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Swine Technology – Nutrition Introductory Animal Nutrition
Michigan State University
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SWINE TECHNOLOGY

Farm Science Series — Extension Bulletin 536 — July 1966

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Nutrition

INTRODUCTORY ANIMAL NUTRITION

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ANIMAL NUTRITION is concerned with the application of scientific knowledge to the day-by-day feeding of livestock. To feed animals intelligently, one should have a thorough understanding of:

1. The differences in the digestive tract of the various species of livestock.
2. The kinds and sources of nutrients required by each class of livestock.
3. The physical and chemical processes which take place from the time feed is eaten until it is utilized by the animal.
4. The combination of feedstuffs that will most adequately supply the animal's needs.

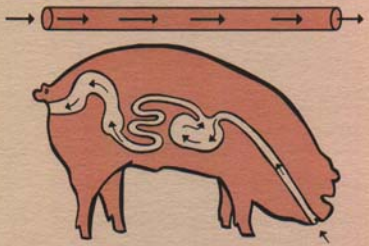
DIGESTIVE SYSTEMS

Animals Differ in Physical Makeup

Animals differ considerably in their ability to utilize various kinds of feeds. To grow rapidly and efficiently, swine must receive a high energy, concentrated grain ration, low in fiber. Cattle, on the other hand, can digest large quantities of fibrous feeds such as hay and grass. The differences in the digestive tract of cattle and pigs largely explain this.

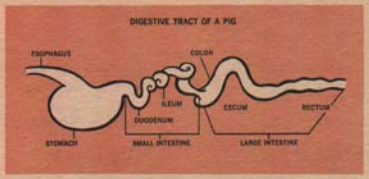
Meat animals are divided into two broad classifications — ruminants and nonruminants. Pigs are nonruminants. They have a single stomach, in contrast to ruminants which have a stomach that is divided into four compartments. Cattle and sheep fall in this category.

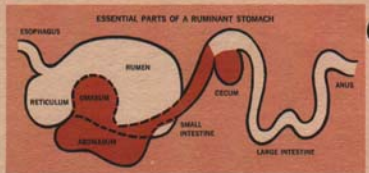
The digestive tract (or gastrointestinal tract) can be considered a continuous hollow tube — open at both ends — with the body built around it. The digestive tract is like a factory assembly line; but instead of building something, this factory takes things apart.



Although ruminants and nonruminants differ in their physical makeup, the job of the digestive tract is the same in all animals. It involves the breaking down of feedstuffs into simple chemical components so the animal can absorb and rearrange them into his own characteristic body composition.

Illustrations courtesy of T. W. Wichersham, Iowa State University.





Digestive Tract of the Pig

The digestive tract of the pig includes five main parts: the mouth, esophagus, stomach, small intestine and large intestine.

The first part of the tract is the MOUTH. Here the mechanical breakdown of feed begins. The chewing and grinding by the teeth increases the surface area of the feed particles. This permits the saliva produced in the mouth to surround and moisten the individual particles. Saliva contains an enzyme which starts the chemical action of digestion. The tongue acts as a plunger driving the food toward the esophagus.

THE ESOPHAGUS is a tube which carries food from the mouth to the stomach. A series of muscle contractions moves the food through the tube. At the end is a trap door called the CARDIA which prevents passage of food from the stomach back into the esophagus.

THE STOMACH is the first reaction chamber. It is a kind of "vat" where hydrochloric acid and enzymes produced by the stomach wall are added to the food. The stomach capacity of a 200-pound hog is approximately 2 gallons. Food which the stomach cannot digest and absorb completely passes on to the small intestine through the PYLORIC valve.

THE SMALL INTESTINE is a very complex tube which lies in a spiral. It is approximately 60 feet in length and has a capacity of $2^1/_2$ gallons. Material entering the intestine is called CHYME. At this point, it is in a fluid or semi-fluid state. Secretions from two important glands, the liver and pancreas, flow into the small intestine and are mixed with the chyme. These secretions contain enzymes that are vital to digestion. The cells lining the walls of the small intestine also produce enzymes that aid in digestion. It is in the small intestine that most of the final steps of digestion take place and is the region where most food nutrients are absorbed.

The first section of the small intestine is called the DUODENUM and it is in this region that the bile duct from the liver opens into the intestine. A few inches beyond, the pancreatic duct opens into the intestine in the area called the ILEUM.

A "blind gut" or CAECUM is found at the junction of the small intestine and large intestine. In most animals, the caecum is small and has little function. But it is very important in some animals such as horses and rabbits. In these animals, fibrous feeds are digested in the caecum.

The wall of the small intestine in healthy pigs has many tiny finger-like projections known as villi. These villi increase considerably the absorptive area of the intestine. In pigs troubled with scours or diarrhea, the villi contract and the cells become inactive. Thus, the feed passes through the tract rapidly and little of the nutrient material is absorbed.

