

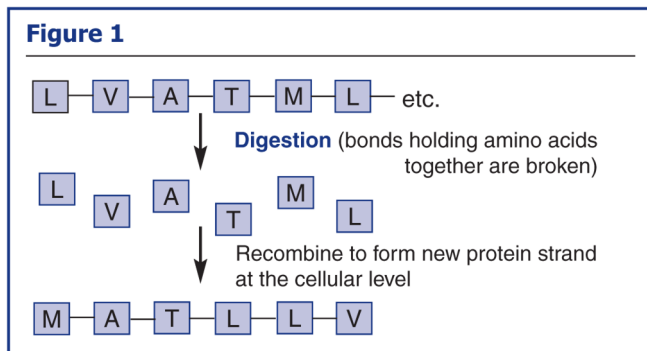
Understanding Nutrient Utilization in Swine

To understand the science of swine nutrition, it is first necessary to understand how major nutritional components are utilized by swine to meet their nutrient needs. Proteins, carbohydrates, fats, vitamins, minerals, and water comprise the major nutritional components required by swine to meet maintenance, growth, and reproduction needs. Water is often an overlooked nutrient, and an unlimited, fresh, clean water source should be provided to swine during all production stages. The following discussion focuses on protein, carbohydrate, and fat utilization within pigs (monogastrics).

Proteins

The positive effects of protein on growth and reproduction have been known for years. Without sufficient protein in the diet, growth and reproductive efficacy and efficiency are reduced. Consequently, protein is essential in swine diets. It is clearly recognized that swine actually require amino acids which make up protein, not protein per se. Amino acids are linked to one another in a chain-like fashion by chemical bonds to form protein.

Figure 1 illustrates a hypothetical protein structure. The letters L-V-A-T-M represent different amino acids and the dashes represent chemical bonds holding the amino acids together. The enzymatic digestion of protein breaks the bonds, freeing amino acids. The individual amino acids released from feed protein are then absorbed into the body through selected sites in the small intestine and distributed to body cells. Within body cells, amino acids are recombined to make new protein specific to body needs. The recombination of amino acids is a well-orchestrated process determined by genetic code within the body. *Additional amino acid nutrition information is contained in subsequent sections of this article.*

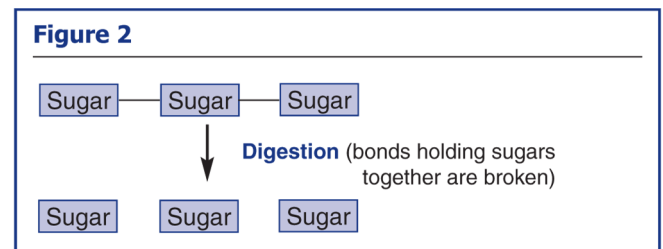


Carbohydrates

Carbohydrates comprise the major portion of swine diets and provide most of the energy to body tissues.

The elements carbon, hydrogen, and oxygen make up carbohydrates. Carbohydrates can be unlinked (individual) or grouped (linked by chemical bond). When more than two carbohydrates are linked together, the group is called a polysaccharide. The principle energy source in corn is starch, a polysaccharide.

Just as amino acids from protein need to be released during digestion, the sugars from polysaccharides (i.e., starch) also need to be released during digestion for absorption (see Figure 2). Complex carbohydrates, such as those that form the woody fiber of plants, are difficult for monogastric animals to digest. Therefore, fibrous carbohydrates cannot be adequately broken down to release sugars (an energy source).

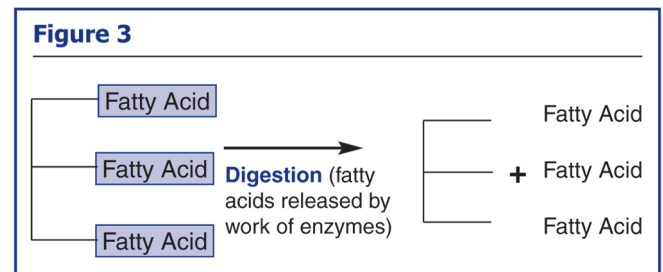


Fats

Fats and oils are also referred to as lipids. Since fats are more energy dense than other classes of nutrients (i.e., carbohydrates and proteins), they are of special importance in meeting swine energy needs. Fats play an important role in:

- Storing energy
- Cell membrane structure
- Hormones
- Absorption of fat-soluble vitamins A, D, E, and K

Unlike the chain-type structure of protein, the structure of a fat molecule looks similar to the letter "E" (see Figure 3).

