gilts	4.8	(12.7)	3.7	(11.0)	

TABLE 120 - THE EFFECTS OF PELLETING AND ANTIBIOTIC ON OVEN DRY GASTRIC LIQUID RESIDUE RESPONSES TO SEX

Treatment		Sex		LSR
		Barrows	Gilts	
		% Angles	% Angles	
Sex mean**		4.7 (12.5)	3.5 (10.8)	(0.8)
Pelleting				
Meal		4.0 (11.5)	2.9 (9.8)	(1.2)
Pellets		5.4 (13.4)	4.2 (11.8)	
Antibiotic				
Nil		4.5 (12.2)	3.6 (11.0)	(1.2)
Add		4.9 (13.4)	3.4 (11.7)	
Pelleting x Antibiotic**				
Meal	nil	4.2 (11.8)	2.6 (9.3)	(1.6)
	add	3.8 (11.2)	3.2 (10.3)	
Pellets	nil	4.7 (12.5)	4.8 (12.7)	
	add	6.1 (14.3)	3.7 (11.0)	

Three-times-a-day feeding significantly increased oven-dried residues in the stomach liquid, particularly on oat hull and coarse moduli rations. Pelleting increased the oven-dried residues as did antibiotic supplementation, however in the latter instance, the response of wheat bran was opposite to that of solka-floc. Barrows had higher residues in the gastric liquid. The significant effect of these treatments appeared to be nullified in the intestinal tract.

TABLE 121 - MAIN EFFECT INFLUENCES ON INGESTA LIQUID PHASE OVEN DRY RESIDUE

Treatment	Region of gastro-intestinal tract					Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	
	%	%	%	%	%	%
Bulk type						
Solka-floc	4.5	6.5	2.4	2.8	2.9	4.3
Wheat bran	4.0	6.3	2.9	3.1	3.3	4.2
Oat hulls	3.8	6.7	2.9	2.8	3.1	4.2
Feeding frequency						
2/day	3.6	6.4	2.6	2.9	3.1	4.0
3/day	4.6	6.6	2.7	3.0	3.1	4.4
Bulk modulus						
Fine	4.1	6.5	2.7	3.1	3.2	4.3
Coarse	4.0	6.5	2.6	2.7	3.0	4.1
Pelleting						
Meal	3.4	6.3	---	2.9	---	4.5
Pellets	4.8	6.7	2.7	---	3.1	4.7
Antibiotic						
Nil	4.0	6.6	2.7	2.9	3.1	4.2
Add	4.1	6.4	2.7	2.9	3.1	4.2
Sex						
Barrows	4.7	6.5	2.6	2.9	3.2	4.4
Gilts	3.5	6.5	2.7	2.9	3.0	4.0
Site mean	4.0	6.5	3.7	2.9	3.1	4.2
Number of observations	93	88	50	39	52	(322)

Liquid phase ash

TABLE 122 - THE EFFECT OF ANTIBIOTIC ON GASTRIC LIQUID ASH RESPONSES TO BULK TYPE

Treatment[1]	Bulk type				Min.	Max.
	Solka-floc		Wheat bran	Oat hulls		
	%	Angles	% Angles	% Angles		
Bulk mean	17.2	(24.5)	21.0 (27.3)	17.2 (24.5)	(2.6)	(2.7)
Antibiotic*						
Nil	19.6	(26.3)	20.3 (26.8)	14.4 (22.3)	(2.6)	(3.8)
Add	14.9	(22.7)	21.8 (27.8)	20.2 (26.7)		

1 Reported as a percentage of ingesta liquid oven dry residue

TABLE 123 - THE EFFECT OF BULK TYPE AND SEX ON GASTRIC LIQUID ASH RESPONSES TO ANTIBIOTIC

Treatment	Antibiotic				LSR
	Nil		Add		
	%	Angles	%	Angles	
Antibiotic mean	18.1	(25.2)	18.9	(25.8)	(2.1)
Bulk type*					
Solka-floc	19.6	(26.3)	14.9	(22.7)	(3.6)
Wheat bran	20.3	(26.8)	21.8	(27.8)	
Oat hulls	14.4	(22.3)	20.2	(26.7)	
Sex*					
Barrows	19.8	(26.4)	17.3	(24.6)	(3.0)
Gilts	16.4	(23.9)	20.5	(26.9)	

The data in Table 122 reveal that in comparison to wheat bran both solka-floc and oat hull rations exhibited reduced ash in the stomach liquid ($P < 0.05$). The effect of antibiotic supplementation on bulk type varied. Antibiotic-free oat hulls yielded a significantly lower ash, however in solka-floc rations antibiotic significantly depressed ash in

the gastric fluid.

On the whole, antibiotic treatment did not alter percent ash in the stomach liquid residue. Interaction effects disclosed that solka-floc bulk type significantly depressed ash in supplemented rations, with oat hulls and in gilt groups significant liquid ash reductions occurred on antibiotic-free rations.

TABLE 124 - THE EFFECT OF ANTIBIOTIC ON GASTRIC LIQUID ASH RESPONSES TO SEX

Treatment	Sex				LSR
	Barrows		Gilts		
	%	Angles	%	Angles	
Sex mean	18.5	(25.5)	18.4	(25.4)	(2.1)
Antibiotic*					
Nil	19.8	(26.4)	16.4	(23.9)	(3.0)
Add	17.3	(24.6)	20.5	(26.9)	

The results in Table 124 revealed that sex differences failed to influence ash levels in the stomach liquid.

Previous indications had been that gastric liquid ash levels were slightly higher on wheat bran rations, this effect appeared to persist through the tract and wheat bran yielded more ash than oat hulls. Data in Table 125 would indicate that apart from segment differences, there was a lack of main effect influences on liquid ash. Such observations agree with the initial observations on the gastric region where it was established that only certain interaction results proved to cause significant fluctuations.

In summary, it appeared that only in antibiotic-containing rations in conjunction with interactions involving bulk type and sex

TABLE 125 - MAIN EFFECT INFLUENCES ON INGESTA LIQUID PHASE ASH

Treatment	Region of gastro-intestinal tract					Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	
	%	%	%	%	%	%
Bulk type						
Solka-floc	17.2	11.4	29.1	25.7	26.2	20.0
Wheat bran	21.0	11.5	29.3	30.1	28.8	22.1
Oat hulls	17.2	10.6	25.4	25.4	26.2	19.1
Feeding frequency						
2/day	18.7	11.3	29.0	27.7	27.5	20.8
3/day	18.3	11.0	27.2	27.1	26.3	20.0
Bulk modulus						
Fine	18.5	11.2	27.0	26.9	26.3	20.1
Coarse	16.4	11.1	28.9	28.1	27.4	20.7
Pelleting						
Meal	19.1	10.8	----	27.4	----	17.2
Pellets	18.0	11.4	28.1	----	26.9	19.4
Antibiotic						
Nil	18.1	11.0	27.2	27.3	26.0	20.3
Add	18.9	11.3	29.1	27.6	27.8	20.6
Sex						
Barrows	18.5	11.0	28.8	26.5	26.3	20.1
Gilts	18.4	11.3	28.5	28.4	27.6	20.7
Site mean	18.5	11.1	28.1	27.4	26.9	20.4
Number of observations	92	88	50	39	52	(321)

differences were there significant changes induced in liquid ash levels. Indications were that the ingesta liquid yielded the highest ash on wheat bran rations and the lowest on oat hulls.

Ingesta protein

TABLE 126 - MAIN EFFECT INFLUENCES ON INGESTA CRUDE PROTEIN
(Dry matter basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	15.4	27.8	14.4	13.5	13.9	14.1	17.3
Wheat bran	15.3	26.9	16.2	15.0	15.9	15.0	17.9
Oat hulls	12.8	24.8	11.2	10.3	10.9	10.0	14.1
Feeding frequency							
2/day	13.8	27.8	14.2	13.2	13.6	13.1	16.7
3/day	15.3	25.2	13.7	12.3	13.5	12.9	16.2
Bulk modulus							
Fine	14.3	25.9	13.5	13.2	13.6	13.2	16.3
Coarse	14.7	27.0	14.3	12.3	13.5	12.8	16.5
Pelleting							
Meal	13.8	25.5	----	12.8	----	12.3	16.7
Pellets	15.2	27.6	14.0	----	13.5	13.7	17.4
Antibiotic							
Nil	14.2	27.3	14.7	13.7	14.1	13.6	16.9
Add	14.8	25.6	13.2	11.9	13.1	12.4	15.9
Sex							
Barrows	15.2	25.2	13.8	13.3	14.0	13.0	16.4
Gilts	13.8	27.8	14.1	12.4	13.1	13.0	16.5
Site mean	14.5	26.5	14.0	12.8	13.5	13.0	16.4
Number of observations	91	93	54	40	56	93	(427)

Footnote: Feed crude protein

Solka-floc = 17.9%
Wheat bran = 18.2%
Oat hulls = 17.6%

TABLE 127 - MAIN EFFECT INFLUENCES ON INGESTA CRUDE PROTEIN
(Wet sample basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	4.37	4.09	2.09	2.84	2.92	3.41	3.48
Wheat bran	3.73	4.04	2.40	2.58	3.08	3.22	3.32
Oat hulls	3.87	4.14	2.12	2.62	2.96	3.01	3.28
Feeding frequency							
2/day	3.64	4.11	2.27	2.82	3.07	3.33	3.35
3/day	4.44	4.08	2.16	2.60	2.97	3.25	3.45
Bulk modulus							
Fine	4.05	4.04	2.13	2.93	3.09	3.35	3.42
Coarse	3.98	4.16	2.29	2.44	2.97	3.23	3.37
Pelleting							
Meal	3.77	3.82	----	2.71	----	3.10	3.45
Pellets	4.26	4.42	2.23	----	3.01	3.47	3.64
Antibiotic							
Nil	3.85	4.20	2.31	2.90	3.17	3.48	3.47
Add	4.17	3.99	2.12	2.54	2.90	3.10	3.32
Sex							
Barrows	4.38	3.86	2.26	2.81	3.16	3.24	3.44
Gilts	3.67	4.36	2.19	2.65	2.88	3.34	3.36
Site mean	4.01	4.11	2.23	2.71	3.01	3.29	3.40
Number of observations	91	93	54	40	56	93	(427)

TABLE 128 - RELATIVE EFFECT OF TREATMENTS ON INGESTA CRUDE PROTEIN

Treatment	Stomach sample		Small i. sample		Cecum sample		Cecum + L. i. sample		Large i. sample		Rectum sample	
	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta
Bulk type												
Solka-floc	+	++	+	0	0	−	0	++	0	0	+	+
Wheat bran	+	−	0	0	+	++	+	−	+	0	++	0
Oat hulls	−−	−	−	0	−	−	−	−	−	0	−−	−
Feeding frequency												
2/day	−	−	+	0	0	0	0	0	0	0	0	0
3/day	+	+	−	0	0	0	0	0	0	0	0	0
Bulk modulus												
Fine	0	0	0	0	0	0	0	+	0	0	0	0
Coarse	0	0	0	0	0	0	0	−	0	0	0	0
Pelleting												
Meal	−	−	−	−							−	−
Pellets	+	+	+	+							+	+
Antibiotic												
Nil	0	−	+	0	+	0	+	+	+	+	+	+
Add	0	+	−	0	−	0	−	−	−	−	−	−
Sex												
Barrows	+	+	−	−	0	0	0	+	0	+	0	0
Gilts	−	−	+	+	0	0	0	−	0	−	0	+

The data in Tables 126, 127 and summarized in 128, indicate that variations in protein content of the ingesta existed on treatments involving bulk type, feeding frequency, pelleting, antibiotic and sex. Only one of these effects was removed by making adjustments for the levels of moisture present in the respective tract segments.

There appeared to be a slight divergence of ingesta protein from ration levels, solka-floc exhibited the highest and oat hulls the lowest protein percentage. In the rectal samples, wheat bran yielded the highest assay of protein and oat hulls the lowest. In the sampling sites assayed, lower levels of protein were in evidence on meal rations. The antibiotic-supplemented rations produced conditions conducive towards reduced protein in the tract. There was a varied response to sex differences and in most instances these variations were small.

Ingesta nitrogen-free extract

Basic differences existed between the nitrogen-free extract (NFE) levels of the three rations, with wheat bran being the highest and oat hulls the lowest (Tables 129, 130 and 131). Indications were that these rankings were not maintained throughout the gastro-intestinal tract, it appeared that in the intestinal region oat hulls consistently yielded higher NFE percentages than solka-floc. Relating the assays to the level of moisture in the tract diluted the NFE of wheat bran to an amount slightly above that of solka-floc in most segments. In the rectal segment it appeared that the greatest reduction in original feed NFE levels occurred on solka-floc rations.

On the dry matter basis NFE levels varied to some extent with feeding frequency, bulk modulus and pelleting; however some of these

effects were nullified by adjusting levels to moisture. These influences may have been a reflection of relative gastric fill and emptying characteristics.

TABLE 129 - MAIN EFFECT INFLUENCES ON INGESTA NITROGEN-FREE EXTRACT
(Dry matter basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	56.5	40.0	41.9	39.1	37.4	35.1	42.3
Wheat bran	61.8	47.2	49.2	48.1	47.6	45.7	50.3
Oat hulls	55.4	43.6	47.7	46.0	45.5	45.3	47.5
Feeding frequency							
2/day	57.1	42.6	46.2	44.9	42.1	42.1	46.2
3/day	58.5	44.6	45.1	46.0	43.0	41.9	47.3
Bulk modulus							
Fine	58.2	44.7	46.9	44.7	44.2	42.5	47.3
Coarse	57.5	42.6	44.6	46.6	41.3	41.5	46.0
Pelleting							
Meal	56.7	44.0	----	45.4	----	42.9	47.5
Pellets	58.9	43.3	45.6	----	42.5	41.1	46.6
Antibiotic							
Nil	57.6	43.1	45.1	45.2	42.8	41.9	46.3
Add	58.1	44.2	46.2	45.6	42.2	42.1	46.8
Sex							
Barrows	59.4	44.3	46.6	45.2	42.4	42.0	47.1
Gilts	56.3	42.9	44.8	45.6	42.6	42.0	46.0
Site mean	57.8	43.6	45.6	45.4	42.5	42.0	46.6
Number of observations	90	92	54	40	54	93	(423)

Footnote: Feed nitrogen-free extract

Solka-floc = 61%
Wheat bran = 66%
Oat hulls = 59%

TABLE 130 - MAIN EFFECT INFLUENCES ON INGESTA NITROGEN-FREE EXTRACT
(Wet sample basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	16.1	5.9	6.1	8.2	7.9	8.5	9.1
Wheat bran	15.1	7.1	7.3	8.3	9.1	9.8	9.8
Oat hulls	16.7	7.3	9.0	11.7	12.4	13.6	12.0
Feeding frequency							
2/day	15.1	6.3	7.4	9.6	9.5	10.7	10.0
3/day	17.0	7.2	7.1	9.7	9.5	10.6	10.5
Bulk modulus							
Fine	16.5	7.0	7.4	9.9	10.0	10.8	10.6
Coarse	15.5	6.6	7.1	9.2	9.1	10.5	10.0
Pelleting							
Meal	15.5	6.6	---	9.6	---	10.8	10.8
Pellets	16.5	6.9	7.3	---	9.5	10.7	10.4
Antibiotic							
Nil	15.6	6.6	7.1	9.6	9.6	10.7	10.4
Add	16.4	6.9	7.4	9.7	9.3	10.5	10.4
Sex							
Barrows	17.1	6.8	7.6	9.5	9.6	10.5	10.5
Gilts	15.0	6.7	6.9	9.8	9.4	10.8	10.0
Site mean	16.0	6.8	7.3	9.6	9.5	10.6	10.3
Number of observations	90	92	54	40	54	93	(423)

TABLE 131 - RELATIVE EFFECT OF TREATMENTS ON INGESTA NITROGEN-FREE EXTRACT

Treatment	Stomach sample		Small i. sample		Cecum sample		Cecum + large i. sample		Large i. sample		Rectum sample	
	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta
Bulk type												
Solka-floc	+	0	−	−	−−−	−	−−−	−	−−−	−	−−	−
Wheat bran	++	−	+	0	++	0	+	−	+	0	+	−
Oat hulls	−	+	0	+	+	+	++	++	++	+	+	++
Feeding frequency												
2/day	−	−	−	−	+	0	+	0	0	0	0	0
3/day	+	+	+	+	−	0	−	0	0	0	0	0
Bulk modulus												
Fine	0	0	+	0	+	0	−	0	+	0	0	0
Coarse	0	0	−	0	−	0	+	0	−	0	0	0
Pelleting												
Meal	−	−	0	0							+	0
Pellets	+	+	0	0							−	0
Antibiotic												
Nil	0	0	0	0	0	0	0	0	0	0	0	0
Add	0	0	0	0	0	0	0	0	0	0	0	0
Sex												
Barrows	+	+	0	0	+	0	0	0	0	0	0	0
Gilts	−	−	0	0	−	0	0	0	0	0	0	0

Ingesta fat

TABLE 132 - MAIN EFFECT INFLUENCES ON INGESTA ETHER EXTRACT
(Dry matter basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	4.04	4.62	2.85	4.53	4.67	4.72	4.30
Wheat bran	2.75	4.03	2.75	4.99	3.59	4.54	3.73
Oat hulls	5.81	5.17	3.69	4.79	4.21	4.33	4.77
Feeding frequency							
2/day	4.33	4.60	3.14	4.68	4.27	4.52	4.30
3/day	4.14	4.65	2.99	4.95	4.20	4.55	4.27
Bulk modulus							
Fine	3.81	4.59	3.32	4.67	4.21	4.65	4.23
Coarse	4.63	4.65	2.83	5.00	4.25	4.41	4.34
Pelleting							
Meal	4.25	4.74	----	4.82	----	4.45	4.52
Pellets	4.21	4.50	3.06	----	4.23	4.62	4.21
Antibiotic							
Nil	4.36	4.81	3.76	5.42	4.44	4.84	4.52
Add	4.09	4.44	2.88	4.18	4.03	4.25	4.04
Sex							
Barrows	4.07	4.38	3.06	4.53	4.43	4.93	4.28
Gilts	4.39	4.89	3.06	5.11	4.03	4.13	4.29
Site mean	4.23	4.62	3.06	4.82	4.23	4.53	4.28
Number of observations	90	93	56	39	55	92	(425)

Footnote: Feed ether extract

Solka-floc = 4.5%
Wheat bran = 2.2%
Oat hulls = 6.6%

TABLE 133 - MAIN EFFECT INFLUENCES ON INGESTA ETHER EXTRACT
(Wet sample basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	1.15	.69	.41	.95	.98	1.14	.91
Wheat bran	.67	.60	.41	.86	.70	.98	.73
Oat hulls	1.75	.86	.70	1.22	1.15	1.30	1.19
Feeding frequency							
2/day	1.14	.68	.50	1.00	.97	1.15	.92
3/day	1.20	.75	.47	1.04	.92	1.15	.94
Bulk modulus							
Fine	1.07	.72	.52	1.03	.96	1.18	.93
Coarse	1.25	.72	.45	.99	.94	1.11	.93
Pelleting							
Meal	1.16	.71	---	1.02	---	1.12	1.00
Pellets	1.18	.72	.50	---	.94	1.17	.93
Antibiotic							
Nil	1.18	.74	.51	1.15	.99	1.24	.98
Add	1.15	.69	.46	.89	.89	1.06	.88
Sex							
Barrows	1.17	.67	.50	.96	1.00	1.23	.95
Gilts	1.17	.77	.47	1.09	.89	1.06	.92
Site mean	1.17	.72	.49	1.02	.94	1.15	.93
Number of observations	90	93	56	39	55	92	(425)

TABLE 134 - RELATIVE EFFECT OF TREATMENTS ON INGESTA ETHER EXTRACT

Treatment	Stomach sample		Small i. sample		Cecum sample		Cecum + Large i. sample		Large i. sample		Rectum sample	
	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta
Bulk type												
Solka-floc	0	0	0	0	-	-	-	-	+	0	+	0
Wheat bran	-	-	-	-	-	-	+	-	-	-	0	-
Oat hulls	+	+	+	+	+	+	0	++	0	+	-	+
Feeding frequency												
2/day	0	0	0	0	0	0	0	0	0	0	0	0
3/day	0	0	0	0	0	0	0	0	0	0	0	0
Bulk modulus												
Fine	-	-	0	0	+	0	-	0	0	0	0	0
Coarse	+	+	0	0	-	0	+	0	0	0	0	0
Pelleting												
Meal	0	0	0	0							0	0
Pellets	0	0	0	0							0	0
Antibiotic												
Nil	+	0	+	0	+	0	+	+	+	+	+	+
Add	-	0	-	0	-	0	-	-	-	-	-	-
Sex												
Barrows	-	0	-	0	0	0	-	0	+	+	+	-
Gilts	+	0	+	0	0	0	+	0	-	-	-	+

The ether extract values of the rations fluctuated. In comparison to wheat bran, there was a two-fold increase in solka-floc and a three-fold increase in oat hull fat levels. For the most part these rankings prevailed in the gastro-intestinal tract, particularly when moisture levels were taken into account. Considering the assay levels, it is obvious that while the fat percentage declined in oat hull rations, solka-floc remained relatively constant and wheat bran actually increased in ether solubles. Some fluctuations occurred on bulk modulus and sex differences, however these were minor differences and did not follow an established pattern. The data in Tables 132, 133 and 134 suggest that there was a definite and persistent decrease in fat levels on antibiotic containing rations in the intestinal tract.

