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Histological Adaptation to Thermal Changes in Gills of Common Carp Fishes *Cyprinus carpio* L.

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ABSTRACT

Investigations were carried out on the gill tissues of common carp *Cyprinus carpio* L. exposed to high levels 31^{o}C, and low levels 18^{o}C of temperature for a total period of successive of 10 days. The histological study of the gill sections of this fish species showed marked histological lesions, include hyperplasia and hypertrophy of the respiratory epithelium, bloody congestion with hemorrhage and abundance of mucous substance, this at high temperature, while at low temperature also showed hyperplasia, shrinkage of blood vessels, fusion of secondary lamellae, cellular atrophy, damage and lamellar disorganization. Lesions were comparatively most severity at low temperature.

Keywords: Histology, Gills, Thermal Changes, *Cyprinus carpio* L..

التأقلم النسجي للتغييرات الحرارية في غلاصم اسماك كارب الاعتيادي (*Cyprinus crpio* L.)

الملخص

تم إجراء فحوصات على أنسجة الغلاصم في اسماك الكارب الشائعة *Cyprinus carpio* L. والمعرضة إلى درجات حرارية من مستويات مرتفعة 31م^{o} ومنخفضة 18م^{o} ولمدة عشرة أيام متتالية. أظهرت الدراسة النسجية للمقاطع الغلصمية في هذا النوع من الأسماك آفات نسجية واضحة تضمنت : فرط تنسج وتضخم في النسيج الطلائي التنفسي، احتقان دموي ونزف مع وجود وفرة من المادة المخاطية بين الصفائح الغلصمية الثانوية، هذا عند المستويات المرتفعة من الحرارة، اما عند المستويات المنخفضة من الحرارة أيضا ظهر فرط تنسج ونزف بالإضافة إلى انكماش الأوعية الدموية الغلصمية، اندماج الصفائح الثانوية الغلصمية، ضمور خلوي، تحطم وعدم انتظام صفائحي، وكانت الآفات النسجية أكثر شدة في حالة الحرارة المنخفضة.

الكلمات الدالة: أنسجة ، الغلاصم ، التغيرات الحرارية، اسماك الكارب.

INTRODUCTION

The gills, which participate in many important functions in fish, such as respiration, osmoregulation and excretion, remain in close contact with the external environment, and particularly sensitive to changes in the quality of the water, are considered the primary target of the contaminants (Poleksic and Mitrovic-Tutundzic, 1994; Mazon *et al*., 2002; Fernandes and Mazon, 2003; Ogundiran *et al*., 2009).

Owing to the direct and continuous contact with aquatic environment, fish gills which are organs for respiratory gas exchange, osmoregulation, excretion of nitrogenous waste products and acid base regulation, are directly affected by contaminants. Fish gill is very sensitive to physical and chemical alterations of the aquatic medium such as: temperature, acidification of the water supply due to acid rain, salts and heavy metals, and to any change in the composition of the environment which is an important indicator of water borne toxicants. Acid and heavy metals pollution has been reported to alter cell structure and induce desquamation to lamellar epithelium and filament epithelium hyperplasia (Leino and McCormick, 1984; Soderberg *et al*., 1984; Crespo and Sala, 1986; Sinhaseni and Tesprateed, 1987; Nowak, 1992; Risburg and Bastide, 1995; Ayoola, 2008a).

There is a close relationship between gill morphological alteration and stress (Peters and Hong, 1985). Gill morphology has been described as a good indicator of the water quality and the general health condition of cultured fish (Peters *et al*., 1984). Szakolczai, (1997) studied the histopathological changes induced by environmental stress in common carp *Cyprinus carpio*, the Japanese colored (carp-Cyprinus), and African cat fish *Calarias gariepinus*. In all the species treated, it was observed that the goblet cells of the gills and the skin increased in number and there was slight detachment of the epithelium of the secondary lamellae was observed.

