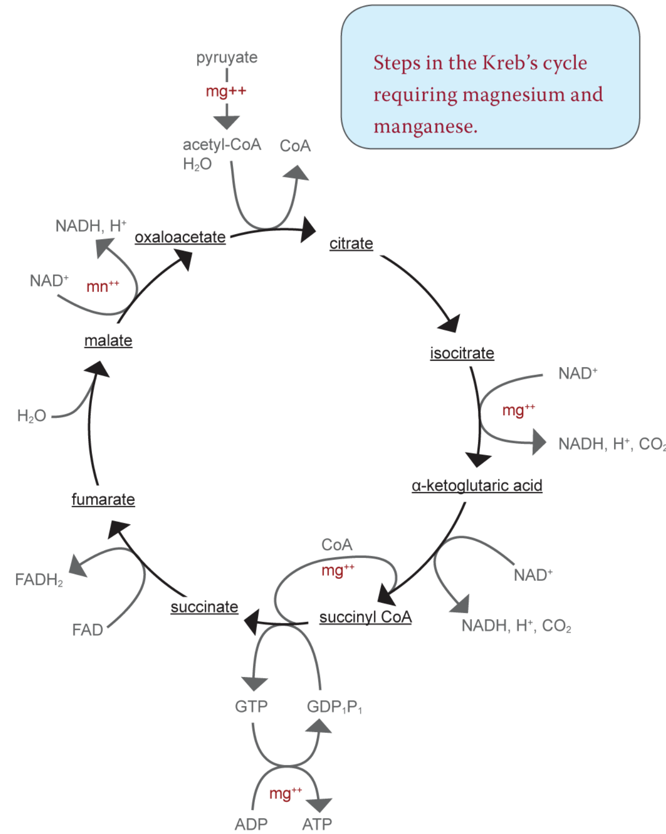
CARBOHYDRATE UTILIZATION

Phosphorus (P) is the second most commonly found mineral in the body, right behind calcium. 85% of P is located in bones and teeth. P is essential for milk secre-

tion, bone mineralization/growth, energy metabolism, fatty acid transport, amino acid metabolism and protein synthesis.

Minerals play a key role in energy metabolism. P is a major part of adenosine triphosphate (ATP) which is the body's energy source for transport of organic substances and synthesizing of proteins and fats. The ATP producing systems are glycolysis, Krebs cycle (Citric acid cycle) and electron transport system (ETS). Magnesium (Mg) and Manganese (Mn) are used in the citric acid cycle to stabilize the enzymes and the ATP molecules. Without adequate levels of P, Mg and Mn, ATP production will greatly decrease, in turn hindering the animal's performance. P also reacts with lipids to create the phospholipid bilayer of the cell membrane. Copper is part of cytochrome C oxidase that converts ADP (adenosine diphosphate) to ATP in the ETS. Glycolysis and the citric acid cycle break down glucose and produce NADH and FADH2 to provide electrons to the electron transport system. The electrons then pass through protein complexes to produce ATP. Copper and Iron are also utilized during this process to continue the flow of



electrons through the ETS.

An animal with a well balanced supply of minerals will be better suited to create more efficient utilization of energy. This means that less overfeeding will take place with the same dietary outcome.

"FOOD ENERGY UTILIZATION FROM CARBOHYDRATES IN ANIMALS"

As science evolves and we gain a better understanding of animal physiology, one thing becomes painfully obvious, there is always more to learn. Animal scientists and nutritionists have studied ruminant nutrition, tirelessly examining and researching the rumen com-

