



Research Paper

Changes in Nitrogen Excretion Pattern in *Channa gachua* kept in a Water-Scarce Condition

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Abstract

Freshwater fishes, typically ammonotelic, excrete highly toxic ammonia directly into the water, but many species shift to urea excretion under water-restricted conditions to avoid internal toxicity. This study investigated how *Channa gachua* adapts its nitrogen metabolism—shifting from ammonotelism to ureogenesis—to survive water scarcity or environmental stress. A total of 100 (one hundred) *Channa gachua* (an air-breathing teleost) were used to study the effects of water restriction. Over a 10-day period, the metabolic response to water restriction was tracked. Both blood and excreted urea and ammonia levels were measured to track the shift in nitrogen excretion. Hepatic glutamate dehydrogenase (GLDH or GDH) activity was measured to evaluate how the liver converts amino acids and ammonia into urea during stress. Environmental conditions, including alkalinity, pH, dissolved oxygen, and free carbon dioxide, were also monitored to simulate habitat degradation. During the experimental period, *Channa gachua* showed a decreasing trend of ammonia excretion ($r = 0.9626$, in correlation with duration). However, excretion of urea, in *Channa gachua* showed significant correlation with increasing duration ($r = 0.936$). Absence of not so prominent correlation of GLDH with duration in the fishes ($r = 0.501$) was also observed. Only a moderate degree of correlation was observed between the activities of glutamate dehydrogenase and excretory ammonia and urea. Though a very high correlation was found between free carbon dioxide and excretory ammonia and urea, but no correlation was found between excretory ammonia and urea with alkalinity of the surrounding medium. The study found that *Channa gachua* triggers ureogenesis as a protective mechanism under water-restricted, stressful conditions to prevent the accumulation of toxic ammonia. The results of the present study may suggest possible impact of stress factors on physiological changes regarding nitrogen excretion in these experimental fishes and the role played by the enzyme glutamate dehydrogenase in regulating the entire mechanism.

1. Introduction

The metabolism of proteins, a fundamental biological process, inevitably leads to the catabolism of amino acids, which produces highly toxic nitrogenous waste. To prevent fatal accumulation, this nitrogen is immediately processed into ammonia, or in higher pH environments, the ammonium ion, which is highly soluble in water. Many aquatic animals, particularly freshwater fish and invertebrates, utilize their water-rich environment to excrete ammonia directly through gills or skin. Because they have access to abundant water, they can constantly flush out this toxic by-product. Terrestrial and semi-terrestrial vertebrates, such as mammals and adult amphibians, convert ammonia into urea within the liver via the urea cycle. While urea requires energy to produce, it is significantly less toxic than ammonia and requires far less water to store and excrete. Some marine organisms, notably sharks, rays, and certain snails, have adapted to retain high levels of urea within their blood and tissues rather than excreting it entirely. This accumulation allows sharks to maintain a slightly higher internal osmotic

pressure (hyperosmotic) compared to the surrounding saltwater. Consequently, water flows into the shark's body passively, eliminating the need to actively drink seawater to combat dehydration, thus assisting with osmoregulation. Sometimes conditions like exposure to exogenous ammonia, water limitations, or alkaline conditions hamper the release of ammonia. The majority of teleost fishes are ammonotelic, i.e., ammonia is simply excreted directly across the gills into the surrounding aqueous environment. But, a functional urea cycle and ureotelism have been documented in a few adult species as adaptations to unusual environmental circumstances as stress, air exposure, high pH, exposure to high concentration of ammonia. In such conditions, some teleosts detoxify ammonia through synthesis of urea by urea cycle in liver (Mommensen and Walsh, 2005).

Anderson et al. (2005) reported an increased concentration of plasma and hepatic urea with salinity and suggested a direct correlation between hepatic productions of urea with osmoregulatory strategy of *Carcharhinus leucas*, a euryhaline elasmobranch. Terjesen et al. (2002) demonstrated pathways for urea production during early life of an air-breathing teleost, the African

