Bioenergetics

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3- Energy Forms 2

Energy Terms (cont.)

Total heat production (HE): energy lost in the form of heat

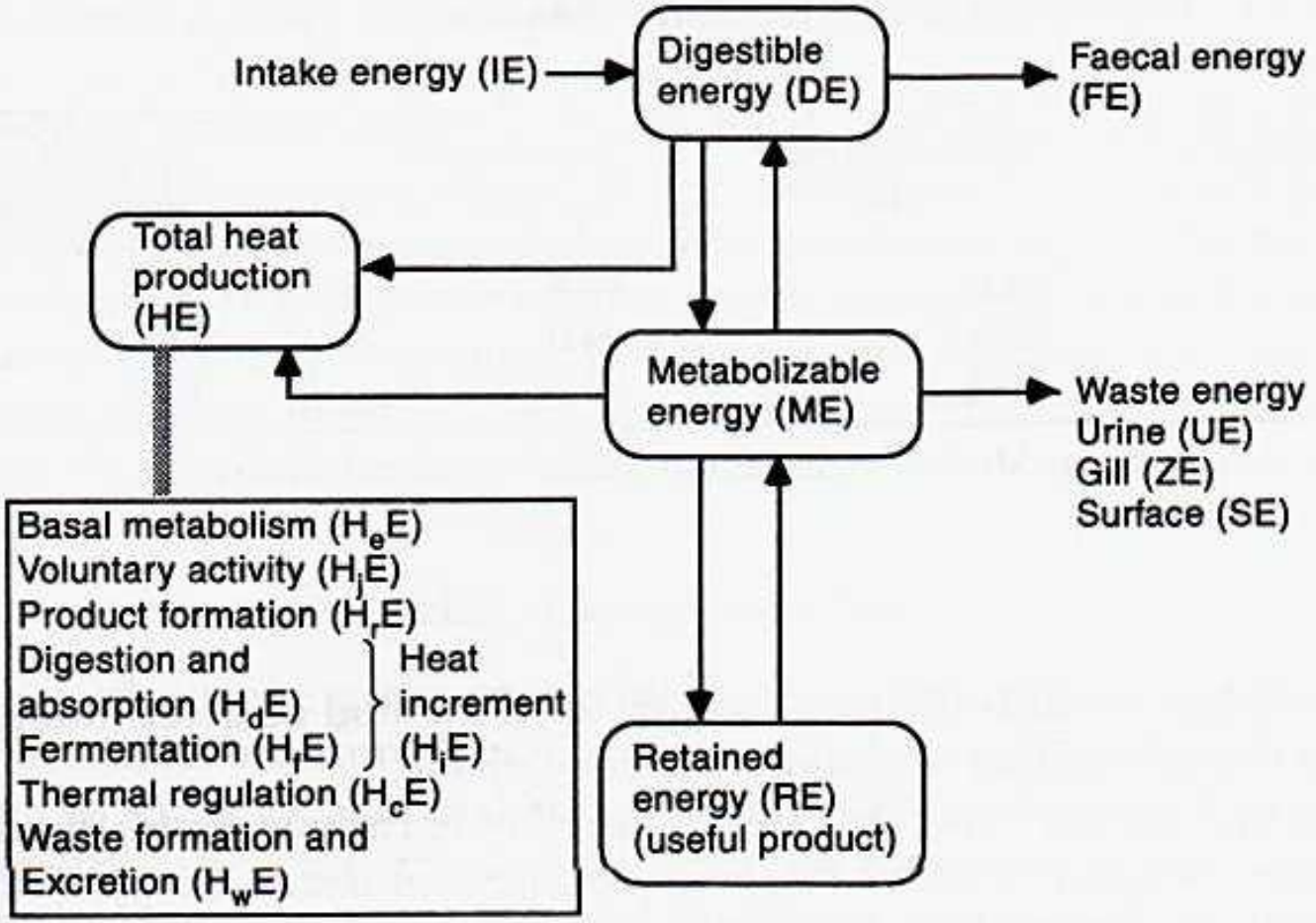
heat lost is sourced from metabolism, thus, HE is an estimate of metabolic rate

measured by temperature change (calorimetry) or oxygen consumption rate

divided into a number of constituents

as per energy flow diagram →→

Energy Flow Diagram



Energy flow in an aquatic organism.

Energy Terms (total heat production)

Basic metabolic rate (H_eE): heat energy released from cellular activity, respiration, blood circulation, etc.

heat of activity (H_jE): heat produced by muscular activity (locomotion, maintaining position in water)

heat of thermal regulation (H_cE): heat produced to maintain body temp (above zone of thermal neutrality)

heat of waste formation (H_wE): heat associated with production of waste products

specific dynamic action (H_iE): increase in heat production following consumption of feed (result of metab), varies with energy content of food, especially protein

Energy Utilization

- Energy intake is divided among all energy-requiring processes
- Magnitude of each depends on quantity of intake plus animal's ability to digest and utilize that energy
- Can vary by feeding mode: carnivorous vs. herbivorous

