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Swine Technology – Nutrition Introductory Animal Nutrition
Michigan State University
Cooperative Extension Service
Farm Science Series

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SWINE TECHNOLOGY

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COOPERATIVE EXTENSION SERVICE
MICHIGAN STATE UNIVERSITY

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 most efficiently, 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.

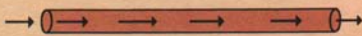
DIGESTIVE SYSTEMS

Animals Differ in Physical Makeup

Animals differ considerably in their ability to use 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 pasture. The differences in the digestive tract of cattle and pigs largely explain this.

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

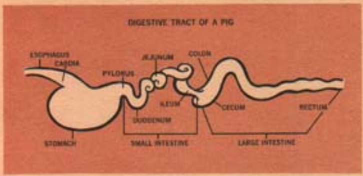
The digestive tract (or gastrointestinal tract) can be considered a continuous hollow tube — open at both ends — with the body built around it. The digestive tract is like a factory assembly line, but instead of building something, this factory takes things apart.

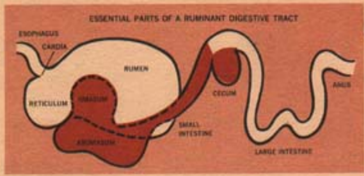


Although ruminants and nonruminants differ in their physical makeup, the job of the digestive tract is the same in all animals. It breaks down feedstuffs into simple chemical components so the animal can absorb and re-arrange them into its own characteristic body composition.

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 digestion of starch. 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 valve 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. The most notable addition is pepsin, which initiates protein digestion. The stomach capacity of a 400-pound hog is approximately 2 gallons. Food which the stomach cannot digest and absorb 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 in the mature hog and has a capacity of 2½ gallons. Material entering the intestine is called CHYME. At this point, it is in a fluid or semi-fluid state. The wall of the small intestine in healthy pigs has many tiny finger-like projections known as villi. These villi considerably increase the absorptive area of the intestine. In pigs troubled with scours, the villi may atrophy or in severe cases degenerate and slough off and greatly reduce the absorptive capacity of the small intestine.

The first section of the small intestine is called the DUODENUM and it is in this region that the secretions from the liver and pancreas flow into the small intestine and are mixed with the chyme. The secretion from the liver is collected in the gall bladder and passes through the bile duct into the small intestine just beyond the pyloric valve. This secretion contains bile acids, cholesterol and lecithin which have a saponifying and emulsifying action on fat.

The secretion from the pancreas passes through the pancreatic duct into the first portion of the small intestine. This secretion contains enzymes which are vital to the digestion of carbohydrates, fat and protein. The cells lining the walls of the duodenum also produce enzymes that aid in digestion. All intestinal digestion begins in the duodenum and continues into the second and third sections of the small intestine, called the JEJUNUM and the ILEUM, where most food nutrients are absorbed. At the end of the ileum, undigested nutrients and secretions pass on to the large intestine through the ILEOCECAL VALVE.

The LARGE INTESTINE collects materials that have escaped digestion and absorption previously. It is approximately 15 feet in length in the 400-pound hog 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.

A "blind gut" or CECUM is found at the beginning of the large intestine. In most animals, the cecum 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 cecum.

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 compartments. 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.

Regurgitation is accomplished by a series of muscular contractions and pressure in the rumen and reticulum. Movement of the cud from the rumen and reticulum into the esophagus is accomplished by an inspiratory effort with a closed glottis. This effort causes a sharp drop in thoracic and esophageal pressure and since the rumen pressure is greater, the cud is aspirated through the cardia into the esophagus and quickly carried to 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.

The rumen and reticulum compartment contains billions of bacteria and protozoa. These minute organisms feed on the fibrous material of forages and break it down so it can be utilized by 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. Much ground grain passes through the rumen quickly and goes to the abomasum for digestion.

Feed passage through the digestive tract of cattle is generally 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 40 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.

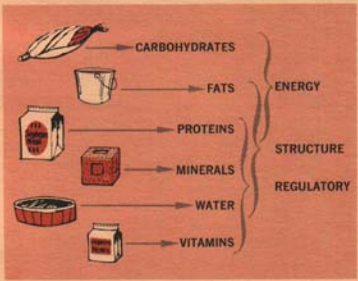
A farmer has a wide variety of ingredients to choose from in formulating a ration. Each ingredient may contain not one but several nutrients in varying amounts. Because ingredients vary in price, and in amount and quality of nutrients contained, judgment must be exercised in the choice made.

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 functions can be described as structural, regulatory, or producers of energy.

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

TABLE 1. Digestive tract capacities of man, pig, horse and cattle.