Gill epithelium is a major site of gaseous exchange (Korai *et al*., 2010) and are an important site for disease production, because they are a rich source of blood, an important media for the infectious agents. Sinse gasous exchange takes place through the gills, they may easily become contaminated from external sources (Awal *et al*., 2001). Sublethal level of detergents have been reported to induce gill damage and impaired active oxygen uptake (Lemke and Mount, 1963) and gill damage in form of hemorrhage has also been observed in *Gambusia affinis* exposed to Diquat (Tat-Sing *et al*., 1983).

Coutinho and Gokhale (2000) found epithelial lifting in the gills of carps *Cyprinus carpio* and tilapias *Oreochromis mossambicus* exposed to the effluents of a waste water treatment plant. Engelhardt *et al*., (1981) observed epithelial lifting and lamellar fusion in rainbow trouts *Oncorhynchus mykiss* exposed to petroleum residues. Similar alterations in the gills have also been reported in the fishes exposed to metals (Oliveira Ribeiro *et al*., 2000; Cerqueira and Fernandes, 2002 ; Martinez *et al*., 2004).

Solid *et al*., (2005) showed that the exposure of gold fish *Carrassius auratus*, and the crucian carp *Carassius carassius* to different degrees of temperature (10, 15, 20, 25)^{o}C for one month, induce alteration in form of gills, range consumption of dissolved oxygen in water and concentration of dissolved oxygen in water.

In Iraq Al-Hamdani and Al-Taee (2009) studied the effect of thermal stress on fish *Carassius auratus*.

The gills have relatively small number of components: epithelium, endothelium, Pillar cells, fibrous and cartilaginous support stroma, in the primary lamellae, and specialized cells such as eosinophil granule cells, and fixed macrophages (Roberts, 2001).

There is no previous study on effect the thermal agent on the histological structure of gill tissue. Therefore, this study is aimed at investigating than possibility of histological changes in the gills of *Cyprinus carpio* on exposure to thermal changes.

MATERIALS AND METHODS

This study is based on fish carp *Cyprinus carpio* L. with the mean weight of 175-200g and standard mean length of 125-140cm and with age of less one year.

Samples were collected from college of agriculture and forests in University of Mosul. The test samples were brought to the laboratory and were placed in glassy pool tanks containing dechlorinated tap water and supplide with aerators and thermostat for a period of two weeks. During this period, they were fed twice daily with standard fish pellet.

The examined fish were divided into three groups (25 sample for each group). The control groups were left under normal conditions to study the normal structure of gills, while the second were exposed to high temperature up to 31^{o}C and the third group were exposed to low temperature up to 18^{o}C at of 24h daily and for 10 days respectively. The gills of the test fishes were excised keeping the filaments and rakers intact, rinsed in normal saline, fixed in 10% formalin for about 24h at 4^{o}C dehydrated in an ethylalcohol series of ascending concentrations, cleared in xylene, infiltrated with paraffin at 56^{o}C, then embedded in paraffin wax (Luna, 1968). Thin sections of the selected gill tissues of about 4 μm was cut by means of a rotatory microtome, dehydrated and stained with haematoxylin and eosin and mounted with D.P.X. The sections were examined and photomicrographs using an Olympus BH_2 microscope fitted with photographic attachment were taken. The prepared slides were used to describe the normal histological structure and histological alterations in gills.

RESULTS

1- Treated group with high temperature:

After exposure to high temperature, the fish gills showed hyperplasia of epithelial cells in branchial secondary lamellae, congestion of blood vessels, hypertrophy of pillar cells (fig. 2). Abundance of mucous substance and hemorrhage between the branchial secondary lamellae (fig. 3) in comparison with control group (fig. 1).

2- Treated group with low temperature:

After exposure to low temperature, the fish gills also showed hyperplasia of epithelial cells at the bases of branchial secondary lamellae as well as shrinkage of branchial blood vessels, fusion the ends of branchial secondary lamellae, atrophy of some epithelial cells and pillar cells of branchial secondary lamellae (fig. 4), damage of some branchial secondary lamellae and lamellar disorganization (fig. 5). Some of lamellar epithelial cells becomes rounded and hemorrhage between the branchial secondary lamellae (fig. 6) in comparison with control group (fig. 1).

