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Digestible energy need (DEN) of selected farmed fish species

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Abstract

Using the energy required (digestible energy need, DEN) to grow 1 kg of wet body weight, feed ration models can be created that accurately calculate the daily feed requirements for specific strains/stocks of fish and farm locality. This study examines the effect of body weight and temperature on the DEN. The relationship was examined using data from the current scientific literature for selected farmed fish species. In general, the DEN increased with increasing body weight for salmoniformes and pleuronectiformes. However, no effect of temperature was found for any groups examined by systematic order or species. Perciformes fish showed no effect of body weight or temperature on the DEN. This may be attributed to differences in the way that body composition changes occur among species as they grow (e.g., changes in fat storage), which in turn may be explained by an adaptation to life in warmer water.

Keywords: Feed consumption; Growth; Growth efficiency; Digestible energy; Fish; Feed management

1. Introduction

Fish farmers using automatic, timer-controlled feeders usually rely on feeding charts or growth models for calculation of the daily feed requirements of the fish (e.g., Iwama and Tautz, 1981; From and Rasmussen, 1984; Austreng et al., 1987; Cho and Bureau, 1998). These are frequently based on temperature and fish size and are often in much generalised form with little room for adjustments based on local conditions and the fish stock being farmed. A better approach for farmers would therefore be to develop feed budgets, based on the daily energetic requirements of their own fish (Alanärä et al., 2001; Bailey and Alanärä, 2001).

The energy need of fish has traditionally been estimated by constructing a complete energy budget, balancing the energy income against energy expenditures (Brett, 1979; Jobling, 1994; De Silva and Anderson, 1995). Estimated expenditures include energy lost in the faeces, energy lost to excretion (urinary, gill, body surface energy loss), energy used for metabolism, and energy deposited as growth. Numerous studies of fish energetics have been performed and many potential sources of error have been identified (Brafield, 1985). Although methods have been im-

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proved, no model is, to our knowledge, available for use in commercial farming conditions.

Alanärä et al. (2001) described an alternative and simplified way of estimating the energy requirements in fish by measuring the energy intake and the corresponding weight increase. This will express the digestible energy need (DEN) (Mega Joules of Digestible Energy per kg = MJ DE kg^{-1}) of the fish for a 1 kg gain in wet body weight. The energy requirement (MJ per day) is then calculated by multiplying DEN with the daily theoretical weight increase (kg). Weight increase can be estimated from previous growth records or theoretical growth models of the particular species of interest and this estimation can be used along with the DEN, taking differences in body weight and temperature into account (see Alanärä et al., 2001 for growth model examples).

From a fish farmer's point of view, the details concerning where energetic expenditures occur are of less importance. What is important is obtaining the maximum return (gain in biomass) per unit input (feed intake). The advantage with the view of the energy budget described by Alanärä et al. (2001) is that, since the values for excretion, and metabolism need not be quantified, the calculation of DEN can be made when the fish are being raised under normal culture conditions. By doing so, energetic costs due to the ingestion and digestion of feed, and to swimming activity are more similar to those used in culture than to those used when a complete energy budget model is used (Alanärä et al., 2001). Due to its ease and relatively low cost of calculation, the DEN can be estimated for a particular strain of fish and under local farm conditions, providing the farmer with a very specific method of evaluating the energetic requirements of the fish.

The aim of this study was to collect data from the published literature and to define and compare the digestible energy need at the species, strain and individual levels.

2. Materials and methods

In order to evaluate the relationship between body size, temperature and DEN for different fish species, a review of the scientific literature was performed. This is a novel method for calculating the daily energy requirements of the fish (Alanärä et al., 2001) and therefore no information on the DEN was available. However, using feed intake, increment of weight gain, energy content of the feed, body weight, and temperature data for various fish species used in intensive culture (see Appendix A for information on data used), the DEN can be estimated using:

$$\mathrm{DEN} = (\mathrm{FI}^{*}\mathrm{DE})/\mathrm{Wi} \quad (1)$$

where FI is the feed intake (kg), Wi is the increment of weight gain (kg), and DE is the digestible energy content of the feed (MJ kg^{-1}).

DE content was chosen as the energy unit as it is a more reliable measurement to use in nutrition and production studies than gross energy (GE) or metabolisable energy (ME) (Jobling, 1983). Apparent digestibility coefficients (ADC) were collected for a large number of species, but the values varied markedly within and between species (Appendix B) depending on experimental conditions and the content of the feed. Therefore, for estimating the digestible energy in the feed, the following values were used: protein, 20.9 kJ g^{-1}; fat, 35.1 kJ g^{-1}; and carbohydrate, 11.0 kJ g^{-1} (Hillestad et al., 1999). These values lie within the range of ADCs found in the literature for carnivorous fish and have been generally accepted by the Norwegian salmon farming industry (Hillestad et al., 1999). However, from a practical point of view, and in lieu of the fact that variation in the ADCs and calculation of DE may be difficult, the GE might also be a suitable alternative for fish farmers.

Due to ontogenetic changes in metabolism and body composition in salmonids (Jobling, 1994), the weight gain for a given amount of ingested energy changes as fish grow. Metabolic rates can be plotted as a function of body weight using a non-linear, allometric relationship, described by the power equation (Wootton, 1991; Eckert et al., 1988):

$$\mathrm{d}M/\mathrm{dBW} = k^{*}\mathrm{BW}^{\alpha} \quad (2)$$

where $\mathrm{d}M/\mathrm{dBW}$ is the instantaneous metabolic rate at a particular body weight, BW is body weight, and k and α are constants. Using similar reasoning, one can derive a simple linear equation with slope, k, and y-intercept, α, relating body weight to DEN:

$$\mathrm{DEN} = \alpha + k \cdot \log_{e} \cdot \mathrm{BW} \quad (3)$$