GROWTH AND CALORIFIC APPROXIMATION IN THE SPECKLED TROUT

(Salvelinus fontinalis)

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INTRODUCTION

FROM the point of view of energy metabolism, appropriate measures of the rate of oxygen uptake would indicate the energy turnover or the capacity of the organism to perform external work in relation to its size and under the prevalent environmental conditions. Estimates of oxygen uptake when considered in conjunction with growth rate and calorific equivalent of the metabolic rate, would permit estimates of the total energy requirements of the individual. It has long been established, that the calorific equivalent of food consumed corresponds to the heat output *plus* the heat equivalent of excreta, and that such a measurement of metabolism can be verified also by indirect calorimetric methods based on the gas exchange of the animal.

A number of early workers: Rubner (1902), Lindstedt (1914), Zuntz (1914) and Wundsch (1934) have established the essential validity of indirect calorimetric methods and the present work based on some preliminary experiments carried out on the speckled trout adds further evidence. Especially in the light of current trends where culture fisheries as a branch of science is given as much importance as capture fisheries, economy in food supply with the maximum of production can be accurately assessed with some knowledge of the energy turnover of the population in question. It is more to stimulate further interest in this field of study rather than to display any completeness of the enquiry that the following are presented.

MATERIAL AND METHODS

The data of oxygen uptake for this study were actually extracted from Job (1955). The apparatus used is shown in Fig. 1. Briefly the device is a double-walled drum—the outer being glass and the inner, metal. The base of the drum also of metal, rests on a turntable. A metal rim is mounted on the free end of the glass wall and is firmly clamped to the base by means

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of lucite brackets. There are two openings on this rim. Through one a measured quantity of water can be introduced from a graduated cylinder mounted on the rim itself, by opening a long handled screw valve. The other opening is for the thermometer. After filling the chamber with water it is sealed from the atmosphere by a rubber gasket (the inner tube of a small aeroplane wheel) which when inflated bound against the metal rim and the

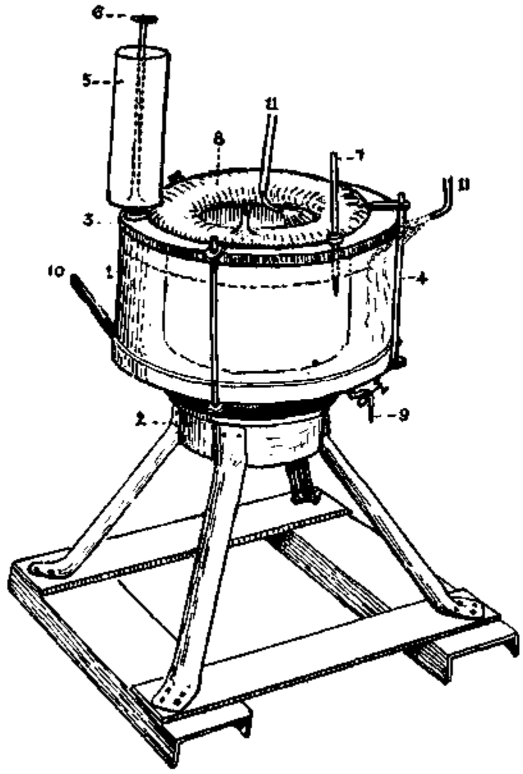

FIG. 1. Apparatus for measuring the active metabolism of fish. (1) Drum, (2) Turntable, (3) Metal rim, (4) Lucite bracket, (5) Graduated cylinder, (6) Screw valve, (7) Thermometer, (8) Rubber gasket, (9) Outlet, (10) V-belt connecting turntable to reduction speed gear, (11) Water jets. [(For an improved and more efficient version of the same apparatus, *see* Fry in Brown (1957)].

inner wall of the drum. Water could be drawn for analysis through the other opening located on the inner wall close to the base of the drum. Since the system is a closed one water could be drawn out only by a simultaneous introduction of water into it. At each sampling therefore 100 ml. of water was introduced from the graduated cylinder and the same amount drawn out. This procedure ensured the constancy of the volume of water in the chamber. During the experiment the entire chamber could be rotated at any constant speed ranging from 1 to 200 r.p.m. and its direction changed at will with the help of a variable speed reduction gear powered by a ·25 HP motor. The size of the chamber used was such as to allow enough room for the fish to swim actively. With the help of water jets playing both on the inside and outside of the chamber the temperature could be maintained at any level to within $\pm$ 0·2° C.

