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Histological Investigation of the Skin Structure in the Common Carp (*Cyprinus carpio*) and the Catfish (*Silurus triostegus*): Aquatic Environment Adjustment

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ABSTRACT

The skin is a barrier separating the internal tissues from the outer environments in aquatic animals. It plays a major role in protection, osmoregulation, and sensory perception. Specimens from ten common carp (*Cyprinus carpio*) and ten catfish (*Silurus triostegus*) have been used to investigate the histological features of their skin. The histological findings of the current study indicated that there was an appreciable variation in the skin architecture between the two selected species. The skin of common carp was covered with scales that were variable in shape and size, in addition to the presence of a thick epidermal layer, keratinocytes, and several mucous layers. In contrast, a thin epidermis layer and a high density of club cells were found in the catfish skin compared to those in common carp. This variation suggested that the common carp skin is better at protecting against external environmental stressors. In contrast, the higher density of goblet cells in the skin of catfish provides secretion of mucous, which may participate in mechanisms of immune functions. Hence, this finding is crucial in understanding the functional influence of these differences in the integument, providing a perception of the adaptation of several types of local fishes to their aquatic environments.

INTRODUCTION

The skin is considered a large protective organ that plays a crucial role against external ecological threats **(Park *et al*., 2003; Chong *et al*., 2005; Mohamed *et al*., 2020)**. It is described as a sensitive organ that is essential for maintaining healthy interconnection characteristics from both an economic and pathological point of view. In fishes, the skin has many functions, including sensory perception, secretion, resistance against microorganisms, as well as the maintenance of osmotic pressure **(Sivakumar, 2000; Khalil, 2010)**. However, there are some variations in skin features among various fish species, such as the presence or absence of scales **(Sire & Akimenko, 2004)**.

The skin of fish skin comprises three primary layers including the outer epidermis, dermis, and deep hypodermis. The external epidermis contains a columnar or cuboidal layer at the epidermal base, but in the middle is a polyhedral, and a superficial (flat) in the upper layer **(Glover *et al*., 2013)**. In certain fish species, the epidermis may consist of up to five distinct layers: corneum, lucidum, granulosum, spinosum, and stratum basal **(Rakers *et al*., 2010)**. Notably, club and mucous cells have been identified in the intermediate layer of the Palembang puffer fish **(Akat *et al*., 2022; Jumma, 2024)**.

Keratinocytes are the predominant cells located in the basal layer of the fish epidermis, where they have a columnar shape. In the superficial layer, these cells appear flattened in species such as eels and marine teleost fish **(Bullock & Roberts, 1974)**. In a previous study, mucous cells (goblet cells) were described as elongated or spherical, with pale acidophilic cytoplasm and basal nuclei **(Al-Banaw *et al.*, 2010)**. However, in salmon, these cells were observed to have a saccular shape **(Robberts *et al.*, 1970)**. It has also been found that the mucus cells in the skin of the Arctic lamprey (*Lethenteron camtschaticum*) contain mucus granules, with basal nuclei located at the apical part of the cells. These cells are responsible for producing larger and more complex secretions, particularly glycoproteins, as they move toward the surface **(Sato, 1982; Alrudainy & Jumaa, 2016)**.

Club cells were described as a flask spherical in shape with the cytoplasm acidophilic. The nucleus is rounded basophilic and placed centrally **(Rai *et al*., 2012)** in Indian major carp (*Catla catla, Labeo rohita,* and *Cirrhina mrigala*). Still, they were not found in Tilapia nilotica (*Oreochromis niloticus*) **(El Shammaa, 1992)**. These cells release a substance that acts as a potent alarm into the water when the skin is exposed to injury. Thus, this substance can be considered a warning signal to other fish, alerting them to potential danger.

The dermis is composed of two distinct layers **(Al-Juhaishi *et al*., 2024)**: the outer layer, known as the stratum spongiosum, is made up of bundles of loose connective tissue, while the inner layer, the stratum compactum, consists of tightly arranged collagen fibers. This structural division has been described in various species, including zebrafish (*Danio rerio*) by **Le Guellec *et al*. (2004)**, *Mystus pelusius* by **Dauod *et al.* (2009)**, and turbot fish (*Scophthalmus maximus*) by **Faílde *et al.* (2014)**. Beneath the dermis lies the hypodermis, a deeper layer of loose connective tissue that connects the dermis to underlying structures. This has been documented in trout (*Oncorhynchus*) **(Kaleta, 2009)** and turbot fish **(Faílde *et al*., 2014)**.

Hence, the aim of this study was to investigate the similarities and differences in histological structure in two local species of fish including the common carp (*Cyprinus Carpio*) and catfish (*Silurus Triostegus*). This would enhance the knowledge of several strategies evolution regarding these important economic species.