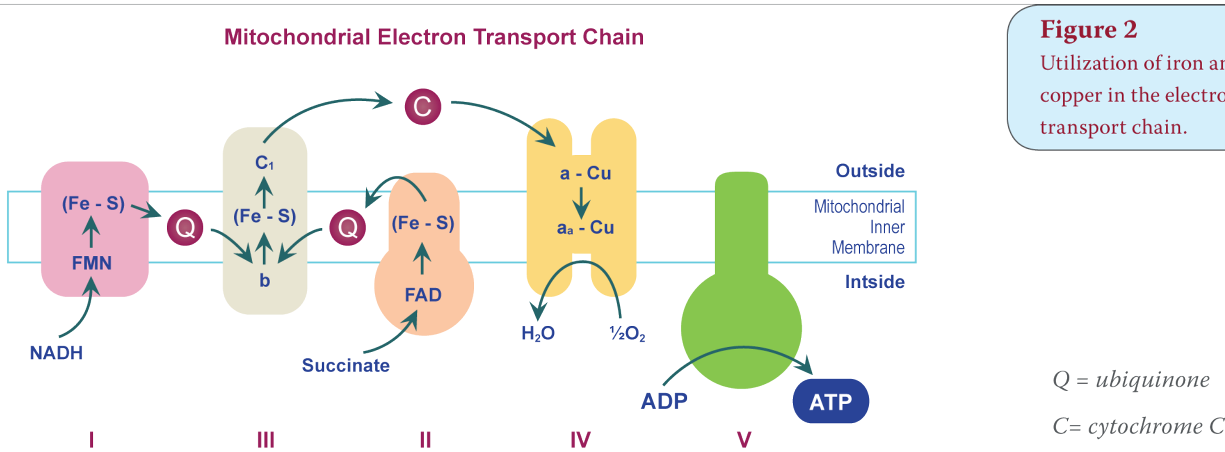


Figure 2
Utilization of iron and copper in the electron transport chain.

plex. Studying how carbohydrates are fermented in the rumen and broken down in the abomassum before being released into the intestines for their absorption and ultimate utilization by the animal for all its functions and purposes. It is a very complex and important system but the story of carbohydrate digestion and utilization does not stop there.

The primary function of carbohydrates in the animal is as a source of energy. To be utilized as a source of energy in the body, carbohydrates must first be degraded into simple sugars.

Carbohydrates are classified into 3 groups; monosaccharides (simple sugars including triose, tetrose, pentose, hexose and heptose) oligosaccharides (disaccharides and trisaccharides) and polysaccharides (starch, glycogen, dextrins, gum, mucilage, inulin, cellulose, etc.). Monosaccharides cannot be hydrolyzed into simpler sugars. However, by the appropriate use of acid or enzymes, the higher saccharides can be hydrolyzed into simple sugars. In the body, the oligosaccharides and polysaccharides are converted to monosaccharides by enzymatic action in saliva (salivary amylase), from pancreatic secretions (pancreatic amylase), and from enzymes produced in the small intestine (i.e. disaccharidases and oligosaccharidases) inclusive of maltase, iso-maltase, lactase, sucrase and trehalase.

Carbohydrate digestion into simple sugars does not end at the beginning of the small intestine. There are opportunities to improve the coefficient of digestion. The coefficient of digestion is a measure in difference between the amount of a nutrient ingested and the amount of the nutrient found in the urine and feces. The percentage of the nutrient being digested is called the digestion coefficient. Each of the 6 basic nutrients; proteins, fats, carbohydrates, minerals, vitamins and water has its own digestion coefficient.

Starch, which occurs abundantly in grains, is generally the main source of carbohydrates in production animal diets. Glycogen, another source of carbohydrate is also found in corn and sorghum. Both starch and glycogen are polymers of glucose. Starch is made up of two types of molecules. A linear polymer called amylase and a branched polymer called amylopectin. Glycogen is made up of a branched polymer very similar to amylopectin. Amylose is a linear polymer of glucopyranose units joined by an alpha linkage at the

Phosphorus requirements of livestock.

Class	Dietary P, %
Lactating Beef Cow, 20 lb peak milk	0.19
Dry Beef Cow, last 1/3 gestation	0.17
Growing Calf	0.19 to 0.24
Dairy Cow, dry	0.23
Dairy Cow, 77 lbs milk/day early lactation	0.42
Dairy Cow, 99 lbs milk/day 90 days in milk	0.36
Dairy Cow, 55 lbs milk/day 90 days in milk	0.32
Swine, 44 – 110 lbs	0.50
Swine, 110 -176 lbs	0.45
Swine, 176 – 264 lbs	0.40
Sow, gestation	0.60
[a]Broiler 0 to 3 wks of age	0.45
[a]Broiler 0 to 3 wks of age	0.35
[a]Broiler 6 to 8 wks of age	0.30
[a]Laying Hen	0.25
[a]Nonphytate Phosphorus	

first and forth carbon atoms (referred to as a 1,4 linkage). The molecular weight of Amylose varies from 150,000 to 600,000 Daltons indicating that there are approximately 1000 to 4000 glucose units per molecule.

Amylopectin from starch is a glycogen polymer held together by two types of alpha linkages, a 1,4 glucopyranose linkage and a 1,6 glucopyranose linkage. The 1,4 linkage forms a straight chain while the 1,6 linkages occur on the straight chain at points where one straight chain branches from another. The molecular weight of Amylopectin varies from about one to six million Daltons. The starch found in corn is composed of approximately 27% amylose and 73% amylopectin. The amylopectin fraction contains 96% 1,4 linkages and 4% 1,6 linkages.

