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THE REPARTITION OF WATER AND Na^+ AND K^+ IONS IN THE TISSUES OF TROUTS TRANSFERRED FROM FRESH WATER INTO THE SEA WATER

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ABSTRACT:

The extra- and intracellular volumes and the distribution of $Na^+$and K^+ions in the extra- and intracellular compartiments of the muscular, renal and intestinal tissues of trouts were measured at different intervals after the transfer into the sea water. The extra- and intracellular volume and the Na^+ content increased, and the K^+ content decreased in the first day,then was seen a slight tendency of coming back to the initial values (except the intracellular volume),which were reached in the marine fully adapted trouts. In these animals a new hydric and ionic equilibrium was reestablished.

The adaptation of animals to hypo- and hyper-osmotic environments implies the existence of a compartment, the extracellular fluid, as a buffer between the external medium and the cytoplasm. An essential element in this regulatory system is the control of the entry and exit of water and salt accross the epithelial permeable membranes located at the body surface. A second selective barrier is located between the extracellular and intracellular compartments and it is represented by the cellular membrane.The literature abounds in papers concerning the role of the

epithelial barrier, but it is rather scarce as concerning the osmotic relations between the extracellular and intracellular fluids (1, 3, 4).

In this paper we studied the variations of the water content and ionic content (Na^+ and K^+) at the external and internal sides of the cellular membrane in the tissues of trout transferred from fresh water into the sea water, during the adaptation period.

MATERIAL AND METHODS

In our experiments the 3-year-old trouts were transferred from the fresh water into sea water with a salinity of 17 ‰ (the average salinity of the Black Sea), then we followed the repartition of water and Na^+ and K^+ ions in the extracellular and intracellular space of the striated muscle, gut and kidney, after 1, 3, 7 and 70 days. For comparison, the water and ionic distribution in tissues from the fresh water trouts and the marine fully adapted trouts (which had been transferred into the sea water 3 years ago, in the seedling stage) were measured, too. Simultaneously, the Na^+ and K^+ concentrations in the serum of the trouts were measured.

The measurement of the total water content was made by drying the tissues at 105°C, and the extracellular volume was measured by the "inulinic space" method. The difference between the total water and the extracellular water represented the intracellular water content.

The total ionic content (Na^+ and K^+) was measured in parallel samples of tissues, by the flame-photometric method. Before this measurement, the tissue samples were kept for 3 hours in a "Cortland" physiological solution (6), in order to obtain an extracellular ionic concentration equal to that of the physiological solution. Knowing the volume of the extracellular fluid and the ionic concentration in this compartment, we calculated both the extra- and intracellular ionic contents, and the intracellular concentration of Na^+ and K^+.

The results represent the mean values obtained from 5–6 individuals.

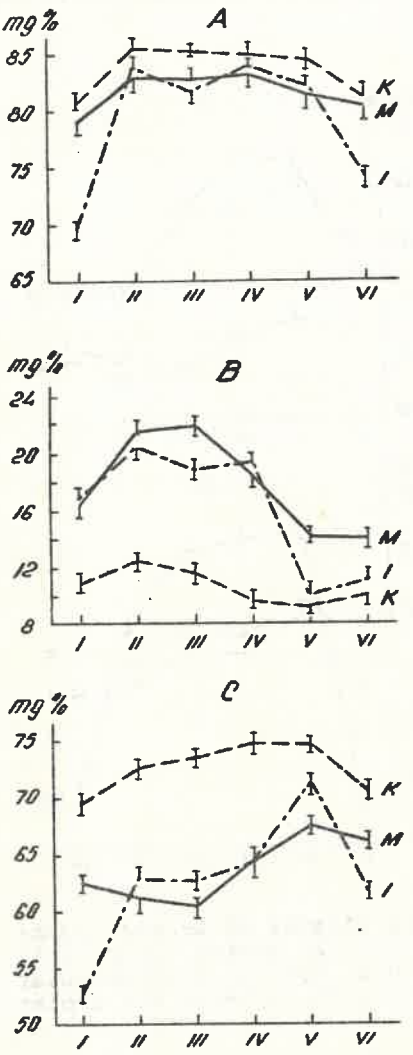

Fig.1- The repartition of water in the tissues of trouts transferred from the fresh water (I) in the marine water, after 1 day (II), 3 days (III), 7 days (IV), 70 days (V) and 3 years (VI). (A: the total water; B: the extracellular water; C: the intracellular water; K: kidney, M: muscle ; I: intestine)