THE LARGE INTESTINE collects materials that have escaped digestion and absorption previously. It is approximately 15 feet in length and has a capacity of slightly more than 2 gallons. One of its main functions is to absorb water. The large intestine also acts as a reservoir for the waste materials that constitute the feces.

Grass, hay, corn cobs, and other fibrous materials are hard to digest. They must be broken down by bacteria before they can be absorbed. Although some bacteria are present in the large intestine of the pig, these feeds pass through the tract so rapidly that most are eliminated partially or totally undigested.

Digestive Tracts of Ruminants

The digestive tract of cattle and sheep is constructed considerably different from that of the pig, which accounts for the fact that the two species of animals utilize entirely different types of rations.

The stomach of ruminants has four compart-

ments. The first compartment is the RUMEN or paunch. Next is the RETICULUM or honeycomb. Since there is no definite partition between the rumen and reticulum, they are generally thought of as one compartment. In this huge "vat," which in mature cattle holds 40 to 60 gallons, feed is stored for several hours while it is agitated, fermented, and digested.

Cattle eat rapidly, seldom pausing to chew. After they have taken in enough feed to fill their rumen, they usually find a comfortable spot to lie while they "chew their cud." This is the process known as rumination. Feed is regurgitated and rechewed. Saliva produced in the mouth is added and the feed is reswallowed.

Rumination is accomplished by a series of muscular contractions and gas pressure in the rumen and reticulum. The reticulum acts as a sort of pump, forcing the bolus up the esophagus into the mouth.

Cattle usually have six to eight rumination periods per day, totaling 5 to 7 hours. Dry feed, such as grass or hay, must be ruminated. Cattle cannot digest it otherwise.

The rumen and reticulum compartment contains millions of bacteria. These minute organisms feed on the fibrous material of forages and break it down so it can be utilized by the cattle.

The third compartment of the ruminant stomach is the OMASUM or manyplies. After the cud is reswallowed, it passes from the reticulum to the omasum. Here muscular contractions continue to grind the feed and squeeze out water.

The fourth and final compartment of the stomach is the ABOMASUM or "true stomach." This is the only compartment of the stomach where digestive juices are produced. It works similarly to the stomach in nonruminants such as the pig. Most ground grain feeds bypass the rumen and go directly to the abomasum for digestion.

Feed passage through the digestive tract of cattle is very slow, requiring almost four days. In the pig, only 24 to 36 hours are required. Pigs do not have a large compartment where feed can be stored while it is digested. Pigs must chew their feed for good digestion before it is swallowed, or the feed must be ground for them.

From this comparison, we can see why cattle are well suited for digesting large amounts of roughages, while pigs must be fed highly concentrated rations.

FEED NUTRIENTS

The science of animal nutrition has made great progress in unraveling some of the mysteries of the conversion of feed to food. However, this is an understandably complex subject and there is still much to be learned.

Plants have the ability to transform raw materials of the soil and air into forage and grain. For many years livestock producers relied solely on these materials as livestock feeds. As the science of animal husbandry has progressed, many supplemental sources of nutrients have been discovered.

Animals differ in the kinds and amounts of nutrients needed. The need is influenced by age, function, disease level, nutrient interaction, environment, etc. It has been established that the pig has a requirement for over 35 individual nutrients. Fortunately, not all are of practical concern. It should be emphasized that the pig has a requirement for nutrients and not for particular ingredients; he does not care what ingredients are used so long as the right nutrients are supplied.

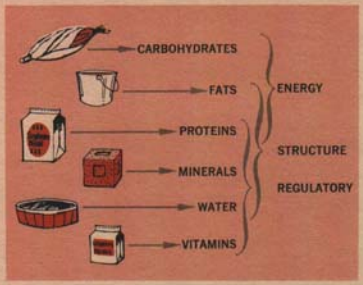
A farmer has a wide variety of ingredients to choose from in formulating a ration. Each ingredient contains not one but several nutrients in varying amounts. Because ingredients vary in price, and in amount and quality of nutrients contained, judgment must be exercised in the choice made.

The nutrient present in largest amount determines how an ingredient is classified. Soybean meal is classified as a protein supplement because it contains largely protein. There are five main categories of nutrients: (1) energy (carbohydrates and fats), (2) protein (amino acids), (3) minerals, (4) vitamins, and (5) water. Their function can be described as structural, regulatory, or producers of energy.

No one nutrient is more important than the other and all are essential. Each nutrient has a particular and specific role or function to perform in the body. If the nutrient is not supplied by the ration, the function (growth, reproduction, lactation, etc.) will obviously be impaired.

