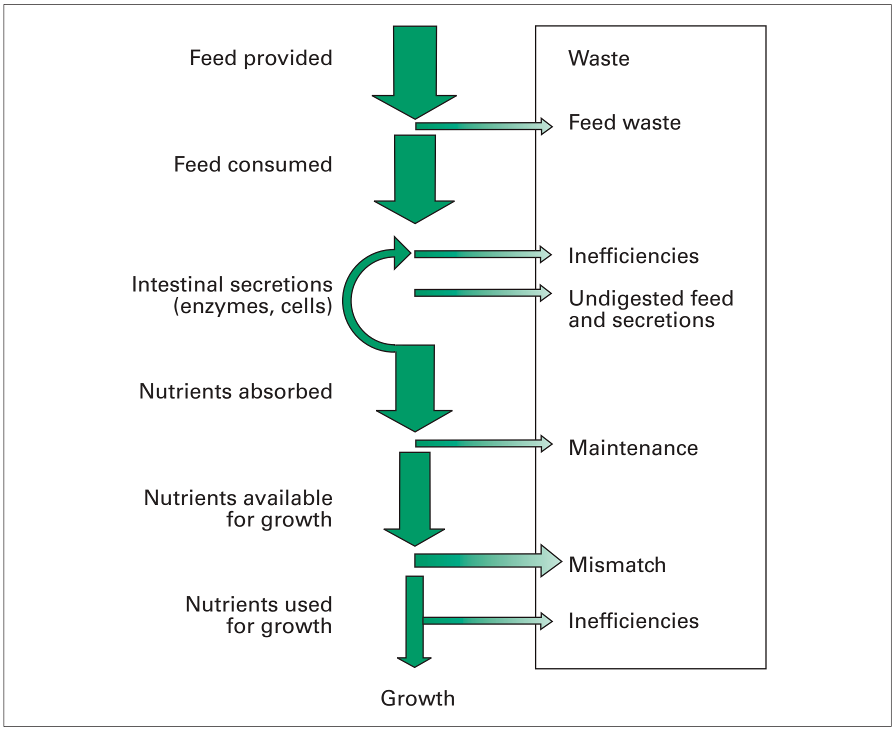

Figure 10-1. Nutrient use (see text for details). Right arrows depict waste production. The size of the arrows is approximately indicative of the N flow through each branch under typical conditions.

Feed waste is typically considered to account for 2% to, in extreme cases, 20% of the feed provided to the animals, and it is an expensive loss of nutrients.

Nutrient Use

When pigs eat feed, several processes need to happen before the animal benefits from the nutrients contained in the feed (Figure 10-1). Before nutrient waste can be reduced, the steps involved in getting the nutrients from the feed bin into the animal and converted into lean meat must be understood. An understanding of the steps where losses occur is even more crucial.

The first waste problem occurs when the feed is consumed. Pigs are sloppy eaters; feed sticks to their noses and chin, and they like to root through the feed. As a result, feed is pushed out of the feeder or is carried around, ultimately ending up in the manure storage area (pit). Feed waste is typically considered to account for 2% to, in extreme cases, 20% of the feed provided to the animals, and it is an expensive loss of nutrients.

Upon consuming the feed, the pig briefly chews it. During chewing, the pig secretes saliva containing enzymes and minerals. This process is rather obvious when it occurs in the mouth, but a similar process occurs throughout the entire digestive tract; enzymes/proteins are secreted together with water and minerals that aid in the digestion and transport of the feed. These secretions occur continuously at a low (basal) rate, but upon eating, secretions increase dramatically, with the increase depending on the feed actually consumed. Typically, for every pound of protein that a pig consumes, it secretes about 1/3 of a pound of protein in the form of enzymes and other proteins into the digestive tract.