In order to maximize the energy contained in carbohydrates, it is important that complete digestion to the monosaccharide stage be accomplished in the gastrointestinal tract. Otherwise, undigested residues will be excreted in the feces and lost.

Any improvement that can be made in the efficiency of digestion of carbohydrates, the major source of energy in feed is of real economic and nutritional importance. To understand the process of improving the digestion coefficient of carbohydrates it is important to look at the mechanism of how carbohydrates are broken down in the digestive system.

Disaccharidase enzymatic activity at the mucosal surface defining the lumen of the small intestine, as distinguished from tissue uptake, can be affected directly through the proper administration of amino acid chelates. These enzymes help break apart the very large molecules of amylose and amylopectin into simple sugars of size that can be absorbed across the intestinal wall (molecular weights of less than 1,000 to 1,500 Daltons).

Disaccharide digestive activity in the intestinal tract begins in the distal duodenum and is maximal in the jejunum and continues throughout the proximal ileum. Disaccharide hydrolysis does not occur in the lumen per se but in or at the surface of the mucosal cells. Secretion of disaccharidase enzymes to the mucosal cells are from the Brunner's glands of the duodenum and the glands of Lieberkuhn both of which are located in the mucous or sub mucous layer of the duodenum or jejunum portions of the small intestine.

Chelated minerals may be added to the diet to improve disaccharide activity. The minerals are taken into the mucosal cells lining the small intestine where they are utilized to facilitate the production and activity of di-

saccharidase enzymes such as maltases, sucrase and lactase. These enzymes promote hydrolysis of disaccharides resulting from degradation of more complex carbohydrates or of sucrose and lactose into simple sugars or monosaccharides for absorption into the intestinal tract.

Amino acid chelates are stable and are absorbed intact through the intestinal tract via an active dipeptide transport system. When properly administered, such chelates can affect disaccharidase production and disaccharide hydrolysis at the brush border membrane of the mucosal cells of the small intestine while still in the lumen.

Examples

46 dairy cows fed ration of corn silage, alfalfa hay, and wheat. Contained, on a percent by weight basis, 15.7% carbohydrate, 1.76% fat and 9.05% protein. The average daily carbohydrate consumption calculated at 3.92 kilograms and the carbohydrate digestion coefficient was determined to be 8.76%.

The group was split into 2 groups of 23 head each. One group received ration fortified with iron, zinc, copper, manganese and cobalt. One group given an inorganic form of these minerals the other given amino acid chelated forms. After 221 days the carbohydrate digestion coefficients were re-measured. The inorganic group was re-measured to be unchanged at 8.76% while the carbohydrate digestion coefficient of the chelated group was calculated at 13.67%, an improvement of 56%

15 swine showed a 57% increase in the digestion

Table 2. Phosphorus content of commonly used feedstuffs.	
Ingredient	**Phosphorus %**
Corn	0.3
Soybean hulls	0.17
Soybean meal	0.70
Distillers grains	0.83
Brewers grains	0.67
Corn gluten feed	1.00
Wheat middlings	1.02
Hominy feed	0.65
Whole cottonseed	0.60

coefficient of carbohydrates.

1000 broiler chicks showed a 57% increase in digestion coefficient.

200 turkeys showed a 55% increase in the digestion coefficient of carbohydrates.

Discussion:

As you can see from the chemistry described above and the examples of the effectiveness of such chemistry there is a great deal to be gained by incorporat-ing Tracer Amino Acid Chelated Minerals into animal feeds. By providing the necessary minerals in a readily bio-available form one can make a significant impact on the coefficient of digestion of carbohydrates.

By helping to facilitate the digestion of carbohydrates into simple sugars and by maintaining and enhancing the natural enzymatic activity of the animal through the administration of appropriate minerals needed for such digestive activity. We can accomplish our goal of increasing the coefficient of digestion of carbohydrates. The examples show that we can have a real impact on the coefficient of digestion, by as much as 50%. This is of tremendous economic importance and should be carefully considered when choosing an organic trace mineral.

Tracer continues to bring cutting edge research and technology to the livestock sector. Use Tracer chelates in your livestock production system and reap the benefits provided by the most scientifically advanced organic minerals available.

Cow in Western Kansas on Tracer Amino Acid Chelates.

Cow on commercial mineral with added metal proteinates in South Dakota.

The photos above show how significant a mineral program can be in regards to carbohydrate utilization. Get the most from your trace mineral program, use Tracer Amino Acid Chelates to “Make Your Mineral Program Better.”