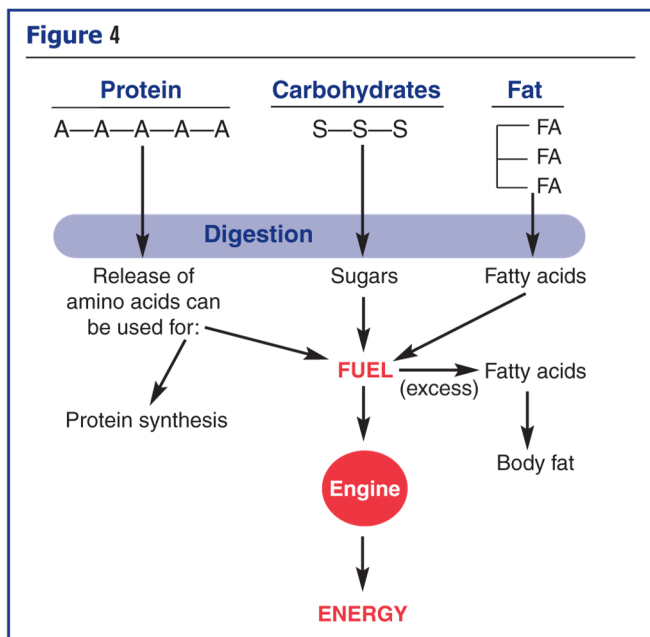


Located at each point of the extended arm is an attached fatty acid. Each lipid molecule contains three fatty acids; hence, the term triglyceride. The letter E-like molecule is

known as the glyceride molecule. The fatty acids attached to the glyceride molecule differ in size (short, medium, and long). During digestion, the enzyme lipase releases (frees) the fatty acids (see Figure 3), which can then be absorbed from the small intestine.

How Energy is Obtained from Amino Acids, Carbohydrates, and Fats

Biologically, it is possible to obtain energy from protein (i.e., amino acids), carbohydrates (i.e., sugars), and fats (i.e., fatty acids) because these nutrients can all produce the same "fuel" (energy) which feeds "engines" located within body cells (see Figure 4). Fat contains more energy than protein or carbohydrate because fatty acids can generate more fuel (energy) per molecule compared to amino acids and sugars. Vitamins are not used as an energy source (cannot be converted into energy), but function as facilitators for assisting chemical reactions needed to generate energy.



Animals become fat when the body does not utilize energy to the degree that it is generated (i.e., the body has more fuel than it can burn). Excess energy is generally converted into fatty acids and stored as body fat.

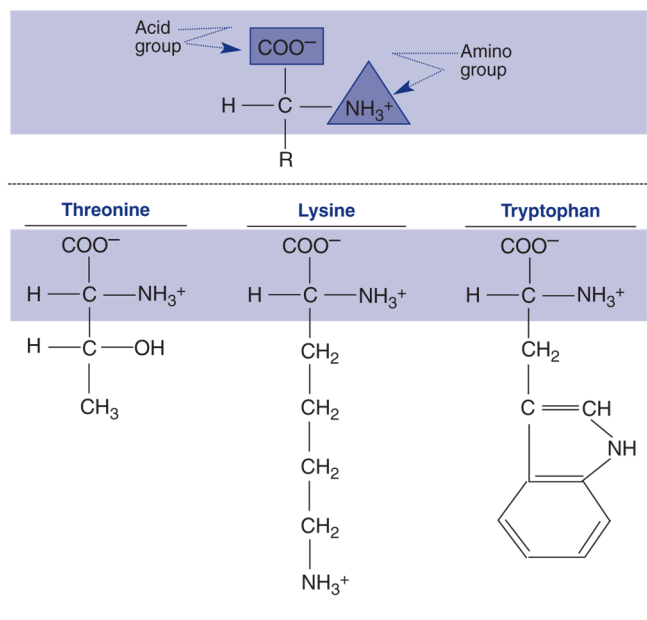
Fate of Excess Protein (Amino Acids)

When compared to carbohydrates and fats, the use of amino acids as an energy source is expensive. Not only is it economically inefficient, but biologically inefficient as well. To understand the inefficiency of using amino acids as an energy source, it is first important to examine the general structure of an amino acid (see Figure 5).

All amino acids contain an amino group (NH_3^+ ; nitrogen-containing compound) and an acid group (COO^-); hence, the term amino acid. All amino acids have the same upper structure while the lower portion of the molecule differs among amino acids (see Figure 5). Since there are 20 different amino acids important for swine production, the lower portion of the amino acid molecule will vary 20 different ways.

Figure 5

The shaded area represents the same basic structure for all amino acids. The "R" represents the portion of the structure that differs for each amino acid.