	Man	Pig	Horse	Cattle
Bodyweight, pounds	165	400	1000	1300
Stomach, quarts	1	8	8	160
Small intestine, quarts	4	9	27	65
Cecum, quarts	0	1	14	10
Large intestine, quarts	1	9	41	25
Total digestive tract, quarts	6	27	90	260



Energy

Energy is the body's fuel supply. Every movement and activity of life involves the expenditure of fuel — energy for breathing, heart action, digestion, muscular movement, as well as heat to keep the body warm. If more energy is consumed than necessary to carry on vital functions, the excess is stored as body fat. In fact, this is what is done to finish hogs. More energy is eaten than needed for growth and body maintenance and the animal lays down fatty tissue with the excess.

The main nutrients supplying energy 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 hemicellulose. All but hemicellulose are very digestible. Crude fiber, however, contains cellulose, hemicellulose and lignin, which are all highly indigestible by the pig.

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

Another group of energy nutrients are the fats and oils. Fat is a very concentrated source of fuel and will supply approximately 2.25 times as much metabolizable energy as an equal weight of carbohydrates. Therefore, a feed high in fat, or a ration containing added fat, is much higher in energy value than a feed or ration low in fat. In addition to supplying energy, certain dietary fats supply essential fatty acids, most commonly linoleic acid.

Energy values are generally expressed in feed tables as total digestible nutrients (TDN), digestible energy (DE) or metabolizable energy (ME). Since energy expenditure can be measured as heat, modern nutritionists measure the energy needs of the animal in calories (a unit of heat). TDN values are converted to DE by assuming one pound of TDN is equivalent to 2,000 kilocalories of DE. ME values are calculated from the formula

$$ME = DE \frac{(96 - 0.2 \times \%\ \text{crude protein})}{100}$$

This formula indicates that ME values are somewhat less than 96 percent of DE values.

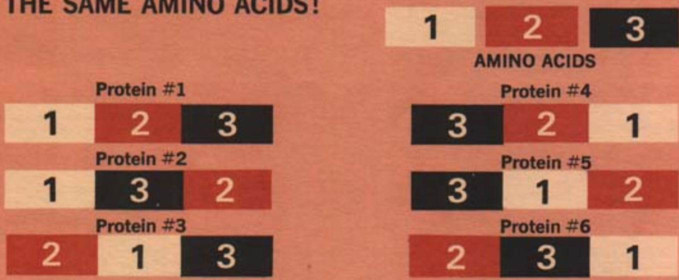
Proteins

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 23 or more amino acids and of these, 10 assume unusual importance for the growing pig 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, it 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	Cysteine
Lysine	Cystine
Methionine	Glutamic acid
Phenylalanine	Glycine
Threonine	Hydroxyglutamic acid
Tryptophan	Hydroxyproline
Valine	Norleucine
	Proline
	Serine
	Tyrosine

NO TWO PROTEINS ARE ALIKE EVEN IF MADE OF THE SAME AMINO ACIDS!



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 information about the amino acids present. 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 on a 16 percent protein ration having a poor amino acid balance.

From a practical standpoint, remember 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, this protein is seriously deficient in the essential amino acid, lysine, and corn is also limiting in tryptophan.

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 in appreciable amounts. 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 needed to meet the nutritional requirements 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 primary fat soluble vitamins that are of practical concern are vitamins A, D and E. Vitamin K may be of concern under some circumstances. Riboflavin, niacin, pantothenic acid, and vitamin B_{12} are the water soluble vitamins most likely to be deficient in the ration. Choline, usually listed with the water soluble vitamins, is also frequently added to practical swine diets. The body can keep reserves of the fat soluble vitamins stored in the body for a considerable length of time. Stores of the water soluble vitamins are 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 in plants. However, green plants and corn 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 signs 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, 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 a compound in 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 vitamin D_2 (from plant products and D_3 (from animal products). Irradiated yeast is a good source of vitamin D_2.

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.

Vitamin E

Vitamin E is a "biological antioxidant" which protects unsaturated fat against oxidation. A number of compounds called tocopherols have vitamin E activity, with the most active being alpha-tocopherol. Since cell membranes in the animal body contain unsaturated fat, a vitamin E deficiency may result in oxidative damage to the cell. This is manifested in the pig by liver necrosis, pale muscle, mulberry heart, edema and sudden death.

Vitamin E is widely distributed in plants, and leafy forages are a good source, particularly alfalfa. Grains also are fair sources of vitamin E, particularly the germs. Most of the vitamin E is removed from soybeans with the oil in the manufacture of soybean meal, thus, soybean meal is a poor source of this vitamin.

The trace element selenium also functions in the body with vitamin E in protecting the body against oxidative damage. The need for vitamin E is more acute when swine feeds are low in selenium. Thus, in areas such as Michigan where feed ingredients are low in selenium and where a majority of swine are reared in confinement without access to forages, supplemental vitamin E or selenium or both are important.

