Updates on Amphibian Nutrition and Nutritive Value of Common Feeder Insects

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KEYWORDS

• Anatomy • Invertebrate prey • Gut-loading • Amphibian • Minerals • Vitamins • Lipid

KEY POINTS

- The study of amphibian nutrition still requires detailed review of species-specific natural prey analysis.
- Invertebrate nutrient composition has been formally studied for more than 60 years and presents the following conclusions: (1) in general, insects are poor in overall calcium content; (2) larval insects have high fat and protein component; and (3) altering the gut contents of some insects can improve their overall nutritive quality.
- There are new guidelines for calcium and vitamin A supplementation that can help augment invertebrate nutrient profiles to match the minimum National Research Council requirements established for rats.

INTRODUCTION

In comparative medicine, practitioners are commonly faced with clinical manifestations of nutritional imbalances in captive amphibians. Studies that evaluate herptile nutrient minimums, digestion, and prey nutrient bioavailability are scarce.[1,2] Limited data are available for commercially prepared and extruded diets for captive insectivores. Information regarding natural diet of insectivores and insect composition does exist and can be found primarily in comparative physiology journals, zoology-focused and herptile-focused journals such as *Copeia*, *Zoo Biology*, and *Journal of Herpetology*. When comparing species-specific natural diets to commercially available invertebrates, what remain are insects that have poor nutritive value as compared

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with natural diets. In this review, basic amphibian gastrointestinal anatomy and life stage food selection in select species are revisited. A detailed review of the major components of nutrition, insect nutritive value, and common nutritional deficiencies in captive amphibians are provided.

The class Amphibia includes 7000 species that span 3 major orders: Anura (frogs and toads), Caudata (salamanders and newts), and Gymnophiona (caecilians). According to the Amphibian Web database (www.amphibiaweb.org), there are approximately 7258 extant amphibian species as of 2014, which comprise 6398 anura, 660 caudata, and 200 caecilians. A general review of amphibian taxonomy is available for interested readers.[3] This review begins with a review of the larval anurans (tadpoles) and adult gastrointestinal anatomy and natural diet specifications.

AMPHIBIAN GASTROINTESTINAL ANATOMY

Larval Amphibians

With the exception of a few species, most larval anurans have been historically grouped as aquatic, omnivorous, or herbivorous feeders. A classification scheme was developed based on the arrangement of the mouth, operacula, and jaw musculature to identify 5 types of tadpoles based on dietary preference.[4–8] In microphagous, suspension-feeding tadpoles, water is actively siphoned into the oral cavity and directed over filter mucous-covered plates in the pharynx, called the branchial seize.[9,10] This filtering structure can remove bacteria, protozoa, and plankton from the water; however, it can also be used to feed on larger material.[9] The lips are composed of a keratin beak and an oral disc, covered in keratin denticles, surrounding the mouth. The denticles rasp food from vegetation or animal remains, and the branchial sieve siphons the organic debris into the mouth for consumption.[5,9]

As detailed in a previous review, the filtered food is transported by cilia into the esophagus and stomach and peristalsis does not occur.[5,10] The stomach serves as a food storage unit and exists as a small dilatation at the end of the esophagus. Digestion occurs in the elongated and narrow small intestine, which is extensively curled within the coelom.[9,11] The larval stomach widens and lengthens during metamorphosis and extensive glandular development occurs as the midgut shortens and widens in the adult.[9,11]

Larval salamanders and caecilians consume a carnivorous diet as do most adult amphibians; therefore, their gastrointestinal anatomy is similar to that of the adult amphibian. They actively hunt with well-developed jaws to seize prey and peristalsis occurs to move captured prey from the esophagus into the stomach. The stomach contains peptic proteolytic enzymes that begin digestion. During metamorphosis, the cellular composition of the gut changes; however, in general, the larval intestinal tract is grossly similar to that the adult tract.[9,11,12] A review of the complex gastrointestinal changes that occur is available.[13]

Adult Amphibians

The components of the gastrointestinal tract of adult amphibians follow the major anatomic pattern seen comparatively in mammals, with few exceptions. Adult amphibians are carnivorous and their oral cavities are large and wide, which serves to accommodate prey capture.[9] The lips are poorly developed. A choana is present, but forms vary based on species. The teeth assist in capturing prey. Many species secrete mucous from the buccal salivary glands, with the exception of *Pipa*, *Siren*, and *Amphiuma* species. Most species have salivary glands; however, they may be lacking in fully aquatic anurans species.[12] The buccal and salivary glands do not aid in digestion.[10]