Ingesta ash

Ration ash levels were within one-half of a percent of each other, the lowest being solka-floc and the highest oat hulls (Tables 135, 136 and 137). Generally there was a progressive increase in the incombustible components of the ingesta as progression down the tract occurred. It appeared that oat hull rations yielded the highest residual ash and solka-floc the lowest, and depending on the assessment basis wheat bran proved to be medial. Other variations existed involving bulk modulus and sex, but these appeared to be random and there were no established patterns of deviation (Tables 135, 136 and 137).

TABLE 135 - MAIN EFFECT INFLUENCES ON INGESTA ASH (Dry matter basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	7.5	10.2	11.6	11.4	11.0	12.3	10.5
Wheat bran	7.1	9.9	12.8	12.4	12.9	13.7	11.2
Oat hulls	8.0	10.7	12.4	13.1	12.6	13.6	11.5
Feeding frequency							
2/day	8.3	10.4	12.5	12.6	12.0	13.2	11.3
3/day	6.8	10.2	11.9	12.4	11.9	13.2	10.8
Bulk modulus							
Fine	8.0	10.5	11.9	12.2	12.2	13.1	11.1
Coarse	7.2	10.1	12.4	12.9	11.8	13.3	10.9
Pelleting							
Meal	7.6	10.1	----	12.5	----	13.4	10.7
Pellets	7.5	10.5	12.2	----	12.0	13.0	10.8
Antibiotic							
Nil	7.4	10.1	11.9	12.5	11.7	12.9	10.8
Add	7.7	10.5	12.4	12.5	12.2	13.5	11.2
Sex							
Barrows	6.9	10.3	12.3	12.6	12.1	13.1	10.9
Gilts	8.2	10.3	12.0	12.4	11.8	13.3	11.1
Site mean	7.6	10.3	12.2	12.5	12.0	13.2	11.0
Number of observations	90	93	56	39	54	93	(425)

Footnote: Feed ash

Solka-floc = 5.4%
Wheat bran = 6.1%
Oat hulls = 6.5%

TABLE 136 - MAIN EFFECT INFLUENCES ON INGESTA ASH (Wet sample basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	2.13	1.50	1.67	2.40	2.31	2.98	2.17
Wheat bran	1.74	1.49	1.89	2.14	2.50	2.95	2.10
Oat hulls	2.42	1.79	2.34	3.34	3.42	4.08	2.85
Feeding frequency							
2/day	2.19	1.53	1.99	2.70	2.72	3.36	2.39
3/day	1.98	1.66	1.88	2.61	2.61	3.32	2.33
Bulk modulus							
Fine	2.27	1.64	1.87	2.71	2.76	3.33	2.41
Coarse	1.93	1.55	1.99	2.55	2.59	3.34	2.30
Pelleting							
Meal	2.07	1.52	----	2.65	----	3.37	2.36
Pellets	2.11	1.68	1.95	----	2.72	3.29	2.35
Antibiotic							
Nil	2.01	1.55	1.87	2.65	2.63	3.30	2.31
Add	2.17	1.64	1.99	2.67	2.69	3.37	2.40
Sex							
Barrows	1.99	1.57	2.01	2.66	2.74	3.25	2.33
Gilts	2.19	1.62	1.86	2.66	2.59	3.43	2.39
Site mean	2.10	1.60	1.93	2.65	2.66	3.34	2.36
Number of observations	90	93	56	39	54	93	(425)

TABLE 137 - RELATIVE EFFECT OF TREATMENTS ON INGESTA ASH

Treatment	Stomach		Small i.		Cecum		Cecum + Large i.		Large i.		Rectum	
	sample		sample		sample		sample		sample		sample	
	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta
Bulk type												
Solka-floc	0	0	0	-	-	--	-	-	--	--	--	-
Wheat bran	-	-	-	-	+	-	0	--	+	-	+	-
Oat hulls	+	+	+	++	0	+++	+	+++	+	+++	+	++
Feeding frequency												
2/day	+	+	0	0	0	0	0	0	0	0	0	0
3/day	-	-	0	0	0	0	0	0	0	0	0	0
Bulk modulus												
Fine	+	+	0	0	0	0	0	-	0	-	0	0
Coarse	-	-	0	0	0	0	0	+	0	+	0	0
Pelleting												
Meal	0	0	0	0							0	0
Pellets	0	0	0	0							0	0
Antibiotic												
Nil	0	0	0	0	0	0	0	0	0	0	-	0
Add	0	0	0	0	0	0	0	0	0	0	+	0
Sex												
Barrows	-	-	0	0	0	+	0	0	0	0	0	-
Gilts	+	+	0	0	0	-	0	0	0	0	0	+

Ingesta crude fiber

TABLE 138 - MAIN EFFECT INFLUENCES ON INGESTA CRUDE FIBER
(Dry matter basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	16.1	17.9	30.6	32.0	32.8	33.7	25.8
Wheat bran	13.1	11.9	19.1	20.2	19.7	21.2	16.9
Oat hulls	18.2	15.9	24.7	25.8	26.5	26.7	22.2
Feeding frequency							
2/day	16.6	15.0	25.5	25.0	27.8	27.1	21.9
3/day	15.1	15.6	25.8	24.6	27.0	27.5	21.7
Bulk modulus							
Fine	15.7	14.9	25.2	25.8	25.4	26.6	21.3
Coarse	15.9	15.6	26.1	23.2	29.0	28.0	22.1
Pelleting							
Meal	17.1	15.4	----	24.8	----	27.2	20.5
Pellets	14.5	15.1	25.7	----	27.4	27.4	21.2
Antibiotic							
Nil	15.9	14.9	25.6	23.7	26.8	26.7	21.4
Add	15.7	15.7	25.7	25.9	28.1	27.9	22.2
Sex							
Barrows	14.3	15.5	24.9	24.4	27.0	27.0	21.3
Gilts	17.4	15.1	26.3	25.2	27.9	27.5	22.3
Site mean	15.8	15.3	25.7	24.8	27.4	27.3	21.8
Number of observations	91	93	54	40	55	93	(426)

Footnote: Feed crude fiber

Solka-floc = 11.9%
Wheat bran = 7.3%
Oat hulls = 9.4%

TABLE 139 - MAIN EFFECT INFLUENCES ON INGESTA CRUDE FIBER
(Wet sample basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + Large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	4.57	2.63	4.44	6.72	6.89	8.16	5.42
Wheat bran	3.20	1.79	2.82	3.47	3.82	4.56	3.25
Oat hulls	5.48	2.65	4.67	6.55	7.21	8.04	5.64
Feeding frequency							
2/day	4.38	2.22	4.08	5.35	6.28	6.88	4.75
3/day	4.38	2.53	4.08	5.19	5.94	6.93	4.77
Bulk modulus							
Fine	4.44	2.32	3.98	5.76	5.76	6.76	4.72
Coarse	4.31	2.41	4.18	4.61	6.38	7.06	4.78
Pelleting							
Meal	4.67	2.31	----	5.26	----	6.86	4.69
Pellets	4.06	2.42	4.09	----	6.11	6.94	4.66
Antibiotic							
Nil	4.31	2.29	4.02	5.02	6.03	6.84	4.67
Add	4.43	2.45	4.14	5.52	6.21	6.98	4.85
Sex							
Barrows	4.12	2.37	4.08	5.15	6.10	6.72	4.65
Gilts	4.63	2.37	4.08	5.39	6.14	7.07	4.87
Site mean	4.38	2.37	4.08	5.26	6.11	6.91	4.76
Number of observations	91	93	54	40	55	93	(426)

TABLE 140 - RELATIVE EFFECT OF TREATMENTS ON INGESTA CRUDE FIBER

Treatment	Stomach sample		Small i. sample		Cecum sample		Cecum + Large i. sample		Large i. sample		Rectum sample	
	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta
Bulk type												
Solka-floc	0	0	+	+	+	+	++	+	+	+	+++	+
Wheat bran	-	-	-	--	-	---	---	-	-	---	--	--
Oat hulls	+	+	0	+	0	++	+	+	0	++	-	+
Feeding frequency												
2/day	+	0	0	0	0	0	0	0	0	-	0	0
3/day	-	0	0	0	0	0	0	0	0	+	0	0
Bulk modulus												
Fine	0	0	0	0	-	0	+	+	-	-	-	-
Coarse	0	0	0	0	+	0	-	-	+	+	+	+
Pelleting												
Meal	+	+	0	0							0	0
Pellets	-	-	0	0							0	0
Antibiotic												
Nil	0	0	0	0	0	0	-	-	0	0	0	0
Add	0	0	0	0	0	0	+	+	0	0	0	0
Sex												
Barrows	-	-	0	0	-	0	0	-	0	0	0	-
Gilts	+	+	0	0	+	0	0	+	0	0	0	+

Ingesta crude fiber

There was on the average a two percent crude fiber difference between each of the bulk types, wheat bran being the lowest and solka-floc the highest. Data in Tables 138, 139 and 140 indicate the levels of crude fiber increased in the tract segments, particularly in segments below the small intestine. The highest assay level of ingesta crude fiber was present on solka-floc rations. On the basis of a percentage increase from original ration levels it appeared that only minor differences existed, although there may have been a slight indication that crude fiber disappearance was greatest in solka-floc feeds. Adjusting the fiber to the levels of moisture in the tract disclosed that in comparison to the other two bulks, there was approximately half the level of crude fiber present in wheat bran fed groups. There was some indication that in lower segments of the tract crude fiber levels on coarse modulus were slightly higher than that on fine modulus.

Ingesta Klasson lignin

Klasson lignin was two percentage units lower on solka-floc rations, as fed, in comparison to the other bulk type rations. Data in Tables 141, 142 and 143 indicate the increase in Klasson lignin levels in the lower tract segments. Indications were that proportionate increases were similar amongst the bulk types, with some suggestion that wheat bran was medial to the other two bulks. In considering the relative moisture levels it became evident that oat hull rations had the highest percentage of Klasson lignin present in the intestinal tract samples. Only minor deviations appeared to be indicated in Klasson lignin percentages on other treatments.

TABLE 141 - MAIN EFFECT INFLUENCES ON INGESTA KLASSON LIGNIN
(Dry matter basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + Large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	10.5	12.9	14.4	14.6	14.9	14.6	13.4
Wheat bran	12.9	15.8	17.9	16.9	18.2	18.0	16.3
Oat hulls	14.2	15.6	18.6	19.5	18.9	19.1	17.2
Feeding frequency							
2/day	13.1	14.4	16.0	17.4	16.6	17.1	15.5
3/day	12.0	15.2	17.3	17.5	17.1	17.3	15.7
Bulk modulus							
Fine	12.5	14.7	17.3	16.4	17.3	17.2	15.6
Coarse	12.6	14.8	16.1	17.1	16.5	17.2	15.5
Pelleting							
Meal	13.4	14.7	----	17.5	----	16.6	15.2
Pellets	11.9	14.7	16.6	----	16.8	17.7	15.4
Antibiotic							
Nil	12.3	14.9	16.8	17.6	17.0	17.2	15.6
Add	12.8	14.7	16.5	17.4	16.7	17.1	15.6
Sex							
Barrows	12.1	15.2	16.5	17.2	16.4	17.2	15.5
Gilts	13.0	14.3	16.8	17.8	17.3	17.2	15.7
Site mean	12.5	14.8	16.6	17.5	16.8	17.2	15.6
Number of observations	91	93	53	40	55	95	(427)

Footnote: Feed Klasson lignin

Solka-floc = 7.4%
Wheat bran = 9.7%
Oat hulls = 9.5%

TABLE 142 - MAIN EFFECT INFLUENCES ON INGESTA KLASSON LIGNIN
(Wet sample basis)

Treatment	Region of gastro-intestinal tract						Treatment mean
	Stomach	Small i.	Cecum	Cecum + Large i.	Large i.	Rectum	
	%	%	%	%	%	%	%
Bulk type							
Solka-floc	2.98	1.90	2.07	3.07	3.13	3.53	2.78
Wheat bran	3.15	2.37	2.65	2.91	3.53	3.87	3.10
Oat hulls	4.27	2.61	3.52	4.95	5.14	5.75	4.32
Feeding frequency							
2/day	3.46	2.13	2.56	3.72	3.75	4.34	3.32
3/day	3.48	2.46	2.73	3.69	3.76	4.36	3.42
Bulk modulus							
Fine	3.54	2.29	2.73	3.64	3.93	4.34	3.40
Coarse	3.41	2.28	2.58	3.39	3.63	4.34	3.29
Pelleting							
Meal	3.60	2.20	----	3.71	----	4.18	3.38
Pellets	3.33	2.38	2.64	----	3.75	4.48	3.35
Antibiotic							
Nil	3.33	2.29	2.64	3.73	3.82	4.40	3.36
Add	3.61	2.29	2.66	3.71	3.69	4.25	3.37
Sex							
Barrows	3.48	2.33	2.71	3.63	3.71	4.28	3.36
Gilts	3.46	2.25	2.60	3.81	3.81	4.42	3.38
Site mean	3.46	2.29	2.64	3.71	3.75	4.35	3.36
Number of observations	91	93	53	40	55	95	(427)

TABLE 143 - RELATIVE EFFECT OF TREATMENTS ON INGESTA KLASSON LIGNIN

Treatment	Stomach sample		Small i. sample		Cecum sample		Cecum + Large i. sample		Large i. sample		Rectum sample	
	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta	Oven dry	Ingesta
Bulk type												
Solka-floc	-	--	--	-	---	--	-	--	--	--	---	--
Wheat bran	0	-	+	0	-	-	0	--	+	-	+	-
Oat hulls	+	+++	+	+	++	+++	+	+++	+	+++	++	+++
Feeding frequency												
2/day	+	0	0	-	-	-	0	0	0	0	0	0
3/day	-	0	0	+	+	+	0	0	0	0	0	0
Bulk modulus												
Fine	0	0	0	0	0	0	0	0	0	+	0	0
Coarse	0	0	0	0	0	0	0	0	0	-	0	0
Pelleting												
Meal	+	+	0	0							-	-
Pellets	-	-	0	0							+	+
Antibiotic												
Nil	0	-	0	0	0	0	0	0	0	0	0	0
Add	0	+	0	0	0	0	0	0	0	0	0	0
Sex												
Barrows	-	0	0	0	0	0	0	0	0	0	0	0
Gilts	+	0	0	0	0	0	0	0	0	0	0	0

Summary

The data in Table 144 indicate that the most frequent variation of the listed tract and ingesta assessments were attributable to the bulk diluents. Ingesta contents in the intestinal tract were the highest on wheat bran and the lowest on oat hulls. Quantity-wise, the largest amount of moisture was present on solka-floc and the lowest on oat hulls; however, on a percentage basis wheat bran replaced solka-floc and oat hulls remained the lowest. The actual amount of ingesta dry matter remained similar in the stomach but a percentage assessment indicated that, based on dry matter levels, in the tract, wheat bran exhibited the highest and oat hulls the lowest hydrophylic properties.

The analysis of the ingesta dry matter analysis disclosed that solka-floc varied in crude protein percentage ranking, it was the lowest in NFE and Klasson lignin, equalled wheat bran in ash and oat hulls in crude fiber. The specific gravity of the ingesta originating from this bulk was similar to oat hulls in the stomach but dropped to the modal group in the intestinal tract. Solka-floc did not appear to influence the tract weight.

Wheat bran-origin dry matter (Table 144) varied in crude protein percentage and proved to be the highest of the bulk types in the rectal segment. Bran ingesta equalled the NFE level of oat hulls and ash in solka-floc, was the lowest in fat and crude fiber, and was slightly below the mean Klasson lignin percentage. The specific gravity of the ingesta on this bulk indicated that it was the most voluminous of the three diluents and there was a suggestion that it may have increased tract weights in the lower tract segments.

TABLE 144 - SUMMARY OF MAIN EFFECTS OF TREATMENTS ON CHARACTERISTICS OF THE GASTRO-INTESTINAL TRACT AND ITS INGESTA CONTENTS

	Ingesta[1]								Gastro-intestinal tract wt.		pH		Specific gravity	
	Weight		Moisture		Dry matter		Specific gravity							
Treatment	Stom.	Int.	Stom.	Int.	Stom.	Int.	Stom.	Int.	Stom.	Int.	Stom.	Int.	Stom.	Int.
Bulk type														
Solka-floc	0	0	+	0	0	0	+	0	0	0	0	0	0	0
Wheat bran	0	+	0	+	0	-	--	-	0	+	0	-	0	0
Oat hulls	0	-	-	-	0	+	+	+	0	0	0	+	0	0
Feeding frequency														
2/day	-	0	-	0	-	0	-	0	0	0	-	0	0	0
3/day	+	0	+	0	+	0	+	0	0	0	+	0	0	0
Bulk modulus														
Fine	0	0	0	0	0	0	+	0	0	0	0	0	0	0
Coarse	0	0	0	0	0	0	-	0	0	0	0	0	0	0
Pelleting														
Meal	0	0	0	0	0	0	-	0	+	+	0		0	
Pellets	0	0	0	0	0	0	+	0	-	-	0		0	
Antibiotic														
Nil	0	0	0	0	0	0	-	0	0	+	-	-	0	0
Add	0	0	0	0	0	0	+	0	0	-	+	+	0	0
Sex														
Barrows	0		0	0	0	0	0	0	-		+	0	0	0
Gilts	0		0	0	0	0	0	0	+		-	0	0	0

1 Gastric moisture and dry matter based on grams, other data in specific units or percent. Gastric data statistically assessed, otherwise signs indicate a 5% deviation from mean.

continued.....