Vitamin K

Vitamin K is one of the essential factors necessary in metabolism for proper blood clotting. Generally, sufficient amounts of vitamin K are synthesized by bacteria in the digestive tract to meet the need of swine. However, this synthesis may be inadequate in situations where high antibiotic levels are used or where clotting inhibitors may be present from molds in the feed.

Riboflavin

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 co-enzymes. A niacin deficiency results in "pig pellagra." This is characterized by 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 almost 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 co-enzyme A which functions in 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 called "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. Commercial concentrates are also available.

Choline

Choline functions as a "methyl donor" in metabolism and can lower the requirement of methionine to the extent that methionine is used for this function. It is also a constituent of some important phospholipids in the body. While choline is probably present in adequate amounts in most practical swine rations, studies have shown a benefit in reproductive performance of sows receiving supplemental choline throughout gestation. Also, since proteins supply most of the choline in swine rations, a reduction in ration protein when synthetic lysine is incorporated into the ration may at the same time create a choline-deficient ration.

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, thiamin, pyridoxine (B_6), biotin and folic acid.

Minerals

Calcium, phosphorus, and salt (sodium and chlorine) are the supplemental 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, selenium 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 is 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.

It is important to supplement both calcium and phosphorus in swine rations. Cereal grains, which make up the bulk of swine rations, are quite low in calcium and only fair sources of phosphorus. Furthermore, 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.

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 pH, and is essential for hydrochloric acid formation in the stomach.

Zinc

The requirement for zinc in the pig ration is very low but when high levels of calcium 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 inefficient feed conversion. This emphasizes the importance of feeding recommended levels of nutrients rather than excessive amounts.

Iodine

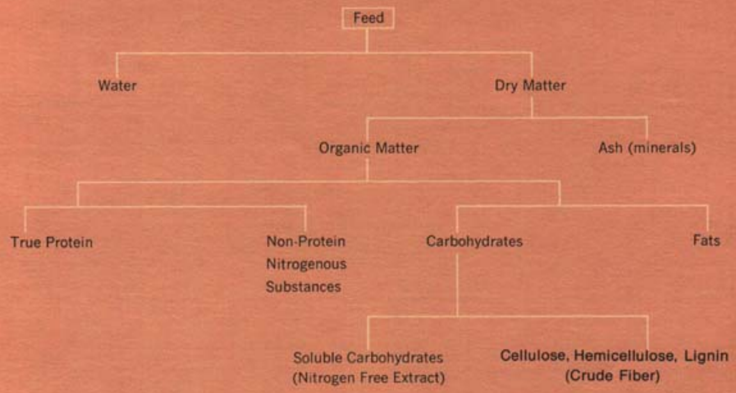
Until it became a general practice to add iodine to salt, hairless, dead pigs at birth were a common occurrence in many regions of the country. Iodine is necessary for thyroxine production which functions in the control of metabolism. When a deficiency exists, the thyroid gland in the neck enlarges in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

Iron and Copper

Iron and copper are necessary for the formation of hemoglobin in the red blood cells and 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 var-

FEED COMPONENTS



ies greatly between pigs of the same litter. In no case is the amount of iron adequate to keep the pig growing at its maximum for more than ten days or two weeks after birth unless soil or some supplemental source of iron is available during the suckling period.

Sow's milk is very low in iron and research to date has not uncovered any way of increasing its iron content. Once a pig begins to consume natural feedstuffs, the danger of anemia is practically nil because most feeds contain sufficient amounts of iron 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 labored, a condition that is sometimes called "thumps." In this condition they are more susceptible to other diseases and parasites. Death may occur in severe cases.

Selenium

Selenium functions with glutathione peroxidase, an enzyme which enables the tripeptide glutathione to perform its role as a biological antioxidant in the body. This explains why deficiencies of selenium and vitamin E result in similar signs. Thus, the deficiency signs described previously for vitamin E may be signs of vitamin E and/or selenium deficiency.

Selenium has recently been approved by the FDA for addition as sodium selenite or sodium selenate at a level of 0.1 ppm of selenium in all swine rations.

Manganese

Manganese functions with many enzymes in soft tissue metabolism and also in bone development. While manganese is usually present in adequate amounts without supplementation in most swine rations, it may not be adequate for optimum reproductive performance of sows.

Other minerals

Other mineral elements required by the pig but present in adequate amounts in practical rations are: magnesium, potassium, sulfur, cobalt, chromium, tin, molydenum, nickel, vanadium, silicon and fluorine.

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 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. Antibiotics may function as follows:

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 intestinal tract and other parts of the body.