Energy Nutrients

Energy nutrients are the body's fuel supply. Every movement and activity of life involves the expenditure of the fuel — energy for breathing, heart action, digestion, muscular movement, as well as heat to keep the body warm. If more energy nutrients are consumed than is necessary to carry on vital functions, the excess is stored as body fat. In fact, this is



what we do when we finish hogs. More energy is fed than is needed for just growth and body maintenance and the animal lays down fatty tissue with the excess.

The main energy nutrients are carbohydrates. There are several forms of carbohydrates in plants. In feed analysis these forms are identified as either nitrogen-free-extract (NFE) or crude fiber. The NFE fraction includes the more soluble carbohydrates — sugars, starch, and some hemi-cellulose. All are very digestible, whereas in crude fiber we have cellulose and other very complex carbohydrates, all rather highly indigestible by the pig.

The kind of carbohydrate a feed contains determines its value as a source of energy for the pig. The cereal grains are widely used in swine feeding because of their very high NFE (60-70%) and low crude fiber.

Another group of energy nutrients are the fats and oils. Fat is a very concentrated source of fuel. A unit of fat will suppy approximately 2.25 times as much energy as a similar unit of carbohydrates. Therefore a feed that is high in fat, or a ration containing added fat, is much higher in energy value than a feed or ration low in fat.

Protein can also be used as a source of energy. However, because protein feeds are usually expensive, we find it more practical to use high carbohydrate (starch and sugars) feeds such as cereal grains as the primary source of energy in swine rations.

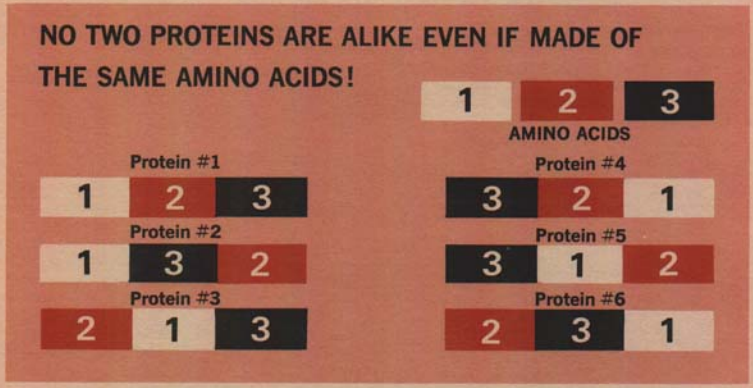
Energy values are expressed in feed tables in several ways, the most popular being digestible nutrients (TDN) and digestible energy (DE). Since energy expenditure can be measured as heat, modern nutritionists measure the energy needs of the animal as calories (a unit of heat). TDN values are converted to DE by assuming one pound of TDN to be equivalent to 2000 kilocaries of DE.

Proteins

While carbohydrates and fats are the principle sources of energy, proteins supply the building materials from which body tissue and many body regulators, such as enzymes and hormones, are made. Each protein is made up of several nitrogen compounds called AMINO ACIDS. They are the bricks and mortar of which bodies are built. No two proteins are alike, even if made of the same amino acids.

There are 22 or more amino acids and of these, 10 assume unusual importance and are called ESSENTIAL amino acids. An essential amino acid is one which the body cannot manufacture (synthesize) in sufficient quantity to permit maximum growth and performance. Therefore, they must be supplied in the ration. The essential and non-essential amino acids are identified as follows:

Essential	*Non-Essential*
Arginine	Alanine
Histidine	Aspartic Acid
Isoleucine	Citrulline
Leucine	Cystine
Lysine	Glutamic Acid
Methionine	Glycine
Phenylalanine	Hydroxyglutamic Acid
Threonine	Hydroxyproline
Tryptophan	Norleucine
Valine	Proline
	Serine
	Tyrosine



The pig has a specific requirement for each of the essential amino acids. Since amino acids are needed for the formation of every new cell, the need is most critical when growth is rapid. This makes ration formulation for the young pig very important, because the protein provided at this time must supply the amino acids for muscle growth (lean meat), internal organs, blood, bone, and all other parts associated with growth and development.

"Quality of protein" is a term used to describe the amino acid balance of protein. A protein is said to be of good quality when it contains all the essential amino acids in good proportion and amount, and to be of poor quality when it is deficient in either content or balance of essential amino acids. From this it is evident that the usefulness of a protein source depends upon its amino acid composition, because the real need of the pig is for amino acids and not for protein as such.

Although it is common practice to refer to "percent protein" in a ration, this term has little meaning unless there is knowledge concerning amino acids present in the ration fed. Quality is just as important as quantity. It is possible for pigs to perform better on a 12 percent protein ration (well-balanced for amino acids) than pigs on a 16 percent protein ration having a poor amino acid balance.