TABLE 144 -continued- SUMMARY OF MAIN EFFECTS OF TREATMENTS ON CHARACTERISTICS OF THE GASTRO-INTESTINAL TRACT AND ITS INGESTA CONTENTS

Treatment	Liquid													
	Viscosity		Surface tension		Oven dry residue		Ash		CP	NFE	Fat	Ash	CF	KL
	Stom	Int.	Stom.	Int.	Stom.	Int.	Stom.	Int.						
Bulk type														
Solka-floc	+	±	0	±	0	0	0	0	±	--	0	-	+	—
Wheat bran	-	±	0	±	0	0	0	0	±	+	-	-	--	-
Oat hulls	0	±	0	±	0	0	0	0	-	+	+	++	+	+++
Feeding frequency														
2/day	-	-	0	0	-	0	0	0	0	±	0	0	0	0
3/day	+	+	0	0	+	0	0	0	0	±	0	0	0	0
Bulk modulus														
Fine	0	0	0	0	0	0	0	0	0	±	0	0	±	0
Coarse	0	0	0	0	0	0	0	0	0	±	0	0	±	0
Pelleting														
Meal	0		-		-		0		-	0	0	0	0	0
Pellets	0		+		+		0		+	0	0	0	0	0
Antibiotic														
Nil	0	-	+	0	0	0	0	0	+	0	+	0	0	0
Add	0	+	-	0	0	0	0	0	-	0	-	0	0	0
Sex														
Barrows	+	0	0	0	+	0	0	0	0	0	±	0	0	0
Gilts	-	0	0	0	-	0	0	0	0	0	±	0	0	0

Abbreviations: Stom. = stomach
Int. = intestinal tract
CP = crude protein
NFE = nitrogen free extract
CF = crude fiber
KL = Klasson lignin
± = variable influences

Oat hull rations produced the highest proportion of dry matter, this was accompanied by the highest percentage levels of NFE, fat, ash, crude fiber and Klasson lignin. Ingesta of this bulk assayed the lowest in crude protein. Specific gravity measures indicated that oat hulls behaved similarly to solka-floc in the stomach, however in the intestinal tract this bulk type proved to be the least voluminous. Oat hulls did not appear to induce changes in tract weight.

Measurements of the gastric liquid yielded significant viscosity differences, with the lowest viscosity being evident on bran and the highest on solka-floc. Data pertaining to intestinal viscosity and surface tension indicated a random variation to the bulk types and a pattern of response did not appear to be present. Intestinal liquid pH appeared to be elevated on oat hull rations and depressed on wheat bran.

Gastric ingesta, moisture, dry matter and specific gravity were reduced on twice-a-day feeding, however these influences were dissipated in the intestinal tract. The only variable dry matter component on the feeding frequency comparison was NFE, even in this instance there was a random variation which could not be interpreted as indicative of general effect. In the stomach, pH, viscosity and oven-dried residues of the liquid phase were reduced on twice-daily feeding. With the exception of viscosity, these effects were nullified in the remaining tract segments.

Bulk modulus as such failed to exhibit a marked influence on the measures listed in Table 44. On fine modulus ingesta specific gravity was increased, there were indications that NFE and crude fiber varied somewhat as well. These latter two trends did suggest that there

may have been associative effects with processing and residual ingesta levels.

Feeding pelleted rations increased gastric ingesta specific gravity significantly, this treatment was also associated with decreased stomach weight. Of the available sampling sites, indications were that the decreased digestive organ weight on pelleted rations persisted in the lower tract segments as well; however, it should be noted that some of these differences were small. Of the chemical components assayed, ingesta dry matter from pelleted rations appeared to be higher in crude protein percentage. Gastric liquid surface tension and oven-dry residues were higher on pelleted rations. The nature of the sampling sites in the intestinal tract was such that no definite conclusions could be drawn, however from the data available it appeared that the listed measurements behaved independently of this treatment.

Antibiotic supplementation increased stomach ingesta specific gravity. From the trends listed in Table 144 it was inferred that the minor but persistent reduction in intestinal tract weights might have been due to the presence of antibiotic in the ration. On the whole, it appeared that antibiotic increased intestinal liquid viscosity but reduced gastric surface tension.

In barrow groups stomach contents were slightly higher ($P < 0.05$) and stomach weights proved to be significantly reduced. The dry matter assessment suggested that very little difference existed between the sexes, only fat levels appeared to exhibit some random fluctuations. Measures conducted on the ingesta fluid indicated that gastric viscosity and oven-dry residue exhibited statistical difference, otherwise there appeared to be only minor differences prevalent between the sexes.

DISCUSSION

A resume of the statistically significant major effects and their interactions, described in the preceeding section (pp. 79 - 244), is presented in Table 145. The succeeding table, Table 146, serves to indicate the relative positions of the main effect deviations in respect to the experimental assessments.

In the interest of brevity and simplification, the discussion, particularly in reference to the interaction effects, will be primarily concerned with those dietary treatments that produced a series of associable effects in several criteria. Some responses observed appear to defy explanation at this stage but they have been included in the tabulated results for possible future reference or study.

Bulk Type

Rations designed to contain 67% TDN, and found experimentally to have energy digestibility coefficients ranging from 67.0 to 68.8%, resulted in finishing period gains averaging 1.5 lb./day. This was, as expected, lower than gains indicated in the NRC standards, but they were above the "lower quartile" reported in Canadian Yorkshire hogs (Bell, 1964). It did not matter whether the energy dilution was accomplished by using 10% Solka-floc, 30% wheat bran, or 20% oat hulls. The increased daily intake of oat hull rations failed to affect growth rate, Contrastingly an accelerated growth rate, attained on a daily feed intake significantly less than that prevalent on oat hulls, favourably affected feed conversion on Solka-floc. Pigs receiving oat hull rations experienced the lowest digestibility of caloric components, however as indicated, the net effect of this was more than compensated by increased feed intakes. Previous reports indicating

TABLE 145 - A SUMMARY OF THE STATISTICALLY SIGNIFICANT TREATMENT EFFECTS AND THE MAJOR INTERACTIONS. SIGNIFICANT EFFECTS DESIGNATED BY X IN APPROPRIATE ROW - COLUMN

	Treatment:	B*	F	M	P	A	S	B					F			
	Interacting with:	(main effects only)						F	M	P	A	S	M	P	A	S
Row No.	Criterion Column No:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	General animal performance															
1.	ADG	..	..	..	X	X	X	X	X	..	..	..	..	..	..	..
2.	ADF	X	X	X	X	..	X	..	X	..	..	..	..	..	..	..
3.	Feed efficiency	X	..	..	..	X	..	..	..	..	..	..	..	..	X	..
	Carcass characteristics															
4.	Loin area	..	..	..	..	..	X	..	X	..	..	..	..	..	..	..
5.	Dressing %	X	X	..	..	X	X	X	..	..	..	..	..	..	..	..
6.	Backfat	X	X	..	..	X	X	..	X	..	..	..	X	..	..	..
	Ration digestibility and performance															
7.	Digest. of Energy	X	..	..	..	..	..	..	X	X	X	..	..	..	..	..
8.	Digest. of Protein	X	..	..	..	X	..	..	..	X	X	..	..	X	..	..
9.	DE intake	X	X	X	X	..	X	..	X	..	..	..	..	..	..	..
10.	DP intake	X	X	..	..	X	X	..	X	..	..	..	..	..	..	..
11.	DP:DE	X	..	X	X	X	X	..	X	X	X	..	..	..	..	..
12.	DE utilization	..	..	..	..	X	..	..	..	..	..	..	..	..	..	..
13.	DP utilization	X	..	..	X	..	..	..	X	..	..	..	..	..	..	..
	Gastric characteristics															
14.	Stomach weight	..	..	..	X	..	X	..	..	..	..	..	..	..	..	..
15.	Ingesta weight	..	X	..	..	..	..	..	..	..	..	..	X	X	..	..
16.	" moisture	X	X	..	..	..	..	..	..	..	..	..	X	X	..	..
17.	" DM	..	X	..	..	..	..	X	..	..	..	..	X	X	..	..
18.	" Specific gravity	X	X	X	X	X	..	..	..	..	..	..	..	..	..	..
19.	Liquid pH	..	X	..	..	X	X	..	..	X	X	..	..	..	..	X
20.	" viscosity	X	X	..	..	..	X	X	..	..	X	X	X	..	..	..
21.	" Surface tension	..	..	..	X	X	..	..	..	..	..	..	X	..	..	X
22.	" OD residues	..	X	..	X	..	X	X	..	..	X	..	X	..	..	..
23.	" ash	..	..	..	..	..	..	..	..	..	X	..	..	..	..	..

* B = bulk type M = bulk modulus A = antibiotic
F = feeding frequency P = pelleting S = sex

continued.....

TABLE 145 (continued) - A SUMMARY OF THE STATISTICALLY SIGNIFICANT TREATMENT EFFECTS AND THE MAJOR INTERACTIONS

	Treatment:	M			P		A	B						
								F				M		
	Interacting with:	P	A	S	A	S	S	M	P	A	S	P	A	S
Row No.	Criterion Column No:	16	17	18	19	20	21	22	23	24	25	26	27	28
	General animal performance													
1.	ADG	..	..	..	..	..	..	..	..	..	..	..	..	..
2.	ADF	..	..	..	X	X	..	..	..	..	..	..	X	..
3.	Feed efficiency	..	..	..	..	..	..	..	..	X	..	..	..	..
	Carcass characteristics													
4.	Loin area	..	..	..	..	X	..	..	..	..	..	..	X	..
5.	Dressing %	..	..	X	..	..	..	..	..	X	X	..	X	..
6.	Backfat	X	..	..	..	..	..	X	..	..	..	..	X	X
	Ration digestibility and performance													
7.	Digest. of Energy	..	..	..	..	..	..	..	..	..	..	..	X	..
8.	Digest. of Protein	..	..	..	..	..	..	..	..	..	..	..	..	..
9.	DE intake	..	..	..	X	..	..	..	..	..	..	..	..	..
10.	DP intake	..	..	..	..	..	..	..	..	..	..	..	..	..
11.	DP:DE	..	..	..	X	..	..	..	..	..	..	..	X	..
12.	DE utilization	..	..	..	..	..	..	..	..	..	..	..	..	..
13.	DP utilization	..	..	..	..	..	..	X	..	..	..	..	..	..
	Gastric characteristics													
14.	Stomach weight	X	..	..	..	..	..	..	..	..	..	..	..	..
15.	Ingesta weight	..	..	..	X	..	..	..	..	..	..	..	..	..
16.	" moisture	..	..	..	X	..	..	..	..	..	X	..	..	..
17.	" DM	..	..	..	..	..	..	..	..	..	..	..	..	..
18.	" Specific gravity	..	..	X	..	..	..	..	..	..	..	X	..	..
19.	Liquid pH	..	..	..	X	..	..	..	..	..	..	..	X	..
20.	" viscosity	..	..	..	..	..	..	X	..	..	..	..	X	..
21.	" Surface tension	..	..	..	..	..	..	..	..	..	..	..	..	..
22.	" OD residues	..	..	..	..	..	..	..	..	..	..	..	X	..
23.	" ash	..	..	..	..	..	X	..	..	..	..	..	..	..

continued .....

TABLE 14.5 (continued) - A SUMMARY OF THE STATISTICALLY SIGNIFICANT TREATMENT EFFECTS AND THE MAJOR INTERACTIONS

Row No.	Treatment: / Interacting with: / Criterion / Column No:	B			F						M			P/A/S
		P		A/S	M			P		A/S	P		A/S	
		A	S		P	A	S	A	S		A	S		
		29	30	31	32	33	34	35	36	37	38	39	40	41
	General animal performance													
1.	ADG	..	..	..	..	..	..	..	..	..	..	X	..	..
2.	ADF	..	..	..	X	X	..	..	..	..	..	..	..	..
3.	Feed efficiency	..	..	..	..	..	..	..	..	..	..	..	..	..
	Carcass characteristics													
4.	Loin area	..	..	..	X	X	..	X	X	..	..	..	..	..
5.	Dressing %	X	..	..	X	..	..	..	X	X	..	..	..	..
6.	Backfat	..	..	..	..	X	..	..	..	..	..	..	..	..
	Ration digestibility and performance													
7.	Digest. of Energy	..	..	..	..	..	..	..	..	..	..	..	..	X
8.	Digest. of Protein	..	..	..	..	..	..	..	..	..	..	..	..	..
9.	Daily DE intake	..	..	..	..	..	..	..	..	..	..	X	..	..
10.	Daily DP intake	..	..	..	..	..	..	..	..	..	..	..	..	..
11.	DP:DE	X	..	..	..	..	..	..	X	..	..	..	..	..
12.	DE utilization	..	..	..	..	..	..	..	..	..	..	..	..	..
13.	DP utilization	..	..	..	..	..	..	..	..	..	..	..	..	..
	Gastric characteristics													
14.	Stomach weight	..	..	..	..	..	..	X	..	..	..	..	..	..
15.	Ingesta weight	..	..	..	..	..	..	..	..	..	..	..	..	..
16.	" moisture	X	..	..	..	..	..	..	..	..	..	..	..	..
17.	" DM	..	..	..	..	X	..	X	..	..	..	..	..	X
18.	" Specific gravity	..	..	..	..	..	..	..	..	..	..	..	..	..
19.	Liquid pH	..	X	X	..	X	..	X	..	..	..	..	X	X
20.	" viscosity	..	..	..	..	X	..	..	..	..	..	X	..	X
21.	" Surface tension	..	..	X	..	..	X	..	..	..	..	..	..	..
22.	" OD residues	..	..	..	..	..	..	..	..	..	..	..	..	X
23.	" ash	..	..	..	..	..	..	..	..	..	..	..	..	..

TABLE 146 - SUMMARY OF MAIN EFFECT TREATMENT VARIATION PATTERNS

	Bulk type			Feedings		Modulus		Pelleting		Antibiotic		Sex	
	Sf	Wb	Oh	2	3	f	c	m	p	nil	add		
General animal performance													
1. ADG	0	0	0	0	0	0	0	-	+	-	+	+	-
2. ADF	-	-	2+	-	+	+	-	-	+	0	0	+	-
3. Feed efficiency	-	0	+	0	0	0	0	0	0	-	+	0	0
Carcass characteristics													
4. Loin area	0	0	0	0	0	0	0	0	0	0	0	-	+
5. Dressing %	0	-	+	-	+	0	0	0	0	-	+	+	-
6. Backfat	0	-	+	-	+	0	0	0	0	0	0	+	-
Ration digestibility and performance													
7. Digest. of Energy	+	+	2-	0	0	0	0	0	0	0	0	0	0
8. Digest. of Protein	-	3-	4+	0	0	0	0	0	0	-	+	0	0
9. Daily DE intake	0	-	+	-	+	+	-	-	+	0	0	+	-
10. Daily DP intake	-	2-	3+	-	+	+	-	0	0	-	+	+	-
11. DP:DE ratio	-	0	+	0	0	-	+	+	-	-	+	-	+
12. DE utilization	0	0	0	0	0	0	0	0	0	-	+	0	0
13. DP utilization	+	+	2-	0	0	0	0	-	+	0	0	0	0

continued .....

Symbols: 0 = no change
- = depressed
+ = increased

in comparison to experimental mean. These symbols equivalent in degree only within treatment comparisons.

v = variation but no discernable pattern. (Used to summarize trends in the tract as a whole).

Abreviations

s = stomach (data based on statistical assessment)

i = intestinal tract entire (data based on means only)

In appropriate rows where neither "s" or "i" designated, entire tract considered.

- proximate components summarized from assessing the results from all the available tract segments.

A blank space indicates insufficient data for comparison.

TABLE 146 (continued) - SUMMARY OF MAIN EFFECT TREATMENT VARIATION PATTERNS

			Bulk type			Feedings		Modulus		Pelleting		Antibiotic		Sex	
			Sf	Wb	Oh	2	3	f	c	m	p	nil	add		
			Gastro-intestinal tract and ingesta measurements												
	Tract:														
14.	Weight	S.	0	0	0	0	0	0	0	+	-	0	0	-	+
15.		I.	0	+	0	0	0	0	0	0	0	+	-		
	Ingesta:														
16.	Weight	S.	0	0	0	-	+	0	0	0	0	0	0	0	0
17.		I.	0	+	-	0	0	0	0	0	0	0	0		
18.	H_2O, weight	S.	+	0	-	-	+	0	0	0	0	0	0	0	0
19.	, %	I.	0	+	-	0	0	0	0	0	0	0	0	0	0
20.	DM, weight	S.	0	0	0	-	+	0	0	0	0	0	0	0	0
21.	%	I.	0	-	+	0	0	0	0	0	0	0	0	0	0
22.	Specific	S.	+	2-	+	-	+	+	-	-	+	-	+	0	0
23.	gravity	I.	0	-	+	0	0	0	0			0	0	0	0
	Dry matter:														
24.	CP, %		v	v	-	0	0	0	0	-	+	+	-	0	0
25.	NFE, %		2-	+	+	v	v	v	v	0	0	0	0	0	0
26.	Ash, %		-	-	+	0	0	0	0	0	0	0	0	0	0
27.	Fat, %		0	-	+	0	0	0	0	0	0	+	-	v	v
28.	CF, %		+	2-	+	0	0	v	v	0	0	0	0	0	0
29.	KL, %		2-	-	3+	0	0	0	0	0	0	0	0	0	0
	Liquid phase:														
30.	pH	S.	0	0	0	-	+	0	0	0	0	-	+	+	-
31.		I.	0	-	+	0	0	0	0			-	+	0	0
32.	Specific	S.	0	0	0	0	0	0	0	0	0	0	0	0	0
33.	gravity	I.	0	0	0	0	0	0	0	0	0	0	0	0	0
34.	Surface	S.	0	0	0	0	0	0	0	-	+	+	-	0	0
35.	tension	I.	v	v	v	0	0	0	0			0	0	0	0
36.	Viscosity	S.	+	-	0	-	+	0	0	0	0	0	0	+	-
37.		I.	v	v	v	-	+	0	0			-	+	0	0
38.	OD residues	S.	0	0	0	-	+	0	0	-	+	0	0	+	-
39.	%	I.	0	0	0	0	0	0	0			0	0	0	0
40.	Ash, %	S.	0	0	0	0	0	0	0	0	0	0	0	0	0
41.		I.	0	0	0	0	0	0	0			0	0	0	0

reduced energy digestibility of Solka-floc rations (Cunningham et al., 1962a) were not verified in these trials. Somewhat in contrast to the trend of diminished energy digestibility, protein digestibility of oat hull rations increased significantly. Animals fed wheat bran encountered the lowest protein digestibility, perhaps reflecting reduced availability of bran protein per se, or possibly reflecting more extensive losses of metabolic fecal protein within bran rations. On these grounds it is evident that the experimental conditions under consideration here did not favor enhanced protein digestibility as previously noted in "wheat bran" rations at this institution (Gorrill et al., 1962).

Differences in the rate and extent of digestion of fibrous ingredients can influence feed intake for a variety of reasons, as discussed in the Literature Review. Increases were obtained in average daily intake of oat hull rations, yet expected differences in total ingesta weight in the stomach at slaughter failed to occur. Assuming that at the time of slaughter there was a maintenance of average daily feed intake patterns prevalent over the entire test period, a lack of gastric-ingesta weight differences between the bulks implies that "gastric half-life" patterns were independent of feed intake. In confirmation of previous reports (Lepkovsky et al., 1957; and others), each feeding, independent of quantity, appeared to evacuate the stomach in similar time intervals.

Total ingesta weight was the lowest on oat hull rations, further assessment revealed that this was a reflection of water content variations. Previous reports (Bell, 1960; Gorrill, 1960), indicating that oat hulls were less capable of absorbing water than wheat bran, were substantiated by the increased intestinal dry matter percentage noted in oat hull-origin

ingesta. Oat hull-fed animals retained more copious quantities of dry matter in the posterior regions of the digestive tract (Tables 71, 84). This was particularly evident in the rectal segment, where the dry matter recoveries of Solka-floc and wheat bran were 76 and 43% that of oat hulls. A minor compensatory effect of total bulk was evident from specific gravity measures of intestinal segment samples. These revealed that unit weights of oat hull-ingesta were the least voluminous. It is apparent that in swine, as in mice (Bell, 1960), oat hull fecal volume was less than that of wheat bran or cellulose.

