

The Chemical Properties of Water-Soluble Vitamins and Their Functions in Nutrient Metabolism in Livestock

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Introduction:

Water-soluble vitamins, primarily the B-complex vitamins and vitamin C, play crucial roles in the metabolism and overall health of farm animals. These vitamins are characterized by their solubility in water, which enables them to be easily absorbed by the body and transported through the bloodstream. Unlike fat-soluble vitamins, water-soluble vitamins are not stored in significant amounts, so they must be regularly supplied through the diet. In farm animals, water-soluble vitamins are essential for energy metabolism, growth, and maintenance of various physiological functions. The B-vitamins, including thiamine (B1), riboflavin (B2), niacin (B3), pyridoxine (B6), folic acid (B9), and cobalamin (B12), act as coenzymes in metabolic pathways such as carbohydrate, fat, and protein metabolism. They help in the synthesis of red blood cells, support nervous system function, and facilitate the proper utilization of nutrients. Vitamin C, though less critical in many farm animals due to their ability to synthesize it, still supports immune function and antioxidant defense. An adequate supply of these vitamins is vital for optimizing the productivity, growth rates, and health of farm animals, directly influencing feed efficiency and reproductive performance.

Vitamin B1 (Thiamine):

- **Chemical Nature:** Thiamine consists of a pyrimidine ring and a thiazole ring. The active form, thiamine pyrophosphate (TPP), plays a crucial role in energy metabolism.
- **Metabolism:** Thiamine is absorbed in the small intestine and converted into TPP, which is vital for energy production in the brain, heart, muscles, and nerves.
- **Functions:** Key for brain energy, heart muscle function, nerve impulse transmission, and red blood cell (RBC) formation.
- **Deficiency Symptoms:**



- **Cattle/Sheep:** Polioencephalomalacia (PEM) with symptoms like blindness, ataxia, and muscle tremors.
- **Swine:** Symptoms include muscle atrophy and heart failure.
- **Poultry and Horses:** Weakness, paralysis, and poor growth.

Vitamin B2 (Riboflavin):

- **Chemical Nature:** Riboflavin's three-ring structure is essential for metabolic processes and energy production.
- **Metabolism:** Absorbed in the small intestine and converted into flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD), both crucial for oxidation-reduction reactions.
- **Functions:** Plays a major role in energy metabolism, antioxidant protection, and nervous system functioning.
- **Deficiency Symptoms:**
 - **Poultry:** Curled-toe paralysis and poor growth.
 - **Swine:** Skin lesions, nervous disorders.
 - **Cattle/Sheep:** Poor growth and lethargy in young animals.
 - **Horses:** Reduced appetite and poor coat condition.

Vitamin B3 (Niacin):

- **Chemical Nature:** Niacin includes nicotinic acid and nicotinamide, both involved in metabolic reactions.
- **Metabolism:** Absorbed in the small intestine and converted into NAD and NADP, essential for energy and lipid metabolism.
- **Functions:** Supports energy production, lipid metabolism, digestive health, and nervous system function.
- **Deficiency Symptoms:**
 - **Poultry:** Black tongue, bowed legs, and poor growth.
 - **Swine:** Dermatitis, diarrhoea, and anorexia.
 - **Cattle/Horses:** Poor weight gain and lethargy.

Vitamin B5 (Pantothenic Acid):

- **Chemical Nature:** Occurs in forms like coenzyme A (CoA), which is critical for energy metabolism.



- **Metabolism:** Absorbed in the small intestine and used for the formation of CoA, vital for carbohydrate, fat, and protein metabolism.
- **Functions:** Energy production, fatty acid metabolism, and neurotransmitter synthesis.
- **Deficiency Symptoms:**
 - **Poultry:** Scaly skin and poor egg production.
 - **Swine:** Nervous system problems like goose-stepping gait.
 - **Cattle/Sheep:** Poor growth and reduced milk production.

Vitamin B6 (Pyridoxine):

- **Chemical Nature:** Exists in three forms, with pyridoxal phosphate being the active coenzyme form.
- **Metabolism:** Converted to pyridoxal 5'-phosphate in the liver, facilitating numerous enzymatic reactions.
- **Functions:** Protein and amino acid metabolism, hemoglobin synthesis, and neurotransmitter production.
- **Deficiency Symptoms:**
 - **Poultry:** Nervous system disorders, poor growth, and feathering.
 - **Swine:** Nervous symptoms, anemia, and skin lesions.
 - **Cattle/Horses:** Reduced appetite, irritability, and poor growth.

Biotin (Vitamin B7):

- **Chemical Nature:** Biotin is essential for carboxylation reactions in metabolism.
- **Metabolism:** Absorbed in the small intestine and utilized in energy metabolism and keratin synthesis.
- **Functions:** Supports hoof, hair, and skin health, energy metabolism, and amino acid breakdown.
- **Deficiency Symptoms:**
 - **Cattle:** Poor hoof quality, laminitis, and weight loss.
 - **Swine:** Dermatitis, hair loss, and poor growth.
 - **Poultry/Horses:** Skin lesions, poor feathering, and hoof issues.

Vitamin B12 (Cobalamin):

- **Chemical Nature:** Organometallic compound with cobalt, essential for energy metabolism and DNA synthesis.

- **Metabolism:** Requires intrinsic factor for absorption in the small intestine, stored in the liver.
- **Functions:** Supports red blood cell formation, DNA synthesis, nervous system health, and energy metabolism.
- **Deficiency Symptoms:**
 - **Cattle/Sheep:** Poor growth, anemia, and neurological issues.
 - **Swine:** Poor growth and reproductive issues.
 - **Poultry:** Feathering issues and reduced egg production.

Folic Acid (Vitamin B9):

- **Chemical Nature:** Composed of a pteridine ring, PABA, and glutamic acid.
- **Metabolism:** Absorbed in the small intestine and converted into its active form, tetrahydrofolate (THF).
- **Functions:** Supports DNA synthesis, red blood cell formation, and amino acid metabolism.
- **Deficiency Symptoms:**
 - **Poultry:** Poor growth, anemia, and perosis.
 - **Swine:** Small litter sizes and reproductive issues.

2. Vitamin C (Ascorbic Acid):

- **Chemical Nature:** Ascorbic acid is a water-soluble vitamin with antioxidant properties.
- **Metabolism:** Synthesized in the liver of most livestock from glucose, except in species like guinea pigs.
- **Functions:** Supports collagen synthesis, immune function, and hormone production. Acts as an antioxidant and enhances iron absorption.
- **Deficiency Symptoms:**
 - **Cattle/Sheep/Pigs:** Rare, but can result in poor wound healing and reduced immune function during stress.
 - **Poultry:** Reduced growth, poor egg production, and increased mortality under stress.
 - **Horses:** Fatigue and poor coat condition.

Vitamin Antagonists and Other Nutrients:

Certain compounds, such as thiaminase (which cleaves thiamine) and avidin (which binds biotin), can interfere with vitamin absorption or function. It's important to consider these factors in livestock diets, as antagonists can reduce the efficiency of vitamin utilization.

Conclusion:

Due to their rapid turnover and limited storage capacity in the body, water-soluble vitamins must be continuously supplied to livestock to support optimal growth, reproduction, and overall health. Deficiencies can result in impaired energy metabolism, reduced growth rates, and a range of metabolic disorders, highlighting their critical importance in animal nutrition. Therefore, understanding the chemical properties and functions of water-soluble vitamins is vital for formulating balanced diets that meet the nutritional needs of livestock and ensure efficient production.