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Short communication

ASSIMILATION EFFICIENCY IN TWO HERBIVORES, *OREOCHROMIS NILOTICUS* AND LARVAE OF *IMBRASIA BELINA*: A COMPARISON

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ABSTRACT: The abilities of two herbivorous animals (*Oreochromis niloticus* and the larva of *Imbrasia belina*) to digest and absorb nutrients (Assimilation efficiency) from their guts were studied. *Oreochromis niloticus* mainly feeds on phytoplankton and the larvae of *I. belina* feeds on leaves of Mophane (*Colophospermum mophane*) and Morula (*Sclerocarya birrea*) trees. The amount of organic matter in the diet of fish (100-600 mg/g D.W.) and assimilation efficiency (8-43%) were variable and an increase in the level of organic matter in the diet of fish resulted in an increase in assimilation efficiency. The organic matter in the diet of *O. niloticus* can only be increased when the fish ingests more algae and this improved lyses of algal cells. The organic content in the diet of the larvae was consistently high (>900 mg/g D.W.) but assimilation efficiency was not always high. The highest assimilation efficiency for the larvae was 36 ± 3.3% and the lowest was 13.2 ± 3.2%. In this study, it has been shown that the amount of organic matter in the diet and larval age are factors that could limit assimilation efficiency in fish and larvae, respectively. The proportion of cellulose material, indigestible organic matter, in the food is another constraint for both animals. As a result, both animals have only achieved about 40% maximum efficiency. Thus, more studies to understand how these and other factors affect assimilation efficiency are essential to improve production of these animals in aquaculture and larviculture.

Key words/phrases: Assimilation efficiency, *Imbrasia belina*, lepidoptera, *Oreochromis niloticus*, saturniidae

INTRODUCTION

The larvae of *Imbrasia belina* (Lepidoptera: Saturniidae) are herbivores and are observed to feed on leaves of several plants. These include *Colophospermum mophane, Sclerocarya birrea, Terminalia sericea, Trema bructeolata* and *Brachystigia speciformis* (Pinhey, 1972; 1975; Mughogo and Munthali, 1995; Ditlhogo, 1996). In Botswana, the larvae of *I. belina* are collected for human consumption. The activity has become a major rural industry and many people collect the larvae to subsequently cook, dry and sell the product (Getachew Teferra *et al.,* 2000b).

Oreochromis niloticus (Pisces: Cichlidae) commonly known as the Nile tilapia is an herbivorous fish that mainly feeds on phytoplankton (Getachew Teferra, 1987; 1993; Getachew Teferra and Fernando, 1989). The fish is abundant in many water bodies of Africa. *O. niloticus* is distributed throughout sub-Saharan Africa, and it has now been widely distributed through the warm regions of the world especially for use in aquaculture. The indigenous people of Africa use this fish as a major source of protein.

The diets of these two animals are less digestible as plant cells are surrounded by cell wall, and many animals including these two do not have the enzyme to lyse the cellulose in the cell wall (Fish, 1960; Personal observation). Therefore, the ability of these herbivorous animals to use plant nutrient sources is limited. The extent to which these two animals digest and absorb the nutrients from their diets (assimilation efficiency) is a major factor that could determine the well being, and growth of these animals. This information is also valuable for people interested in culturing these two species. Hence, this work attempted to determine the assimilation efficiencies of these two species of animals and their abilities to use plant foods.

MATERIALS AND METHODS

Fish were collected during day light hours with bottom trawl net from Lake Tana, Ethiopia for 13 months, March 1992 to March 1993. Stomach contents (food) and the contents of the last few cm of the digestive tract (faeces) ranging in number from 5-15 samples for each month were separately removed and dried at 100°C. Dry samples were ground to pass through a 600 μm mesh, and stored in glass vials under refrigeration pending analyses.

The leaves of *C. mophane* on which eggs of *I. belina* had been deposited were collected from the Mophane forests of Botswana in December 1998. The leaves were placed into petri dishes in a laboratory until the eggs hatched. After hatching the larvae were transferred into petri dishes. Ten petri dishes, each containing a larva, were placed on a laboratory bench. The larvae were fed *ad libitum* with fresh leaves from two plants, *C. mophane* (Mophane tree) and *S. birrea* (Morula tree). Every day the dishes were cleaned and the faeces collected. The faeces was then placed on a sheet of aluminium foil to dry to constant weight in an oven at 100° C. Fresh leaves of each plant were also dried in an oven. Each of the different types of leaves (the food) and the faeces were separately ground in a Warring blender to pass through a 600 µm sieve. The faeces from the larvae were collected at two stages when the larvae were young instars and when they had grown to be old instars. The larvae have 5 instars. The first two are considered young and the rest were classified as old instars. A total of 6 samples for each size and for each plant leaf were collected. The faeces were then used for chemical analyses.