Significant effects of bulk type on gastric ingesta densities were demonstrated. In association with 580, 466 and 544 gm. of dry matter for Solka-floc, wheat bran, and oat hulls; 2100, 2000 and 1700 cc. volumes were calculated for the recovered stomach samples yielding 0.29, 0.23 and 0.32 gm. dry matter per cc. volume. In regions of high fluidity - viz., small intestine - volume differences between the bulks were no longer apparent. The more distal regions, with their increasing dry matter proportions, exhibited marked differences in comparative bulkiness of their contents and especially between wheat bran and oat hulls. These differences have been considered above. It is postulated that such effects could initially affect feed intake, particularly on the twice-a-day feeding group, and subsequently influence excretion patterns once the ingesta reached the distal regions. Interaction effects (Table D Appendix) reveal that in this experiment such influences on daily feed intake were absent. Ritter (1956) had noted that in response to applied pressures the colon contracted, bran by its inherent bulk characteristics may have been more influential in inducing such a colonic response.

Colonic contraction could propel residual ingesta into the rectal region and propagate the defecation response. This latter effect might explain the relatively small in situ fecal samples recovered on bran rations and the larger samples on oat-hull-fed groups.

Assessment of the dry matter effects are rendered difficult in view of the original ration differences and because of the changes resulting from the digestive process. These assays were not only related to an oven dry basis, but in an attempt to reflect conditions in the gut, percentages were also related to the observed moisture levels. Crude protein assays, particularly those of oat hull rations, revealed a marked decline in the stomach. Nitrogen dilution, or an increase in protein levels, as reported by Nasset et al. (1963) and others, was in evidence in the small intestine; however it appeared to be smaller than some reports (Rosenthal and Nasset, 1958) would indicate. The changes in crude protein levels approximated rankings expected from digestibility coefficients, the disappearance being the greatest in oat hulls and the least in wheat bran. In oat hull rations; crude fiber, "Klasson lignin" and ether extract values were prevalent in the ingesta in higher levels than originally found in the feedstuff.

The greatest alkalinity of intestinal fluid occurred in the oat hull-fed pigs. Wilson (1962) had indicated the relative importance of pH in affecting intestinal absorption, particularly of inorganic salts. The occurrence of such an effect in these trials was not evident from the ash levels found in the ingestal fluids.

In confirmation of previous observations (Troelsen and Bell, 1962), dressing percentage and gains on oat hull rations were superior

to those obtained on Solka-floc and wheat bran. Backfat and dressing percentage increases on oat hulls reflect changes in daily feed intake and ingesta characteristics. These findings also substantiate observations (Berg and Plank, 1963) that degree of finish influences carcass yield. Carcass differences were further accentuated by the largest proportion of B grade carcasses being produced on oat hull rations, whereas wheat bran yielded the most A's. The skin has been shown to contribute materially to the establishment of the water equilibrium between ingestal contents and the body during the digestive process (Lepkovsky et al., 1957). In these trials differences in carcass yield could have been influenced by the degree of dehydration at the time of slaughter. This effect would be expected to be the least on the drier types of ingesta, namely oat hull rations; therefore evisceration losses would be reduced on this diet. Both Lepkovsky et al.(1957) and Harper and Spivey (1958) had implicated the osmotic effects of the ingested diet on this phenomenon. Osmotic pressures were not obtained in these trials and those physical assessments of the liquid phase of the ingesta that were collected appeared to bear little relationship to animal performance.

The main effects of bran, as compared to oat hulls and Solka-floc, were the findings that it resulted in the lowest dressing percentage and backfat, the greatest amount of water in the intestinal contents and increased intestinal weight. The dressing percentage and backfat reductions on bran rations agree with previous observations at this institution (Troelsen and Bell, 1962). Increased ingestal moisture on bran substantiated previous reports indicating greater fecal moisture

on bran fed pigs (Cooper and Tyler, 1959). In rats Lepkovsky et al. (1957) observed constancy of intestinal moisture irrespective of food intake fluctuations, attributing this effect to the aforementioned body regulatory mechanisms. In the swine trials currently under consideration ingestal moisture percentage exceeded those reported by Lepkovsky et al, in addition, interbulk moisture level differences were evident. These variations were observed to be minimal in regions of high moisture, such as the small intestine and cecum (Table 77 and Appendix E).

Fibrous diets have been demonstrated to increase intestinal tract size (Handgrodinger, 1955; Brownlee, 1959) through increases in degree of musculature (Halsworth and Coates, 1962). Such changes may have been the effect or mechanisms for the increased tract weights on bran rations, however it is difficult to reconcile this property to this particular bulk type and not to the others as well. Lepkovsky et al's concept may suggest an alternative method in that the water influx into the intestine on bran rations may have induced an increase in intestinal tissue hydration on this bulk type. Increased visceral weight, higher moisture ingesta, possible differences in tissue dehydration and a leaner carcass would all be contributing factors to the reduced dressing percentage evident on bran rations.

Despite similar energy digestibility values to Solka-floc, as well as identical daily feed intakes, the gross caloric level of bran rations were sufficiently lower to result in significant reductions in in daily DE intakes. This finding, associated with a lower dressing percentage (meaning a lower carcass weight at a fixed live-body weight), are both involved in the reduced backfat deposition evident in this test.

Further confirmation of the reduced adiposity in bran-fed lots was evidenced by the increases in the number of Grade A carcasses produced.

Apparent bulkiness of the ingested bran was revealed by the significantly depressed specific gravities of the stomach samples, this trend was maintained in the intestinal tract as well. Visual observations confirmed the retention of "flakiness" of bran (a characteristic cited by Gorrill, 1960) and the evidence of more gas production by this constituent (Cooper and Tyler, 1959). An observed characteristic of the liquid phase of the ingesta had been its uniformity under the treatment variables and its tendency to exhibit specific gravities approximating one (Table 89). Wheat bran rations, with a higher proportion of ingestal liquid, would be expected to exhibit a higher specific gravity when considered from this aspect. Gasses, in all probability, would be poorly retained in the ingestal samples once they were removed from the gut. It is evident then that bran "flakiness", attained either through particle swelling or structural maintenance, was the principle effector mechanism for the observed intestinal bulk characteristics of wheat bran rations in these trials. It appeared that the only significant benefits of this characteristic on animal performance relating to digestive processes were improvements in the digestibility coefficient of energy and digestible protein utilization.

Dry matter assessments were obscured by the conditions referred to above in the discussion on oat hulls. However, as previously pointed out (p. 229), the ether extracts from bran-origin ingesta appeared to be increased above the other rations, particularly in relation to original ration levels. This implies that the increased fat originated from either

bacterial synthesis, or possibly through increases in metabolic fecal fat. Other investigators (Friend et al., 1963) have reported quantitative similarities of VFA components in cellulose and wheat bran based rations.

In comparison to the other two dietary diluents utilized in this trial, Solka-floc rations did not evoke marked changes in ingesta characteristics. This does not imply that this bulk source exerted no influence, it indicated that under the conditions encountered in these trials it was medial in effects to the other two diluents or, as noted in previously mentioned instances, it performed similarly to one or other of the diluents.

The bulk type X pelleting interaction (Table 145, column 9) is of interest in that the differences in the digestibility coefficients of both energy and protein on the different rations tend to confirm the contradictory influences of pelleting reported in the literature, whereas pelleting depressed the protein digestibility coefficient in Solka-floc and wheat bran, and the energy digestibility coefficient in Solka-floc, it did not alter either coefficient in oat hulls. It was also evident that within the bulk types the degree of pelleting influence on protein digestibility coefficients varied. Utilizing pelleted Solka-floc as the basis of comparison, the protein digestibility coefficient increased in oat hull and decreased in wheat bran rations. These data indicate that the "pelleting response" on digestibility coefficients was contingent upon the ration make up.

Significant divergencies in energy and protein digestibility coefficients were also noted within the bulk type X antibiotic interaction (Table 145, column 10). A significant oat hull digestible energy depression

occurred on antibiotic supplemented rations. Highest protein digestibility was obtained on oat hull rations; however this bulk type, unlike Solka-floc and wheat bran, failed to show a significant improvement in protein digestibility in the antibiotic supplemented groups. Significant changes of the physical assessments of the liquid phase within the BA interaction did not appear to coincide consistently with the observed alterations in digestibility coefficients.

The "antibiotic effect" noted above is reminiscent of the pelleting response previously considered. Varied results pertaining to the use of antibiotics appear in the literature and were discussed previously. Therefore on the basis of published reports and the current observations, it was concluded that ration formulation may well be one of the predisposing factors in determining the nature and magnitude of the antibiotic response.

Feeding frequency

In accord with expectations, and previous reports (Berg and Bowland, 1958; Braude et al., 1963), increased opportunity to feed resulted in an increased daily feed intake; however proportioning the average daily feed intake into meals demonstrated that on three feedings the mean intake per meal was only 70% of that on two feedings. Average daily gains on three daily feedings, although improved, were not significantly different and feed utilization remained statistically similar. A consequence of the increased feed intake on three daily feedings were significant increases in daily intakes of DE and DP. These effects were instrumental in increasing average backfat, dressing percentage (due to increased carcass yields in fatter animals), and the doubling of the number of B Grade hogs (Table 38) on three times a day feeding.

As previously mentioned, the majority of animals were slaughtered following consumption of the noon meal. Expectations would be that a greater residue of feed would occur in the proximal regions of the digestive tracts of such animals, whereas in the twice-a-day fed groups larger quantities of residues would be found in the more distal regions of the tract. The calculated feed consumption per meal averaged 2.67 and 1.90 lbs. of feed for the two- and three-times-a-day fed animals. This indicates that on the latter feeding regime the proportionate degree of proximal tract filling would be partly offset by a reduced intake per meal; however it must be recalled that stomach emptying rate is independent of the quantity of food ingested, therefore in this instance the post-feeding time element would be the qualifying factor. Statistical assessment of the gastric mass, moisture, and dry matter, indicated that increases did exist on three times a day fed groups. These differences appeared to persist only as far as the small intestine, beyond this site the degree of fill was similar regardless of the feeding system employed. This either suggests differences in intestinal transit, or in all probability indicate that the morning feed intake in both groups had been relatively similar in quantity.

Specific gravity of the stomach contents of pigs fed thrice daily indicated an increased density. While the total weight of water was higher in the stomach, actual moisture percentage (Table 77) was lower on three daily feedings. In view of the relative similarity of the liquid phase specific gravities, gross ingestal density changes probably reflect an active digestion process. The effects of digestive action were also manifest in terms of the increased gastric acidity in

pigs fed more frequently. Increases in viscosity and oven-dry residue in the stomach liquids on these lots may possibly reflect gastric secretions and solubilization of feed components. The apparent persistence of viscosity increases in the intestinal tracts of these animals suggests that fluid flow through the pylorus of the solubilized components of the noon meal had already commenced.

Modulus of fineness

Bulk modulus, as indicated in Tables 3 and 4, consisted of a range rather than distinct modulus groups. The greatest relative difference between "coarse" and "fine" categories existed in wheat bran. Dry bulk density measurements, which are indicators of volume characteristics as well, corroberated these observations. Similarly by these criteria, the least difference between the two modules existed in oat hulls, in which instance there had been considerable overlapping of particle sizes. Thus it is not possible to make rigid comparisons in these studies between bulk sources within specified modulus classifications. However it is possible to gain some information as to whether or not particle size of the fibre source has any influence upon animal response to diets.

In this trial, finer module, comprising from 10 to 30 per cent of the ration, significantly increased feed intake; however, through a non-significant change in the daily rate of gain, feed conversion remained unaltered. The increases in feed intake did create a significant increase in daily intakes of DE and DP, the proportion being such that the DP:DE ratio declined; nevertheless carcass quality remained relatively consistent.

Although the initial feed densities averaged out to be similar between the two modules (Table B, Appendix), fine module-origin ingesta

exhibited a significantly increased specific gravity, or reduced bulkiness in the stomach. This module induced difference did not persist in the intestinal tract.

Interactions between bulk type X modulus (Table 145, column 8) reveal the effects of particle size ranges on bulk type. In general growth rate changes closely followed alterations in the daily feed intake patterns. On the fine module Solka-floc ration growth rate was expedited without a concomitant increase in feed intake. This resulted in superior feed conversion. Energy digestibility coefficients of wheat bran and oat hulls were dependent upon module. Pigs receiving coarse module attained a higher energy digestion coefficient on wheat bran, whereas those fed oat hulls reacted adversely in this respect. Within this interaction, daily DE and DP intakes and DP utilization fluctuations could be attributed chiefly to feed intake variations. In one instance, that of fine Solka-floc, for reasons not evident in this trial, a significant improvement in DP utilization was observed.

The aforementioned changes in nutrient digestibility and mean daily intakes, particularly caloric intake, significantly altered the backfat deposition in the experimental animals considered within the BM interaction. Changes in loin area appeared to be less responsive to these factors, only in the pigs fed fine wheat bran were significant improvements obtained.

The occurrence of significant treatment effects in terms of gains, feed consumption and carcass quality (Table 145) indicates some relationship to particle size in the bulk component of the diet. The greatest effects on these measurements occurred on wheat bran rations. In this

trial an interdependence of module on bulk type was evident, and the data revealed that the influences of fine wheat bran resembled those on coarse oat hulls.

Alterations in daily feed intake effected changes in backfat but not loin area in the comparisons made within the feeding frequency X modulus X antibiotic interaction (Table 145, column 33). Despite higher feed intakes by those animals fed fine module feeds three times a day, gastric dry matter recoveries were higher in those receiving the coarse module rations. This observation suggests that fine module bulks either passed through the stomach at a faster rate or were capable of being rendered sooner into such a condition that expulsion would be initiated. In spite of such differences, there were no further alterations in ration digestibility.

Pelleting

Pellets used in this trial were prepared in a laboratory mill where die temperatures during the pelleting process may not have attained that typical of commercial mills. Furthermore, while excellent pellets were produced on the wheat bran ration, oat hull pellets, particularly those of fine module, proved to be more fragile and yielded a higher proportion of "fines".

In agreement with published reports (Gorrill and Bell, 1960; Seerly et al., 1962, 1962a; and others) daily gain and feed intake increases were evident on the pelleted rations; however, contrary to some reports, feed utilization and carcass characteristics remained similar to those on meals. This latter observation is in agreement with previously published results from this institution (Troelsen and Bell, 1962). Daily

gains, feed and energy intake, attained in these trials on either meals or pellets, were lower than those quoted by the NRC for comparable weight ranges in bacon hogs. However, daily gains were within the "mid-range" category reported in a study based on growth rates of Canadian hogs (Bell, 1964), amongst which the Yorkshire breed had been considered.

The increased feed intake on pellets created a significant rise in the daily DE intake, thereby depressing the DP:DE ratio; nevertheless significant alterations in carcass characteristics were absent. Significant increases in daily DE intake on pellets may have allowed sparing of protein and thereby contributed to the superior DP utilization noted on these rations.

Pelleted rations, with an initially higher density (Table B, Appendix), exhibited a higher specific gravity in the stomach. Initial indications were that the reduced bulk of ingesta from pelleted rations persisted in the intestinal tract, however due to a change in the sampling technique further meaningful comparison could not be made.

On pelleted rations a significant decrease in the stomach weight was noted, there were suggestions that this effect may have persisted in other regions of the tract as well, but as noted above the change in sampling methods restricted representative comparisons.

Antibiotic

The antibiotic mixture used in this experiment was approximately 200 ppm total antibiotic. Goldberg (1959) considered levels of 50 to 1000 ppm as high level feeding, usually utilized under disease conditions. In the current trial the objective of high level antibiotic useage was to influence microbial action on the fibrous components of the diet. Based

on concepts previously reviewed (Welch et al., 1958; Oswald and Welch, 1958) the antibiotic combination utilized in these rations would be expected not only to effect a wide bacterial spectrum, but to act synergistically as well.

The antibiotic combination did not exert a significant effect on daily feed intake, but daily rate of gain increased by 0.13 lb., an increase of close to 10%. The superior rates of gain increased feed utilization on the supplemented rations and further confirmed similar tendencies reported in the literature. As a consequence of antibiotic use, dressing percentage was significantly improved, however loin area, backfat and carcass grades remained unaffected.

Protein digestibility, DP;DE ratio, and DP utilization were enhanced by antibiotic inclusion, this enhancement of protein uptake was in agreement with literature reports (Goldberg, 1959). In contrast to previous results at this institution (Gorrill et al., 1960), energy digestibility in the current trial was not influenced by antibiotic supplementation. Possible reasons for this difference might be explained by the fact that unlike the finishing period rations considered in this thesis, Gorrill et al. studied the grower stage. Not only did they utilize a lower level and a different antibiotic combination, but they also used different ration components.

Specific gravity of the antibiotic-containing feeds proved to be significantly increased in the stomach. Slight differences in moisture percentage occurred, indicating that supplemented samples were drier even though there were no quantitative differences between either dry matter or moisture. This particular effect of antibiotic activity is difficult to

explain, particularly in view of the lack of further differences between the two rations. On the basis of existing moisture differences (Table 77), it is postulated that antibiotic supplementation, either through an effect on water intake and/or effects on stomach emptying characteristics may have effected such changes.

Liquid pH, in both the stomach and the intestinal samples, was higher in the supplemented rations. Goldberg (1959) referred to such a pH shift in the "intestinal mileaux" as a mode of antibiotic response. Other data confirming Goldberg's concepts on antibiotic action included a reduction of surface tension in the gastric liquid phase, a further difference noted in these trials was the increased viscosity indicated in the intestinal fluids.

Intestinal tract weights were reduced on antibiotic supplemented feeds, particularly in the lower tract regions (Table 94). This reduction in intestinal tract weight on antibiotic supplemented rations agrees with previous reports (Vonk et al., 1957b; Goldberg, 1959; and others). In view of the superior dressing percentages evident on antibiotic supplemented animals, in spite of similar amounts of "fill" and other carcass characteristics, it appears that this reduction was instrumental in increasing carcass yield.

Although significant increases of daily feed and digestible energy intakes on pelleted antibiotic-containing rations were present (pelleting X antibiotic interaction, Table 145, column 19), growth rate and carcass quality remained consistent. It would appear that the initial effects were similar to that of pelleting and the effects of antibiotic on daily gain were modified. Significant alterations in the gastric measures

did not follow the pattern of variation noted in feed intakes. In the absence of statistical assessment, conclusions based on percentage differences, were that a drier ingesta prevailed on the supplemented rations.

The series of significant interactions in the bulk type X modulus X antibiotic interaction group (Table 145, column 27) appeared to be influenced most consistently by the nature of the antibiotic treatment. Average daily feed intakes of Solka-floc and oat hulls increased significantly in response to the antibiotic supplementation of the coarse module. Under similar conditions wheat bran rations were consumed in smaller amounts. Energy digestibility of oat hull rations had been shown to be higher on the finer module, however it was demonstrated that antibiotic supplementation suppressed this effect. In contrast to this, the supplementation of fine module Solka-floc enhanced energy digestibility. These results would suggest that the influence of antibiotic on daily feed intake and energy digestibility was dependent not only upon the bulk diluent in the ration, but on the bulk particle size as well.

Greater backfat deposition was concomitant with increased daily intakes of antibiotic supplementation of coarse module Solka-floc and oat hulls. The depressed backfat on supplemented coarse bran was related to the lowered feed intake, however in the fine module this combination increased backfat without changes in feed intake or digestibility coefficients. The effect of improved dressing percentage proved to be significant on coarse oat hull rations, where increased feed intake had been previously demonstrated. Contrastingly, on fine module bran rations

dressing percentage and loin area improvements on supplemented rations occurred without associated changes in feed intake or ration digestibility. It is evident, as mentioned above, that the antibiotic activity in these trials was dependent upon both bulk type and module.

Sex

Average daily gain and feed intake were significantly higher in barrow groups, confirming literature reports (Troelsen and Bell, 1962; Berg and Plank, 1963; and others). In partial confirmation of a previous observation at this institution (Troelsen and Bell, 1962), a non-significant improvement in feed utilization was noted in gilts. Barrow carcasses exhibited reduced loin area, dressing percentage and proportion of A grades, in conjunction with an increased backfat. Most of these observations implicate the production of fatter carcasses, a tendency frequently noted in barrows (Troelsen and Bell, 1962; Fletcher et al., 1963; Judge, 1964; and others).

