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Opinion Article

Dynamic Assessment of Feed Nutrient Bioavailability and Digestive Performance in Aquatic Animals

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DESCRIPTION

Aquafeed digestibility kinetics examines how quickly and completely nutrients and energy from formulated diets are released, broken down, absorbed, and used by cultured aquatic animals. Digestibility is often summarized as one percentage, but digestion is a changing process shaped by feeding schedule, ingredient composition, digestive anatomy, enzyme activity, water temperature, body size, and physiological status. Studying when nutrients become available can reveal how effectively a diet supports growth, maintenance, and metabolic function. This perspective is valuable because fish, shrimp, and other farmed species differ widely in digestive structure and capacity.

Digestion begins as soon as feed is consumed. Particles absorb water and encounter mechanical action, digestive fluids, enzymes, and microorganisms. Proteins are broken into peptides and amino acids, fats are hydrolyzed into smaller molecules and fatty acids, and carbohydrates are converted into simpler sugars. The time required for these reactions depends on the physical structure of the feed and the biology of the animal. Nutrients in an easily accessible form may be released quickly, while those protected by tough plant tissues or dense feed structures may require more time before they can be absorbed.

A kinetic description may include the early rate of nutrient disappearance, the time needed to achieve a particular level of digestion, the final fraction absorbed, and the amount of residue remaining in the digestive tract. Considering these factors together gives a more complete picture than relying on a final digestibility coefficient. Two diets can have similar apparent protein digestibility while producing different nutrient-release profiles. One may deliver amino acids rapidly after feeding, while the other may provide a more gradual supply.

Physical feed properties strongly affect the timing of digestion. Particle size, hardness, density, moisture, water stability, and manufacturing conditions all influence how quickly feed hydrates and breaks apart. Extrusion, pelleting, drying, and grinding can change the internal structure of ingredients and alter enzyme access. Smaller particles usually offer more surface area for enzymatic action, although excessive grinding may reduce water stability or affect feeding behavior. Formulators must therefore balance particle characteristics with the needs of the target species and production system.

Protein ingredients illustrate the importance of digestion rate. Fishmeal, poultry-derived meals, soybean products, insect meals, microbial proteins, and plant concentrates differ in amino acid composition, protein structure, and susceptibility to digestive enzymes. Excessive heating may reduce nutrient availability, while certain naturally occurring compounds can interfere with enzyme function. Slow protein breakdown may prolong the presence of nitrogenous material in the gut and increase nitrogen losses. Conversely, very rapid release may not always align with absorption and tissue protein synthesis, making the timing of amino acid availability an important consideration.

Lipid digestion follows a distinct pathway because fats must first be dispersed into small droplets. Bile components assist emulsification, allowing lipases to act more effectively. Digestion rate is influenced by lipid source, fatty acid composition, droplet size, feed structure, and interactions with other dietary components. Saturated and highly unsaturated fatty acids may differ in absorption and subsequent metabolic use. These distinctions matter when formulating diets for species that require particular essential fatty acids for growth, development, or health.

Carbohydrate processing also varies among aquatic animals. Some species can digest starch efficiently, whereas others have limited capacity to use carbohydrate-rich diets. Heat treatment during feed manufacture can gelatinize starch and improve enzyme access. However, excessive carbohydrate inclusion may affect digestive conditions, nutrient partitioning, and metabolic balance. Monitoring the progression of carbohydrate digestion can help determine whether a diet supplies glucose at an appropriate rate and quantity.

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Water temperature is a major determinant of digestive timing. Fish and many other cultured aquatic animals depend on environmental temperature to regulate metabolic activity. Temperature changes can affect enzyme function, gut movement, feed intake, and the duration of gastrointestinal passage. A diet that performs well under warm conditions may produce a different nutrient-release pattern in cooler water. Feed evaluation should therefore include temperatures representative of the intended farming season or production environment.

CONCLUSION

Aquafeed digestibility kinetics offers a valuable way to view feed utilization as a process that unfolds over time. Determining when nutrients become available, how long digestion continues, and how much material is ultimately retained provides insight that a single digestibility value cannot capture. Greater attention to these patterns can support more precise formulation, improved feeding management, reduced nutrient losses, and better evaluation of emerging ingredients in aquaculture. As animals grow, feed intake, gut capacity, and passage time may change. Digestibility trials should clearly identify the life stage tested rather than assuming that results apply equally across the production cycle.