The organic contents of the foods from the two animals and their respective faeces were determined by igniting a known weight of sample in a muffle furnace at 550° C for 4 hours. The weight loss after ignition was the weight of the organic content in the sample, and the weight of un-ignited material was the amount of ash in the sample (AOAC, 1995). Assimilation efficiency, the ability of the animal to digest and absorb nutrients from its diets, was calculated by ash-ratio method of Conover (1966) with ash as the unassimilated reference material, using the formula:

$$A.E. = (Food - Faeces)/Food$$

where 'Food' is the ratio of organic matter to ash in the food, and 'Faeces' is the ratio of organic matter to ash in the faeces (mg organic matter.mg^{-1} Ash).

RESULTS

The per cent assimilation efficiency in the larva ranged between 13.2 ± 3.2% to 36.3 ± 3.3%, (n=6) and 26.7 ± 1.6% to 30.5 ± 1.7% (n=6) when fed leaves of *C. mophane* and *S. birrea*, respectively (Fig. 1). There were significant differences in assimilation of organic matter in the two types of leaves; and the age of the larvae determined the extent of digestion and absorption; and hence young larvae assimilated less than older larvae particularly when fed Mophane leaves (Fig. 2). The organic content of the two leaves is high and is usually more than 90% dry weight, but it is mostly indigestible cellulose that could be a factor for limiting assimilation efficiency.

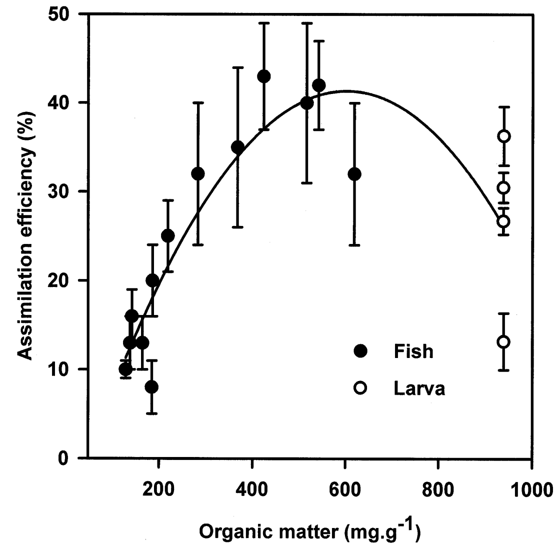

Fig. 1. The relationship between organic matter in the diet and assimilation efficiency in *O. niloticus* and the larvae of *I. belina*. The vertical bars are means ± S.D.

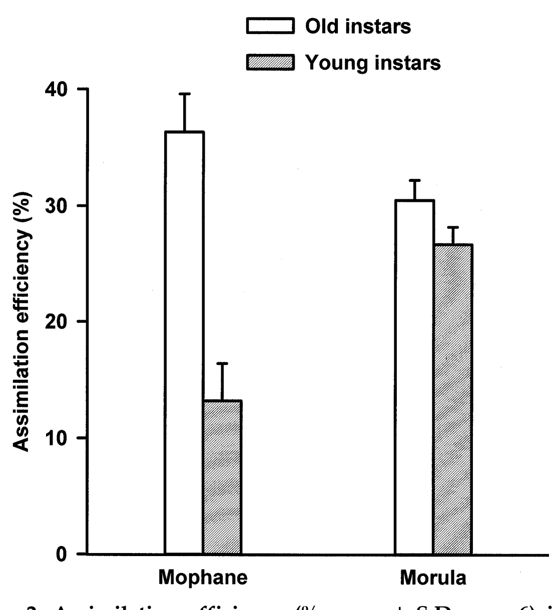

Fig. 2. Assimilation efficiency (% mean ± S.D., n = 6) in young and old instar larvae of *I. belina* when fed Mophane and Morula leaves.

The percent assimilation efficiency in *O. niloticus* ranged between 8.0 ± 3.0% and 43 ± 6.0%, (n = 5-15, for each monthly sample) and an increase in the level of organic matter in the diet of the fish resulted in an increase in assimilation efficiency (Fig. 1). This fish feeds during day light hours from dawn to dusk and stops feeding at night. Studies have shown that when the stomach is full at dusk, the pH of the stomach becomes more acidic (Fig. 3)

(Getachew Teferra and Fernando, 1989; Zenebe Tadesse and Getachew Teferra, 1998) indicating that acid lyses of phytoplankton is the means for breaking down and releasing the contents of the cells.

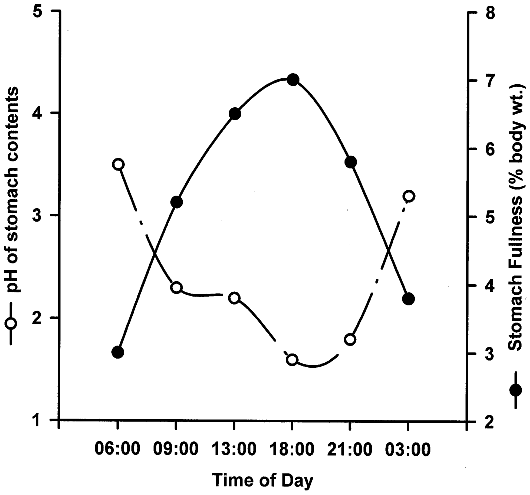

Fig. 3. Stomach fullness and stomach pH in *O. niloticus* at different times of the day (modified from Getachew Teferra and Fernando, 1989).