As a consequence of increased daily feed consumption, the intakes of DE and DP were increased in barrows in such a manner as to diminish the subsequent DP:DE ratio. These effects undoubtedly resulted in carcass changes in this sex.

The only site where comparable weights on the digestive organs were available, the stomach, indicated a significant reduction in barrows. Fletcher et al. (1963) has indicated the existence of visceral weight differences between the sexes, stating that females tended to exhibit a greater visceral weight. The lower dressing percentage in barrows would suggest that either this trend did not prevail in other regions of the digestive tract, or that other carcass or visceral effects masked this

characteristic, In view of the significant increases in daily feed intake by barrows the expected increase in degree of fill would be expected to have a detrimental influence on carcass yield. The independence of stomach emptying characteristics and quantity of feed ingested on stomach half-life serves to explain the lack of significant difference between quantities of gastric ingesta recovered from the two sexes.

Gastric liquid pH, viscosity, and oven-dry residues were significantly depressed in gilts. It is open to conjecture whether these effects were attributable to quantity of feed ingested, passage characteristics, or to other differences. In this trial it is evident that such factors failed to influence either ration digestibility or carcass quality.

A tendency, particularly evident on pelleted rations, was the significant increase in feed consumption by barrows (pelleting x sex interaction; Table 145, column 20). This increase in feed intake was of particular interest in that the otherwise significant difference in loin area between the two sexes was absent in pellet-fed comparisons.

SUMMARY AND CONCLUSIONS

In the swine industry of today it may be desirable to maximize feed intake at certain stages in the life cycle and restrict intake at other times. A substantial body of information is available in the literature documenting the effects of fibrous diluents, feeding frequency, modulus of fineness, pelleting, antibiotics and sex of pig, on performance and carcass quality of finishing pigs. The information available concerning the interplay or interaction between two or more of these factors is very limited.

Feed formulation from the chemical (or nutrient) point of view does not ensure desired or predicted performance without due consideration being given to physical aspects and processing methods. Further complications arise when two or more ingredients or processing techniques, having either growth promoting or inhibiting properties, are to be incorporated simultaneously into a ration or feeding program.

The trial described in this thesis was an attempt to re-assess the effects of several types of fibrous diluents, feeding frequencies, fiber moduli, pelleting, antibiotic supplementation and sex in finishing swine. The experiment was designed factorially in order to permit study of all possible interactions and to determine whether the effects were independent, additive, antagonistic or non-existent. The response criteria included weight gains, feed intakes, digestibility coefficients for dry matter, energy and protein, carcass traits, gastrointestinal weights, and a variety of chemical and physical measurements of the ingesta in selected gastro-intestinal tract segments. Assays on the ingesta included specific gravity, Klasson lignin and proximate principle components. Ingestal fluid assessment included specific gravity, pH, viscosity, surface tension, solids and ash.

The diets and treatments under study included cellulose (Solka-floc), wheat bran and oat hulls as fiber or bulk sources, twice and thrice daily feeding, two moduli (fine and coarse), meal and pellets, presence or absence of an antibiotic supplement, and gilts and barrows. All diets were designed to be isocaloric and nutritionally adequate.

In most instances daily feed intakes were increased by the use of oat hulls, by feeding three times daily, by feeding the finer module fibrous diluent, by pelleting, and when feeding barrows. However, increased feed consumption did not always result in faster growth rates. Only in the case of pelleted rations and with barrows did this occur. In several instances the efficiency of feed conversion was altered. For example, feed conversion was improved by cellulose but was impaired by oat hulls. Pigs receiving antibiotic-supplemented rations grew faster without consuming significantly more feed simply because of better feed efficiency. Such findings inevitably suggest or imply possible changes in composition of body gain and changes in carcass quality.

Digestibility was found to be modified by certain experimental treatments. With oat hull rations protein digestibility appeared to be improved whereas the energy coefficient was reduced. The digestibility of both protein and energy were improved as a result of antibiotic supplementation, thereby explaining not only the superior feed conversion noted above but also the 10% acceleration in growth rate. It was observed however that the modulus of the diet exerted an influence upon the nature of the response to dietary antibiotic.

Modulus effects proved to be many and varied. It is also probable that failure to achieve corresponding degrees of fineness among the three

bulk sources complicated the interpretation of the findings. In general fine grinding was associated with increased feed intakes, sometimes with better digestibility coefficients, and where the resulting increase in digestibility was large, fat deposition in the body was increased. Changes in loin area were seldom observed but the range in daily digestible energy intakes was not great compared to that encountered in commercial practise. One noteworthy aspect of modulus was the observation that finely ground bran did not exhibit the characteristic responses of intact bran, indicating that physical form, probably flakiness, is implicated in its exertion.

Pelleting resulted in increased feed consumption and growth rate. In this study carcass quality was not adversely affected by pelleting. However, the digestible energy content of the ration was moderate, feed, energy and protein utilization remained similar to that obtained on meal-type rations, and the pigs were not full-fed, hence caution is warranted in extrapolating these findings to self-feeding practises.

Carcass grades in general followed a predictable pattern. Those rations that resulted in increased feed intakes or improved digestibility promoted increased fat deposition. The fattest carcasses were obtained from pigs fed oat hull rations, the leanest from those fed wheat bran.

Dressing percentages were found to be highest in pigs fed oat hull rations and in those fed three times daily. These results were mainly attributable to the increased yield characteristic of fatter carcasses. Although there were indications of reduced visceral weights in pigs fed either pelleted or antibiotic supplemented feeds, and in barrows, corresponding improvements in carcass yield occurred only in those lots receiving the antibiotic supplemented feeds.

Where variations of ingestal moisture content existed they were found to be of practical significance. Oat hull rations resulted in a drier type of ingesta and there were indications of similar effects with antibiotic supplemented diets. In contrast, it is evident that the reduced dressing percentages of pigs fed bran rations were related to increased visceral weights, both as to fill and actual organ weight. Such pigs had the greatest percentages and absolute amounts of intestinal fluids. In accord with published reports, it was postulated that the retention of fluids in the gut may influence the relative degree of tissue hydration and thereby prove instrumental in determining dressing percentage and shrink.

The density characteristics of stomach ingesta tended to reflect the density characteristics of the dry feed. Pelleted or fine module rations resulted in higher stomach densities. It was also observed that antibiotic-fortified diets led to increased stomach density. These effects subsided in the lower regions of the digestive tract, hence it is possible that the appetite-inducing characteristics of pelleting, fine modulus and antibiotics are manifested mainly in terms of stomach capacity for dry matter.

Density differences incurred as a result of source of bulk (cellulose, wheat bran or oat hulls) tended to be maintained throughout the gastrointestinal tract. Wheat bran rations produced the most voluminous ingesta whereas oat hulls produced the least. The retention of more copious quantities of oat hull ingesta in the rectal segments reflects the importance of lumen distention as a factor in the defecation mechanism.

More frequent feeding, wherein a noon meal had been consumed

shortly before slaughter, resulted in increased fill and increased ration bulkiness in the proximal portions of the digestive tract. However there were no marked differences in lower regions of the digestive tract within comparisons between the two feeding frequencies.

The results of analysis of dry matter and of physical measurements of the ingestal fluids revealed a number of differences related to the experimental treatments, however obvious correlations between these characteristics and animal performance or ration utilization were absent. Interpretation of the chemical composition of ingesta leaves much to be desired, of course, because of the effects of digestive action, intestinal secretions, differential separation of dietary components, and the lack of a suitable marker for evaluating not only digestive uptake but also quantitative and rate of passage aspects. Despite these limitations, some interesting findings emerged. There were indications of increased fecal fat from bran rations. Variations in stomach pH generally reflected differences in feed intake. Rations supplemented with antibiotic showed changes in pH, surface tension and viscosity.

In providing an overall evaluation of this project two impressions emerge. Firstly, and perhaps surprisingly, the attempt to bring together so many factors resulted in a large number of high order interactions which rendered interpretation difficult and which demand further research to resolve certain issues. Secondly, the results obtained confirm the fact that defining a ration simply in terms of the recognized (chemical) nutrient requirements for the animal species in question leaves much to be desired. The ability or willingness to consume a diet, and effects on digestibility and rate of passage, are factors which may result in marked differences in

the performance of animals fed diets isocaloric and nutritionally adequate in conventional terms.

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APPENDIX

A. Management

1. $AgNO_3$ Pigmarker

Outline:

A calculated quantity of silver nitrate is added to a 5% solution of methylcellulose to render it 0.25 N $AgNO_3$. Store in a wide mouthed dark glass jar to protect from light until applied. Clean site of application. To apply paste use rubber gloves. Stain dyes hair and skin a brownish color, ideally suited for white pigs. The following 200 cc recipe is adequate for marking 30 - 40 pigs.

Procedure.

1. Mix 10 gm. powdered methylcellulose (4000 cps) in 50 ml. hot (80^{o}-90^{o}C) distilled water (Methylcellulose should be mixed with 1/5 to 1/3 of total water required).
2. To 150 ml. distilled water add 6.8 gm. $AgNO_3$, when dissolved mix into above slurry.
3. Transfer paste to screw top jar, and let solidify (may require cooling). Protect from light.
4. Apply sparingly to staining site on animal. Rub in. Stain development is accelerated by sunlight, indoors it will darken within 24 hours.

B. Experimental Procedures and Analyses

1. The Cr_2O_3 Indicator Method for Nutrient Digestibility Determination

a) Feed preparation

1. Weigh 100 lbs. air dry feed into conical Mixal mixer.
2. Obtain at time of weighing duplicate 100 gm. samples of feed for moisture determination. Oven dry over night at 105^{o}-110^{o}C.

Recalculate % Cr_2O_3 to oven dry basis.

3. Mix 454 gm. Cr_2O_3, 200 gm. vegetable oil (Mazola oil, etc.) and 400 ml. Skelly F to a creamy consistency. Start mixer, slowly add Cr_2O_3 from container with portions of Cr_2O_3-feed, mix.

4. Allow 10-15 min. mixing to blend evenly. Place Cr_2O_3-feed mix in open container to permit Skelly F to evaporate. Due to volatile vapours mix and evaporate in a well ventilated place.

5. Where required, feeds may be pelleted following Cr_2O_3 incorporation and drying.

b) Feeding during trial.

1. Remove previous feed, clean hoppers. Add sufficient amount of Cr_2O_3 containing feed to last throughout test period - ie. 50 lbs. at finishing stage.

2. Allow minimum of 48 hours of acclimatization period to enable feed and fecal Cr_2O_3 distribution to equilibrate. (Clawson et al., 1955; Moore, 1958).

c) Sample collection and handling.

1. Prepare feces preservative by mixing in a glass container: 1000 ml. distilled H_2O, 2 gm. $HgCl_2$ and 10 gm. H_3BO_4. Store in a glass jar.

2. During collection period samples may be satisfactorily stored in labelled 2 lb. size polyethylene bags.

3. Commence collection period following 3 day acclimatization period (see above). Use fore and afternoon sampling times -

ie. 8:30 a.m. and 4:30 p.m., to avoid influences of diurnal variations in fecal Cr_2O_3. (Horvath et al., 1958; Moore, 1958).

4. Place a 50 - 100 gm. freshly voided fecal sample at each collection period into bags (when sampling time arrives disturbing animals, such as driving them into alleyways, scale room etc., appears to cause animals to defacate more readily). Following first fecal collection add 150 ml. preservative ($HgCl_2$-H_3BO_4 preparation, step 1) and mix well. Bag may be conveniently closed using a 4 inch length of paper enclosed wire - "Twistem" tie. Further additions are thoroughly mixed with the previously collected samples - both to ensure sample uniformity and to distribute preservative. Bags may be stored without refrigeration until the collection period completed.
5. Following end of 3 day collection period knead sample well, and either freeze in plastic bags and store at -15°C ± 2° or process further.

d) Preparation of samples for analysis.

1. Using a graphite pencil identify a sufficient quantity of small half ounce portion cups[1]. Dry overnight in oven at 105°C, record dry cup weight.
2. Place thawed sample into a Waring Blendor (Homogenizer blades must be sharp). Add a quantity of water to ensure a stable homogenate - thick but easily poured. Homogenize at full speed until well homogenized. During homogenization heat is evolved, to alleviate this condition it may be desirable to place samples

1. No. 050 Lily Portion Cup., Lily Cups Ltd., Toronto 13, Canada.

into homogenizer cup in a partially frozen state.

3. Reduce homogenizer speed to slow, ladle out samples and fill 12 of the numbered and weighed portion cups. (A small aluminum bottle top used as a ladle proved to be ideal for sampling homogenate).

4. Freeze and store sample containing portion cups or oven dry for further analysis. To prevent splattering pre-dry sample-containing cups in forced draft oven overnight at approximately 60°C. Complete drying by raising temperature to 105°-110°C, or preferably transfer to a vacuum oven and dry at 80°C, for at least 6 hours.

5. Oven dried samples are stored in jars with tight fitting lids.

e) Chromic sesquioxide analysis

Outline: A modification of Bolin et al's. (1952) method, utilizing perchloric acid for organic matter destruction and chromic ion conversion to chromate, permits the use of colorimetric techniques to assay chromic sesquioxide. To assay samples containing 1 gram organic matter a pre-ashing technique using heat prior to addition of perchloric oxidizing mixture, was utilized.

Perchloric acid dilution alleviates the hazards involved in its use in "wet ashing" organic substances. The analyst must be aware of the possible consequences of using perchloric acid and at no time allow excessive reconcentration of liquids, accumulation or improper disposition of fumes. Chromic sesquioxide, being relatively insoluble is non-toxic, however the more soluble chromate salts formed

following oxidation may constitute a potential hazard and prolonged contact with the skin should be avoided. (van Neer, 1963).

Procedure:

1. Obtain weight of oven dried sample in portion cup (sec. e, step 5). Place cup containing sample in identified porcelain crucible - ie. Coors No. 230 size No. 1. Ash at 450° - 500°C for 6 - 8 hours. At this temperature ashing is almost complete yet cup contents retain original shape. Use of higher temperatures collapses this "structure" allowing Cr_2O_3 to contact and possibly fuse into glazing on crucible. Pre-ashing unnecessary where total dry matter is less than one gram. Fine powders have a tendency to adhere to the neck of the digestion flask during insertion and thereby escape chemical action, to avoid this wrap the sample in a small quantity of paper. An alternate method, whereby further organic matter addition is circumvented is to pellet the original ground sample in a small hand press[1]. The resultant pellets may be conveniently weighed and then dropped into the digestion flask.
2. If sample pre-ashed, quantitatively transfer to a 12 1/2 cm. filter paper - ie. Whatman 42 - or a 2 1/2 - 3 inch square of wax paper (the wax released during digestion aids in foam prevention). Place sample into a 100 ml. Kjedlhal flask calibrated and marked to contain 110 ml. Add 3 or 4 glass beads to prevent bumping during digestion.
3. From an automatic pipette add 10 ml. oxidizing reagent (5 gm. $Na_2MoO_4 \cdot 2H_2O$ dissolved in 1 liter distilled water into which thoroughly mix 1 liter 70 - 72% perchloric acid) into digestion flask. Heat on rack over electric hotplate in fume hood, rotating containers occasionally. Remove

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1. Parr No. 2811 Pellet Press, Parr Inst. Co. Moline, Ill., U.S.A.

from heat when organic matter destruction indicated by appearance of the green color of Cr_2O_3 persists. Cool flasks to touch.

4. Add additional 10 ml. oxidizing reagent, flushing any adhering particles from the sides into bottom of flask. Resume heating until all chromic oxide converted to chromate - indicated by a color change to yellow or orange. Swirl flask, rotate and boil an additional 2 - 3 minutes. Do not boil dry. Cool.
5. Using distilled water make to 110 ml. volume, mix. Filter through a medium paper - ie. Whatman 40. Discard initial 25 ml. of filtrate, retain remaining portion for colorimetry.
6. Where Cr_2O_3 content is high there will be too great an optical density to accurately predict Cr_2O_3 concentration, in these cases prepare a suitable dilution.
7. Set colorimeter - ie. Bausch and Lomb Spectronic 20 - at 440 λ and read per cent transmittance "T" against distilled water standard set at 100% "T".
8. Using the per cent "T" reading, determine mg. Cr_2O_3 in 110 ml. sample by using a standard curve prepared previously. Report either as mg. or per cent Cr_2O_3 per gm. dry matter.

Preparation of standard curve.

1. Use sample of Cr_2O_3 used in feeding trial. Oven dry and digest duplicate 0.1000 gm. samples as indicated above. Quantitatively transfer oxidized sample to a 100 ml. volumetric, and make to volume. Using these quantities and dilutions reference solution contains 1 mg. Cr_2O_3 equivalent per ml.
2. Prepare serial dilutions from 10 µgm. to 100 µgm. Cr_2O_3 per ml. Read per cent transmittance "T" of dilution on Bausch and Lomb Colorimeter

as before.

3. Plot Log T vs. µgm. Cr_2O_3 per ml. on one cycle semilogarithmic graph paper. Regression is of the form:

$$Y = a + bX$$

where Y equals log T and X is µgm. Cr_2O_3 per ml.

4. Prepare chart of % T vs. µgm. Cr_2O_3/ml. from a range of 40% to 95% "T" using either graph or regression equation.

5. Following reading of samples, use the aforementioned chart to convert % T to µgm. Cr_2O_3 per ml. Calculations must account for sample weights and dilutions used, thus:

$$\text{µgm. } Cr_2O_3 \text{ per ml. x 110} = \gamma/110 \text{ ml.}$$

used to arrive at total Cr_2O_3.

$$\% \ Cr_2O_3 = \frac{\gamma/110 \text{ ml. x dilution factor}}{\text{O.D. sample weight x10000}}$$

2. Klasson Lignin

Outline:

To remove nitrogenous and other soluble substances, hydrolyze a fat free sample with 2N HCl (Hussar and Robblee, 1962). Following hydrolysis filter off liquid phase, wash residue with a few portions of washing solution. Remaining residue is treated with a H_2SO_4-H_3PO_4 mix according to Jayme et al. (1958). Wash, dry and weigh residue, ignite and report weight loss in H_2SO_4-H_3PO_4 residue as Klasson Lignin.

Procedure:

1. Weigh approximately 1 gm. fat free sample into 150 ml. beaker. Add 100 ml. 2N HCl to which 0.25 gm./liter alconox (wetting agent) has been added. Mix well with a stirring rod, ensuring thorough wetting of sample. Add

a few shavings of paraffin wax. Cover beaker with watch glass.

2. Autoclave 3 hours at 15 psi. Following autoclaving add a pinch of celite to hot liquid. Attach a medium porosity sintered glass filter stick to a suction unit, insert filter stick into an aqueous celite suspension to form a mat over the end. Maintain suction to hold mat and insert filter stick into beaker containing hydrolyzed sample, draw off solubles. Rinse residue with a few portions of hot 0.5% saline, followed by successive portions of alcohol and petroleum ether. Remove residue from end of filter stick by tapping off celite mat. Allow residue to dry at room temperature.

3. Break up residue mat with a stirring rod, add 15 - 20 ml. H_2SO_4-H_3PO_4 mixture. (6 vol. 72% H_2SO_4, 1 vol. 81% H_3PO_4). Mix well. Incubate, with aggitation, at 35°C for 45 minutes.

4. Quantitatively transfer residue to 800 ml. beaker, add 400 ml. hot distilled water. Boil 15 minutes on reflux stand - ie. crude fiber apparatus. Remove and allow to settle 5 - 10 minutes.

5. Decant liquid through asbestos mat in gooch crucible, (acid-base washed, reignited, medium fiber asbestos, re crude fiber method - A.O.A.C. (1960). Quantitatively transfer residue to gooch, wash residue with hot 1/2% saline, rinse with successive portions of ethyl alcohol and petroleum ether. Dry residue in vacuum oven at 70°C, weigh.