DISCUSSION

Environmental conditions can result in two types of structural changes in tissues of the organism. One is the result of the direct toxic effect of the pollutants leading to degeneration and necrosis. The second is a result of compensatory mechanisms that deal with

environmental stressor as in cellular hyperplasia (Hughes and Perry, 1976). In the present case, it seems that our results are of compensatory mechanisms.

All histological lesions observed in the gills of *Cyprinus carpio* in this study, are categorized under lamellar cell hyperplasia and hypertrophy, cellular atrophy, bloody congestion and hemorrhage, lamellar fusion and lamellar damage, these findings could be linked with increase in the activities of the test organisms exposed to the changing environment, diffusion distance from surrounding water to capillaries and at the some time an increase in the amount of tissue (blood corpuscles) in the blood spaces of secondary lamellae and this fact agreed with the opinion of (Olojo *et al*., 2005; Antonio *et al*., 2007; Ayoola 2008a and b).

Under high temperature, cellular hyperplasia and hypertrophy were an important feature. Cells are principally derived from the primary lamellae, they migrate distally, resulting in an accumulation of cells at the leading edge of the secondary lamellae, known colloquially as (clubbing) of lamellae (Roberts, 2001). As a result, this alterations could contribute to an increase in the diffusion distance from surrounding water to capillaries and simultaneously increase in the amount of tissue in the secondary lamellae and impair the diffusion of oxygen through the swollen epithelium (Bhagwant and Elahee, 2002). This result is in line with the submission of (Wedemeyer *et al*., 1990; Ayoola, 2008a).

Moreover, the gills showed bloody congestion, where, some changes in blood vessels may also occur, when fishes suffer a more severe type of stress. In this case, damaged pillar cells can result in an increased blood flow inside the lamellae, causing dilation of the marginal channel, bloody congestion or even an eneurysm (Takashima and Hibiya, 1995; Rosety-Rodriguez *et al*., 2002; Martinez *et al*., 2004).

The rupture of the gill epithelium could cause heamorrhage, this lesion can be interpreted as areflection of the direct action of the thermal agent on the tissue (Temmink *et al*, 1983). The presence of mucous-filled cavity observed in the gill filaments of *Cyprinus carpio* may be considered as an ion trap to concentrate trace elements from surrounding water and favour cell adhesion between the neighbouring secondary lamellae (Tao *et al*., 2000). It may as well serve to protect the epithelia against both mechanical abrasion and infection as suggested by Olson and Fromm (1973).

Under low temperature, the gills shows close similarity to lesions brought about by high temperature specially lamellaer cell hyperplasia and hemorrhage between the branchial secondary lamellae, as well as the presence of partial fusion of some secondary lamellae, which is example of defense mechanism (Camargo and Martinez, 2007), and may have been protective in that they could diminish the vulnerable gill surface area (Richmonds and Dutta, 1989; Takashima and Hibiya, 1995). Secondary lamellar fusion may take place as an ultimate result of massive lamellar hyperplasia causing a solid fusion of many or all of the lamellar capillaries within amass of hyperplastic epithelium. However, usually, the level of proliferation is less, but because of changes in the consistency of the mucous with loss of surfactant properties, individual secondary lamellae may adhere focally, to produce alamellar complex. This response occurs with a number of stimuli such as with protozoan parasite infections (Goldes *et al*., 1988), also with chronic aluminum effects in (acid rain) toxicity in brown trout (Karlsson-Norrgren *et al*., 1986 a and b) and with reduced temperature as in present study. On the other hand, shrinkage of branchial blood vessels and cellular atrophy, this lesions might be due to unfavourable environmental conditions such as

reduced water level, and comparatively low oxygen content associated with low water temperature (Chandra, 1987).

