Variations in growth and optimal temperature for growth in haemoglobin genotypes of Atlantic cod

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Abstract

We studied growth properties of different hemoglobin genotypes of juvenile Atlantic cod (*Gadus morhua*) reared at four constant temperatures (7, 10, 13, 16ºC), and in a group of fish moved successively from 16 to 13 and 10ºC. The genotype *Hb-I(2/2)* displayed the overall highest growth rate in the temperature range 13-16ºC, whereas the *Hb-I(1/1)* genotype showed the highest overall growth at the lowest temperature (7ºC). Accordingly, we found a significant interaction between genotype and temperature. Optimal temperature for growth (Topt.G) varied between the genotypes with the genotype *Hb-I(1/2)* displaying the highest (mean±SE) Topt.G (14.5±0.8ºC) and *Hb-I(1/1)* the lowest (12.5±0.2ºC).

Introduction

Studies are non-consistent, but differences in physiological and behavioural properties of the cod haemoglobin genotypes have been indicated. In the present study we wanted to investigate whether optimal temperature for growth varies between genotypes and whether growth differences (if any) are more pronounced at optimal temperature than at sub- and super-optimal temperatures.

Materials and methods

Juvenile cod (*Gadus morhua,* n= 220) were individually tagged and distributed randomly into 10 rearing tanks and gradually acclimated over to the five experimental temperatures regimes of 7°C, 10°C, 13°C, 16ºC and temperature-step group (T-step group). The experiment lasted for 95 days. Individual growth trajectories were analysed using a growth curve analysis model (GCM). Optimal temperatures for growth (ToptG) for each haemoglobin genotype were calculated as the zero solution to the first derivative of the parabolic regression equations. Asymptotic standard error of mean (SEM) for ToptG was calculated based on individual growth data. After termination of the growth experiment blood (0.2 ml) for genetic analysis was sampled from the caudal vessels and kept on ice until analysed. All samples were analysed by agar gel electrophoresis.

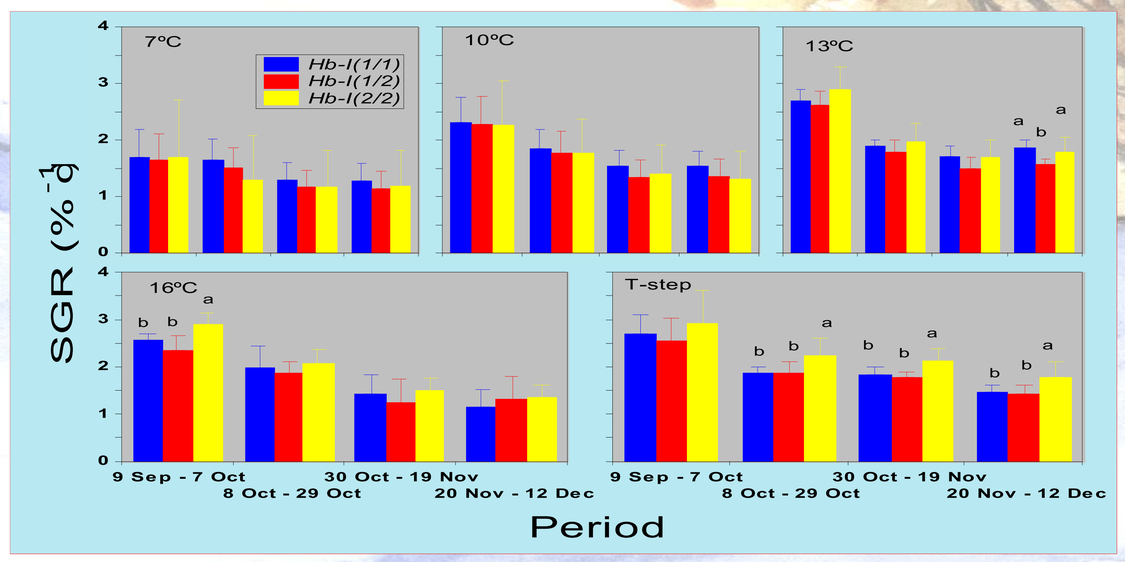

Fig. 1. Genotype specific mean growth rates (± SEM) of individually tagged cod reared under five temperature regimes. Different letters denote significant differences (Student-Newman-Keuls test, $p < 0.05$) within each temperature regime.