6. Ignite residue, obtain weight loss of the ingnited samples.

7. Weight loss due to ashing of the acid insoluble residues represents the "Klasson lignin" portion calculated as follows:

$$\% \text{ Klasson lignin} = \frac{\text{O.D. } H_2SO_4\text{-}H_3PO_4 \text{ residue wt. - Wt. of incombustible residues}}{\text{O.D. sample weight}} \times 100$$

Report Klasson lignin on a fat corrected basis.

TABLE A - FEED ANALYSIS

		Solka-floc	Wheat bran	Oat hulls
Dry matter	%	92.8	91.5	92.2
Crude protein	%	17.9	18.2	17.6
Ether extract	%	4.5	2.2	6.6
Crude fiber	%	11.9	7.3	9.4
Klasson lignin	%	7.4	9.7	9.5
N.F.E.	%	61.0	66.0	59.3
Ash	%	5.4	6.1	6.5
Gross energy	Cal./gm	4.56	4.44	4.65
Calorie:protein ratio (Digestible Calories/gm DCP)		22.2	21.6	21.3
Protein:calorie ratio (Gms. DCP/therm DE)		45.5	46.3	47.0

TABLE B - AIR DRY FEED DENSITY IN GM./CC[1]

Feed type:	Meal		Pellets	
Bulk modulus:	Fine	Coarse	Fine	Coarse
Solka-floc	0.53	0.47	0.62	0.58
Wheat bran	0.44	0.33	0.54	0.51
Oat hulls	0.56	0.50	0.53	0.58

1 Mean density values for:

Solka-floc = 0.55
Wheat bran = 0.46
Oat hulls = 0.54

Meal = 0.47
Pellets = 0.56

Fine module = 0.54
Coarse " = 0.50

TABLE C - CARCASS GRADES

No. times fed per day	Anti-biotic fed	Sex	Solka-floc				Wheat bran				Oat hulls			
			Fine		Coarse		Fine		Coarse		Fine		Coarse	
			Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet	Meal	Pellet
2	Nil	M	B	A	A	A	A	A	A	B	B	B	A	A
		F	A	A	A	A	A	A	A	A	A	A	A	A
	Add	M	B	A	A	A	A	A	A	B	B	B	B	B
		F	B	A	A	A	A	A	A	A	B	B	A	A
3	Nil	M	B	B	A	B	A	A	B	B	B	A	B	B
		F	B	A	A	A	B	A	A	A	A	A	A	A
	Add	M	B	B	B	B	B	A	A	B	A	B	B	B
		F	A	A	A	A	A	A	A	A	A	A	B	A

TABLE D - RESPONSE CRITERIA MEANS[1]

	1. Ave. daily gain	2. Ave. daily feed intake	3. lbs. feed per lb. gain	4. Loin area	5. Warm carcass dressing percentage
	lb.	lb.	lb.	cm.^{2}	%
Main effects:					
Bulk types					
Solka-floc	1.52	5.38**	3.57**	3.57	75.00**
Wheat bran	1.45	5.38	3.72	3.76	73.92
Oat hulls	1.53	5.80	3.81	3.57	75.96
LSR for means min.	0.08	0.21	0.13	0.18	0.62
max.	0.08	0.22	0.14	0.19	0.64
Feeding frequency					
2/day	1.47	5.34**	3.65	3.60	74.68**
3/day	1.53	5.70	3.75	3.66	75.24
Bulk modulus					
Fine	1.52	5.63*	3.72	3.65	74.88
Coarse	1.48	5.41	3.68	3.61	75.04
Pelleting effects					
Meal	1.45**	5.39**	3.75	3.61	74.98
Pellets	1.56	5.65	3.64	3.65	74.94
Antibiotic effects					
Nil	1.44**	5.47	3.82**	3.58	74.68*
Added	1.57	5.57	3.58	3.69	75.24
Sex effects					
Barrows	1.60**	5.96**	3.74	3.46**	74.55**
Gilts	1.40	5.10	3.66	3.80	75.37
LSR for means	0.06	0.17	0.11	0.15	0.50
1st order interactions:					
Bulk type x Feeding frequency					
Sf x 2	1.54*	5.30	3.43	3.49	73.97**
x 3	1.49	5.47	3.70	3.64	76.04
Wb x 2	1.39	5.18	3.72	3.73	74.36
x 3	1.51	5.59	3.71	3.79	73.47
Oh x 2	1.47	5.54	3.78	3.58	75.71
x 3	1.59	6.06	3.84	3.55	76.21
Bulk type X Bulk modulus					
Sf x f	1.58*	5.65**	3.58	3.45**	74.89
x c	1.45	5.11	3.55	3.69	75.12
Wb x f	1.41	5.25	3.74	3.93	73.65
x c	1.50	5.51	3.71	3.59	74.19
Oh x f	1.57	5.98	3.84	3.57	76.11
x c	1.49	5.62	3.78	3.57	75.81

1 * P 0.05; ** P 0.01

continued....

TABLE D - continued

	1. Ave. daily gain	2. Ave. daily feed intake	3. lb. feed per lb. gain	4. Loin area	5. Warm carcass dressing percentage
	lb.	lb.	lb.	cm.^{2}	%
Bulk type X Pelleting					
Sf x m	1.51	5.35	3.55	3.50	74.72
x p	1.52	5.41	3.58	3.63	75.28
Wb x m	1.36	5.17	3.84	3.85	73.91
x p	1.55	5.59	3.61	3.67	73.93
Oh x m	1.47	5.64	3.88	3.57	76.30
x p	1.60	5.95	3.74	3.57	75.62
Bulk type X Antibiotic					
Sf x nil	1.43	5.28	3.70	3.49	74.90
x add	1.60	5.49	3.43	3.64	75.11
Wb x nil	1.43	5.43	3.83	3.75	73.60
x add	1.48	5.33	3.62	3.78	74.24
Oh x nil	1.45	5.71	3.93	3.50	75.53
x add	1.62	5.89	3.69	3.64	76.38
Bulk type x Sex					
Sf x b	1.60	5.84	3.66	3.36	74.53
x g	1.43	4.93	3.47	3.78	75.48
Wb x b	1.54	5.71	3.75	3.64	73.94
x g	1.37	5.05	3.70	3.88	73.90
Oh x b	1.65	6.29	3.82	3.39	75.18
x g	1.41	5.31	3.80	3.75	76.74
LSR for means min.	0.03	0.10	0.20	0.25	0.87
max.	0.04	0.11	0.22	0.29	1.00
Feeding frequency X Bulk modulus					
2 x f	1.51	5.44	3.62	3.66	74.44
x c	1.43	5.24	3.68	3.54	74.92
3 x f	1.53	5.81	3.82	3.64	75.32
x c	1.41	5.59	3.68	3.68	75.16
Feeding frequency X Pelleting					
2 x m	1.41	5.20	3.72	3.53	74.78
x p	1.53	5.48	3.58	3.67	74.58
3 x m	1.48	5.58	3.79	3.69	75.17
x p	1.58	5.83	3.71	3.63	75.31
Feeding frequency X Antibiotic					
2 x nil	1.42	5.27	3.71*	3.58	74.33
x add	1.52	5.41	3.59	3.63	75.03
3 x nil	1.45	5.68	3.93	3.58	75.02
x add	1.61	5.73	3.57	3.74	75.46

continued ...

TABLE D - continued

	1. Ave. daily gain	2. Ave. daily feed intake	3. lb. feed per lb. gain	4. Loin area	5. Warm carcass dressing percentage
	lb.	lb.	lb.	$cm.^2$	%
Feeding frequency X Sex					
2 x b	1.55	5.74	3.70	3.44	74.17
x g	1.39	4.94	3.59	3.76	75.19
3 x b	1.64	6.15	3.78	3.48	74.93
x g	1.42	5.25	3.72	3.84	75.55
Bulk modulus X Pelleting					
F x m	1.46	5.52	3.81	3.61	75.07
x p	1.59	5.73	3.62	3.69	74.70
C x m	1.44	5.25	3.69	3.62	74.89
x p	1.52	5.58	3.67	3.61	75.19
Bulk modulus X Antibiotic					
F x nil	1.48	5.63	3.82	3.58	74.73
x add	1.56	5.62	3.61	3.72	75.03
C x nil	1.39	5.31	3.82	3.58	74.62
x add	1.57	5.52	3.54	3.65	75.45
Bulk modulus X Sex					
F x b	1.63	6.09	3.78	3.48	74.74*
x g	1.42	5.16	3.66	3.82	75.03
C x b	1.57	5.80	3.70	3.45	74.36
x g	1.39	5.03	3.66	3.78	75.71
Pelleting X Antibiotic					
M x nil	1.41	5.46**	3.89	3.53	74.66
x add	1.48	5.31	3.62	3.69	75.30
P x nil	1.46	5.48	3.75	3.62	74.60
x add	1.65	5.83	3.54	3.68	75.29
Pelleting X Sex					
M x b	1.51	5.70*	3.70	3.32**	74.50
x g	1.38	5.08	3.72	3.91	75.45
P x b	1.68	6.19	3.69	3.60	74.70
x g	1.43	5.11	3.59	3.70	75.19
Antibiotic X Sex					
Nil x b	1.53	5.88	3.83	3.44	74.32
x g	1.34	5.06	3.81	3.71	75.03
Add x b	1.66	6.01	3.66	3.48	74.78
x g	1.47	5.13	3.50	3.89	75.71
LSR for means min.	0.09	0.25	0.16	0.21	0.71
max.	0.10	0.27	0.18	0.23	0.77

continued ...

TABLE D - continued

	1. Ave. daily gain	2. Ave. daily feed intake	3. Lb. feed per lb. gain	4. Loin area	5. Warm carcass dressing percentage
	lb.	lb.	lb.	cm.^{2}	%
Significant 2nd order interactions:					
Bulk type X Feeding frequency X Antibiotic					
Sf x 2 x nil			3.50*		73.64*
x add			3.36		74.30
x 3 x nil			3.91		76.15
x add			3.50		75.93
Wb x 2 x nil			3.70		73.60
x add			3.77		75.12
x 3 x nil			3.95		73.61
x add			3.46		73.35
Oh x 2 x nil			3.93		75.76
x add			3.63		75.66
x 3 x nil			3.92		75.31
x add			3.76		77.10
Bulk type X Feeding frequency X Sex					
Sf x 2 x b					73.04**
x g					74.90
x 3 x b					76.02
x g					76.06
Wb x 2 x b					74.70
x g					74.03
x 3 x b					73.19
x g					73.76
Oh x 2 x b					74.78
x g					76.64
x 3 x b					75.58
x g					76.83
Bulk type X Bulk modulus X Antibiotic					
Sf x f x nil		5.70*		3.48	75.25**
x add		5.61		3.41	74.52
x c x nil		4.86		3.50	74.54
x add		5.37		3.88	75.71
Wb x f x nil		5.21		3.76	72.98
x add		5.29		4.11	74.37
x c x nil		5.65		3.74	74.23
x add		5.38		3.44	74.15
Oh x f x nil		5.99		3.50	75.96
x add		5.96		3.64	76.26
x c x nil		5.42		3.49	75.11
x add		5.82		3.64	76.50

continued ...

TABLE D - continued

	1. Ave. daily gain	2. Ave. daily feed intake	3. lb. feed per lb. gain	4. Loin area	5. Warm carcass dressing percentage
	lb.	lb.	lb.	$cm.^2$	%
Bulk type X Pelleting X Antibiotic					
Sf x m x nil					74.96**
x add					74.50
x p x nil					74.83
x add					75.73
Wb x m x nil					73.87
x add					73.96
x p x nil					73.34
x add					74.51
Oh x m x nil					75.15
x add					77.45
x p x nil					75.92
x add					75.32
LSR for means min.	0.05	0.14	0.28	0.36	1.23
max.	0.05	0.16	0.33	0.42	1.45
Feeding frequency X Bulk modulus X Pelleting					
2 x f x m		5.44*		3.49	74.29**
x p		5.44		3.83	74.59
x c x m		4.96		3.57	75.28
x p		5.52		3.51	74.56
3 x f x m		5.61		3.72	75.85
x p		6.02		3.56	74.80
x c x m		5.54		3.67	74.50
x p		5.65		3.70	75.82
Feeding frequency X Bulk modulus X Antibiotic					
2 x f x nil		5.33*		3.70*	
x add		5.55		3.62	
x c x nil		5.20		3.46	
x add		5.27		3.63	
3 x f x nil		5.94		3.46	
x add		5.69		3.81	
x c x nil		5.42		3.69	
x add		5.77		3.68	
Feeding frequency X Pelleting X Antibiotic					
2 x m x nil				3.58*	
x add				3.48	
x p x nil				3.58	
x add				3.77	
3 x m x nil				3.49	
x add				3.90	
x c x nil				3.67	
x add				3.59	

continued ...

TABLE D - continued

	1. Ave. daily gain	2. Ave. daily feed intake	3. Lb. feed per lb. gain	4. Loin area	5. Warm carcass dressing percentage
	lb.	lb.	lb.	cm.^{2}	%
Feeding frequency X Pelleting X Sex					
2 x m x b				3.39**	74.32*
x g				3.68	75.25
x p x b				3.50	74.02
x g				3.85	75.13
3 x m x b				3.25	74.69
x g				4.14	75.65
x p x b				3.71	75.17
x g				3.54	75.45
Feeding frequency X Antibiotic X Sex					
2 x nil x b					73.71*
x g					74.96
x add x b					74.63
x g					75.43
3 x nil x b					74.93
x g					75.11
x add x b					74.93
x g					75.99
Bulk modulus X Pelleting X Sex					
F x m x b	1.49*				
x g	1.42				
x p x b	1.76				
x g	1.41				
C x m x b	1.54				
x g	1.34				
x p x b	1.60				
x g	1.45				
LSR for means min.	0.04	0.11	0.23	0.29	1.00
max.	0.05	0.13	0.26	0.34	1.16
General mean	1.50	5.52	3.70	3.63	74.96
Number of observations	96	96	96	96	96
Error M.S. used	0.0236	0.1781	0.0755	0.1259	1.472
D.F. for error M.S.	38	38	38	38	38

TABLE D - RESPONSE CRITERIA MEANS

	6. Ave. backfat (of 3 measures)	7. Dry matter digesti-bility (D.M.)	8. Digesti-bility of Energy (D.E.)	9. Digesti-bility of Protein (D.P.)	10. Ave. daily D.E. intake
	in.	%	%	%	Mcal.
Main effects:					
Bulk types					
Solka-floc	1.21**	68.0**	68.5*	78.2**	7.17**
Wheat bran	1.14	68.8	68.8	76.8	6.80
Oat hulls	1.27	66.0	67.0	81.5	7.47
LSR for means min.	.06	1.3	1.5	1.6	0.33
max.	.06	1.4	1.6	1.6	0.35
Feeding frequency					
2/day	1.16**	68.0	68.4	79.1	6.95*
3/day	1.26	67.2	67.8	78.5	7.31
Bulk modulus					
Fine	1.22	67.9	68.5	78.5	7.32**
Coarse	1.20	67.1	67.7	79.2	6.94
Pelleting effects					
Meal	1.20	67.7	68.1	79.3	6.96*
Pellets	1.22	67.5	68.0	78.3	7.30
Antibiotic effects					
Nil	1.18*	68.0	68.2	77.4**	7.12
Add	1.23	67.3	67.9	80.3	7.14
Sex effects					
Barrows	1.29**	67.5	68.0	78.3	7.64**
Gilts	1.14	67.3	68.2	79.4	6.61
LSR for means	.05	1.1	1.3	1.3	0.27
1st order interactions:					
Bulk type X Feeding frequency					
Sf x 2	1.12	68.8	69.0	78.5	7.05
x 3	1.30	67.3	67.9	77.9	7.17
Wb x 2	1.11	69.5	69.4	77.2	6.61
x 3	1.18	68.2	68.1	76.3	7.00
Oh x 2	1.24	65.7	66.6	81.7	7.19
x 3	1.30	66.2	67.3	81.4	7.76
Bulk type X Bulk modulus					
Sf x f	1.26**	68.2**	68.7**	77.7	7.47**
x c	1.16	68.0	68.2	78.7	6.74
Wb x f	1.08	67.0	67.3	75.8	6.51
x c	1.20	70.6	70.3	77.7	7.11
Oh x f	1.31	68.5	69.3	81.8	7.99
x c	1.23	63.5	64.5	81.3	6.96

continued ...

TABLE D - continued

	6. Ave. backfat (of 3 measures)	7. Dry matter digesti-bility (D.M.)	8. Digesti-bility of Energy (D.E.)	9. Digesti-bility of Protein (D.P.)	10. Ave. daily D.E. intake
	in.	%	%	%	Mcal.
Bulk type X Pelleting					
Sf x m	1.22	69.3	70.0*	79.4*	7.15
x p	1.20	66.9	67.3	77.0	7.06
Wb x m	1.11	68.6	68.2	78.0	6.49
x p	1.18	69.0	69.4	75.6	7.13
Oh x m	1.25	65.3	66.4	80.6	7.24
x p	1.29	66.6	67.5	82.5	7.70
Bulk type X Antibiotic					
Sf x nil	1.18	67.7**	67.9*	77.0*	6.90
x add	1.24	68.5	69.0	79.5	7.31
Wb x nil	1.14	68.6	68.5	74.2	6.83
x add	1.14	69.1	69.1	79.3	6.79
Oh x nil	1.23	67.6	68.4	81.0	7.63
x add	1.31	64.3	65.6	82.1	7.32
Bulk type x Sex					
Sf x b	1.27	68.3	68.8	77.5	7.71
x g	1.15	67.8	68.2	78.9	6.50
Wb x b	1.22	68.6	69.1	76.6	7.25
x g	1.07	69.1	68.5	76.9	6.36
Oh x b	1.38	65.0	65.9	80.7	7.97
x g	1.16	67.0	68.0	82.4	6.98
LSR for means min.	0.08	1.9	2.2	2.2	0.47
max.	.09	2.1	2.5	2.5	0.53
Feeding frequency X Bulk modulus					
2 x f	1.19*	68.2	68.7	78.7	7.13
x c	1.12	67.8	68.0	79.6	6.77
3 x f	1.24	67.6	68.2	78.2	7.52
x c	1.28	66.9	67.3	78.9	7.10
Feeding frequency X Pelleting					
2 x m	1.23	68.7*	68.9	80.3*	6.83
x p	1.21	67.4	67.8	78.0	7.07
3 x m	1.16	66.8	67.2	78.4	7.10
x p	1.23	67.7	68.3	78.7	7.52
Feeding frequency X Antibiotic					
2 x nil	1.10	68.3	68.6	77.7	6.88
x add	1.20	67.7	68.1	80.6	7.02
3 x nil	1.26	67.6	67.9	77.0	7.36
x add	1.26	66.9	67.7	80.0	7.26

continued ....

TABLE D - continued

	6. Ave. backfat (of 3 measures)	7. Dry matter digesti-bility (D.M.)	8. Digesti-bility of Energy (D.E.)	9. Digesti-bility of Protein (D.P.)	10. Ave. daily D.E. intake
	in.	%	%	%	Mcal.
Feeding frequency X Sex					
2 x b	1.29	68.0	68.4	78.7	7.47
x g	1.14	68.0	68.3	79.6	6.43
3 x b	1.29	66.9	67.5	77.8	7.82
x g	1.11	67.6	68.0	79.2	6.80
Bulk modulus X Pelleting					
F x m	1.23*	67.7	68.2	78.8	7.13
x p	1.21	68.1	68.7	78.1	7.51
C x m	1.16	67.7	68.0	79.8	6.79
x p	1.26	67.0	67.4	78.6	7.08
Bulk modulus X Antibiotic					
F x nil	1.20	68.3	68.7	76.7	7.39
x add	1.23	67.5	68.2	80.2	7.25
C x nil	1.16	67.6	67.8	78.1	6.85
x add	1.23	67.0	67.6	80.3	7.02
Bulk modulus X Sex					
F x b	1.29	67.8	68.5	78.5	7.95
x g	1.14	68.0	68.4	78.4	6.70
C x b	1.29	67.0	67.4	78.1	7.34
x g	1.11	67.6	68.0	80.4	6.53
Pelleting X Antibiotic					
M x nil	1.18	68.2	68.5	77.4	7.11*
x add	1.21	67.2	67.7	88.3	6.81
P x nil	1.19	67.7	68.0	77.4	7.13
x add	1.25	67.4	68.0	79.3	7.46
Pelleting X Sex					
M x b	1.27	67.3	67.8	78.8	7.35
x g	1.12	68.2	68.4	79.8	6.57
P x b	1.31	67.6	68.1	77.2	7.94
x g	1.13	67.4	68.0	79.0	6.66
Antibiotic X Sex					
Nil x b	1.28	67.3	67.8	76.8	7.59
x g	1.09	68.6	68.7	78.0	6.65
Add x b	1.30	67.6	68.1	79.7	7.70
x g	1.16	67.0	67.7	80.8	6.58
LSR for means min.	0.07	1.5	1.8	1.8	0.38
max.	.07	1.7	2.0	1.9	0.41

continued ...