RESULTS

1. REPARTITION OF WATER

A day after the trouts had been transferred into the sea water, the total water content of tissues was significantly increased (Fig. 1 a). During the following days, a slight tendency to a slow recurence of the normal values was observed, so that in the marine adapted animals, the recorded values were close to the normal ones.

In the first day after the transfer, both the extra- and intracellular volumes were increased, except the muscle, where the intracellular volume decreased and continued to do so for some 3 days (Fig. 1 b,c). After 70 days the extracellular water content was lower and the intracellular water content was higher than the normal values of the fresh water trouts, and this phenomenon was maintained even in the fully marine adapted trouts.

2. REPARTITION OF Na^+

The transfer of the trouts into the sea water was followed, in the first day, by a rapid increase in the tissue total Na^+ content, then a slow coming back to the normal values was recorded (Fig. 2 a). In the marine adapted fishes the total Na^+ content in the tissues was closely to the values of the fresh water animals.

The extracellular Na^+ content increased too in the first day, but the following recurence was more rapid, so that after the 70 days it was complete (Fig. 2 b).

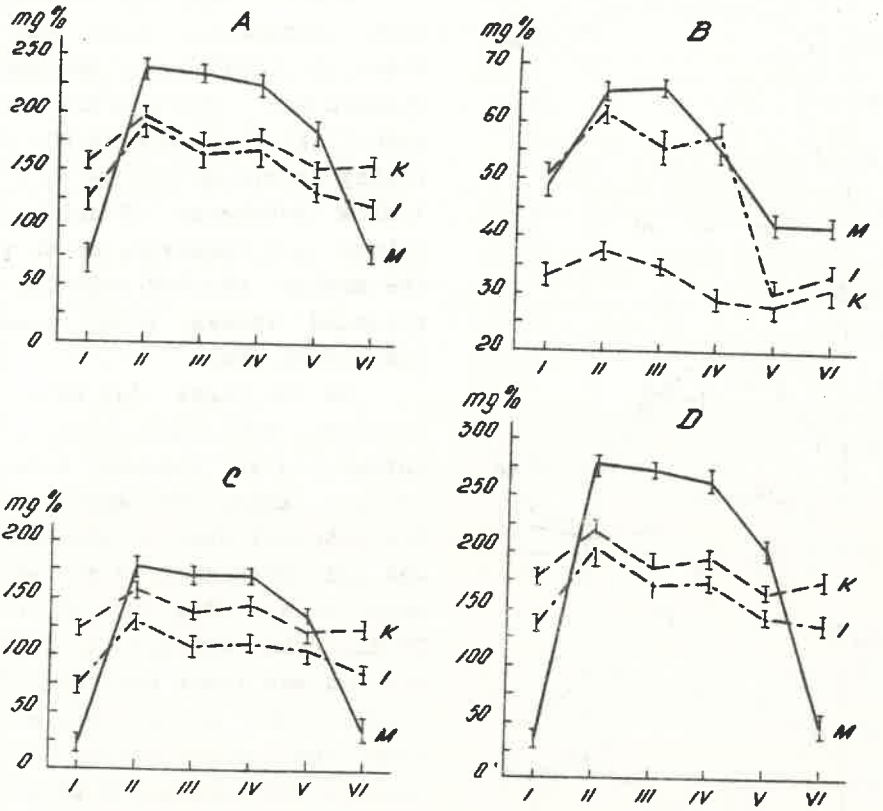

Fig. 2 - The repartition of Na^+ in the tissues of trouts transferred from the fresh water in the marine water (I-VI and K,M,I: as in Fig.1; A: total Na^+; B: extracellular Na^+; C: intracellular Na^+; D: intracellular Na^+ concentration)

These variations in the extracellular Na^+ represented, however the changes in the extracellular space; the actual variations in the extracellular Na^+ concentration are represented, in fact, by the Na^+ concentration in the serum (Fig.3). The intracellular Na^+ content and concentration changed in the same manner as the total Na^+ content (Fig. 2 c,d).

