

Improving Atlantic cod quality through tailored early nutrition

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EarlyCOD project

Norway's cod industry is gaining renewed momentum, with annual production of farmed cod (*Gadus morhua*) expected to reach over 40,000 tonnes by 2030. This progress is driven by advances in breeding programs that have significantly improved the species' growth potential. However, reaching this target also depends on the consistent supply of high-quality juveniles from cod hatcheries. Atlantic cod larvae are sensitive to nutritional imbalances, and early weaning remains a delicate process often associated with skeletal deformities and variable survival rates. Recent findings from the EarlyCOD project offer valuable insights into practical ways to address these bottlenecks. The results showed that combining cryoplankton with species-tailored microdiets can significantly enhance organ development and improve skeletal quality in cod larvae. The EarlyCOD project (Eurostars-3, E!219) is a collaborative initiative between Portugal and Norway, led by SPAROS Lda., CIIMAR and Planktonic AS, with key contributions from ODE AS, Nord University and SINTEF Ocean. The goal was to develop species-specific feeding protocols that combine innovative live feeds and customized microdiets, ultimately improving growth, organ ontogeny, and skeletal development of cod larvae.

Rethinking early feeding strategies

Traditional cod rearing relies on enriched rotifers and *Artemia* as live feeds, which are nutritionally limited. Research has shown that natural zooplankton, such as barnacle nauplii, offer more balanced nutrition and contribute to improved larval performance. EarlyCOD took this concept further by testing a combination of cryopreserved prey — Cryo- μ (plankton eggs), Cryo-S (small barnacle nauplii), and Cryo-L (large barnacle nauplii) — alongside tailor-made microdiets with highly digestible ingredients. Two trials were conducted at

ODE AS (Norway), rearing cod larvae from 3 to 66 and 67 days after hatching (DAH), respectively. Larvae were distributed into triplicate 400 L tanks under controlled conditions (8.8–10.8 °C, continuous light). Experimental diets were produced by SPAROS and differed mainly in the origin of phospholipids (PL) — vegetable PL-rich diets (D1) and marine PL-rich diets (D2).

Better organ development and lower deformities when combining novel live feeds and tailored microdiets

Results from the trials demonstrated that the inclusion of Cryo- μ , Cryo-S, and Cryo-L enhanced organ ontogeny compared to the conventional rotifer-based protocol. By 15 DAH, cod larvae from both experimental groups already exhibited earlier gill development (Figure 1), characterized by the presence of erythrocytes essential for efficient oxygen and carbon dioxide exchange. By 30 DAH, larvae fed diets D1 and D2 showed more advanced tissue differentiation and greater cellular maturity, compared to the control group (CTRL) fed a commonly used commercial microdiet. This accelerated developmental trend continued throughout the trial, particularly after the introduction of microdiets (20–27 DAH). At 66 DAH, larvae from treatment D1 displayed notably improved intestinal ontogeny, with longer villi and a higher abundance of goblet cells — key histological indicators of enhanced nutrient absorption capacity and strengthened mucosal immunity.

By the end of the trial, the benefits of the experimental feeding protocols were also evident at the skeletal level. Fish receiving the experimental diets — especially treatment D1 — displayed fewer skeletal anomalies and a significantly reduced incidence of severe deformities, such as scoliosis (Figure 2). A closer look at tissue histology highlighted the decisive role of dietary PL in supporting healthy larval development. Because

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15 DAH	D1	D2	CTRL
Anterior Intestine	3	2	2
Posterior Intestine	4	3	4
Liver	2	2	2
Eyes	3	3	3
Gills	3	3	1