From a practical standpoint, we need to keep in mind that the problem of building a balanced ration for swine is centered around correcting the deficiencies of cereal grains. Although corn, wheat, and barley may contain from 8 to 12 percent protein, the protein is seriously deficient in two of the essential amino acids, tryptophan and lysine (see Table 1, page 11).

Previously we stated that when an excess of energy is consumed by the pig, it is stored in the form of fat. Protein is not stored in the body as such. If an excess of protein is fed, the unused nitrogen portion is discarded as urea in the urine and the carbon fraction is used as a source of energy. From an economic standpoint, it is unprofitable to feed more protein than is needed to meet the nutritional requirement of the pig.

Vitamins

Vitamins are complex organic compounds which are needed in minute amounts but are essential for health and normal body functions. Like amino acids, each has a specific function to perform. They are classified into two groups — fat soluble and water soluble. The two main fat soluble vitamins that are of practical concern are vitamins A and D. Riboflavin, niacin, pantothenic acid, and vitamin B_{12} are the water soluble vitamins that are most likely to be deficient in the ration. The body can keep reserves of the fat soluble vitamins stored in the body for a considerable length of time. Storage of the water soluble vitamins is depleted quite rapidly.

Vitamin A

The vitamin A needs of swine can be met by either vitamin A or carotene. Vitamin A does not occur free in nature. However, green plants and grains do contain a yellow pigment called carotene which can be converted to vitamin A by the animal body. The combination of vitamin A and carotene present in the ration is referred to as its vitamin A activity.

Deficiency symptoms in growing pigs are incoordination of movement, loss of control of the hind legs, weakness of the back, and night blindness. Sows may fail to come into heat, resorb their fetuses or have young born dead with various deformities and defects. Vitamin A is also needed for normal vision and growth of new cells which line the respiratory, digestive, and reproductive tracts.

Carotene is easily destroyed by the ultraviolet rays of the sun and by heat. The carotene content of corn and legume hay usually deteriorates quite rapidly in storage. Therefore, fish liver oil or a commercial synthetic concentrate is a more practical and reliable source of vitamin A.

Vitamin D

Vitamin D is sometimes called the "sunshine" vitamin, since the action of sunlight on the skin produces vitamin D. As long as hogs are exposed to the sun there is no danger of a deficiency. Living plants do not contain vitamin D. Plants that mature or are cut and cured in the sun contain some vitamin D as a result of radiation by sunlight. Pigs can utilize equally the vitamin D_2 form (from plant products) and the D_3 form (from animal products). Irradiated yeast (D_2) is the cheapest concentrate available.

Vitamin D is needed for efficient assimilation of calcium and phosphorus and therefore required for the growth of strong bones. A lack of vitamin D will result in stiffness and lameness, rickets, broken or deformed bones, enlargement of joints, and general unthriftiness.

Riboflavin (B_2)

Riboflavin is one of the B complex vitamins and is sometimes referred to as vitamin B_2. It functions in the body as a constituent of several enzyme systems. Therefore, a deficiency of riboflavin results in a wide variety of symptoms. In growing swine, a deficiency may cause loss of appetite, stiffness, dermatitis, and eye problems. Poor conception and reproduction have been noted in gilts fed riboflavin, deficient rations. Pigs may be born prematurely, dead, or too weak to survive.

Milk products, other animal proteins, alfalfa meal, and distillers' solubles are good sources. Commercial concentrates are also available.

Niacin

This vitamin plays an important part in body metabolism as a constituent of two coenzymes. A niacin deficiency results in "pig pellagra." This means diarrhea, rough skin, and retarded growth.

Recent research has shown that niacin, as it occurs in cereal grains, is in a "bound" form and in the case of corn may be nearly completely unavailable to swine. It should be assumed that all niacin in cereal grains and their by-products is completely unavailable. The protein source and content of the ration can also affect the niacin requirement since tryptophan, an amino acid, can be converted to niacin.

Pantothenic Acid

Pantothenic acid is a constituent of coenzyme A which functions in cellular oxidation of food materials. It also plays an essential role in fat and cholesterol synthesis. Corn-soybean meal rations are apt to be deficient in this vitamin.

A lack of this vitamin may result in poor growth, diarrhea, loss of hair, and a high stepping gait of the hind legs often referred to as "goose-stepping." Dried milk products, condensed fish solubles, and alfalfa meal are high in pantothenic acid. It is also available in concentrated form.

Vitamin B_{12}

Vitamin B_{12} was discovered in 1948 and was first known as the "animal protein factor." It derived its name from the fact that it is associated with sources of animal protein. This vitamin stimulates the appetite, increases rate of growth, improves feed efficiency, and is necessary for normal reproduction. It is found in animal protein sources, being particularly rich in fish solubles.

Other Vitamins

Other vitamins that are required by the pig but are either present in adequate amounts in practical rations or are synthesized in the body are vitamins C, E, K, thiamine, pyridoxine (B_6), choline, and biotin.