catfish, *Clarias gariepinus* Burchell. Lindley et al. (1999) studied muscle as the primary site of urea cycle enzyme activity in an alkaline lake adapted Tilapia, *Oreochromis alcalicus grahami*. Chadwick et al. (1999) reported the excretion of nitrogen and expression of urea cycle enzymes in the Atlantic cod (*Gadus morhua* L.). Glutamate dehydrogenase (GLDH or GDH) is a pivotal mitochondrial enzyme bridging nitrogen metabolism and carbon energy pathways, operating in the catabolic direction to break down glutamate into α -ketoglutarate and ammonia. It is unique in its ability to utilize either NAD⁺ or NADP⁺ as a coenzyme for oxidative deamination (Voet, 1990). Within the hepatic mitochondrial matrix, the enzyme glutamate dehydrogenase facilitates the reversible oxidative deamination of L-glutamate into 2-oxoglutarate and free ammonia (NH₃). Under conditions of excessive GDH activity—often due to activating mutations that bypass regulatory inhibition by GTP—there is a pathological surge in ammonia production. Simultaneously, this relentless conversion depletes the mitochondrial pool of glutamate, a necessary substrate for synthesizing N-acetylglutamate. NAG is the essential allosteric activator of carbamoyl phosphate synthetase I, the rate-limiting enzyme that initiates the urea cycle. Consequently, high GDH activity causes a dual threat: it produces excessive ammonia while paradoxically sabotaging the liver's ability to detoxify it into urea, leading to severe hyperammonemia (Fang et al., 2002).

Elasmobranch fishes, the coelacanth, aestivating lung fishes, amphibians and mammals synthesise urea by the urea cycle; but, urea synthetic activity is generally insignificant in teleostean fishes (Mommensen and Walsh, 1989). The vast majority of teleost fishes are ammonotelic excreting ammonia as the major nitrogenous end product (Wood, 1993; Saha and Ratha, 1998). However, under certain circumstances such as high ambient ammonia or aerial exposure, ammonia excretion is inhibited, and toxic ammonia concentrates in blood and body tissues. Fishes are generally known to tolerate relatively higher accumulation of ammonia than mammals (Wood, 1993; Saha and Ratha, 1998). Given the ongoing scientific debates regarding the precise metabolic connection between glutamate dehydrogenase (GDH) activity and the shift in nitrogenous waste excretion, this study investigated the patterns of ammonia and urea production. It focused on analyzing hepatic GDH activity in the freshwater fish *Channa gachua* to understand how they adapt their excretory processes.

2. Materials and Methods

2.1 Experimental Fish

Channa gachua were collected from a local pond and were kept in the aquarium for acclimatization.

2.2 Experimental Design

Total hundred fishes were collected. Those hundred

fishes were divided in ten sets, each set comprising ten fishes to be sacrificed in ten consecutive days.

Out of eleven aquariums used, one aquarium was kept only with water. It acted as “control water”. In the other ten aquariums, fishes were kept as experimental specimen. Every day, one fish from one aquarium was sacrificed for the experiment. The experiment was continued till tenth day. Excretory urea, excretory ammonia and hepatic glutamate dehydrogenase activity were estimated in total ten fishes in ten consecutive days for both normal and experimental fishes. Enzyme activity was measured in the liver tissue of the freshly killed fishes of normal and experimental group. Alkalinity and free carbon di oxide were tested in the normal and experimental water.

2.3 Processing of the collected sample

The liver tissue from the normal and experimental fishes was weighed and homogenized using distilled water. The homogenized tissue was centrifuged and the supernatant was used for enzyme assay.

2.4 Estimation of ammonia and urea

Ammonia was estimated by following the method of Anken and Schiphorst (1974). Urea was estimated by following Crest Biosystems Modified Berthelot method by Fawcett and Scott (1960).

2.5 Estimation of glutamate dehydrogenase

Glutamate dehydrogenase activity was determined by following the method of Doherty (1970).

3. Results

From the experimental findings, it was observed that *Channa gachua* showed significant physiological shift in nitrogen excretion when subjected to experimental conditions, like water restriction. The fish shifts from predominantly excreting ammonia (ammoniotelism) to a higher proportion of urea excretion (ureotelism) as an adaptive mechanism to avoid toxicity under reduced water availability. During the experimental period, urea excretion showed a substantial increase, ranging from 81% to 1177%, while ammonia excretion was observed to fluctuate or decrease (e.g., from 2087% to 19% or a steady decrease in blood ammonia). Blood urea levels show a steady increase (Table 2), while blood ammonia shows a decreasing trend (Table 1) over the experimental period. However, hepatic glutamate dehydrogenase activity exhibited a fluctuating trend throughout the study period (Table 3).

Table 1: Presenting the % deviation of excretory ammonia from the mean values of normal control (mg/dl) in *Channa gachua*.

	Days									
% deviation	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th
<i>C. gachua</i>	2087.50	1750.94	1177.14	993.42	591.67	706.94	318.01	144.00	36.11	19.74

Table 2: Presenting the % deviation of excretory urea from the mean values of normal control (mg/dl) in *Channa gachua*.