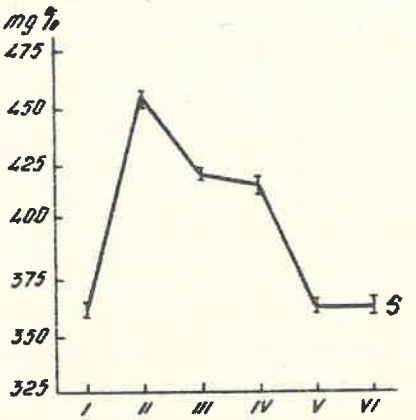

Fig. 3 - The Na^+ concentration in the serum of trouts transferred from the fresh water in the sea water.

3. REPARTITION OF K^+

In the first day after the transfer of the trouts into the sea water the total K^+ content was strongly reduced and remained so for long time (Fig. 4 a). Even though a slight tendency to return to the normal values was observed, the recovery was complete after 3 years only, i.e. in the marine fully adapted trouts. The extracellular K^+ content followed the same variations as the extracellular volume (Fig. 4 b), but the K^+ concentration in the serum was raised throughout the 70 days after the transfer of the animals into the sea water (Fig. 5). However, in the marine fully adapted trouts the serum K^+ concentration was lower than in the fresh water ones. The observed K^+ loss from the tissues was due in fact to the K^+ leakage from the intracellular compartment. Indeed, the intracellular K^+ content and concentration were drastically reduced in the first day after the transfer, and this situation was found even after 70 days. After 3 years only, in the marine adapted animals, the normal intracellular K^+ concentration was fully restored (Fig. 4 c,d).