The chamber was filled with water at the desired temperature and the fish introduced into it. The partly inflated rubber gasket was pushed down into position and rapidly inflated with both the inlet and the outlet open, so as to equalize the pressure inside the chamber to that of the atmosphere, as otherwise the fish released air into the chamber creating air pockets. The gasket was now squeezed all round in order to release any air lock that might have been formed. The chamber was now rotated rapidly for 30 secs., before the initial sample of the experiment was drawn and from then on at intervals of half to one hour as the case may be, samples were drawn for analyses. The speed and direction of the chamber were such as to make the fish swim actively against the current and maintain a steady position in the chamber—the fish not being allowed to move forward or slip back.

In spite of the seal, some contamination of the water in the chamber especially when the partial pressure of oxygen was low took place through diffusion from the gasket as well as from the atmosphere itself. Suitable corrections were made for this error. The rate of oxygen consumption was calculated from the mean rate of fall in the dissolved oxygen against the total volume of the water in the chamber and expressed in ml./hr. For an improved model of the apparatus please see Fry, 1957.

The feeding experiments were performed on two fish of nearly the same size and average weight of 89 gm. at 17° C. In order to obtain the calorific approximations the fish were held in well-aerated water in a trough of about 10 L. capacity. The fish were fed with fresh minnows *ad libitum* over a period of two weeks. After some training the fish learnt to take the food almost as it was being offered. The unconsumed remnants of the minnows were removed one hour after feeding. The insoluble fæcal matter was collected every 12 hrs. and dried to a constant weight. The heat of combustion of the dried matter was measured according to the procedure described in *Parr Manual No.* 120 (1948)* using a single valved oxygen bomb

* Oxygen Bomb Calorimetry and Oxygen Bomb Combustion Methods. *Parr Manual* 120, 1948, pp. 79. Parr Instrument Co., Moline, Ill., U.S.A.

and a plain calorimeter. Briefly the apparatus consists of three parts: (1) The oxygen bomb in which the material whose heat of combustion is to be determined is ignited electrically in an atmosphere of pure oxygen; (2) The calorimeter bucket holding a measured quantity of water and a Beckman's thermometer and stirrer; and (3) an insulated jacket to prevent changes in the ambient temperature from affecting the temperature in the bucket.

RESULTS AND CALCULATION OF DATA

As was stated earlier the value obtained from Job (1955) was that an 89 gm. fish consumed 8 lit. of oxygen in two weeks. As there is evidence in the literature to show that fish normally maintains its metabolic rate at or near its maximum this value was taken as such for estimating the calorific output.

During the same period the mean weight of minnows consumed per fish was 91 gm. and the gain in weight, in other words the average growth, was 11 gm. The insoluble fæcal matter collected amounted to 3·3 gm./fish, (dry weight). The calorific value of the minnows was found to be 86·3 cal./100 gm. (wet weight) and for the fæces 2·3 cal./gm. (dry weight). With these basic data the following calculations and approximations were made:

The net food consumed per fish	= (91 − 11)
(*i.e.*), food eaten − weight gained	= 80 gm. wet weight
Calorific value of net consumption	= [80×(86·3/100)]
	= **68·9** cal.
Calories excreted as fæces	= (3·3×2·3)
	= **7·6** cal.

From the analysis provided by Schmidt (1950) and on the basis of the calorific content measured, it was assumed that the food ingested contained 16% of protein (and negligible quantities of fat and carbohydrate) on wet weight basis. Then the weight of protein consumed was [80×(16/100)] = 12·8 gm. It was further assumed that the nitrogen from the metabolism of this protein was excreted in the nitrogenous fractions found by Smith (1929) for the excretion of nitrogen by the carp. From his table for branchial and urinary nitrogen excretion in the carp and from the table of heats of combustion of organic compounds given in Hodgman (1945) it was estimated that the calorific value of such nitrogenous products was 6·49 cal./gm. For details see Table I.