MATERIALS AND METHODS

Histological samples were taken from many regions of ten common carp (*Cyprinus Carpio*) and ten catfish (*Silurus Triostegus*), from both sides including, cranial, middle, and caudal. The specimens were examined in both longitudinal and transverse sections. Fish were collected from Tikrit Governorate, Iraq. After collecting samples, they were fixed in neutral buffer formalin (10%), then dehydrated in alcohol, and clarified in xylene before being embedded in paraffin wax. The sections were cut in a thickness of about 5-7μm to stain them by using hematoxylin and eosin (H&E) for general description **(Cardiff *et al*., 2014)**.

RESULTS

Histological examination showed that the skin in both the common carp (*Cyprinus Carpio*) and catfish (*Silurus Triostegus*) is composed of three distinguished layers which include the epidermis, dermis, and hypodermis. In both, the common carp (*Cyprinus Carpio*) and catfish (*Silurus Triostegus*), the epidermis is the outermost layer of the skin that contains various cells including keratinocytes, mucous cells (goblet cells), and sensory cells (Figs. 1, 5). The skin of the common carp was characterized by the presence of scales, which exhibited variability in shape, size, and pattern. In contrast, scales were absent in the catfish (Figs. 2, 3). While, in the common carp, the epidermis was noticed to contain club and mucous cells. The club cells were elongated, rounded, and oval shapes, they situated in the superficial and middle layer of the epidermis. The mucous cells exhibited a variety in shape, ranging from rounded to goblet forms. These mucous cells were predominantly located within the superficial layer of the epidermis (Fig. 4). Pigment cells were elongated and distributed inside the epidermis taking a black color shape. In the catfish (*Silurus Triostegus*), the epidermis was a thin layer having a similar organization of cells, but it contained a high density of club cells.

The dermis in the common carp (*Cyprinus Carpio*) was comprised of three layers: the *stratum adiposum*, *stratum compactum*, and *stratum spongiosum* (Figs. 1, 5), while dermis of the catfish (*Silurus Triostegus*) was composed of two layers, including the *stratum spongiosum* and *stratum compactum*. Within the dermis, numerous melanocytes were diffused (Fig. 5). The *stratum spongiosum* was identified by a layer of loose connective tissue that contains collagen fibers, melanocytes, and blood vessels. The *stratum adiposum* was further differentiated into two layers: the upper thin layer consists of loose connective tissue that houses melanocytes, fibroblast cells, and blood vessels, while the lower thick layer was predominantly composed of adipose cells arranged in clusters, each encased by a connective tissue capsule. The stratum compactum was distinguished by regular bundles of collagen fibers (Figs. 1, 5). Finally, the deepest layer was a hypodermis formed from a loose connective tissue layer that contained many white adipose cells (Figs. 1, 5).

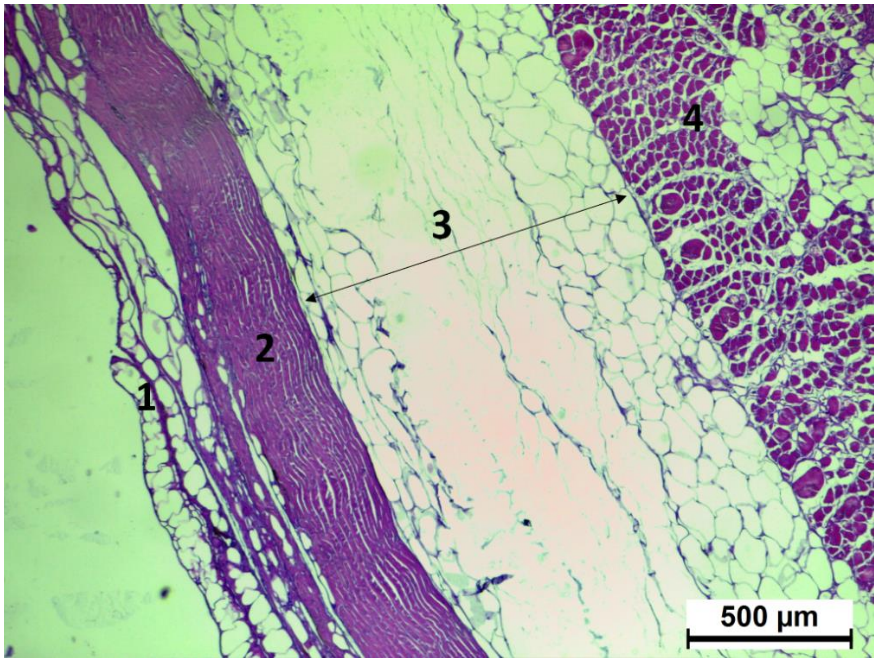

Fig. 1. Histological slide of common carp skin identifying the following structures: **1)** Epidermis; **2**) Dermis; **3)** Hypodermis; **4)** Muscles. H&E stain

