Metabolic adaptation of the chicken embryo to oxygen deficiency during incubation

Oxygen deficiency is a common stimulus during life. To prevent the development of hypoxia on the tissue level, organisms counteract oxygen deficiency using various mechanisms of adaptation. In this thesis, the influence of a reduced oxygen content in the incubation air on the chick embryo was examined.

The embryos passed through a chronic oxygen defciency (15% O_2) from D 6 to 12 (critical window) and an additional acute anoxic period on D18. In addition, one group was incubated exposed to a combination of hypoxia (15% O_2) and Hyperthermia (40°C) for 24 h on D10. The gene expression levels of hypoxia inducible genes (AMPK, Enolase, PFK, VEGF) were determined using real-time PCR for detection of messenger RNA in embryonic heart tissue. Furthermore, the masses of the embryo and its heart were acquired.

Interpretation of the PCR data showed an age dependent increase of hypoxia inducible gene expression due to an increasing oxygen demand during embryonic development and a constant oxygen supply. Incubation under chronic (D6-12) mild (15% O_2) hypoxia caused no increase in gene expression of the tested genes. Incubation under acute (30-45 Minutes) anoxia on D18 also had no effect on the expression levels of the genes examined in heart tissue. Only the combination of hypoxia and hyperthermia on D10 resulted in an increased expression of the examined hypoxia inducible genes. The embryonic body and heart mass was unchanged under chronic and acute hypoxia.

These results suggest that other regulative mechanisms than increased gene expression of hypoxia inducible genes are most relevant during hypoxia. Such adaptive mechanisms conserve the energy content of heart tissue and prevent a delay in mass development during oxygen deficiency. Only the combination Hyperthermia and Hypoxia makes an increase of gene expression indispensable. The hypoxia induced hypometabolism is an adaptive mechanism which reduces the energy demand by down regulation of metabolism during oxygen deficiency. Particularly a decrease of membrane permeability lowers the level of energy consumption. Mild hypoxia and physiologic temperature leads to an active decrease of metabolism and survival without intracellular oxygen deficiency. In contrast, hyperthermia stimulates the metabolism and consequently increases the level of energy consumption. Therefore, increased gene expression is required to adapt to a combination of hypoxia and hyperthermia. The hypoxia-induced hypometabolism seems to anticipate the gene regulative reaction during mild hypoxia.

The results of this study contribute to the further characterization of the capability of the embryo to react to oxygen deficiency and describe a new chronology of adaptive mechanisms in dependency to the gravity of hypoxia.