TABLE D - continued

	6. Ave. backfat (of 3 measures)	7. Dry matter digesti-bility (D.M.)	8. Digesti-bility of Energy (D.E.)	9. Digesti-bility of Protein (D.P.)	10. Ave. daily D.E. intake
	in.	%	%	%	Mcal.
Significant 2nd order interactions:					
Bulk type X Feeding frequency X Bulk modulus					
Sf x 2 x f	1.19*				
x c	1.06				
x 3 x f	1.33				
x c	1.26				
Wb x 2 x f	1.04				
x c	1.17				
x 3 x f	1.12				
x c	1.24				
Oh x 2 x f	1.35				
x c	1.13				
x 3 x f	1.27				
x c	1.33				
Bulk type x Feeding frequency X Pelleting					
Sf x 2 x m		71.3*			
x p		66.4			
x 3 x m		67.2			
x p		67.4			
Wb x 2 x m		69.5			
x p		69.5			
x 3 x m		67.7			
x p		68.6			
Oh x 2 x m		65.2			
x p		66.3			
x 3 x m		65.5			
x p		67.0			
Bulk type X Bulk modulus X Pelleting					
Sf x f x m		68.5*			
x p		68.0			
x c x m		70.0			
x p		65.9			
Wb x f x m		66.6			
x p		67.5			
x c x m		70.5			
x p		70.5			
Oh x f x m		68.2			
x p		68.8			
x c x m		62.5			
x p		64.4			

continued ...

TABLE D - continued

	6. Ave. backfat (of 3 measures)	7. Dry matter digesti-bility (D.M.)	8. Digesti-bility of Energy (D.E.)	9. Digesti-bility of Protein (D.P.)	10. Ave. daily D.E. intake
	in.	%	%	%	Mcal.
Bulk type X Bulk module X Antibiotic					
Sf x f x nil	1.27*	66.6**	66.9*		
x add	1.25	69.9	70.5		
x c x nil	1.10	68.8	68.8		
x add	1.23	67.1	67.6		
Wb x f x nil	1.04	67.2	67.4		
x add	1.12	66.9	67.2		
x c x nil	1.24	70.0	69.7		
x add	1.17	71.3	71.0		
Oh x f x nil	1.30	71.1	71.9		
x add	1.32	65.9	66.9		
x c x nil	1.16	64.1	64.8		
x add	1.30	62.8	64.2		
Bulk type X Bulk module X Sex					
Sf x f x b	1.33*				
x g	1.19				
x c x b	1.22				
x g	1.10				
Wb x f x b	1.11				
x g	1.05				
x c x b	1.33				
x g	1.08				
Oh x f x b	1.44				
x g	1.18				
x c x b	1.31				
x g	1.14				
Bulk type X Pelleting X Sex					
Sf x m x b		68.4*			
x g		70.1			
x p x b		68.2			
x g		65.6			
Wb x m x b		68.7			
x g		68.4			
x p x b		69.4			
x g		68.8			
Oh x m x b		64.7			
x g		66.0			
x p x b		65.3			
x g		68.0			
LSR for means min.	0.04	2.7	3.1	3.1	0.63
max.	0.04	3.1	3.7	3.6	0.78

continued ...

TABLE D - continued

	6. Ave. backfat (of 3 measures)	7. Dry matter digesti-bility (D.M.)	8. Digesti-bility of Energy (D.E.)	9. Digesti-bility of Protein (D.P.)	10. Ave. daily D.E. intake
	in.	%	%	%	Mcal.
Feeding frequency X Bulk modulus X Antibiotic					
2 x f x nil	1.12**				
x add	1.26				
x c x nil	1.10				
x add	1.14				
3 x f x nil	1.28				
x add	1.20				
x c x nil	1.23				
x add	1.32				
Bulk module X Pelleting X Sex					
F x m x b					7.48*
x g					6.79
x p x b					8.41
x g					6.61
C x m x b					7.22
x g					6.36
x p x b					7.47
x g					6.70
Bulk module X Antibiotic X Sex					
F x nil x b		68.4*			
x g		68.2			
x add x b		67.4			
x g		67.7			
C x nil x b		66.3			
x g		68.9			
x add x b		67.8			
x g		66.3			
Pelleting X Antibiotic X Sex					
M x nil x b		66.5**	67.0**		
x g		70.0	70.0		
x add x b		68.0	68.6		
x g		66.4	66.9		
P x nil x b		68.1	68.7		
x g		67.2	67.4		
x add x b		67.1	67.6		
x g		67.7	68.5		
LSR for means min.	0.03	2.2	2.5	2.5	0.54
max.	0.03	2.5	2.9	2.9	0.62

continued ...

TABLE D - continued

	6. Ave. backfat (of 3 measures)	7. Dry matter digesti-bility (D.M.)	8. Digesti-bility of Energy (D.E.)	9. Digesti-bility of Protein (D.P.)	10. Ave. daily D.E. intake
	in.	%	%	%	Mcal.
General mean	1.21	67.7	68.1	78.8	7.13
Number of observations	96	96	96	96	96
Error M.S. used	0.0125	6.815	9.419	9.307	0.4224
D.F. for error M.S.	38	38	38	38	38

TABLE D - RESPONSE CRITERIA MEANS

	11. Ave. daily D.P. intake	12. Gm. D.P. per Mcal. D.E.	13. D.E. per lb. D.M.	14. Mcal. D.E. per lb. gain	15. Gm. D.P. per lb. gain
	gm.	gm.	Kcal.	Mcal.	gm.
Main effects:					
Bulk types					
Solka-floc	321**	45.5*	1422	4.17	213**
Wheat bran	315	46.3	1387	4.20	219
Oat hulls	350	47.0	1414	4.39	231
LSR for means min.	14.6	0.9	32.8	0.23	9.0
max.	15.2	0.9	34.3	0.23	9.4
Feeding frequency					
2/day	320*	46.1	1413	4.76	219
3/day	338	46.4	1402	4.81	222
Bulk modulus					
Fine	335	45.8*	1414	4.83	221
Coarse	323	46.8	1401	4.74	221
Pelleting effects					
Meal	324	46.6*	1407	4.84	225*
Pellets	334	45.9	1408	4.72	216
Antibiotic effects					
Nil	320**	45.1**	1412	4.98**	224
Add	337	47.4	1403	4.59	217
Sex effects					
Barrows	349**	45.9*	1405	4.82	221
Gilts	308	46.6	1410	4.75	221
LSR for means	11.9	0.8	26.8	0.18	7.3
1st order interactions:					
Bulk type X Feeding frequency					
Sf x 2	317	45.3	1433	4.56	205
x 3	325	45.6	1411	4.84	220
Wb x 2	304	46.2	1400	4.77	220
x 3	326	46.5	1374	4.68	217
Oh x 2	338	47.1	1407	4.95	232
x 3	362	46.9	1421	4.92	230
Bulk type X Bulk modulus					
Sf x f	323**	43.4**	1422**	4.72	204**
x c	319	47.6	1422	4.68	221
Wb x f	305	46.9	1355	4.66	218
x c	326	45.8	1418	4.78	219
Oh x f	375	47.1	1465	5.12	240
x c	325	47.0	1362	4.75	222

continued ...

TABLE D - continued

	11. Ave. daily D.P. intake	12. Gm. D.P. per Mcal. D.E.	13. D.E. per lb. D.M.	14. Mcal. D.E. per lb. gain	15. Gm. D.P. per lb. gain
	gm.	gm.	Kcal.	Mcal.	gm.
Bulk type X Pelleting					
Sf x m	323	45.3**	1443	4.74	214
x p	319	45.6	1401	4.66	212
Wb x m	308	47.5	1376	4.82	228
x p	323	45.2	1398	4.63	209
Oh x m	340	47.1	1402	4.98	234
x p	360	46.9	1426	4.89	228
Bulk type X Antibiotic					
Sf x nil	309	45.0*	1410*	4.84	218
x add	333	45.9	1433	4.55	208
Wb x nil	308	44.9	1382	4.82	216
x add	323	47.8	1392	4.63	221
Oh x nil	345	45.4	1444	5.29	239
x add	356	48.6	11384	4.58	223
Bulk type X Sex					
Sf x b	344	44.9	1429	4.82	216
x g	298	46.1	1414	4.57	210
Wb x b	332	45.9	1393	4.76	219
x g	298	46.8	1381	4.68	218
Oh x b	372	46.9	1392	4.88	227
x g	329	47.1	1436	4.99	235
LSR for means min.	20.6	1.2	46.4	0.31	12.2
max.	25.2	1.3	50.2	0.35	13.4
Feeding frequency X Bulk modulus					
2 x f	324	45.7	1419	4.73	215
x c	315	46.8	1408	4.79	223
3 x f	345	45.9	1410	4.94	226
x c	331	46.8	1394	4.68	218
Feeding frequency X Pelleting					
2 x m	316	46.5	1424	4.87	225
x p	324	46.0	1402	4.65	213
3 x m	331	46.8	1390	4.82	225
x p	344	45.9	1414	4.80	219
Feeding frequency X Antibiotic					
2 x nil	309	45.0	1420	4.88	220
x add	330	47.4	1407	4.64	219
3 x nil	332	45.2	1404	5.08	229
x add	344	47.5	1400	4.54	216

continued ...

TABLE D - continued

	11. Ave. daily D.P. intake	12. Gm. D.P. per Mcal. D.E.	13. D.E. per lb. D.M.	14. Mcal. D.E. per lb. gain	15. Gm. D.P. per lb. gain
	gm.	gm.	Kcal.	Mcal.	gm.
Feeding frequency X Sex					
2 x b	341	45.9	1414	4.85	222
x g	298	46.5	1412	4.66	216
3 x b	357	46.0	1396	4.79	219
x g	318	46.8	1408	4.87	226
Bulk modulus X Pelleting					
F x m	329	46.4	1406	4.91	224
x p	340	45.2	1422	4.75	218
C x m	318	46.9	1408	4.78	224
x p	329	46.7	1394	4.69	218
Bulk modulus X Antibiotic					
F x nil	327	44.3	1421	5.00	221
x add	342	47.2	1408	4.67	220
C x nil	313	46.0	1403	4.96	228
x add	332	47.6	1399	4.51	214
Bulk modulus X Sex					
F x m	361	45.6	1415	4.92	224
x p	308	45.9	1413	4.75	218
C x m	338	46.2	1395	4.72	218
x p	308	47.4	1407	4.75	224
Pelleting X Antibiotic					
M x nil	319	45.0**	1415	5.06	228
x add	328	48.3	1399	4.63	223
P x nil	321	45.2	1409	4.90	221
x add	347	46.6	1408	4.55	211
Pelleting X Sex					
M x b	339	46.4	1400	4.88	226
x g	308	46.9	1414	4.81	225
P x b	360	45.5	1410	4.76	216
x g	309	46.4	1406	4.69	217
Antibiotic X Sex					
Nil x b	301	45.1	1403	4.96	223
x g	340	45.2	1421	5.00	226
Add x b	359	46.8	1408	4.68	218
x g	316	48.1	1399	4.50	216
LSR for means min.	16.8	1.0	37.6	0.25	10.4
max.	18.2	1.0	41.0	0.27	10.9

continued ....

TABLE D - continued

	11. Ave. daily D.P. intake	12. Gm. D.P. per Mcal. D.E.	13. D.E. per lb. D.M.	14. Mcal. D.E. per lb. gain	15. Gm. D.P. per lb. gain
	gm.	gm.	Kcal.	Mcal.	gm.
Significant 2nd order interactions:					
Bulk type X Feeding frequency X Bulk modulus					
Sf x 2 x f					198*
x c					212
x 3 x f					211
x c					230
Wb x 2 x f					218
x c					222
x 3 x f					219
x c					216
Oh x 2 x f					229
x c					235
x 3 x f					250
x c					209
Bulk type X Bulk modulus X Antibiotic					
Sf x f x nil		43.2**	1386*		
x add		43.5	1459		
x c x nil		46.8	1435		
x add		48.4	1408		
Wb x f x nil		45.4	1358		
x add		48.4	1353		
x c x nil		44.5	1405		
x add		47.1	1432		
Oh x f x nil		44.2	1518		
x add		49.9	1413		
x c x nil		46.6	1369		
x add		47.4	1356		
Bulk type X Pelleting X Antibiotic					
Sf x m x nil		44.9*			
x add		45.8			
x p x nil		45.1			
x add		46.1			
Wb x m x nil		45.1			
x add		49.9			
x p x nil		44.8			
x add		45.6			
Oh x m x nil		45.0			
x add		49.2			
x p x nil		45.9			
x add		48.0			
LSR for means min.	29.1	1.7	65.6	0.44	18.0
max.	34.3	1.8	77.3	0.52	18.9

continued ...

TABLE D - continued

	11. Ave. daily D.P. intake	12. Gm. D.P. per Mcal. D.E.	13. D.E. per lb. D.M.	14. Mcal. D.E. per lb. gain	15. Gm. D.P. per lb. gain
	gm.	gm.	Kcal.	Mcal.	gm.
Feeding frequency X Pelleting X Sex					
2 x m x b		46.6*			
x g		46.3			
x p x b		45.2			
x g		46.8			
3 x m x b		46.2			
x g		47.5			
x p x b		45.8			
x g		46.0			
Pelleting X Antibiotic X Sex					
M x nil x b			1383*		
x g			1447		
x add x b			1416		
x g			1382		
P x nil x b			1422		
x g			1396		
x add x b			1399		
x g			1417		
LSR for means min.	23.8	1.4	53.6	0.36	14.7
max.	27.4	1.5	61.6	0.41	16.9
General mean	329	46.3	1408	4.78	221
Number of observations	96	96	96	96	96
Error M.S. used	825.08	2.925	4.179	0.1868	313.47
D.F. for error M.S.	38	38	38	38	38

TABLE D - RESPONSE CRITERIA MEANS

	Stomach				
	16. Total content	17. Total water content	18. Total dry matter content	19. Organ weight	20. Ingesta specific gravity
	gm.	gm.	gm.	gm.	
Main effects:					
Bulk types					
Solka-floc	2070	1490*	580	688	.978**
Wheat bran	1839	1373	466	690	.933
Oat hulls	1702	1154	554	644	.979
LSR for means min.	384.9	255.4	129.8	48.8	.019
max.	402.3	267.0	135.6	51.0	.020
Feeding frequency					
2/day	1654**	1207*	447*	665	.955*
3/day	2087	1471	620	682	.972
Bulk modulus					
Fine	1829	1317	512	669	.978**
Coarse	1911	1361	554	678	.949
Pelleting effects					
Meal	1752	1258	494	708**	.946**
Pellets	1989	1420	572	640	.981
Antibiotic effects					
Nil	1868	1361	511	678	.955**
Add	1873	1317	556	669	.972
Sex effects					
Barrows	1946	1382	568	645*	.969
Gilts	1795	1296	499	702	.958
LSR for means	314.3	208.6	105.9	39.9	.016
1st order interactions:					
Bulk type X Feeding frequency					
Sf x 2	1890	1378	512*	684	.973
x 3	2249	1601	648	690	.984
Wb x 2	1730	1278	453	678	.925
x 3	1949	1469	480	702	.941
Oh x 2	1341	965	376	633	.967
x 3	2063	1344	732	655	.990
Bulk type X Bulk modulus					
Sf x f	2018	1465	552	703	.987
x c	2122	1514	608	672	.970
Wb x f	1879	1385	494	679	.960
x c	1800	1361	439	701	.906
Oh x f	1592	1101	491	626	.986
x c	1812	1208	617	662	.972

continued ...

TABLE D - continued

	Stomach				
	16. Total content	17. Total water content	18. Total dry matter content	19. Organ weight	20. Ingesta specific gravity
	gm.	gm.	gm.	gm.	
Bulk type X Pelleting					
Sf x m	2146	1525	621	719	.973
x p	1994	1454	539	656	.981
Wb x m	1619	1209	410	722	.912
x p	2060	1538	522	658	.955
Oh x m	1492	1039	452	682	.952
x p	1912	1269	656	606	1.006
Bulk type X Antibiotic					
Sf x nil	1931	1451	480	669	.966
x add	2209	1529	680	706	.990
Wb x nil	1948	1462	486	694	.930
x add	1731	1284	447	686	.936
Oh x nil	1726	1171	568	672	.974
x add	1678	1138	540	616	.988
Bulk type X Sex					
Sf x b	2140	1532	618	643	.994
x g	1999	1457	542	732	.963
Wb x b	1988	1488	500	657	.927
x g	1692	1259	432	723	.940
Oh x b	1709	1137	586	636	.986
x g	1695	1173	522	652	.972
LSR for means min.	54.4	361.3	183.5	69.0	.027
max.	61.3	406.7	206.5	77.7	.031
Feeding frequency X Bulk modulus					
2 x f	1804*	1310*	493*	655	.973
x c	1504	1103	400	675	.937
3 x f	1855	1323	532	684	.983
x c	2319	1619	708	681	.961
Feeding frequency X Pelleting					
2 x m	1738*	1256*	481**	682	.936
x p	1570	1158	413	649	.974
3 x m	1767	1259	508	734	.955
x p	2406	1683	733	631	.989
Feeding frequency X Antibiotic					
2 x nil	1582	1169	412	650	.956
x add	1726	1245	481	680	.964
3 x nil	2155	1553	610	706	.965
x add	2020	1390	630	659	.979

continued ...

TABLE D - continued

	Stomach				
	16. Total content	17. Total water content	18. Total dry matter content	19. Organ weight	20. Ingesta specific gravity
	gm.	gm.	gm.	gm.	
Feeding frequency X Sex					
2 x b	1630	1167	462	627	.960
x g	1678	1247	431	704	.951
3 x b	2262	1597	673	664	.978
x g	1912	1346	567	701	.965
Bulk modulus x Pelleting					
F x m	1625	1166	458	681*	.966
x p	2034	1468	567	658	.990
C x m	1880	1349	530	734	.926
x p	1943	1373	578	622	.972
Bulk modulus X Antibiotic					
F x nil	1776	1295	481	667	.977
x add	1883	1339	544	672	.979
C x nil	1960	1427	542	690	.934
x add	1862	1295	567	667	.964
Bulk modulus X Sex					
F x b	1768	1262	507	646	.975*
x g	1890	1372	518	693	.981
C x b	2123	1502	629	645	.963
x g	1700	1220	480	711	.935
Pelleting X Antibiotic					
M x nil	1589*	1166*	422	721	.944
x add	1915	1349	566	695	.947
P x nil	2148	1556	600	636	.967
x add	1830	1285	545	644	.996
Pelleting X Sex					
M x b	1940	1383	557	688	.967
x g	1546	1132	432	727	.950
P x b	1951	1380	579	603	.988
x g	1842	1460	566	677	.974
Antibiotic X Sex					
Nil x b	1988	1466	531	649	.957
x g	1748	1256	492	708	.954
Add x b	1903	1298	605	642	.981
x g	1842	1336	506	697	.962
LSR for means min.	444.6	295.0	149.8	56.3	.022
max.	481.7	319.7	162.3	61.0	.024

continued ...