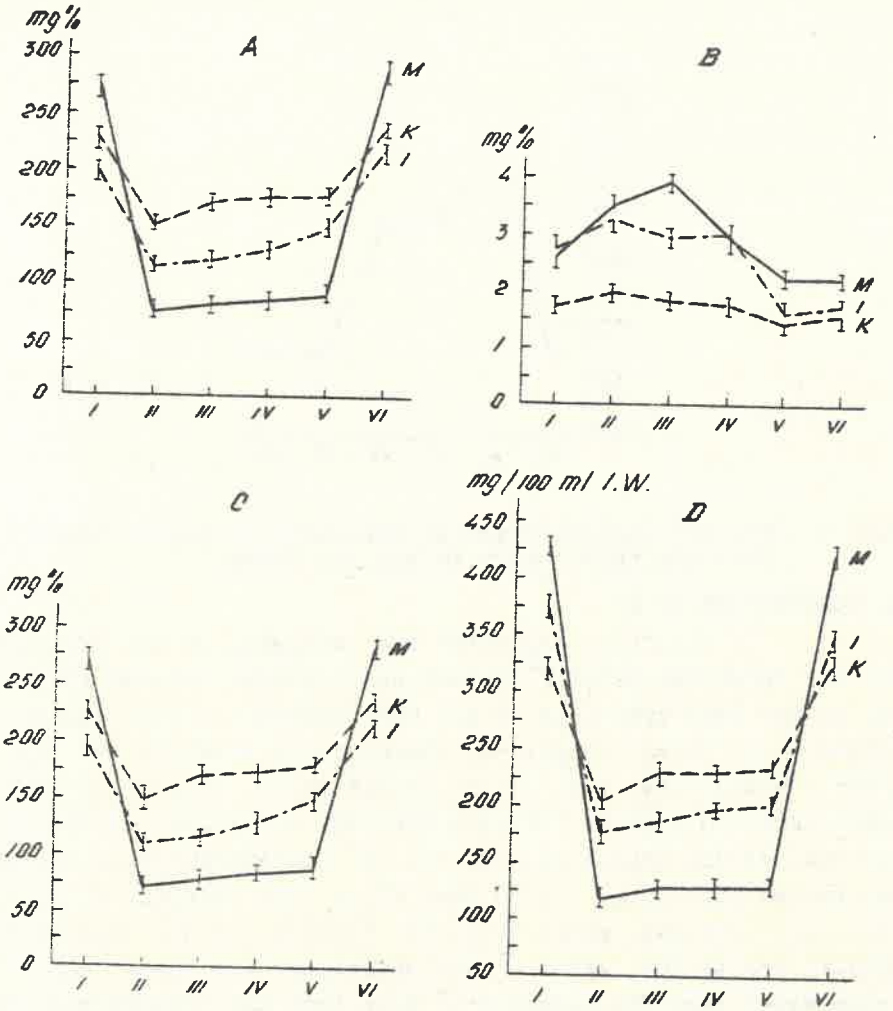

Fig. 4 - The repartition of K^+ in the tissues of trouts transferred from the fresh water in the marine water (I-VI and K, M, I: as in Fig.1; A: total K^+; B: extracellular K^+; C: intracellular K^+; D: intracellular K^+ concentration).

DISCUSSION

It is well known that the osmoregulatory balance in an hyper-osmotic medium is dominated by the osmotic water loss by the animals. In this context, the increased tissue water content,

observed in our experiments after the transfer of the trouts into the sea water, appears to be very surprising. However, many years ago, SMITH (5) was the first to propose that marine teleosts drink sea water to replace the water osmotically lost across the body surface. Subsequently, it was shown that 60-80% of the ingested water is intestinally absorbed and this fraction increased with increasing the salt concentration of the ingested water (2). Analysis of the rectal fluid or intestinal content showed that about 99% of Na^+ and Cl^- from the ingested water was absorbed, therefore the salt was absorbed more rapidly than the water (2).

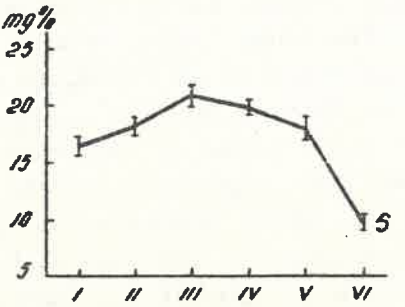

Fig. 5 - The K^+ concentration in the serum of trouts transferred from the fresh water in the sea water

Having in mind these findings, the increase of the tissue water content observed by us when the trouts were transferred into the sea water seems no more surprising. It is clear that the intestinally absorbed water is distributed, during the first day, mainly in the extracellular space, but it enter also the intracellular compartment of the kidney and gut. In the muscle, which represent the major part of the body weight, there is an osmotic loss of water during the first 3 days after the transfer. Then the extracellular volume decreases and the cells gain water. This water gain may be attributed to the sodium influx, that makes the intracellular medium hyperosmotic with respect to the extracellular one.

Concerning the ionic content, it appears to be normal that the tissues should accumulate Na^+ and lose K^+ according to the concentration gradients of these ions. Indeed, after the transfer of the trouts into the sea water the Na^+ concentration

gradient across the cellular membrane decreased dramatically, but the decrease of the K^+ concentration gradient was less marked.

Although the osmotic and ionic concentration gradients across the epithelial membranes were inverted in the sea water trouts as compared to the fresh water trouts, the ionic concentration gradients across the cellular membranes were never inverted in the adaptation period of the trouts. This fact suggests a reestablishment of a new hydric and ionic equilibrium in the marine adapted trouts, which implies a series of adaptive modifications in the membrane passive permeability and in the active ionic transport. A characteristic of this new equilibrium may be an increase of the cellular volume, with a parallel diminution of the extracellular space. The ionic composition of the extra- and intracellular mediums is modified too. Thus, the serum K^+ concentration is lower and the intracellular Na^+ concentration is higher in the marine adapted trouts than in the fresh water ones.

Because the osmotic gradient and the ionic concentration gradient across the epithelial membranes are inverted in the marine adapted trouts, it must be admitted that the major adaptive modifications take place at this level. These may be the modifications of the passive permeability and/or modifications of the sense and rate of the active ionic transport.

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