TABLE I

Consolidated table of branchial and urinary nitrogen excretion in the freshwater carp, Cyprinus carpio *(Smith, 1929) and heats of combustion of the various compounds (Hodgman, 1945)*

Constituents of excretion	% excreted	Heat of combustion calories	Heat of combustion/gm. calories	Total calories per gm. of excreta
Ammonia ..	60·0	..	..	..
Urea ..	5·3	151·6	28·7	..
Uric acid ..	0·2	460·2	1·6	..
Amine ..	6·6	500·0 (mean)	50·0	..
Creatine ..	5·4	559·8	72·0	..
*Undetermined (Trimethylamine ?) ..	20·5	578·6	84·7	..

* The undetermined part is probably Trimethylamine (Smith, 1929). Prosser *et al.* (1950) however maintain that it is absent from the muscle of eel and carp and hence not likely to be that compound. However for the purpose of calculation it has been taken as such, tentatively.

The metabolism of 12·8 gm. of protein would (on the basis that the ratio of nitrogen in it is $\frac{1}{6}$) result in (12·8/6) = 2·13 of excretory N and the calorific value of this amount would be on the basis of the estimates indicated above (2·3×6·49) = 13·8 cal.

Since the calorific value of minnows and salmonoids is not the same, conversion of minnows into trout flesh would have probably involved greater retention of the calories consumed. The salmonoids typically have a calorific value of 600–1000 cal./lb., Schmidt (1950). The minnows consumed had on the other hand a much lower value, *i.e.*, 390 cal./lb. (86·3 cal./100 gm.). If a calorific value of 600 cal./lb. (mean) is taken for 11 gm. of trout flesh gained it will reduce the heat output further by [(600—390)/452]× 11 = **5·1** cal. Thus the calories dissipated would be (7·6 + 13·8 + 5·1) = **26·5** cal. On this basis then, the net calorific output would become (68·9—26·5) = **42·4** cal.

As already stated the calorific value of minnows being low and since they were starved at the time of the experiment, it was assumed that the calorific value obtained with the calorimeter for the minnows represented the heat of combustion of protein and negligible quantities of fat and carbohydrate. From the table given by Kleiner (1948) the oxygen equivalents of combustion of protein was taken to be 4·3 calories per litre. Since the calorific equivalent for fat is also of the same order (4·4 cal. = 1 lit. O_2) and since it has been shown by Schmidt (1950) and Geng (1925) that fish have very little carbohydrate, this factor 4·3 used in the present calculation would be justified.

It works out then, that 42·4 calories of minnows consumed would correspond to 9·8 lit. of oxygen in two weeks. From Job (1955) it was estimated that the net steady consumption of oxygen would be 8 lit. over the same period. Taking into account the wide range of assumptions this figure would seem a remarkably close estimate and establish the essential validity of indirect calorimetry as deduced from oxygen consumption measurements of the fish.

For the convenience of the reader the entire set of calculations is summed up in Table II below.

TABLE II

Data of the entire experiment have been summed up in order to obtain the calorific balance and the main features of the calculations indicated. The experiments were based on two fish of nearly the same size and of mean weight of 89 gm.

Total calories ingested (91 — 11) gm. at 0·863 cal./gm.		= **68·9** cal.
Less—		
Calories in fæces 3·3 gm. at 2·3 cal./gm.	= 7·6 cal.	
Calories in other excretions 3·13 gm. at 6·49 cal./gm.	= 13·8 cal.	
Gain in calorific values of trout flesh 11 gm. at 0·68 cal./gm.	= 5·1 cal.	
(Total)		= 26·5 cal.
Net calories expended		= **42·4** cal.
Oxygen equivalent of 42·4 cal. at 4·3 cal./lit. O_2 (42·4 ÷ 4·3)		= **9·8** lit. O_2
Mean value of active metabolism for fish of this size		= **8·0** lit. O_2

SUMMARY

The results obtained from a simple feeding experiment and the active oxygen consumption experiment showed that the metabolic rate can be

equated with the calorific output in the speckled trout with reasonable agreement.

The oxygen consumption of a fish of 89 gm. over a period of two weeks at 17° C. was 8·0 litres. During the same period the metabolic equivalent of the net calories amounted to 9·8 litres (approximate).

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