Bioenergetics

PhD. student
Dr. A. Y. Al-Dubakel.

10-Urinary and Branchial Energy and Metabolizable Energy
11- Factors Affecting Metabolic Waste Output

Urinary and Branchial Energy

- Digestion of a diet leads to the absorption of amino acids, fatty acids, and sugars, which are the principal metabolic fuels for the body. Catabolism of fats and carbohydrates results in the formation of carbon dioxide and water. The catabolism of amino acids yields ammonia in addition to carbon dioxide and water. Excretion of nitrogenous waste compounds, of which ammonia amounts to about 85% in most fish species , results in non-fecal energy losses since these compounds contain energy.
- Although ammoniotelic, fish excrete small amounts of urea. Urea cycle enzymes have been detected in several species of fish.

Urinary and Branchial Energy

- Urinary excretion of other types of combustible materials, such as trimethylamine (TMA) and trimethylamine oxide (TMAO), in certain marine teleosts is also known to occur but has not been quantified under intensive culture conditions.
- All these non-fecal energy losses, mainly through
- the gills (branchial energy loss; ZE) and some through the kidneys (urinary energy loss; UE), are unaccounted for by the DE value of a diet, meaning that the DE value of a diet overestimates its actual energy value to the fish.
- The physiologically available fuel value of the diet to the fish is the metabolizable energy (ME) value, defined as follows:

$$\mathrm{ME} = \mathrm{IE} - (\mathrm{FE} + \mathrm{UE} + \mathrm{ZE})$$

Urinary and Branchial Energy

- In the rainbow trout, endogenous (branchial and urinary) nitrogen excretion (UNe+ZNe) rates measured in fish after 3 to 4 days of fasting have been found to vary between 80 and 130 mg N/kgBW/ d.

  (endogenous UE+ZE = 2.0–3.2 kJ/kg/day), affected most by water temperature and body weight .
- Some recent studies with Atlantic salmon suggest that the values might be much lower. With regard to marine fish, data show that the UNe rates in European seabass, gilthead seabream, or turbot would be in the range of 100 to 160 mg N/kg/day (endogenous UE+ZE = 2.5–4.0 kJ/kg/day), comparable to the values found for rainbow trout.

Urinary and Branchial Energy

Measurement

- Direct determination of the ME values of fish diets is technically difficult because of the need to measure both branchial and urinary losses released into the aquatic environment in which the fish live. 1- Smith (1971) attempted to overcome these difficulties and developed a procedure which allowed the estimation of the ME values of a number of feedstuffs using rainbow trout 165–530 g in body weight. Before the assays, the fish were anesthetized to allow the insertion of a cannula for urine collection.

Urinary and Branchial Energy

- The fish were then confined in a tank with a diaphragm separating the front from the rear portion of the body; they were force-fed the feed as a single daily meal under anesthetic.
- The ME values determined by this procedure as a fraction of the DE values ranged from 0.72 to 0.93 (mean = 0.87). The procedures employed to separate and collect nitrogen excreted via the gills and kidneys (including force-feeding) involved considerable handling and were stressful to the fish, which increased the loss of nitrogen and combustible matter.

Urinary and Branchial Energy

- The increase in nitrogen output, together with the low food intake attained by force-feeding of a single daily meal, might be expected to result in a negative nitrogen balance and a low ratio of ME-to-DE values for many of the feed ingredients studied. This strongly suggests that energy losses via the gill and kidney were greater than would be the case for unrestrained fish feeding normally.

Urinary and Branchial Energy

- 2- Kaushik (1980) was the first to estimate the postprandial excretion rates in a flow-through system in a continuous manner using an auto-analyzer.
- This method allows continuous monitoring of ammonia and urea nitrogen excretion under normal physiological conditions even in larval fish.
- Under these conditions, however, attention should be paid to the maintenance of a constant flow rate and the precise measurement of low concentrations of ammonia in the outlet water. Application of such a technique has revealed postprandial patterns of ammonia nitrogen excretion to be very similar among phylogenetically different species .

Urinary and Branchial Energy

3- Urinary cannula or noninvasive measurement of the urine flow rate in conjunction with spot sampling of urine is another approach that has been used to estimate the urinary excretion of glucose and UE of fish .

4- Because direct measurement of UE+ZE requires sophisticated and time consuming techniques, the use of an indirect method to estimate UE+ZE based on nitrogen losses by the fish is considered simpler . Since UE+ZE occurs mainly as nitrogenous product losses, the total non-fecal nitrogen loss, branchial and urinary, is estimated by the difference between digested nitrogen and recovered nitrogen as shown in the following expression:

$$\mathrm{ZN} + \mathrm{UN} = \mathrm{DN} - \mathrm{RN}$$

$$\mathrm{ZE} + \mathrm{UE} = (\mathrm{ZN} + \mathrm{UN})\ 24.9\ \mathrm{kJ\ g^{-1}\ N}$$

$$\mathrm{ME} = \mathrm{DE} - (\mathrm{ZE} + \mathrm{UE})$$

Urinary and Branchial Energy

$$ZN + UN = DN - RN$$

$$ZE + UE = (ZN + UN)\ 24.9\ \mathrm{kJ\ g^{-1}\ N}$$

$$ME = DE - (ZE + UE)$$

where ZN is branchial N loss; UN, urinary N loss; DN, digestible N intake; RN, recovered tissue N; ZE, branchial energy loss; UE, urinary energy loss; ME, metabolizable energy; and DE, digestible energy. It has been determined that, in general, ammonia represents at least 85% of the nitrogenous wastes, whereas urea represents less than 15%. The energy of combustion value of ammonia (82.3% N, by weight) and urea (46.7% N, by weight) is (24.9 kJ/g N) and (22.5 kJ/g N), respectively .

Factors Affecting Metabolic Waste Output

The egestion of combustible matter (i.e., FE) depends on the susceptibility of the feed components to digestion and absorption by the fish, and there are few significant interactions between the feed ingredients of diets that might influence their digestibility. Thus, the DE value of an ingredient is relatively independent of the composition of the diet in which it is fed.

In contrast, the loss of combustible matter through the gills, or in the urine, depends upon a variety of factors, such as the composition of the diet (overall balance of the amino acids and digestible energy content) and other factors (physiological state of the animal, stress, etc.).