Ten of the 20 amino acids can be synthesized within the pig's body in sufficient quantities and are referred to as *non-essential amino acids*. The other ten amino acids that cannot be synthesized or cannot be synthesized at a sufficient rate to enable optimal growth or reproduction must be provided in the diet for proper growth or reproduction. These ten amino acids are referred to as *essential amino acids* (see Table 1). When the dietary supply of one essential amino acid is used up, it is referred to as the limiting essential amino acid, and formation of protein ceases even though the other essential amino acids are available. In typical swine corn-soybean meal diets, the first limiting essential amino acid is lysine, which explains why lysine is often added to swine diets.

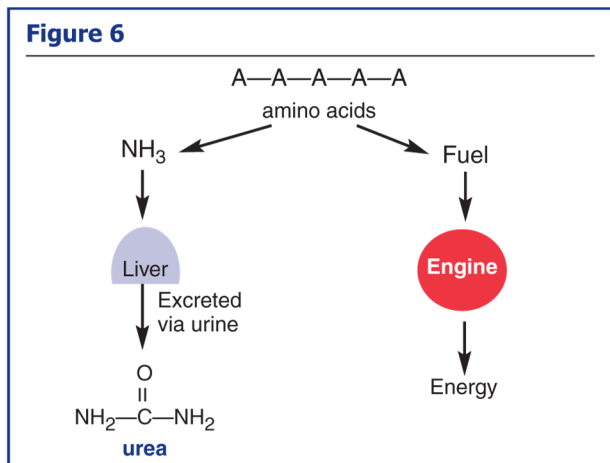
Table 1

Essential Amino Acids for Swine

- Lysine
- Threonine
- Methionine
- Tryptophan
- Arginine
- Isoleucine
- Histidine
- Leucine
- Valine
- Phenylalanine

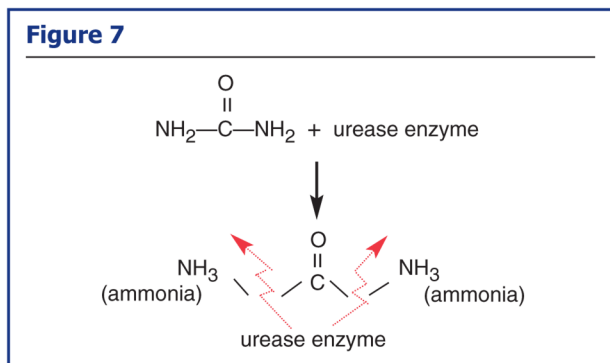
When an amino acid is utilized for energy, the amino group (nitrogen-containing portion) is removed from the amino acid structure. The remainder of the amino acid "skeleton" is used to generate energy. If the removed amino group is not reused for synthesis of a new amino acid or other nitrogen-containing product, the amino group is collected and carried to the liver and converted into an end

product called urea (see Figure 6), which is formed by two amino groups bonded to a carbon atom. Urea is then removed from the body via urine. Overfeeding protein can generate high levels of urea, which is excreted in the urine. It is important to understand that it costs the body *four units of energy (adenosine tri-phosphate or ATP) to produce one unit of urea*. Therefore, when amino acids are used for energy, the body must supply energy to remove the excess amino groups. Consequently, the use of amino acids for energy is inefficient.



How Overfeeding Amino Acids Leads to High Levels of Ammonia and Nitrogen Pollution

Within urea, the chemical bonds holding the amino groups to the carbon atom can be broken via action of the urease enzyme excreted by microorganisms in the environment (see Figure 7). Once amino groups are released, they are quickly converted into ammonia. Therefore, overfeeding protein not only serves as an inefficient use of energy, but leads to increased nitrogen (urea) excretion and higher ammonia levels resulting from urease enzymatic activity upon the urea molecule.



In review:

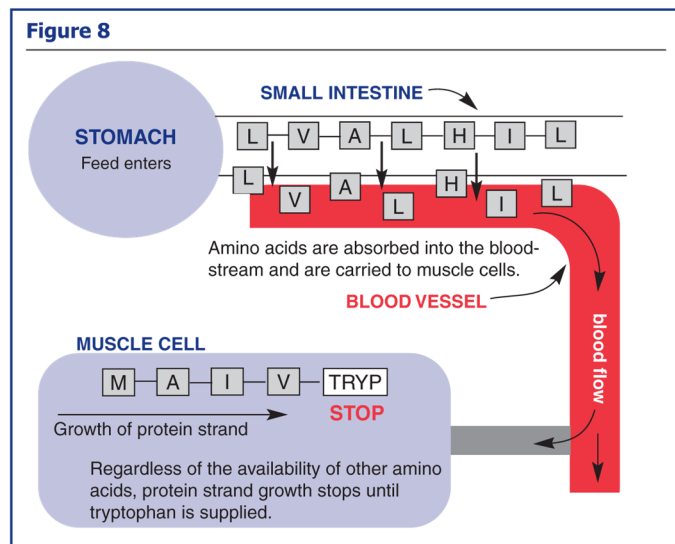
- Digestion of protein causes the release of amino acids.
- Abundance of amino acids not utilized by the body will be broken down for elimination since they cannot be stored in the body.
- During the breakdown of amino acids, the amino groups (nitrogen groups) are removed and eliminated via urine as urea (excess nitrogen excreted).

