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Evaluation of new microparticulate diets for early weaning of Atlantic cod (*Gadus morhua*): Implications on larval performances and tank hygiene

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Abstract

In recent years, interest in the intensive culture of Atlantic cod (*Gadus morhua*) has increased dramatically due to several factors including a reduced supply of cod from capture fisheries, a high market price for wild cod and the suitability of the species for culture. One of the major problems facing the industry has been the high cost and unreliability of live feeds, specifically the live feed *Artemia*. The main objective of this project was to determine whether *Artemia* use could be reduced or replaced completely with two novel microparticulate diets (MPD's), without negatively compromising growth, survival performance and tank hygiene under simulated commercial conditions.

The experiment consisted of four treatments, a live feed control treatment (group A), a 50% *Artemia* replacement treatment with MPD-1 (group B), a 100% *Artemia* replacement treatment with MPD-1 (group C) and a 100% *Artemia* replacement treatment with MPD-2 (group D). All treatments were run in triplicate. Growth performances, development (standard length, eye diameter, myotome height and wet weight), water quality (bacteriology and spectrophotometry) and survival were measured throughout the duration of the trial.

The results of the experiment indicate that the treatments containing *Artemia* (groups A and B) both achieved significantly higher growth rates than treatments that did not contain *Artemia* (groups C and D). The highest survival rates achieved at 70 dph were in treatments A and D (13.8%±0.7% and 14.2%±2.1% respectively) when compared to treatments B and C (11.8%±0.3% and 5.5%±1.3% respectively). Survival was also significantly higher in treatment B than in treatment C. This study demonstrates that while the best growth and survival rates are still achieved when cod larvae are fed *Artemia*, combining live feeds and commercially available MPD's (co-feeding) can produce comparable growth and survival rates thus potentially reducing the reliance on live feeds. However the complete replacement of *Artemia* with MPD's still significantly reduced growth potential suggesting that the nutritional composition of MPD's, requires further investigation.

Keywords: Cod larvae; Microparticulate diets; Weaning; Growth; Survival; Water quality

1. Introduction

The recent resurgence of interest in the intensive culture of Atlantic cod has been driven primarily by depletion of wild stocks, a relatively high market price,

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and the suitability of cod for culture purposes. Research in Northern Europe and North America has resulted in enhanced production protocols that have led to an increased production of juvenile fish. These combined factors have helped to make the intensive culture of cod economically feasible.

The weaning of larval and juvenile fish from live feeds onto an artificial diet is an extremely important phase in hatchery production. Despite recent advancements several limitations still exist, including low survival and growth rates and very high costs during the early larval stages of cod production (Rosenlund et al., 1997; Planas and Cunha, 1999; Baskerville-Bridges and Kling, 2000a; Callan et al., 2003). The main factor contributing to these costs is the production of live feeds including rotifers and *Artemia,* which can represent up to 50% of the total feed costs of juvenile fish production (Le Ruyet et al., 1993). *Artemia* alone can represent up to 40% of the total feed costs, or 80% of the live feed costs (Baskerville-Bridges and Kling, 2000a).

In order to reduce reliance on live feeds such as *Artemia*, research has been conducted over the last decade to find an alternative to live feeds. This research has led to the development of many different artificial diets that can generally be differentiated into conventional weaning diets for juvenile fish and microparticulate diets (MPD's) for the early weaning of larvae. Until very recently, the principle concerns with the general use of MPD's in marine larval rearing were that feeding with MPD's has resulted in poor growth and survival rates (Hamlin and Kling, 2001; Cahu and Zambonino Infante, 2001; Blair et al., 2003; Stoss et al., 2004). It has been suggested that poor performance of MPD's is due to low residence time in the water (Cahu and Zambonino Infante, 2001; Stoss et al., 2004), low palatability, low ingestion rates due to low digestibility of the diet because of inadequate digestive enzyme activity or poor nutritional composition of the diet (Baskerville-Bridges and Kling, 2000a). However, as shown in sea bass, digestive functions are efficient before the onset of exogenous feeding (Zambonino Infante and Cahu, 1994; review by Cahu and Zambonino Infante, 2001). Furthermore, a recent study on digestive capacity in haddock and cod larvae reported that both would be capable of digesting protein and lipids at the time of mouth opening (Perez-Casanova et al., 2006). The hypothesis suggesting that formulated microdiet failure was due to deficient enzymatic activity can thus be rejected. However, diets still need to meet specific nutritional requirements of the larvae. The small particle size associated with MPD's has led to the leaching of water-soluble nutrients, such as amino acids, from the feed. Leaching occurs due to the large surface-to-volume ratio of the small particles and can significantly compromise the nutritional value of the inert diet (Baskerville-Bridges and Kling, 2000a; Yúfera et al., 2002; Kvåle et al., 2006; Hamre, 2006). Furthermore the feeding of manufactured MPD's prone to leaching could have serious negative effects on the water quality of larval rearing systems, resulting in increased mortality rates which are unrelated to the digestible characteristics of the feed (Baskerville-Bridges and Kling, 2000b). Finally the buoyancy characteristics of the MPD particles have also been of concern. A high settling velocity can cause the MPD particles to sink to the bottom of the rearing tank, rendering them unavailable to the larvae and causing further degradation of water quality (Cahu and Zambonino Infante, 2001; Stoss et al., 2004) which can only be counteracted by increased manpower effort in tank cleaning. Irrespective of these concerns, increasingly more established production protocols are being developed in Europe for several warm-water marine species. The successful use of MPD's has been demonstrated for the early weaning (8 dph) of the gilthead sea bream (*Sparus aurata*) (Fernandez-Diaz and Yufera, 1997; Yúfera et al., 1999) and as early as at the fifth day post-hatch in Dorado (*Salminus brasiliensis*) (Vega-Orellana Orestes et al., 2006). Successful protocols may be adapted from their original format to work for the culture of cold-water species like cod (Planas and Cunha, 1999). Further development of MPD's for marine finfish larvae could help to reduce reliance on the current heavy use of live feeds, (specifically *Artemia*), simplify production protocols and reduce the overall cost of marine juvenile larvae production.

Acceptable growth rates are difficult to maintain using live feed exclusively due to the low nutritional content of the feed and the restricted feed intake of small larvae. Yet lower performances are also commonly reported when manufactured feeds are used exclusively from exogenous feeding. Combining live feed and manufactured MPD's, also known as co-feeding, from an early developmental stage has been shown to greatly improve the growth and survival as well as the cost effectiveness of producing many species of marine finfish larvae (Person-Le Ruyet et al., 1993; Kolkovski et al., 1997; Rosenlund et al., 1997). The main advantages of a co-feeding regime are twofold; it can help to improve and stabilize the nutritional condition of the larvae as well as pre-conditioning the larvae to accept a manufactured feed at an earlier stage (Rosenlund et al., 1997, Cañavate and Fernández-Díaz, 1999). This can result in a shorter weaning period