TABLE D - continued

	Stomach				
	16. Total content	17. Total water content	18. Total dry matter content	19. Organ weight	20. Ingesta specific gravity
	gm.	gm.	gm.	gm.	
Significant 2nd order interactions:					
Bulk type X Feeding frequency X Sex					
Sf x 2 x b		1280*			
x g		1476			
x 3 x b		1765			
x g		1438			
Wb x 2 x b		1320			
x g		1235			
x 3 x b		1655			
x g		1283			
Oh x 2 x b		901			
x g		1029			
x 3 x b		1370			
x g		1380			
Bulk type X Bulk modulus X Pelleting					
Sf x f x m					.972*
x p					1.000
x c x m					.975
x p					.965
Wb x f x m					.956
x p					.966
x c x m					.867
x p					.944
Oh x f x m					.969
x p					1.000
x c x m					.935
x p					1.010
Bulk type X Pelleting X Antibiotic					
Sf x m x nil		1201*			
x add		1849			
x p x nil		1700			
x add		1209			
Wb x m x nil		1201			
x add		1216			
x p x nil		1723			
x add		1353			
Oh x m x nil		1096			
x add		983			
x p x nil		1245			
x add		1294			
LSR for means min.	769.7	511.1	259.5	97.6	.032
max.	906.5	602.0	305.6	115.0	.036

continued ...

TABLE D - continued

	Stomach				
	16. Total content	17. Total water content	18. Total dry matter content	19. Organ weight	20. Ingesta specific gravity
	gm.	gm.	gm.	gm.	
Feeding frequency X Bulk modulus X Antibiotic					
2 x f x nil			391*		
x add			596		
x c x nil			571		
x add			493		
3 x f x nil			434		
x add			367		
x c x nil			649		
x add			768		
Feeding frequency X Pelleting X Antibiotic					
2 x m x nil			436*	655*	
x add			527	709	
x p x nil			389	646	
x add			436	651	
3 x m x nil			409	786	
x add			606	681	
x p x nil			811	626	
x add			654	637	
Pelleting X Antibiotic X Sex					
M x nil x b			522*		
x g			323		
x add x b			592		
x g			540		
P x nil x b			540		
x g			660		
x add x b			618		
x g			472		
LSR for means min.	628.5	417.3	211.9	79.7	.032
max.	722.7	479.8	243.6	91.6	.036
General Mean	1870	1339	533	674	.964
Number of observations	96	91	91	96	96
Error M.S. used	575,558.6	253,522	65,399.9	9,252.7	.0014496
D.F. for error M.S.	38	33	33	38	36

TABLE D - RESPONSE CRITERIA MEANS

	Stomach - liquid phase						
	21. pH	22. Viscosity	23. Surface tension	24. Oven dry residues		25. Ash in oven dry residue	
		centipoise	dynes/cm.	%	(Angles[1])	%	(Angles)
Main effects:							
Bulk types							
Solka-floc	4.46	2.23**	47.6	4.5	(12.2)	17.2	(24.5)
Wheat bran	4.38	1.45	46.5	4.0	(11.5)	21.0	(27.3)
Oat hulls	4.51	1.86	46.7	3.8	(11.2)	17.2	(24.5)
LSR for means							
min.	0.17	0.31	1.56		(1.0)		(2.6)
max.	0.17	0.32	1.63		(1.0)		(2.2)
Feeding frequency							
2/day	4.36*	1.69*	47.4	3.6**	(11.0)	18.7	(25.6)
3/day	4.54	2.00	46.5	4.6	(12.3)	18.3	(25.3)
Bulk modulus							
Fine	4.51	1.75	47.3	4.1	(11.7)	18.5	(25.5)
Coarse	4.39	1.95	46.7	4.0	(11.6)	18.4	(25.4)
Pelleting effects							
Meal	4.45	1.73	46.1**	3.4**	(10.6)	19.1	(25.9)
Pellets	4.46	1.97	47.8	4.8	(12.6)	18.0	(25.1)
Antibiotic effects							
Nil	4.32**	1.73	47.9**	4.0	(11.6)	18.1	(25.2)
Add	4.58	1.97	46.0	4.1	(11.7)	17.9	(25.8)
Sex effects							
Barrows	4.57**	2.03**	46.7	4.7**	(12.5)	18.5	(25.5)
Gilts	4.33	1.66	47.3	3.5	(10.8)	18.4	(25.4)
LSR for means	0.14	0.25	1.3		(0.8)		(2.1)
1st order interactions:							
Bulk type X Feeding frequency							
Sf x 2	4.43	2.14*	48.7	4.1*	(11.7)	16.6	(24.0)
x 3	4.48	2.33	46.5	4.8	(12.6)	17.9	(25.0)
Wb x 2	4.25	1.46	46.0	4.0	(11.5)	21.6	(27.7)
x 3	4.51	1.45	47.0	4.0	(11.5)	20.6	(27.0)
Oh x 2	4.39	1.48	47.4	3.0	(9.9)	18.3	(25.3)
x 3	4.64	2.23	46.1	4.8	(12.6)	16.3	(23.8)
Bulk type X Bulk modulus							
Sf x f	4.54	1.96	47.4	4.3	(12.0)	18.0	(25.1)
x c	4.38	2.51	47.8	4.6	(12.4)	16.4	(23.9)
Wb x f	4.44	1.51	47.4	4.2	(11.8)	19.9	(26.5)
x c	4.32	1.40	45.6	3.8	(11.2)	22.2	(28.1)
Oh x f	4.55	1.78	46.9	3.8	(11.2)	17.7	(24.9)
x c	4.48	1.93	46.6	3.8	(11.3)	16.8	(24.2)

1 Angular transformation of data according to Johnson (1950)

continued ...

TABLE D - continued

	Stomach - liquid phase						
	21. pH	22. Viscosity	23. Surface tension	24. Oven dry residues		25. Ash in oven dry residue	
		centipoise	dynes/cm.	%	(Angles)	%	(Angles)
Bulk type X Pelleting							
Sf x m	4.31**	2.09	46.6	3.8	(11.2)	16.7	(24.1)
x p	4.61	2.37	47.8	5.2	(13.2)	17.7	(24.9)
Wb x m	4.57	1.43	45.8	3.5	(10.8)	21.9	(27.9)
x p	4.19	1.48	47.3	4.5	(12.2)	20.3	(26.8)
Oh x m	4.46	1.67	46.0	3.0	(10.0)	18.7	(25.6)
x p	4.57	2.05	47.5	4.7	(12.5)	15.9	(23.5)
Bulk type X Antibiotic							
Sf x nil	4.22*	1.86*	48.6	3.9*	(11.4)	19.6*	(26.3)
x add	4.70	2.61	46.6	5.1	(13.0)	14.9	(22.7)
Wb x nil	4.39	1.45	46.6	4.5	(12.2)	20.3	(26.8)
x add	4.37	1.45	46.5	3.5	(10.8)	21.8	(27.8)
Oh x nil	4.37	1.87	48.6	3.7	(11.1)	14.4	(22.3)
x add	4.66	1.85	44.9	3.9	(11.4)	20.2	(26.7)
Bulk type X Sex							
Sf x b	4.62	2.66*	47.6	5.1	(13.0)	16.7	(24.1)
x g	4.29	1.81	48.3	3.9	(11.4)	17.7	(24.9)
Wb x b	4.50	1.52	46.3	4.8	(12.6)	21.0	(27.3)
x g	4.26	1.39	46.8	3.3	(10.4)	21.0	(27.3)
Oh x b	4.55	1.92	46.8	4.3	(11.9)	18.0	(25.1)
x g	4.48	1.79	46.7	3.4	(10.6)	18.7	(25.6)
LSR for means							
min.	0.23	0.43	2.2		(1.4)		(3.6)
max.	0.26	0.49	2.5		(1.6)		(4.1)
Feeding frequency X Bulk modulus							
2 x f	4.41	1.75*	48.5*	4.0*	(11.5)	19.4	(26.1)
x c	4.31	1.64	46.3	3.4	(10.6)	18.1	(25.2)
3 x f	4.61	1.75	46.0	4.2	(11.8)	17.7	(24.9)
x c	4.47	2.26	47.1	4.8	(12.7)	18.7	(25.6)
Feeding frequency X Pelleting							
2 x m	4.36	1.53	46.3	3.2	(10.3)	19.1	(25.9)
x p	4.36	1.85	48.5	4.2	(11.8)	18.4	(25.4)
3 x m	4.53	1.93	45.9	3.6	(11.0)	18.9	(25.8)
x p	4.55	2.08	47.2	5.4	(13.5)	17.5	(24.7)
Feeding frequency X Antibiotic							
2 x nil	4.24	1.54	48.4	3.6	(10.9)	17.3	(24.6)
x add	4.48	1.85	46.4	3.8	(11.2)	20.2	(26.7)
3 x nil	4.41	1.92	47.4	4.5	(12.3)	18.8	(25.7)
x add	4.67	2.09	45.7	4.5	(12.2)	17.6	(24.8)

continued ....

TABLE D - continued

	Stomach - liquid phase						
	21. pH	22. Viscosity	23. Surface tension	24. Oven dry residues		25. Ash in oven dry residue	
		centipoise	dynes/cm.	%	(Angles)	%	(Angles)
Feeding frequency X Sex							
2 x b	4.37**	1.95	46.4*	4.3	(11.9)	18.7	(25.6)
x g	4.35	1.44	48.4	3.1	(10.1)	18.7	(25.6)
3 x b	4.77	2.12	47.0	5.1	(13.0)	18.4	(25.4)
x g	4.31	1.89	46.1	4.0	(11.5)	18.1	(25.2)
Bulk modulus X Pelleting							
F x m	4.50	1.54	46.6	3.3	(10.5)	19.5	(26.2)
x p	4.52	1.95	47.9	4.9	(12.8)	17.6	(24.8)
C x m	4.40	1.92	45.6	3.4	(10.8)	18.5	(25.5)
x p	4.39	1.98	47.8	4.7	(12.5)	18.3	(25.3)
Bulk modulus X Antibiotic							
F x nil	4.41	1.71	48.3	4.0	(11.5)	19.4	(26.1)
x add	4.62	1.79	46.3	3.9	(11.4)	17.7	(24.9)
C x nil	4.24	1.75	47.6	4.0	(11.6)	16.8	(24.2)
x add	4.54	2.15	45.8	4.0	(11.6)	20.0	(26.6)
Bulk modulus X Sex							
F x b	4.67	1.96	47.1	4.8	(12.6)	18.8	(25.7)
x g	4.36	1.53	47.4	3.4	(10.7)	18.3	(25.3)
C x b	4.47	2.10	46.3	4.6	(12.4)	18.3	(25.3)
x g	4.31	1.80	47.1	3.6	(10.9)	18.5	(25.5)
Pelleting X Antibiotic							
M x nil	4.23*	1.60	47.2	3.3	(10.5)	17.9	(25.0)
x add	4.66	1.86	45.0	3.4	(10.8)	20.2	(26.7)
P x nil	4.42	1.85	48.6	4.8	(12.6)	18.3	(25.3)
x add	4.49	2.08	47.0	4.9	(12.7)	17.6	(24.8)
Pelleting X Sex							
M x b	4.53	1.92	45.6	4.0	(11.5)	19.4	(26.1)
x g	4.36	1.54	46.6	2.9	(9.8)	18.7	(25.6)
P x b	4.61	2.14	47.8	5.4	(13.4)	17.7	(24.9)
x g	4.30	1.79	47.9	4.2	(11.8)	18.1	(25.2)
Antibiotic X Sex							
Nil x b	4.39	1.82	47.6	4.5	(12.2)	19.8*	(26.4)
x g	4.26	1.63	48.2	3.6	(11.0)	16.4	(23.9)
Add x b	4.75	2.24	45.7	4.9	(12.8)	17.3	(24.6)
x g	4.40	1.69	46.3	3.4	(10.7)	20.5	(26.9)
LSR means min.	0.19	0.35	1.8		(1.2)		(3.0)
max.	0.21	0.38	2.0		(1.2)		(3.2)

continued ....

TABLE D - continued

	Stomach - liquid phase							
	21. pH	22. Viscosity	23. Surface tension	24. Oven dry residues		25. Ash in oven dry residue	
		centipoise	dynes/cm.	%	(Angles)	%	(Angles)
Significant 2nd order interactions:							
Bulk type X Feeding frequency X Bulk modulus							
Sf x 2 x f		2.23*					
x c		2.05					
x 3 x f		1.69					
x c		2.98					
Wb x 2 x f		1.49					
x c		1.43					
x 3 x f		1.53					
x c		1.37					
Oh x 2 x f		1.53					
x c		1.43					
x 3 x f		2.03					
x c		2.44					
Bulk type X Bulk modulus X Antibiotic							
Sf x f x nil	4.46*	1.88*		3.9*	(11.4)		
x add	4.62	2.04		4.8	(12.6)		
x c x nil	3.97	1.85		3.8	(11.3)		
x add	4.78	3.18		5.4	(13.4)		
Wb x f x nil	4.36	1.42		4.1	(11.7)		
x add	4.53	1.59		4.3	(11.9)		
x c x nil	4.42	1.48		4.9	(12.8)		
x add	4.21	1.32		2.5	(9.0)		
Oh x f x nil	4.40	1.82		4.0	(11.5)		
x add	4.70	1.73		3.6	(10.9)		
x c x nil	4.34	1.91		4.1	(11.7)		
x add	4.62	1.96		4.3	(11.9)		
Bulk type X Pelleting X Sex							
Sf x m x b	4.61*						
x g	4.01						
x p x b	4.64						
x g	4.58						
Wb x m x b	4.55						
x g	4.60						
x p x b	4.44						
x g	3.93						
Oh x m x b	4.43						
x g	4.49						
x p x b	4.66						
x g	4.48						

continued ....

TABLE D - continued

	Stomach - liquid phase				
	21. pH	22. Viscosity	23. Surface tension	24. Oven dry residues	25. Ash in oven dry residue
		centipoise	dynes/cm.	% (Angles)	% (Angles)
Bulk type X Antibiotic X Sex					
Sf x nil x b	4.35*		48.7**		
x g	4.08		48.6		
x add x b	4.98		45.4		
x g	4.43		48.0		
Wb x nil x b	4.37		47.1		
x g	4.41		46.0		
x add x b	4.63		45.5		
x g	4.12		47.6		
Oh x nil x b	4.44		47.1		
x g	4.30		50.1		
x add x b	4.65		46.4		
x g	4.67		43.4		
LSR for means					
min.	0.33	0.61	3.1	(2.0)	(5.2)
max.	0.35	0.72	3.7	(2.4)	(6.1)
Feeding frequency X Bulk modulus X Antibiotic					
2 x f x nil	4.21*	1.48**			
x add	4.61	2.02			
x c x nil	4.26	1.60			
x add	4.36	1.68			
3 x f x nil	4.60	1.93			
x add	4.62	1.56			
x c x nil	4.22	1.90			
x add	4.72	2.63			
Feeding frequency X Bulk modulus X Sex					
2 x f x b			47.0*		
x g			50.1		
x c x b			45.8		
x g			46.8		
3 x f x b			47.2		
x g			45.0		
x c x b			46.7		
x g			47.4		

continued .....

TABLE D - continued

	Stomach - liquid phase				
	21. pH	22. Viscosity	23. Surface tension	24. Oven dry residues	25. Ash in oven dry residue
		centipoise	dynes/cm.	% (Angles)	% (Angles)
Feeding frequency X Pelleting X Antibiotic					
2 x m x nil	4.22*				
x add	4.50				
x p x nil	4.25				
x add	4.47				
3 x m x nil	4.24				
x add	4.83				
x p x nil	4.59				
x add	4.51				
Bulk modulus X Pelleting X Sex					
F x m x b		1.64*			
x g		1.44			
x p x b		2.29			
x g		1.61			
C x m x b		2.21			
x g		1.63			
x p x b		1.99			
x g		1.97			
Bulk modulus X Antibiotic X Sex					
F x nil x b	4.42*				
x g	4.39				
x add x b	4.91				
x g	4.33				
C x nil x b	4.35				
x g	4.13				
x add x b	4.59				
x g	4.48				
Pellets X Antibiotic X Sex					
M x nil x b	4.42**	1.83*		4.2**	(11.8)
x g	4.04	1.37		2.6	(9.3)
x add x b	4.64	2.01		3.8	(11.2)
x g	4.69	1.70		3.2	(10.3)
P x nil x b	4.36	1.81		4.7	(12.5)
x g	4.48	1.89		4.8	(12.7)
x add x b	4.86	2.48		6.1	(14.3)
x g	4.12	1.68		3.7	(11.0)

continued ....

TABLE D - continued

	Stomach - liquid phase						
	21. pH	22. Viscosity	23. Surface tension	24. Oven dry residues		25. Ash in oven dry residue	
		centipoise	dynes/cm.	%	(Angles)	%	(Angles)
LSR for means							
min.	0.17	0.50	2.6		(1.6)	1	(4.2)
max.	0.31	0.57	2.9		(1.9)		(4.8)
General mean	4.45	1.85	47.0	4.0	(11.6)	18.5	(25.5)
Number of observations	94	92	92	92		92	
Error M.S. used	0.1064	0.3617	9.464		(3.874)		(25.87)
D.F. for error M.S.	36	34	34	34		34	

TABLE E - SUMMARY OF PHYSICAL AND ANALYTICAL MEASUREMENTS ON INGESTA SAMPLES

Measure		Magnitude and direction of deviation from stomach values					
		Stomach[1]	Small intestine[2]	Cecum	Cecum + large intestine	Large intestine	Rectal
Moisture	%	72.3	+ 12.2	+ 11.8	+ 6.5	+ 5.4	+ 2.4
Dry matter	%	27.7	- 12.2	- 11.8	- 6.5	- 5.4	- 2.4
Crude protein							
a. wet sample basis	%	4.01	+ 0.10	- 1.78	- 1.30	- 1.00	- 0.72
b. dry matter basis	%	14.5	+ 12.0	- 0.5	- 1.7	- 1.0	- 1.5
Ether extract							
a. wet sample basis	%	1.17	- 0.45	- 0.68	- 0.15	- 0.23	- 0.02
b. dry matter basis	%	4.23	+ 0.39	- 1.17	+ 0.59	0	+ 0.30
N.F.E.							
a. wet sample basis	%	16.0	- 9.2	- 8.8	- 6.4	- 6.5	- 5.4
b. dry matter basis	%	57.8	- 14.2	- 12.2	-12.4	-15.3	-15.8
Ash							
a..wet sample basis	%	2.10	- 0.50	- 0.17	+ 0.55	+ 0.55	+ 1.24
b. dry matter basis	%	7.57	+ 2.73	+ 4.58	+ 4.95	+ 3.38	+ 5.63
Crude fiber							
a. wet sample basis	%	4.38	- 2.01	- 0.30	+ 0.88	+ 1.73	+ 2.53
b. dry matter basis	%	15.8	- 0.5	+ 9.9	+ 9.0	+11.6	+11.5
Klasson lignin							
a. wet sample basis	%	3.46	- 1.17	- 0.82	+ 0.25	+ 0.29	+ 0.89
b. dry matter basis	%	12.5	+ 2.3	+ 4.1	+ 5.0	+ 4.3	+ 4.7
Specific gravity							
a. ingesta		0.9635	- 0.0566	- 0.0500	- 0.0255	- 0.0141	
b. liquid phase		1.019	+ 0.009	- 0.007	- 0.004	- 0.004	
pH		4.45	+ 2.14	+ 1.51	+ 1.75	+ 1.57	
Viscosity (centipoise)		1.85	+ 0.72	- 0.25	+ 1.43	+ 1.44	
Surface tension (dynes/cm.)		47.0	- 8.2	+ 0.8	+ 0.6	± 1.5	
Oven dry liquid residue %		4.0	+ 2.5	- 1.3	- 1.1	- 0.9	
Oven dry liquid residue Ash %		18.5	- 7.4	+ 9.6	+ 8.9	+ 8.4	

1 General mean values
2 Deviation in actual units