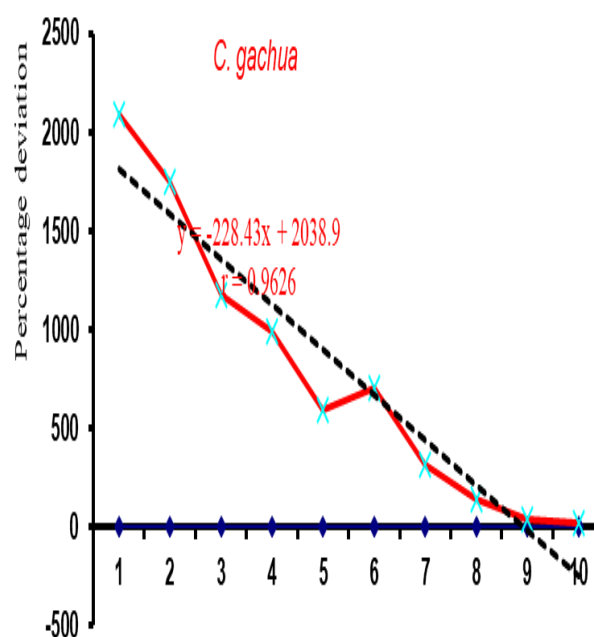
	Days									
% deviation	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th
<i>C. gachua</i>	81.25	147.56	216.12	424.70	545.67	660.24	792.30	967.90	1021.17	1177.38

Table 3: Presenting the % deviation of hepatic glutamate dehydrogenase activity from the mean values of normal control (U/mg) in *Channa gachua*.

	Days									
% deviation	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th
<i>C. gachua</i>	46.25	43.75	43.90	75.00	4.70	127.84	117.64	19.23	136.70	95.29

4. Discussion

Under normal physiological conditions, most teleost fishes are ammonotelic, meaning they primarily catabolise proteins and excrete nitrogenous waste directly as highly toxic ammonia (NH₃) through their gills, a process that requires substantial water availability. However, when subjected to environmental stressors—such as high ambient ammonia concentrations, water restriction (low water availability), or alkaline water—fishes can exhibit remarkable metabolic plasticity, altering their nitrogen excretion mechanism to switch from ammonotelism to ureotelism (Saha et al., 2003). In the present study, the physiological changes in *Channa gachua* in relation to ammonotelic and ureotelic nitrogen excretion and the effect of glutamate dehydrogenase is tried to probe with monitoring the excretory nitrogen forms as urea and ammonia in the rearing media. In *Channa gachua* a higher urea excretion 81% to 1177% (Table 2) against 2087% to 19% ammonia excretion (Table 1) was observed during the experimental period. The trend of decreasing excretory ammonia in *Channa gachua* is highly correlative with duration i.e., $r = 0.9626$ (Figure 1) signifying a persistent and definite decrease in ammonia excretion with increase in duration of experiment (Fig.1). However, the excretory urea in *C. gachua* showed a steady increase along with duration ($r = 0.936$ respectively) (Figure.2).

**Figure 1:** Presenting the percentage deviation of excretory ammonia from the mean values of normal control in *Channa gachua*

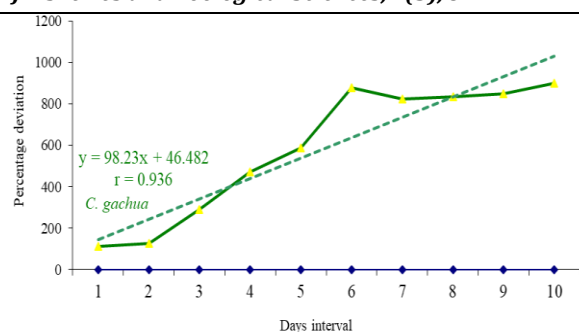


Figure 2: Presenting the percentage deviation of excretory urea from the mean values of normal control in *Channa gachua*

However, hepatic glutamate dehydrogenase activity, in the experimental fishes, exhibited a fluctuating trend throughout the experimental period (Table 3) with $r = 0.4809$ (Fig. 3).