- Production of urea is inefficient (four units of energy are needed to produce one unit of urea).
 - The amino group is freed from the urea molecule by the urease enzyme, resulting in ammonia release.
- Some research has shown feeding animals an extract from the yucca plant (*Yucca schidigera*) can help minimize ammonia odors. The exact mechanism of action is still not clearly understood. It is believed the mode of action of yucca extract is inhibition of urease enzyme activity and, thus, the minimization of ammonia odor. The source of urease enzyme predominately comes from *E. coli*. Since *E. coli* relies on nitrogen for making its own amino acids to form protein, it excretes the urease enzyme to aid in obtaining needed amino groups.

A Deficiency of Essential Amino Acids Can Also Lead to Higher Levels of Ammonia and Excretion of Excess Nitrogen

Most information normally discusses excess nitrogen excretion as a result of overfeeding protein. However, deficiencies in one or more essential amino acids can also result in excess nitrogen excretion. To understand this process, one needs to have a basic understanding of how protein is formed. The formation of muscle protein will be used as an example since lean protein deposition is important in today's swine industry. Keep in mind, while the example is simple, protein synthesis is actually very complex.

After digestion of protein, amino acids are released and most are absorbed from the small intestine. Amino acids that are not absorbed are excreted. The absorbed amino acids are carried (via the bloodstream) to the protein manufacturing site (i.e., body cell). Essentially, protein from the diet is broken down into amino acids. Within the body cells, amino acids are recombined into protein specific to body needs (see Figure 8).



The example in Figure 8 uses muscle (lean) as the growing tissue needing amino acids for protein growth. The order of amino acid recombination into protein is tightly regulated. In Figure 8, the protein strand is growing from left to right. Assume the beginning amino acid in the sequence is methionine (M) followed by arginine (A), then isoleucine (I), then valine (V). As each amino acid is added, the protein

strand grows longer. Now, assume the next amino acid in the sequence is tryptophan (T-R-Y-P). However, the diet being fed only contains a marginal amount of tryptophan. Regardless of the abundance of all other amino acids required to build the muscle, protein strand growth will not continue (i.e., lean growth rate is reduced) until the amino acid tryptophan is supplied.

Therefore, additions of only synthetic L-lysine will not correct the tryptophan deficiency. The body will not substitute any other amino acid in the growing protein strand (chain). However, since the animal continues to consume and digest protein (releasing amino acids), the level of amino acids in the bloodstream increases because they cannot be utilized until the limiting amino acid is inserted into the chain. Consequently, a buildup of amino acids in the bloodstream occurs. As the amino acid level in the blood rises, the body reacts by breaking down excess amino acids. As previously discussed, the breakdown of amino acids causes release of amino groups, which leads to urea formation and elimination via urine. A deficiency in one or more essential amino acids will result in excretion of more nitrogen. In summary, excess nitrogen excretion can result from not only overfeeding protein, but also from underfeeding protein as well. Amino acid overformulation or underformulation will create an excess of amino acids. Failure to switch diets at the appropriate weight based on ration formulation will also have the same effect.

How a Deficiency of Essential Amino Acids Leads to More Body Fat

When lean growth is slowed due to inadequate amounts of essential amino acids, the level of available energy begins to accumulate because less energy is being used for lean growth. When this occurs, the body begins to convert the extra energy into fatty acids and eventually body fat (see Figure 4). This explains why pigs become fatter when fed diets limited in one or more essential amino acids.

Summary

The economical formulation of swine diets demands a clear understanding of nutrient utilization within pigs. It is easy to understand why overfortification of rations is economically inefficient. Economic inefficiencies (growth reduction, increase in carcass fat, and increased nitrogen excretion) are created when the pig is not supplied with sufficient amounts and ratios of essential amino acids. Success in swine production hinges, in part, on the ability of producers to consistently and precisely meet swine nutrient needs.