Minerals

Calcium, phosphorus, and salt (sodium and chloine) are the minerals needed in largest quantities by the pig. Others are required in small amounts and are known as "trace minerals." These are iron, copper, zinc, iodine, and manganese. Although minerals constitute a small percentage of the swine ration, their importance to the health and well-being of the pig cannot be minimized.

Calcium and Phosphorus

Calcium and phosphorus make up over 70 percent of the minerals in the body and are particularly important for skeletal growth and bone strength. Approximately 99 percent of the calcium and 80 percent of the phosphorus of the body are present in the bones and teeth.

The 20 percent of body phosphorus which occurs in the soft tissues is widely distributed and an important part of many enzyme systems that have essential functions in body metabolism. A deficiency of one or the other of these minerals can result in poor and inefficient gains, rickets, broken bones, and posterior paralysis.

A large excess of either calcium or phosphorus interferes with the absorption of the other. Thus it is important to have a suitable ratio between the two minerals. The most favorable calcium to phosphorus ratio is 1.2:1 to 1.5:1. As stated previously, vitamin D is necessary for the proper utilization of these two minerals.

There is more likely to be a deficiency of calcium than of phosphorus in swine rations, since cereal grains, which make up the bulk of swine rations, are quite low in calcium and fair sources of phosphorus. However, about one-half to two-thirds of the phosphorus in cereal grains is present in the form of phytin phosphorus, a form of phosphorus which may be poorly utilized.

Zinc

The requirement for zinc in the pig ration is very low but when high levels of calcium and/or phosphorus are fed, zinc utilization is impaired and the requirement is increased. A zinc deficiency results in a mange-like skin condition called "parakeratosis." Other symptoms are poor growth and inefficiency of feed conversion. This emphasizes the importance of feeding recommended levels of nutrients rather than excessive amounts.

Salt (Sodium and Chlorine)

Salt contains both sodium and chlorine, vital elements found in the fluids and soft tissues of the body. Salt improves the appetite, promotes growth, helps regulate body temperature, and is essential for hydrochloric acid formation in the stomach.

Until it became a general practice to add iodine to salt, hairless, dead pigs at birth were a common occurence in many regions of the country. Iodine is necessary for thyroxine production which functions in the control of metabolism. When a deficiency exists, the thyroid gland in the neck enlarges due to an attempt to make more thyroxine.

Iron and Copper

Iron and copper are necessary for the formation of hemoglobin in the red blood cells and the prevention of nutritional anemia. Hemoglobin serves as a carrier of oxygen throughout the body.

As the unborn pig develops, a supply of iron and copper is stored in the body. The amount stored varies greatly between pigs of the same litter. In no case is the amount adequate to keep the pig growing at its maximum for more than ten days or two weeks unless soil or some supplemental source of iron and copper are available during the suckling period.

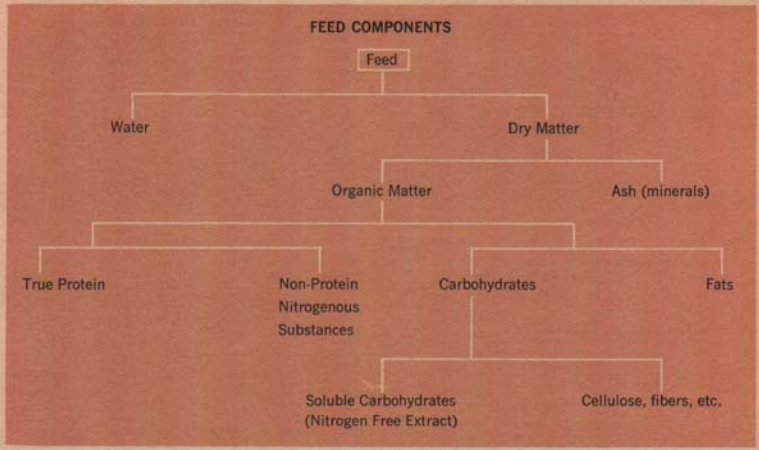
Sow's milk is very low in both iron and copper. Research to date has not uncovered any way of increasing the content in the milk. Once a pig begins to consume natural feedstuffs, the danger of anemia is practically nil because most feeds contain sufficient amounts of iron and copper to meet the pig's requirement.

Anemic pigs lose their appetite and become weak and inactive. In more advanced stages of the deficiency, the pig's breathing becomes heavy, a condition that is sometimes called "thumps." In this condition they are more susceptible to other diseases and parasites. Death may also occur in severe cases.

Water

Water is so common we seldom think of it as a nutrient. But water is the largest single part of nearly all living things. The body of a baby pig is about three-fourths water.