30 DAH	D1	D2	CTRL
Anterior Intestine	4	3	4
Posterior Intestine	4	4	2
Liver	4	4	2
Eyes	4	3	3
Gills	3	2	2

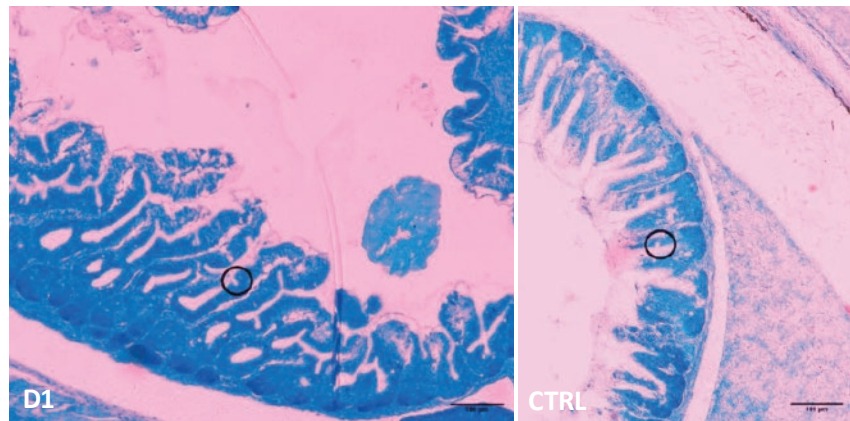


Figure 1. From left to right: histology scores based on Pacorig *et al.* 2022 (“0” means poor development and “5” optimal development) highlighting improved ontogeny of gills and posterior intestine in D1 and D2 groups; histologic sections of anterior intestine of cod larvae (66DAH) from D1 and Control (CTRL) groups, with presence of goblet cells (circle).

cod larvae have limited capacity to synthesize PL during early ontogeny, they rely on dietary sources to support membrane formation, lipid transport, and bone mineralization. Diets incorporating an improved balance of phospholipid sources promoted earlier cell differentiation, improved tissue development, and reduced skeletal anomalies. This resulted in a more balanced musculoskeletal system and an overall superior larval morphology by the end of the rearing period. These results align with previous findings in other marine species, confirming that phospholipid quality is key to reducing deformities and improving organ maturation in marine fish larvae.

Earlier weaning, stronger growth

A complementary trial within the EarlyCOD project explored how the timing of inert feed introduction affects growth and survival. In this experiment, weaning of cod larvae with a SPAROS microdiet started

either early (12 DAH) or at the conventional 20 DAH. The outcome was clear: fish with earlier introduction of microdiet displayed significantly greater standard length and body weight at all sampling points, without compromising survival. Early co-feeding resulted in more consistent larval performance and represents a promising, low-risk strategy for hatchery managers to gradually reduce live-feed dependency while maintaining predictable outcomes in growth and quality. These results support the idea that introducing dry feed earlier — in combination with Cryoplankton and high-performance microdiets — can accelerate weaning and promote stronger, more consistent larval growth.

Implications for hatchery management

The EarlyCOD trials clearly demonstrated that targeted nutritional innovation can drive substantial improvements in the quality of Atlantic cod larvae.

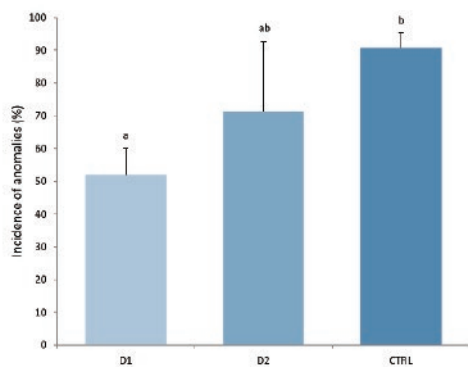


Figure 2. From left to right: Incidence of skeletal anomalies (%) in cod larvae from treatments D1, D2 and Control; Example of cod larvae from CTRL group showing scoliosis (staining with Alizarin red).