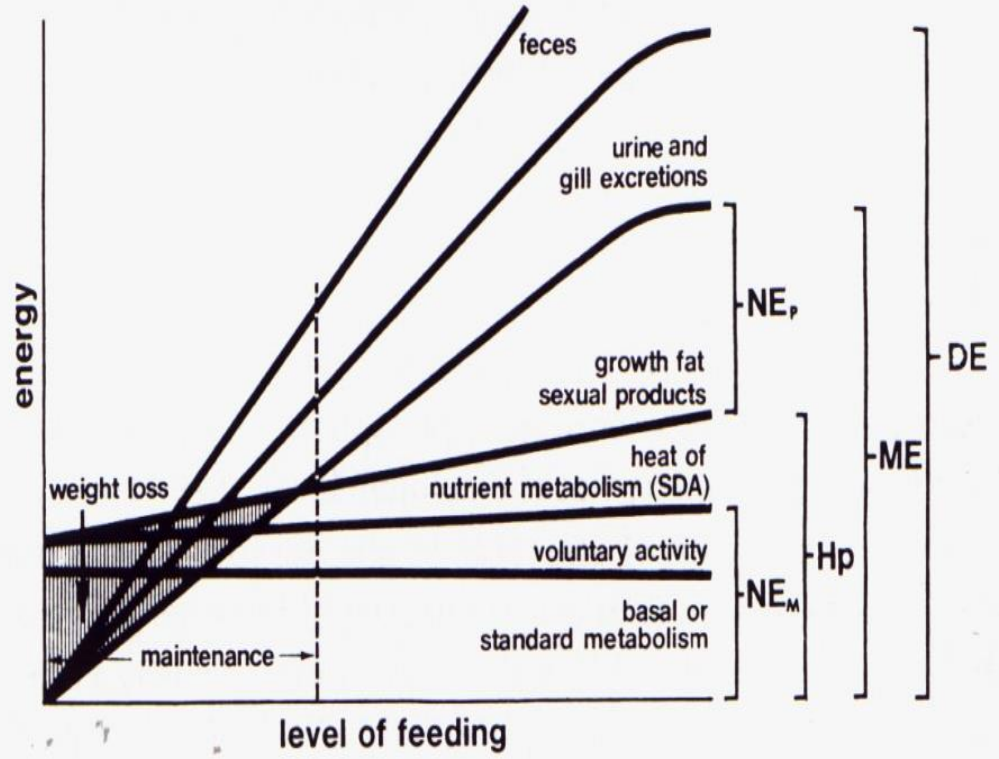


FIG. 1.2

Energy intake and distribution among energy-requiring processes. (From Smith, *In* "Studies on the Energy Metabolism of Cultured Fishes", 1976 Thesis, Cornell University.)

From Halver (page 7)

Focus: Gross Energy

Energy content of a substance is typically determined by completely oxidizing (burning) the compound to carbon dioxide, water and other gases

the amount of energy given off is measured and known as **gross energy**

gross energy (GE) is measured by a device known as a **bomb calorimeter**

other devices: gradient chamber, infra red detector

Gross Energy of Feedstuffs

Table 2.2. GROSS ENERGY VALUES FOR SOURCES OF CARBOHYDRATES, FATS, AND PROTEINS DETERMINED BY BOMB COLORIMETER

Substrate	kcal/
Glucose	3.77
Cornstarch	4.21
Triglyceride:	
Beef fat	9.44
Soybean oil	9.28
Casein	5.84

Gross Energy of Feedstuffs

Fats (triglycerides) have about twice the GE as carbohydrates

this is because of the relative amounts of oxygen, hydrogen and carbon in the compounds

energy is derived from the **heat of combustion** of these elements: C= 8 kcal/g, H= 34.5, etc.

typical heat of combustion of fat is 9.45 kcal/g, protein is 5.45, COH is 3.75

Available Energy

Gross energy only represents the energy present in **dry matter (DM)**

it is not a measurement of its energy value to the consuming animal

the difference between gross energy and energy available to the animal varies greatly for different foodstuffs

the key factor to know is how digestible the food item is

digestible energy also varies by species

Digestible Energy

The amount of energy available to an animal from a feedstuff is known as its **digestible energy (DE)**

DE is defined as the difference between the gross energy of the feed item consumed (IE) and the energy lost in the feces (FE)

two methods of determination: direct or indirect

by the direct method, all feed items consumed and feces excreted are measured

Digestible Energy

The indirect method involves only collecting a sample of the feed and feces

digestion coefficients are calculated on the basis of ratios of energy to indicator in the feed and feces

indicator?: an inert indigestible compound added to the feed

indicators: natural (fiber, ash) or synthetic (chromic oxide)

DE Calculations

Direct Method

$$\% \text{ DE} = \frac{\text{Feed energy} - \text{Fecal energy}}{\text{Feed energy}} \times 100$$

Indirect Method

$$\% \text{ DE} = 100 - \left[\frac{\text{Feed energy}}{\text{Fecal energy}} \times \frac{\text{Fecal indicator}}{\text{Feed indicator}} \right] \times 100$$

Metabolizable Energy

This is even more detailed distinction of energy availability

it represents DE minus energy lost from the body through gill and urinary wastes

much more difficult to determine

must collect all urinary wastes while fish is in water!!!

$$\%ME = \frac{\text{Intake energy - (E lost in feces, urine, gills)}}{\text{Feed energy}} \times 100$$

Metabolizable Energy

Use of ME vs DE would allow for a much more absolute evaluation of the dietary energy metabolized by tissues

however, ME offers little advantage over DE because most energy is used for digestion in fish

energy losses in fish through urine and gills does not vary much by feedstuff

fecal energy loss is more important

forcing a fish to eat involuntarily is not a good representation of actual energy processes

Energy Ratios for Rainbow Trout

Table 2.3. RATIOS OF DIGESTIBLE TO GROSS ENERGY (DE/IE) AND METABOLIZABLE TO DIGESTIBLE ENERGY (ME/DE) FOR RAINBOW TROUT

Feedstuff	DE/IE	ME/DE
Anchovy fish meal	.91	.94
Whitefish meal	.84	.94
Soybean meal, without hulls	.79	.94
Meat meal	.71	.95
Cottonseed meal, without hulls	.63	.93
Wheat middlings	.40	.91

Source: Calculated from values in NRC (1981).