Damage done to the some branchial secondary lamellae may be indicated that the reduced temperature caused impairment in gaseous exchange efficiency of the gills (Hossam and Fagr., 2007; Ayoola, 2008a and b).

In conclusion the present study showed that histopathology is a useful biomarker for environmental contamination. These responses indicate that physical alterations were severe enough to lead to structural changes at the tissue level,specially when elevating and reducing of water temperature.

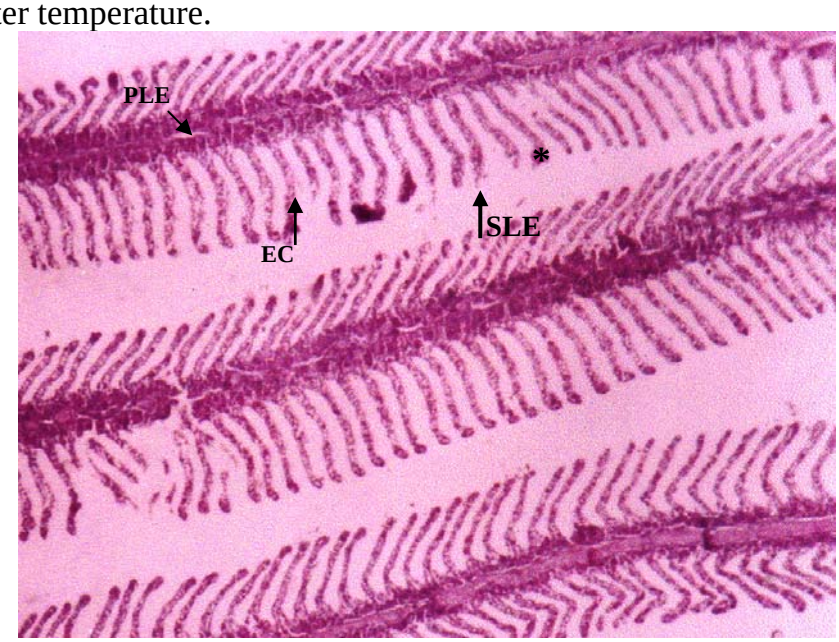

Fig. 1: Section from control fish gill showing primary lamellae (PLE), Secondary Lamellae (SLE), epithelial cells (EC), and water channel (*). X100. H & E

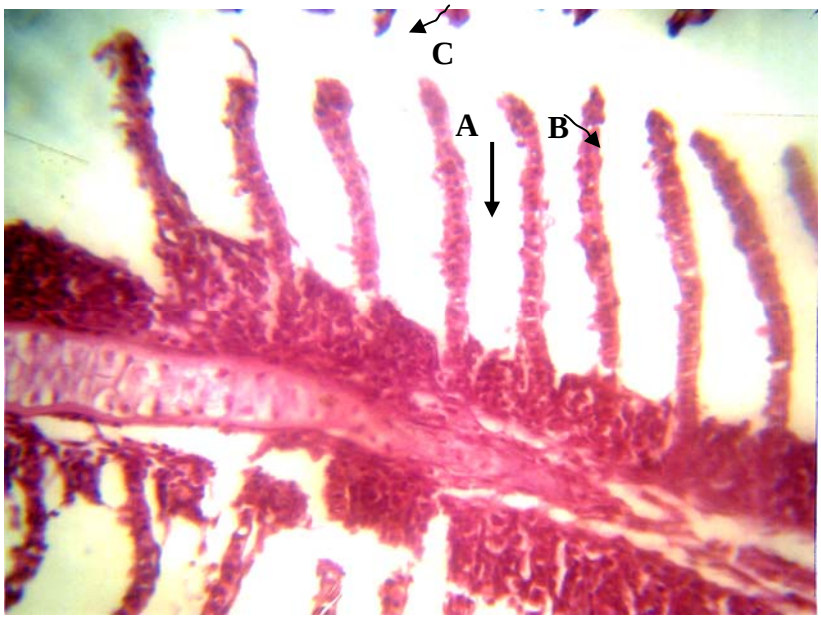

Fig. 2: Section from fish gill treated with high temperature showing hyperplasia of the epithelial cells (A), hypertrophy of the pillar cells (B) and blood congestion (C)-X400 H & E.