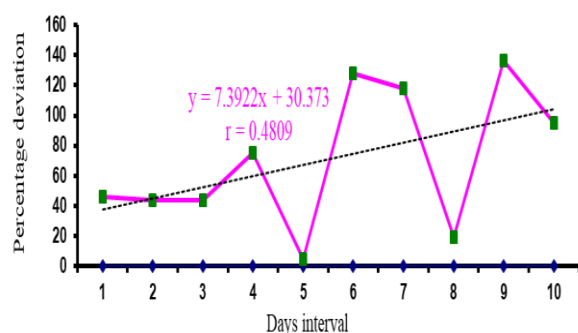


Figure 3: Presenting the percentage deviation of glutamate dehydrogenase activity from the mean values of normal control in *Channa gachua*

The correlation between alkalinity and excretory ammonia & urea is not so prominent (Fig. 4-a and 4-b).

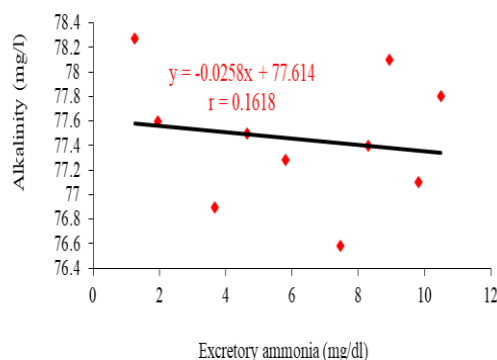


Figure 4-a: Presenting the correlation between the mean values of excretory ammonia (mg/dl) and alkalinity (mg/l) in *Channa gachua*.

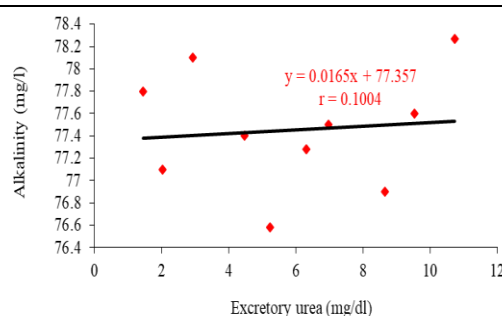


Figure 4-b: Presenting the correlation between the mean values of excretory urea (mg/dl) and alkalinity (mg/l) in *Channa gachua*

However, the relationship with free carbon dioxide is observed to be uniformly high in the experimental fish with both excretory ammonia and excretory urea (Fig. 5-a and 5-b).

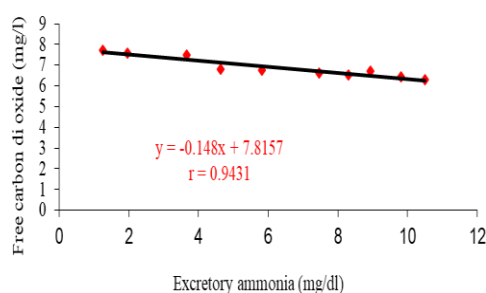


Figure 5-a: Presenting the correlation between the mean values of the excretory ammonia (mg/dl) and free carbon dioxide (mg/l) in *Channa gachua*.

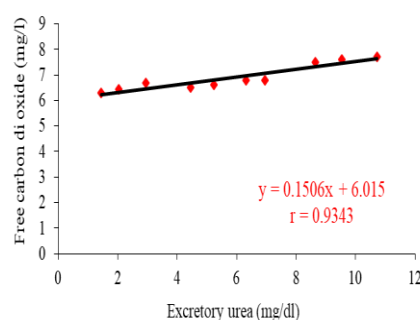


Figure 5-b: Presenting the correlation between the mean values of excretory urea (mg/dl) and free carbon dioxide (mg/l) in *Channa gachua*

From this set of correlation studies it may be commented that free carbon dioxide is more related with the variation in amount and type of nitrogen excretion in the form of ammonia and urea. Frequent fluctuation in glutamate dehydrogenase activity and absence of relationship with excretory ammonia and urea may be explained with the

fact that the changing glutamate dehydrogenase activity is a resultant of overall production of ammonia and its conversion to urea under a changeover condition alternating between ammonotelism and ureotelism in the present study (Choudhury et al., 2012).

However, it is also observed with interest that whatever may be the state of glutamate dehydrogenase activity; the metabolically generated ammonia is efficiently disposed as either excretory ammonia or is converted to urea for excretion.

5. Conclusion

From the present study it may be concluded that *Channa gachua*, though ammonotelic by nature, if faces conditions like water scarcity, may convert ammonia to urea to excrete the excess nitrogenous wastes as urea.

6. Statements and Declarations

Ethical Approval: Not Applicable

Conflict of Interest: No conflict of interest was reported by the authors.

Funding statement: Not applicable

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