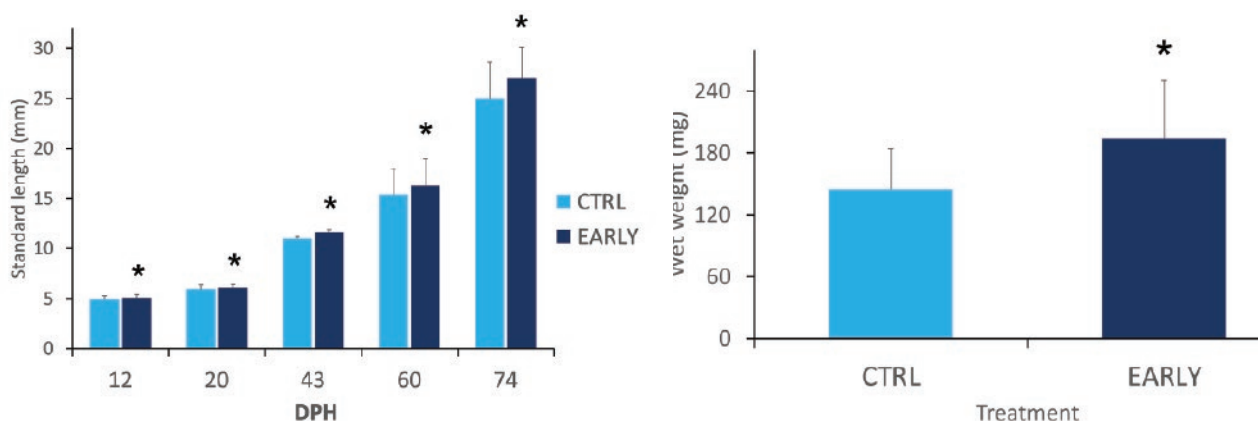
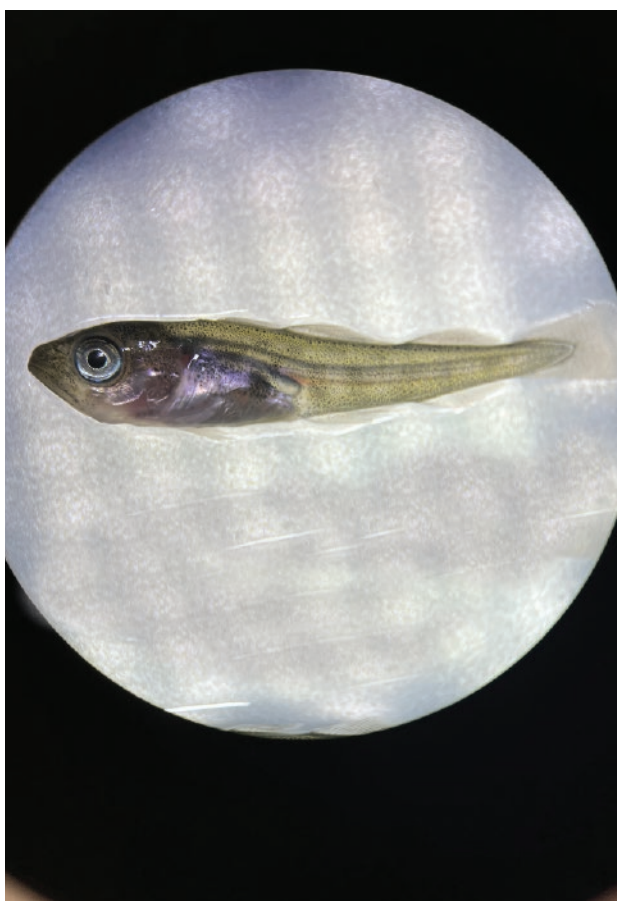


Figure 3. From left to right, cod larvae Standard length (A) and Wet Weight (B) in early vs. conventional dry-feed introduction treatments. Early co-feeding (12 DPH) significantly improved larval size (* $p < 0.05$).



The integration of cryopreserved live feeds with species-tailored microdiets resulted in marked benefits for larval performance, including enhanced organ development, reduced skeletal deformities, improved larval quality, and a smoother transition to inert feeds – contributing to overall operational efficiency. Across all

experimental groups, growth rates (10–11%/day) were maintained at or above typical hatchery standards, confirming that improvements in quality were achieved without compromising productivity. These findings represent a significant step forward toward establishing robust, nutritionally optimized weaning protocols that can enhance the efficiency, consistency, and long-term sustainability of cod aquaculture in Europe.

Acknowledgements

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