Water performs many tasks in the body. It makes up most of the blood which carries nutrients to the cells and carries waste products away. Water is



necessary in most of the body's chemical reactions. In addition, water is the body's built-in cooling system. It regulates body heat and acts as a lubricant.

Life on earth would not be possible without water. An animal can live longer without food than without water.

Feed Additives

In addition to the nutrients previously discussed, there are certain feed additives that have become somewhat standard ingredients of rations for growing swine. The most common of the additives are ANTIBIOTICS. They are not nutrients and thus cannot be considered as dietary essentials. Antibiotic feeding generally increases average daily gain, improves feed efficiency, improves uniformity of performance, and may reduce death loss during the growing period.

Regardless of the standard of sanitation practiced, within each swine facility there is an "environmental disease level." It may or may not be obvious to the casual observer, depending upon its degree of severity. The disease level may be present in many different forms. It may be confined to the gastro-intestinal tract or may be a localized or general systemic infection.

Just how antibiotics counter these unfavorable conditions and bring about improved performance in growing swine is not exactly known. However, they apparently do have an influence on the intestinal bacteria and improve the health of the animal, as unthrifty pigs respond more to antibiotic feeding than do healthy ones. It is believed that antibiotics function in the following manner:

1. They favor bacteria that synthesize known or unknown nutrients needed by the animal.
2. They inhibit the growth of nutrient-destroying micro-organisms.
3. They improve the availability and/or absorption of certain nutrients.
4. They inhibit the growth of organisms that produce excessive amounts of ammonia and other toxic waste products in the intestine.
5. They prevent or control certain diseases in the intestional tract and other parts of the body.

Pigs up to 100 pounds in weight give the greatest response to antibiotic feeding. There is some difference of opinion regarding the advisability of continuous "low-level" feeding of these growth stimulators. Some researchers maintain that low level feeding may sensitize the pig so he will not re-

spond favorably to higher therapeutic doses when serious disease outbreaks occur.

DIGESTION, ABSORPTION, and METABOLISM

In the discussion up to this point we have attempted to show how the digestive tract of swine and ruminants differ, and to enumerate the various nutrients required by swine for maximum growth and performance. Now we will take a look at the many physical and chemical changes that feeds must undergo in the process of digestion so that the nutrients can be absorbed and utilized by the pig. From a nutritional standpoint, all consumed feed is considered to be outside the body until it actually passes through the lining of the digestive tract and enters the circulatory system (blood and lymph).

Digestion in the Mouth

In pigs, carbohydrate digestion begins in the mouth. The first step is to break starch into disaccharides (combination of two simple sugars). There are three pairs of salivary glands in the pig's mouth which produce a mixed secretion known as saliva. Saliva contains an enzyme, ptyalin, that initiates the breakdown of starch.

The digestion of starch in the mouth is not complete but some simple sugars may be released, giving a sweet sensation with certain feeds. The chief function of saliva is to serve as a lubricant which allows swallowing of dry feed. Saliva may be produced even before feed enters the mouth, triggered by sounds from an automatic feeding system.

Digestion in the Stomach

The presence of food in the stomach stimulates the production of hydrochloric acid. Salt (sodium chloride) in the ration furnishes chlorine which combines with hydrogen to form this hydrochloric acid. The acid stops the action of salivary ptyalin which prevents further breakdown of starch until it reaches the small intestine.

Protein digestion begins in the stomach. The hydrochloric acid converts pepsinogen, produced in the stomach lining, into the protein-digesting enzyme, pepsin. Pepsin breaks the protein into short protein chains and prepares it for final digestion in the small intestine.

Although the main digestion taking place in the stomach is that of protein, some fat digestion does occur. Gastric lipase, an enzyme produced in the stomach, begins the digestion of fat into fatty acids and glycerol.

Liver and Gall Bladder

The liver is the largest gland in the body and has many important functions. One of these functions is concerned with digestion, namely, the secretion of bile. The gall bladder acts as a storage bag for bile and has its opening into the small intestine. Bile aids the digestion and absorption of fat in the small intestine by (1) assisting in fat emulsification, (2) activating pancreatic lipase, and (3) increasing the solubility of fatty acids.

Pancreas

The pancreas, located between the folds of the small intestine, is another important gland associated with digestion. It produces a secretion, pancreatic juice, and empties the secretion into the small intestine by means of the pancreatic duct. The pancreatic juice contains three protein splitting enzymes — trypsin, chymotrypsin, and carboxypeptidase. It also contains the fat-digesting enzyme, pancreatic lipase, and the carbohydrate-digesting enzyme, pancreatic amylase.

Digestion in the Small Intestine

It is in the small intestine that most of the final digestion of nutrients takes place. Enzymes produced by the cells lining the small intestine as well as enzymes secreted by the liver and pancreas complete the job of digestion. Disaccharides (carbohydrates) are broken down to simple sugars such as glucose, fats into fatty acids, and protein chains into amino acids. These are the end products of digestion.