The best-fit line drawn through all assimilation efficiency values for both fish and larvae showed that the maximum efficiency (asymptotic value) is about 40% (Fig. 1).

DISCUSSION

The feeding process in *I. belina* involves biting and chewing leaves. Chewing effectively macerates the leaves and exposes the contents of the cells to digestive enzymes in the gut. This kind of mechanical digestion has its own limitations. The device (mandibles) used for chewing the tissue and the levels of softness in the leaves are important. In older larvae, as the mandibles and the muscle associated with it grow, they become robust and powerful. This means that older larvae can easily chew plant tissues and assimilate better than younger larvae. The difference in assimilation efficiency between young and old is particularly high in larvae fed *C. mophane* because the leaves of *C. mophane* have more vascular tissues and are less succulent than the leaves of *S. birrea* making chewing more demanding for the young larvae. Therefore, The nature of the leaves is another factor that can affect assimilation efficiency.

All plant cells are surrounded by cell wall and the organic contents in the leaves of these two plants are therefore mostly indigestible cellulose. This material is not available as a source of nutrient for animals that do not have the enzyme cellulase. Cellulases of animal origin have only been identified in few species (Begon *et al.*, 1990) and the larvae of *I. belina* have not been implicated to produce the enzyme. In our laboratory, crude gut content from the larvae was added to pure cellulose to see if this produced reducing sugars. Preliminary observations did not show cellulase activity. Hence mechanical digestion opens up the cells and only the cellular contents become vulnerable to the digestive enzymes of the larvae. The limitations in mechanical digestion itself coupled with the relatively small amount of susceptible organic material for digestion are the major factors that could lower assimilation efficiency in these larvae.

Various authors (Moriarty, 1973; Pyne, 1978; Getachew Teferra and Fernando, 1989) have concluded that *O. niloticus* digest their plant diets using extreme acid secretion in the stomach to lyse algal cells and detrital materials including bacteria. Studies have also shown that when the stomach of fish is full at dusk, the pH of the contents of the stomach becomes low (Getachew Teferra and Fernando, 1989; Zenebe Tadesse and Getachew Teferra, 1998). In this fish, stomach acid dissolves the cell wall material and releases the cellular contents into the gut for digestion and later for absorption. Phytoplankton in the environment exist as unicellular, filamentous, colonial or multi-cellular growth forms. The first three forms are common in freshwaters. The implication is that these growth forms are discrete units that could easily become susceptible to stomach acidity. The extent of acidity is a limitation in this case, and to what extent the stomach is full determines the level of acidity in the stomach. As the fish starts to ingest early in the morning, the pH of the stomach is high and as the day progresses the pH decreases. The process of digestion and absorption in the morning is rather limited as compared to that in the afternoon and this contributes an element of variation in the efficiency of digestion in this fish.

This fish also lives in waters of different productivity. In productive waters, the fish will have access to plenty of food and the stomach can reach the full range easily while in less productive waters the stomach never becomes full. In waters that have variable seasonal productivity, access to plenty of food depends on the season of the year. It is plausible to assume that assimilation efficiency could vary seasonally as the amount of food ingested could affect the level of acidity in the stomach. For example, at the end of the rainy season from June to September, Lake Tana was productive and the organic content in the food of the fish was high (Getachew Teferra et al, 2000a); and it was also found that assimilation efficiencies were proportionally high during these months. The organic matter in the diet of *O. niloticus* can only be increased when the fish ingests more algae. The increase in the stomach fullness stimulates stomach acid secretion and this improves lyses of algal cells. A high level of organic matter implies that the stomach of fish is full of materials from living sources, e.g. algae. Therefore, during seasons of high productivity, the fish feeds at full capacity resulting in improved digestion and absorption.

The maximum assimilation efficiency in the fish appears to be a little higher (43%) than in the larvae (36%) because the phytoplankton that makes the bulk of the food in the fish has relatively less cell wall material and no vascular tissue, and this makes it easier to be digested in the fish gut. The drop in assimilation efficiency when the organic matter exceeded 600 $mg.g^{-1}$ is difficult to explain but it is postulated that the fish during this time might have fed on detrital material that was rich in refractory organic material. Both these animals have their own limitations, even though the larvae use mechanical digestion and the fish acid lyses as ways and means for releasing the contents of the tissues in their guts. As a result the maximum efficiency at which both utilize their food did not exceed 40%. Further studies to find factors that can maximize assimilation efficiency in these animals such as proportions of different types of nutrients in the food and amount of food, may be useful to improve their production in aquaculture and larviculture.

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