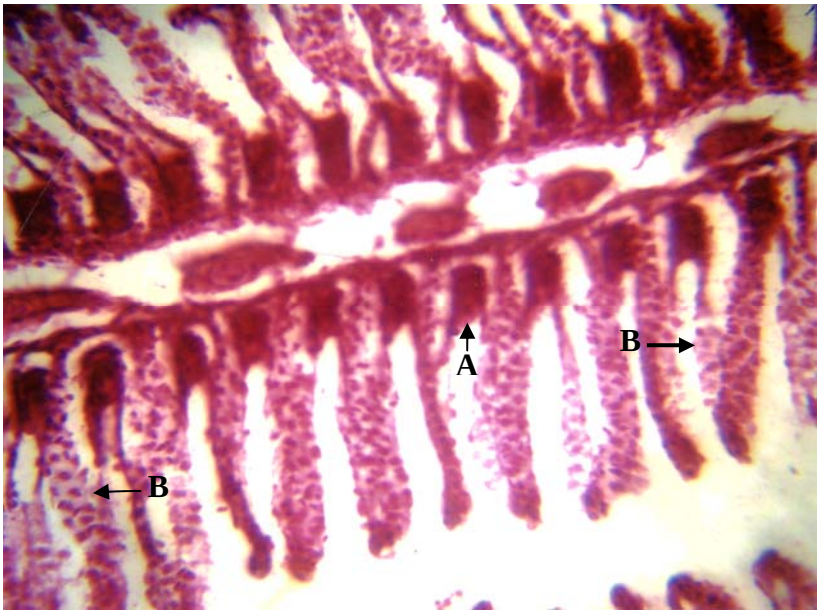

Fig. 3: Section from fish gill treated with high temperature showing abundance of mucous substance (A) and epithelium rupture with hemorrhage (B). X400. H & E.

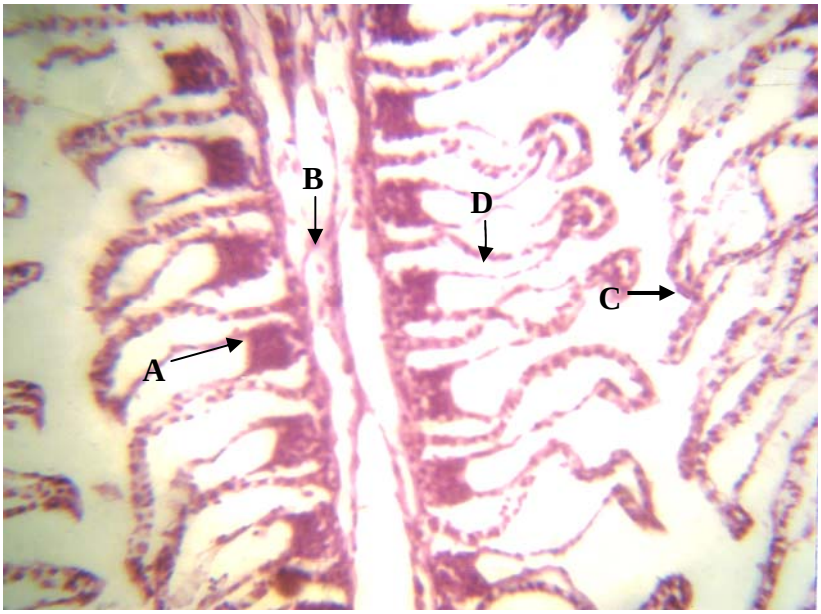

Fig. 4: Section from fish gill treated with low temperature showing hyperplasia of the epithelial cell between the bases of secondary lamellae (A), shrinkage of blood vessels (B), fusion the ends of secondary lamellae (C) and cellular atrophy (D). X400. H & E.

