Bioenergetics

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Energy Utilization

Animals require a continuous supply of energy for those functions of the body immediately necessary for maintaining life regardless of whether or not feed is consumed. A major portion of this energy is spent for basal metabolism (HeE), a smaller portion of energy is also spent for voluntary or resting activity such as minor bodily movements and muscular activity.

HeE represents use of energy for such things as the circulation of the blood, pulmonary ventilation, repair and replacement of cells, membrane transport of ions (especially of sodium and potassium), and muscle tone.

Under basal conditions, all the energy released by these processes appears as heat. In fish, HeE is known to be related to both body weight and temperature.

Energy Utilization

A number of terms have thus arisen to describe the standardized measurements of "minimal metabolism". With domesticated animals, and hence fish under aquaculture conditions, what is usually measured is the fasting heat production (HEf) .

HEf has been regarded as a close approximation of HeE.

In fish, oxygen consumption of free swimming animals fasted for 3 to 7 days to eliminate the effect of the consumption of feed and its subsequent metabolism is the most common approach to measuring basal metabolism

Energy Utilization

Available data on the HEf of fish show that, for a given weight, they are five to twenty-fold lower than that of terrestrial vertebrates , approx. 30-40 kJ per kg $BW^{0.824}d^{-1}$ for rainbow trout between 15 and 18°C whereas 170 to 590 kJ $(kgBW^{0.75})^{-1}d^{-1}$ has been reported for domestic animals .Such low energy needs for survival can be attributed to the lack of expenditure for thermoregulation, lower sodium pump activity, their aquatic mode of life, and the mode of nitrogen excretion (ammoniotelism).

Energy Utilization

- HeE in absolute term (kJ /animal /day) increases with the mass of the animal. The logarithm of the HeE increases in a linear way with the logarithm of the body mass .However, the slope of this relation is lower than 1. This means that in all the species, animals of smaller size spend more energy per unit of mass that the animals of larger size. For example, on a kilogram basis, a large shark produces around 1000 times less heat than fish larvae .
- The relationship of body weight to metabolic rate in animals can be described by the general equation $Y = aW^b$, where Y is the metabolic rate, W is the body weight, and a is a constant which is dependent on species and temperature. The value of the exponent for fish has been described as ranging from 0.50 to 1.00. Detailed observations by several authors with different fish species suggest that across species the exponent is more than 0.7 and less than 0.9.

Energy Utilization

Water temperature is the major factor determining HeE of fish. Based on a mathematical analysis of

oxygen consumption data from several trials estimated that HeE of rainbow trout as a function of water temperature could be described as:

$$HeE = (-1.04 + 3.26T - 0.05T^2)\ (BW^{0.824})^{-1}\ \ d^{-1}$$

where

T is water temperature (°C)

BW is body weight (kg)

Energy Utilization

The energy losses associated with transformation of the substrates and their retention in tissues represent a very large proportion of the cost of growing in animals.

Converting glucose into glycogen costs 5% of the energy of glucose as heat whereas converting glucose into lipids entails a heat loss equal to about 30% of its GE . Conversion of dietary lipids into body lipids is, in theory, about 96%, therefore 4% of GE of lipids is dissipated as heat. Conversion of dietary amino acids into body proteins is, in theory, 86% efficient . Conversion of amino acids into body lipids is, in theory, only 66% efficient and 34% energy is lost as heat.

Energy Utilization

Determining the cost of nutrient deposition and inter-conversion in practice is not an easy task. Many studies have approached the problem in an empirical manner by trying to relate ME or DE intakes to recovered energy (RE). Studies involving the rearing of fish under the variety of conditions (water temperature, feeding level, fish size, etc.) have shown that efficiency of energy utilization (i.e. slope of RE as a function ME intake) was, surprisingly, fairly constant and, consequently, fairly easily predicted. A relatively large number of studies have showed a highly significant linear relationship between ME intake (or feed intake) and carcass energy gain (RE).

Energy Utilization

Efficiency of energy utilization (Kpf, RE/ME intake) was found to be between 0.5 and 0.75 in most studies . This suggests that, in practice, cost of nutrient deposition can easily be calculated as a constant proportion of energy deposited regardless of fish size and water temperature. This approach has been used in most feed requirement models .

The partial efficiency of ME utilization for whole-body growth *(Kpf)*
For protein deposition *(Kp),* and for lipid deposition *(Kf)*

Energy Utilization

The net energy cost for protein retention is 2.54 kJ per kJ of protein retained (that is 1.54 kJ of heat expended for each 1 kJ of protein deposited) equivalent to a Kp of 39.5%.When all related factors are accounted for in the analysis, the energy cost for protein deposition does not appear different between different species.

REp =protein & REf = fat

Energy Utilization

The calculated energy cost for lipid retention was 1.4 kJ and 1.1 kJ per kJ lipid deposited (i.e. heat losses of 0.4 or 0.1 kJ per each 1 kJ lipid deposited) when deposited from non-lipid or lipid respectively. These are equivalent to a kf = 90% when deposited from lipid and kf = 70% when deposited from non-fat substrates.Partial efficiencies of ME utilization:

Species	**protein deposition (Kp)**	**lipid deposition (Kf)**
Cyprinus carpio	**0.56**	**0.72**
Dichentrarchus labrax	**0.53**	**0.90**
Sparus aurata	**0.47**	**0.66**
Epinephelus aeneus	**0.44**	**0.60**