THE ENDOCRINE CONTROL OF NA^+,K^+-ATPASE α-SUBUNIT EXPRESSION AND ENZYME ACTIVITY IN THE GILL OF ATLANTIC SALMON: A COMPARISON OF A NATURAL HYPOTHYROID MODEL WITH THYROID HORMONE TREATMENT

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Thyroid hormones have been implicated in many of the physiological changes that occur during salmon smoltification, however the role of thyroid hormones in osmoregulation has been suggested to be a modulatory one, interacting with growth hormone and cortisol to regulate the osmoregulatory machinery in the gill. Here we present data from two experiments seeking to elucidate the specific localization and functional actions by thyroid hormones during smoltification in the Atlantic salmon (*Salmo salar* L.).

The first experiment compared endocrine and branchial smoltification-related changes in an anadromous strain and a landlocked strain of Atlantic salmon. Previously, we have reported the osmoregulatory differences between these landlocked and anadromous strains and demonstrated a 3-fold difference in

Na^+,K^+-ATPase activity and the inability for the landlocked strain to survive long term in seawater (Nilsen *et al.*, in press). We show now that in the landlocked strain circulating thyroxine (T_4) and growth hormone (GH) peak levels were 50% those of the anadromous strain during smoltification. The hormone levels increased in the anadromous strain in April and both strains reached their peak levels in May. Moreover, the number of Na^+,K^+-ATPase α-subunit immunoreactive cells and the intensity of the immunoreaction was higher in the anadromous compared with the landlocked strain.

In a second experiment, anadromous Atlantic salmon parr were given a treatment with L-thyroxine by immersion for 6 weeks, from early March to mid April. Thyroxine-treatment increased GH levels up to 4-fold those of controls, reaching peak values after 6 weeks of treatment, levels which were not obtained by controls until 5 weeks later. The treatment however, had no effect on Na^+,K^+-ATPase activity, which increased in both groups from week 3 until the end of the treatment. These results appear consistent with previous studies showing little or no effect of thyroid hormones on osmoregulation. However, further immunocytochemical analysis also revealed that there was an increased number of Na^+,K^+-ATPase α-subunit immunoreactive cells in the thyroxine-treated group, especially in the secondary lamellae. The thyroxine treatment increased the number of chloride cells and the Na^+,K^+-ATPase α-subunit within the cells.

In addition, *in situ* hybridization revealed expression of thyroid hormone receptor β-subunit (TR-β) in chloride cells, i.e. a target for thyroid hormone action on osmoregulatory capacity in the gill. These data combined suggest that thyroid hormones can regulate key osmoregulatory elements in the gill directly; and indirectly through the GH system. These data support a modulatory role of thyroid hormones in osmoregulation, acting on the proliferation of chloride cells and/or the expression of the Na^+,K^+-ATPase α-subunit. The Na^+,K^+-ATPase activity, on the other hand, is dependent on the availability of other critical factors, such as growth hormone, cortisol and their receptors, the Na^+,K^+-ATPase β-subunit, and hitherto undefined variables.

References

Nilsen, T. O., L. O. E. Ebbesson and S. O. Stefansson, 2002. Smolting in anadromous and landlocked strains of Atlantic salmon (*Salmo salar*). Aquaculture 00: 000-000.

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