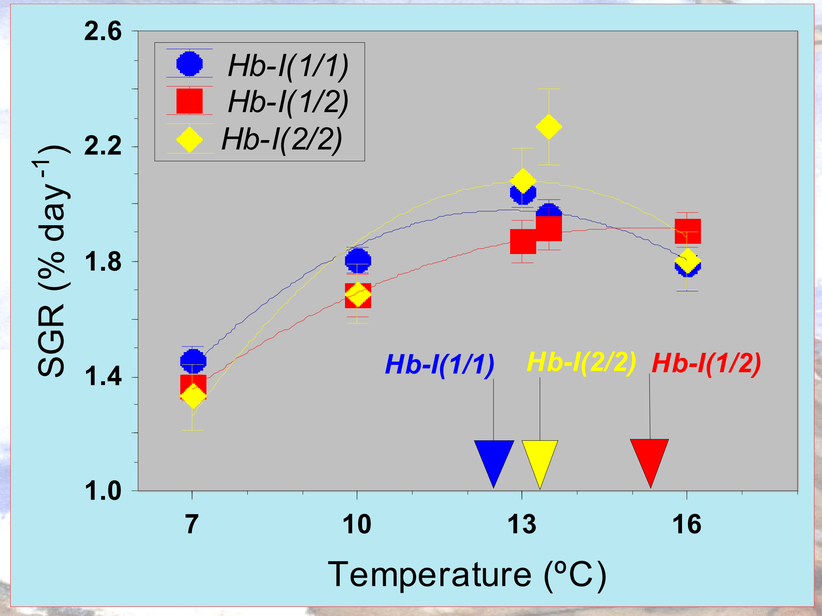

Fig. 2. Overall mean growth rates (±SE) of the three hemoglobin genotypes of juvenile cod plotted against temperature. Arrows mark ToptG of the different genotypes.

Results

Mean individual growth trajectories varied significantly between genotypes with the genotype *Hb-I(2/2)* displaying highest overall mean growth of the three genotypes (Fig. 1). Growth also varied among temperatures, with the overall highest growth rates for all genotypes seen in the T-step group and at 13ºC (*Hb-I(1/1)*) and the lowest at 7ºC. The optimal temperature for growth varied among the genotypes (Fig. 2). The *Hb-I(1/1)* had the lowest Topt. G (mean±SE) (12.5±0.2ºC) whereas the Topt. G for the *Hb-I(1/2)* and *Hb-(2/2)* genotypes were found to be 13.1±0.2ºC, and 14.5±0.8ºC, respectively.

Discussion

Variation in ToptG between genotypes has been reported for turbot (Imsland et al. 2000) and it has been postulated that this mechanism might be an adaptation to variable temperature conditions in the distribution area of the species. Atlantic cod is the major demersal fish resource distributed on the continental shelves and banks on both sides of the North Atlantic Ocean (review Imsland and Jónsdóttir, 2003) distributed in a variety of temperature conditions. Genotypic adaptation to environmental gradient as indicated in the present study is a possible evolutional mechanism to increase the overall fitness of the species.

Conclusions

1. **Growth of juvenile cod varied between haemoglobin genotypes with *Hb-I(2/2)* showing the highest growth of the three genotypes, whereas no differences were found between the *Hb-I(1/1)* and *Hb-I(1/2)* genotypes.**
2. **The biological significance of this relationship between biochemical genetic variation and physiological properties might be variation in growth pattern, ultimate size and age at first maturity.**
3. **The co-variation between haemoglobin genotypes and growth may be of some value in future breeding programs on cod as genotypes may be selected based on environmental conditions at different rearing sites.**