Pigs up to 100 pounds in weight give the greatest response to antibiotic feeding.

DIGESTION, ABSORPTION AND METABOLISM

So far, 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, amylase, 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

TABLE 2. Digestive enzymes and their activity

Food Source	Enzyme	Origin	Product of digestion
Carbohydrates			
Starch	Amylase	Saliva, pancreas	Maltose
Maltose	Maltase	Small intestine	Glucose
Lactose	Lactase	Small intestine	Glucose, galactose
Sucrose	Sucrase	Small intestine	Glucose, fructose
Fats and oils			
Lipids	Lipase	Stomach, pancreas	Monoglycerides, glycerol, fatty acids
Proteins			
Milk protein	Rennin	Stomach	Coagulates milk protein
Protein	Pepsin + HCl	Stomach	Polypeptides
Polypeptides	Trypsin	Pancreas	Peptides
Polypeptides	Chymotrypsin	Pancreas	Peptides
Peptides	Carboxypeptidase	Pancreas	Peptides, amino acids
Peptides	Amino peptidase	Small intestine	Peptides, amino acids
Dipeptides	Dipeptidase	Small intestine	Amino acids
Nucleoproteins	Nucleotidase	Small intestine	Nucleotides, nucleosides
	Nucleosidase	Small intestine	Purines, pyrimidines, H_3PO_4

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 amylase 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 secretions of the liver and pancreas complete the job of digestion. Disaccharides (carbohydrates) are broken down to simple sugars such as glucose, fats into monoglycerides, glycerol and fatty acids, and protein 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 rumen of cattle contains billions of bacteria and protozoa. The structural material of these small organisms is protein (amino acids). The microorganisms feed on the proteins in the rumen and split off ammonia. 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 microorganisms in the rumen die and pass to the small intestine, the protein in their bodies is digested and the amino acids absorbed into the blood stream. All the amino acids needed by cattle are present in the microorganisms. Thus, there are no "essential" amino acids as in the case of swine. Unfortunately, the digestive tract of swine does not contain a large population of 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 and lymph is known as ABSORPTION. Most absorption is from the small intestine.

After absorption, the end products of digestion are carried through the blood or lymph 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 use made of it by the animal.

During metabolism, most end products are modified 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, subtract the dry weight from the original weight; divide this difference by the original weight and multiply by 100.

Another fairly simple analysis is the determination of mineral content of feed. Minerals are inorganic chemicals. They do not contain carbon, so they will not burn. When feed is completely burned, a whitish-grey ash (mineral matter), is left. If the weight of the ash is divided by the original weight of the feed and this quotient multiplied by 100, 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 percent of nitrogen in a feed can be determined. Multiplying this percent by 6.25 (16% nitrogen divided into 100 = 6.25) gives the percent 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 percent 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 crude fat, or ETHER EXTRACT. If the weight of the ether extract is divided by the weight of the original feed sample and this quotient multiplied by 100, the percent of crude fat is obtained. While most of the crude fat in grains and other concentrates is composed of true fats or triglycerides, much of the crude fat in forages is composed of waxy substances which are not true fats and are poorly digested.

It is important to know the fiber content of feed because fiber is poorly digested by the pig. Therefore, swine feeds with a high fiber content are less nutritious. A sample of feed is dissolved in weak acid and alkali solutions. The insoluble material is then dried, weighed and burned. The weight loss of insoluble residue during the ashing process is referred to as crude fiber and is considered indigestible by swine.

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 hemicellulose and lignin. All of these except hemicellulose and lignin are readily digested in the digestive tract.

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

GLOSSARY

Atrophy is a wasting away of a part of the body due to improper nourishment or hormone levels or the effects of disease.

Calorie is a unit of heat or energy.

Crude protein is a measure of all the nitrogen-containing compounds in a feed and is calculated multiplying percent nitrogen times 6.25.

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.

Digestible protein is the amount of crude protein in a feed which can be digested and absorbed. 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.

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.

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

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.

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 or proteins.

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

Metabolism concerns food after it has been digested. It includes 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.

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

Nonruminants are animals that do not have a rumen. Pigs and horses are nonruminants.

Ruminants are animals with more than one compartment in their stomachs, including a rumen where extensive fermentation takes place. They are sometimes thought of as having four stomachs. Cattle and sheep are ruminants. Only ruminants chew a "cud."

Saponification is the process of forming soaps from fat.

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

The material in this bulletin has been prepared to give swine producers a fundamental background in animal nutrition. How the information may be applied will be discussed in Extension Bulletin 537 entitled "Nutrition: Swine Feeds and Feeding." Both of these publications are available through your county Cooperative Extension Service or from the MSU Bulletin Office, P.O. Box 231, East Lansing, MI 48824.

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