Secreted enzymes break down the feed, and then amino acids (the building blocks for protein), carbohydrates (sugars for energy), and fats (for energy and essential fatty acids) are taken up (absorbed). The process of taking up the nutrients makes the nutrients available to the animal, and the fraction of the nutrients that are taken up is called the digestible fraction. The digestibility of a typical corn-soybean meal (C-SBM) feed is 93%.

In addition to not being able to digest all of the nutrients that are consumed, the animal also loses a portion of the enzymes and nutrients that are secreted into the digestive tract. The material lost is called the endogenous loss and is equivalent to approximately 8% of the dietary protein consumed.

The endogenous losses and the undigested feed fraction end up being excreted in the feces. Prior to excretion, though, they are subjected to bacterial fermentation in the large intestine. This fermentation process leads to the conversion of some of the carbohydrates (fiber) to volatile fatty acids, such as acetic, propionic, and butyric acid. These compounds can be taken up from the large intestine and used as an energy source by the animal. However, if these compounds are excreted with the feces, they can contribute to odor. Butyric acid, as an example, is particularly unpleasant.

Proteins are fermented in the large intestines as well, producing a host of odorous compounds, including para-cresol, hydrogen sulfide, putrescine, cadaverine, and skatole. In effect, most of the compounds responsible for malodor that swine emit can be traced to protein fermentation, either in the large intestines or in the excreta.

When animals produce enzymes and other secretions for the digestive process, inefficiencies in their production occur (like sawdust when cutting pieces of wood from a tree trunk). These inefficiencies lead to amino acids being broken down to ammonia, which ultimately ends up being excreted (typically as urea with the urine). Typically, 10% of the dietary N is excreted because of these inefficiencies.

So far, we have lost 25% of the dietary protein: 7% was not digested, 8% was lost in the form of endogenous (intestinal) losses, and another 10% was lost due to inefficiencies associated with the digestive effort. The remaining 75% of the protein is considered bio-available (available for biological functions). However, these figures are for typical diets; diets relying strongly on poorly digestible or difficult to digest feedstuffs will have a lower bio-availability.

Table 10-1. True ileal amino acid profiles for maintenance and for growth, expressed relative to lysine (based on 1998 NRC, in which lysine is used as the reference amino acid).

Amino Acid	Maintenance	Growth
Lysine	100	100
Threonine	151	60
Tryptophan	26	18
Methionine	28	27
Sulfur amino acids	123	55
Valine	67	68
Leucine	70	102
Isoleucine	75	54
Histidine	32	32
Phenylalanine	50	60
Phenylalanine + Tyrosine	121	93
Arginine	-200	48

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When evaluating a diet's nutritional value, it is important to consider the availability of the amino acids and how the profile of available amino acids matches the animal's amino acid requirements. The latter can be determined based on the maintenance requirement (thus the animal's weight) and lean gain.

Usually, for every pound of protein that the pig grows, approximately 1/3 of a pound of protein is broken down, resulting in 1/20 of a pound of N being excreted as waste… .

Pigs need amino acids both for maintenance and for growth. Amino acids for maintenance typically end up being broken down (burned for energy) after serving their function, leading to the production of waste N. Fortunately, only a small portion of the amino acids ingested are required for maintenance in growing pigs (in nonproducing animals, maintenance and endogenous losses forms the sole requirement for amino acids). The amino acid requirement for maintenance is also very specific for the different amino acids (Table 10-1). Animals have a low maintenance need for lysine, while the maintenance need for threonine is much larger. The amino acid requirement for maintenance is a function of the animal's weight; a baby pig requires very little, while a market-weight hog requires approximately 25 times as much. The composition of the amino acid mix required, though, is virtually constant; both the baby pig and the market-weight hog require more threonine than lysine for maintenance.

Growth is the increase in mass and size of muscle and organs (such as the liver and heart). The proteins that compose muscles and organs have a specific composition. For example, lysine makes up 7% of the protein. As a result, amino acids required for growth have a specific profile as well (Table 10-1), which is considerably different from the maintenance requirement.