Digestion of Protein

Special mention should be made regarding the digestion of protein because the process differs in ruminants and nonruminants. It has been pointed out previously that the pig has a requirement for amino acids, not protein. Unless the swine ration contains essential amino acids in the proper proportion, the pig will not perform satisfactorily. This is not true in the case of ruminants (cattle).

The paunch of cattle contains millions of bacteria. The structural material of these small organisms is protein (amino acids). The bacteria feed on the proteins in the paunch and convert them into ammonia gas. They can use this simple form of nitrogen to build amino acids for their own bodies, or

they can convert one amino acid into another. The bacteria can also utilize other nonprotein forms of nitrogen such as urea.

As the bacteria in the paunch die and pass to the small intestine, the protein in their bodies is digested and the amino acids absorbed into the blood stream of the steer. All the amino acids needed by cattle are present in the bacteria. Thus, there are no "essential" amino acids as in the case of swine. Unfortunately, the intestinal tract of swine does not contain these useful bacteria.

Absorption and Metabolism

Nutrients are of no value to the pig until they are broken down into their simplest components so they will pass through the wall of the digestive tract. The passage of digested nutrients into the blood stream is known as ABSORPTION.

Most absorption is from the small intestine. Both proteins and carbohydrates are absorbed mostly in the first part of the small intestine. The rate of absorption decreases as the food moves along. Most fat is also absorbed in the small intestine with the aid of liver bile.

After absorption, the end products of digestion are carried through the blood stream and most of them end up in the muscle cells or the liver. This is where much metabolism takes place. METABOLISM is concerned with the changes which take place in digested food after it has been absorbed and the use made of it by the animal.

During metabolism, most end products are broken down a little further to provide the specific type fuel or material that is needed by the cells. Some are used to replace worn-out cells and some to build new body tissue. Others are used for energy or stored for later use.

DETERMINING WHAT'S IN FEEDS

Research has provided the information that is available about the different kinds of nutrients. The scientist has developed methods by which the amount of each nutrient in a feed can be accurately determined. Knowing the nutrient content of a feed is very important to livestock raisers.

Water is one of the nutrients that is fairly easy to determine. A sample of feed is weighed and heated slightly above the boiling point of water. It is held at this temperature until the feed stops losing weight. The sample is again weighed and this weight is subtracted from the weight before heating. The difference between the two weights represents the amount of water or moisture in the feed. To find the percentage of water, divide the dry weight by the original weight.

Another fairly simple analysis is to find out how much mineral is in the feed. Minerals are inorganic chemicals. They do not contain carbon, so they will not burn. When feed is completely burned, a whitish-gray ash (mineral matter), is left. If the weight of the ash is divided by the original weight of the feed before burning, the percent mineral is obtained.

The determination of protein is more complicated. Recall that protein is made up of carbon, hydrogen, and oxygen plus nitrogen. Protein is about 16% nitrogen. Using certain chemical procedures, the amount of nitrogen in a feed can be determined. Multiplying this amount by 6.25 (16% nitrogen divided into 100 = 6.25) gives the amount of CRUDE PROTEIN in a feed. It is called crude protein because it includes all nitrogen compounds. There may be some nitrogen compounds in the feed which are not true proteins.

Another test is for the amount of fat in the feed. Since fat dissolves in ether, a sample of the feed is heated in ether for several hours. Then the feed is removed, and the ether is evaporated. The residue that is left is the fat, or ETHER EXTRACT.

It is important to know the fiber content of feed because it is hard to digest. Therefore, hog feeds with a high fiber content are less nutritious. A sample of feed is dissolved in a weak acid or alkali solution. Any material that will not dissolve is fiber and is considered to be indigestible by swine. It will be remembered that the cells lining the stomach secrete a weak acid solution that aids in the digestion of carbohydrates.

If the percentage of water, minerals, fat, fiber, and protein are added together, the total will be something less than 100 percent. This difference is referred to as NITROGEN-FREE EXTRACT. This extract includes the more soluble carbohydrates — sugars, starch and some cellulose. All of these are readily digested in the digestive tract.

By adding the digestive organic nutrients (protein, nitrogen-free extract and fat $\times$ 2.25) we can tell the "energy value" of a feed. TDN — total digestible nutrients — is the term used.

This material has been prepared to give swine producers a fundamental background in animal nutrition. How the information may be applied will be discussed in the swine nutrition series to follow.