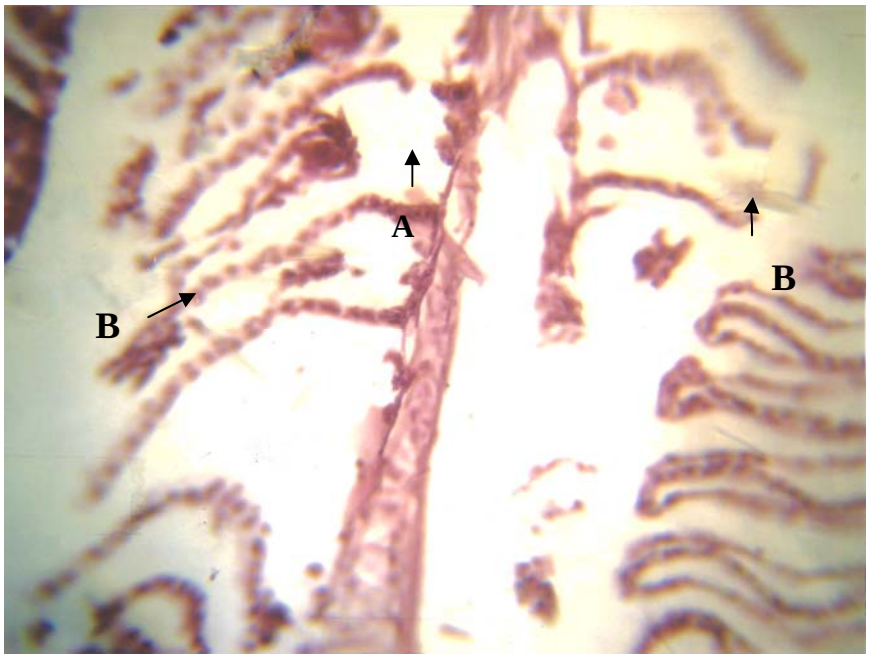

Fig. 5: Section from fish gill treated with low temperature showing damage of some secondary lamellae (A) and lamellar disorganization (B). X400. H & E.

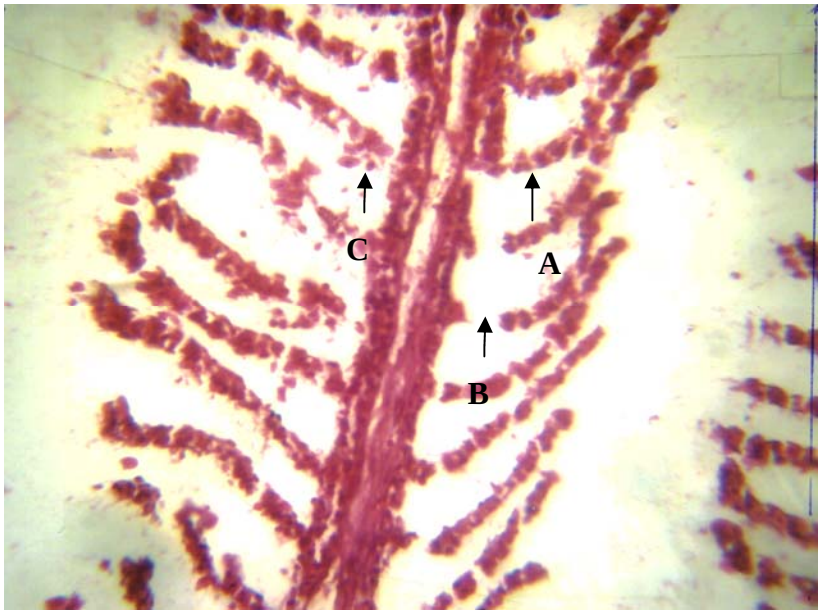

Fig. 6: Section from fish gill treated with low temperature showing rounded epithelial cells (A), damage of secondary lamellae (B) and hemorrhage (C). X400. H & E.

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