By combining the amino acid profile required for growth with that required for maintenance, the animal's amino acid requirement can be calculated (taking into account the above indicated losses). For young, fast-growing animals, the amino acid requirement will be close to the "growth" profile. For older, slower-growing animals, the amino acid requirement will be close to the "maintenance" requirement. For example, for a 5-pound pig, 2.6% of the lysine requirement and 6.1% of the threonine requirement is for maintenance, while for a 250-pound pig, 8.8% of the lysine requirement and 19.4% of the threonine requirement is for maintenance.

A nutritionist's objective is to make diets that meet this combined profile by combining ingredients such as corn, soybean meal, meat and bone meal, and synthetic amino acids, taking into consideration losses occurring in the digestive process. If an animal does not receive enough of one amino acid, the animal's growth will be compromised. The maintenance needs are obligatory (the animal cannot function properly without), and thus amino acids are first used for maintenance with the remainder available for growth. As indicated, the ratio of amino acids required for growth is fixed. If a deficiency occurs in one amino acid, the accretion (growth) of all other amino acids will be compromised as well (the strength of a chain is determined by its weakest link).

When evaluating a diet's nutritional value, it is important to consider the availability of the amino acids and how the profile of available amino acids matches the animal's amino acid requirments. The latter can be determined based on the maintenance requirement (thus the animal's weight) and lean gain.

Growing muscle is not very efficient. Animals continuously build new proteins but also break down old proteins. Theoretically, when breaking down protein, amino acids are released, and thus no loss of amino acids would be expected from this process (only a waste of energy). However, inefficiencies occur in the process of breaking down protein (like sawdust when cutting wood), and the result of these inefficiencies is that amino acids are converted to energy and N excretion. Usually, for every pound of protein that the pig grows, approximately 1/3 of a pound of protein is broken down, resulting in 1/20 of a pound of N being excreted as waste (mainly in the urine). A typical

125-pound pig growing 2.2 pounds per day grows about 0.3 pound of protein per day (most growth is actually water) and thus excretes about 0.015 pound of N per day linked to this protein growth.

Amino acids that are absorbed but not used for growth ultimately end up being degraded. In this degradation, usable energy is formed as well as ammonia. This ammonia is typically excreted in the urine as urea. Urea is very unstable and upon mixing with feces is broken down to ammonia, which volatilizes, leading to ammonia emission from animal production facilities.

For minerals, the story of digestion and utilization is very similar, but each of the minerals has its own peculiarities. Losses occur during the digestive process because not all of the minerals in the feed can be digested and also because endogenous losses of minerals occur. In addition, the uptake (absorption) of some of the minerals is regulated to prevent toxicity problems. For example, animals will only take up the amount of calcium that is required for proper functioning. For minerals such as copper and zinc, uptake is not as tightly regulated, but when excesses are consumed, they are secreted back into the intestines: for zinc via pancreatic secretions and for copper via bile. The “apparent” digestibility of these minerals is thus affected by the quality of the feed but also by the quantity of the mineral contained in the feed. Zinc and copper can also accumulate in tissues such as the liver, which can serve as a temporary storage.

As for amino acids, minerals are used for maintenance and for growth, with specific mineral requirement profiles required for each. For example, the maintenance requirement for iron is very low (because it is recycled very effectively), but the requirement for growth is rather high. Magnesium, however, is relatively important for maintenance and less important for growth.

Points of attack to improve nutrient utilization can be deduced easily from the above description of nutrient utilization. In the following sections, each aspect of nutrient utilization is examined to see what improvements can be made, while Appendix A and the Excel® spreadsheet provided on the CD-ROM and at <http://mark.asci.ncsu.edu/nutrition/nitrophos.htm> provide a quick assessment tool for evaluating conformity of an operation with the outlined suggestions. Appendix B provides an assessment tool that evalutes your knowledge of and compliance with pertinent local legislation.