Table 1 — Energy, Protein, Amino Acid Content of Common Swine Feeds

	Dig. Energy K cal.	TDN %	Crude Fiber %	Protein %	Argi-nine	Histi-dine	Isoleu-cine	Leucine	Lysine	Methi-onine	Cystine	Phenyl-alanine	Threo-nine	Trypto-phan	Valine
Energy Sources															
Barley	1400	70	6	11.6	.58	.30	.52	.82	.50	.18	.21	.66	.44	.16	.67
Corn	1600	80	2	9.0	.38	.22	.35	1.06	.24	.19	.13	.41	.31	.06	.44
Oats	1300	65	11	11.8	.70	.23	.55	1.00	.43	.15	.21	.65	.40	.15	.62
Wheat	1600	80	3	12.7	.75	.37	.60	0.99	.42	.21	.24	.77	.45	.21	.68
Sorghum, milo	1560	78	2	11.1	.43	.30	.50	1.26	.27	.10	.15	.48	.36	.12	.56
Bakery waste	1600	80	1	10.0	—	—	—	—	—	—	—	—	—	—	—
Fat, tallow	3990	199	—	0											
Protein Sources															
Cottonseed meal	1460	73	12	40.5	4.20	1.02	1.59	2.51	1.66	0.62	0.84	2.11	1.38	0.59	1.97
Linseed meal	1360	68	9	35.7	3.16	0.71	1.66	2.11	1.21	0.63	0.61	1.68	1.32	0.57	2.02
Soybean meal	1500	75	6	45.4	3.28	1.13	2.52	3.54	2.86	0.59	0.73	2.15	1.87	0.77	2.42
Fishmeal	1240	62	1	61.1	3.52	1.57	3.32	4.79	5.44	1.80	1.10	2.55	2.51	0.64	3.78
Meat scrap	1300	65	2.5	51.0	3.63	0.87	1.70	3.14	2.98	0.68	0.64	1.80	1.66	0.36	2.46
Tankage	1360	68	2	60.5	3.51	1.75	1.63	5.50	3.89	0.67	0.50	2.72	1.98	0.49	3.71
Skimmilk, dry	1600	80	0	34.0	1.15	0.84	2.15	3.18	2.45	0.85	0.31	1.67	1.61	0.47	2.36
Alfalfa meal	600	30	28	17.3	0.78	0.48	0.82	1.17	0.70	0.31	0.30	0.82	0.64	0.33	0.88
Requirement															
25-50 lb. pig	1600	80		16-18	.20–.25	.20–.23	.52–.55	.60–.67	.74–.75	.30–.35	0.20	.54–.55	.45	.12–.13	.46–.50
Sample Ration:															
Corn 75															
Soybean m. 22															
Mineral, Vitamin, etc. 3	1530	76.5	3	16.7	1.01	0.41	0.82	1.57	0.81	0.27	0.26	0.78	0.64	0.21	0.86
100%															

1. Information from NRC Publication No. 1192, Illinois Circular 866, and Feed Bag Red Book
2. Cystine can be used to meet 40-50% of the methionine requirement; also tyrosine can replace 30% of the need for phenylalanine

GLOSSARY

Digestion is the process which breaks down food before it is absorbed from the gastro-intestinal tract into the body. It includes all the activities of the digestive tract and its glands.

Metabolism concerns food after it has been digested. It is the changes which take place in digested food after it has been absorbed from the digestive tract. In metabolism, body tissue is built and energy is used.

Ruminants are animals with more than one compartment in their stomachs. They are sometimes thought of as having four stomachs. Cattle and sheep are ruminants. Only ruminants chew a "cud."

Nonruminants are animals that have one stomach. Pigs and horses are nonruminants.

Enzymes are digestive juices which act as catalysts — in other words, they speed up chemical reactions in digestion.

Crude protein (total protein) is a measure of all the nitrogen-containing compounds in a feed. Some nitrogen compounds are not true proteins, so this is only a rough measure.

Digestible protein tells approximately the amount of true protein in a feed. In roughage rations, it is figured at 60 percent of the crude protein. In high-concentrate rations it is 75 percent of the crude protein.

Ether extract is a term applied to the material that can be dissolved out of a sample of feed heated in ether. Fat has 2.25 times the energy value of carbohydrates. When the energy value of a feed is being calculated, the ether extract is multiplied by 2.25.

Fiber content of a feed is the amount of hard-to-digest carbohydrates. Most fiber is made up of cellulose.

Nitrogen-free extract (NFE) of a feed indicates the more easily digested carbohydrate. The NFE is mostly starch and sugars.

Calorie is a unit of heat.

Total digestible nutrients (TDN) is the energy value of a feed. It is the sum of the digestive organic nutrients (protein, nitrogen-free extract, and fat $\times$ 2.25).

Digestible energy (DE) is another method of expressing the energy value of a feed. Total digestible nutrients are converted to digestible energy by assuming one pound of TDN to be equivalent to 2000 kilocalories of digestible energy.

Essential amino acids are those amino acids which cannot be made in the body from other substances or which cannot be made in sufficient quantity to supply the animal's needs.

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