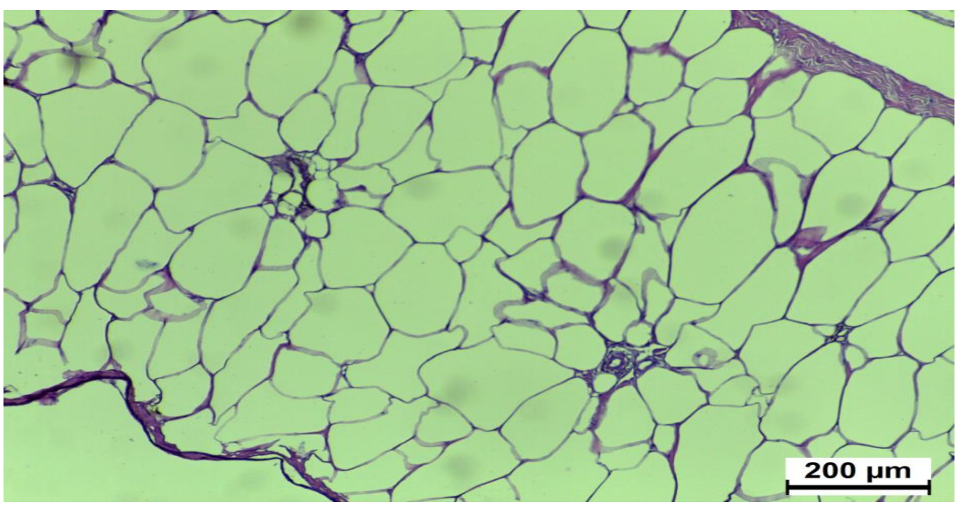

Fig. 2. Histological slide of common carp skin identifying the site of scales vary in shape, size, and pattern. H&E stain

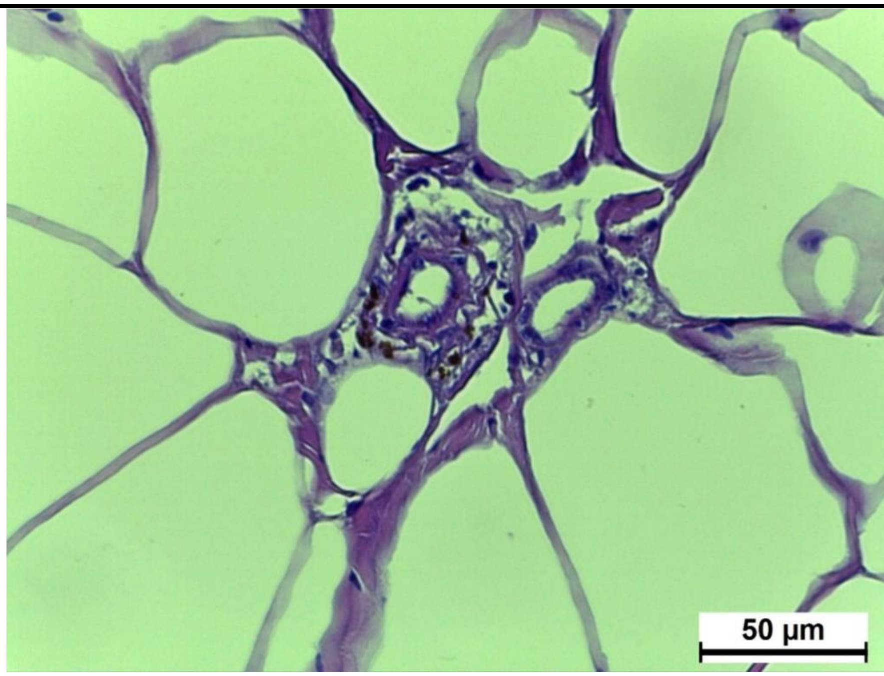

Fig. 3. Sites of scales in common carp skin vary in shape, size, pattern, and epidermal cells. H&E stain

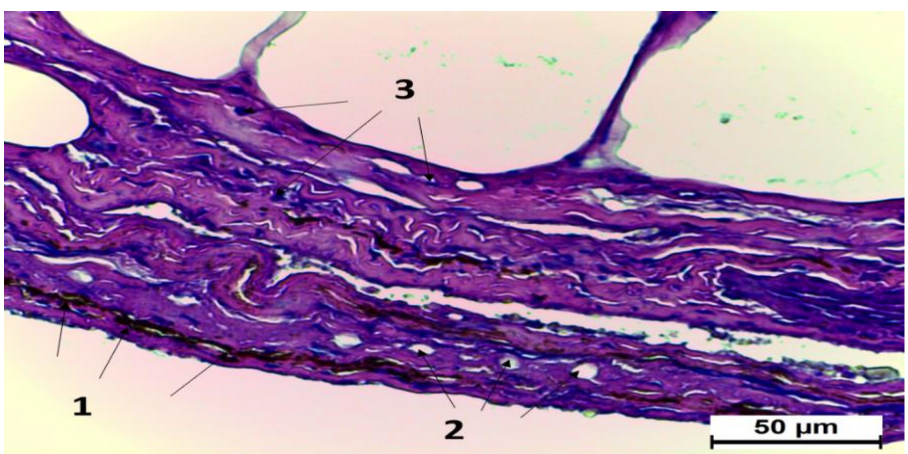

Fig. 4. Histological slide of common carp skin identifying: **(1)** Keratinocytes; **(2)** Mucous cells, and **(3)** Small scales H&E stain

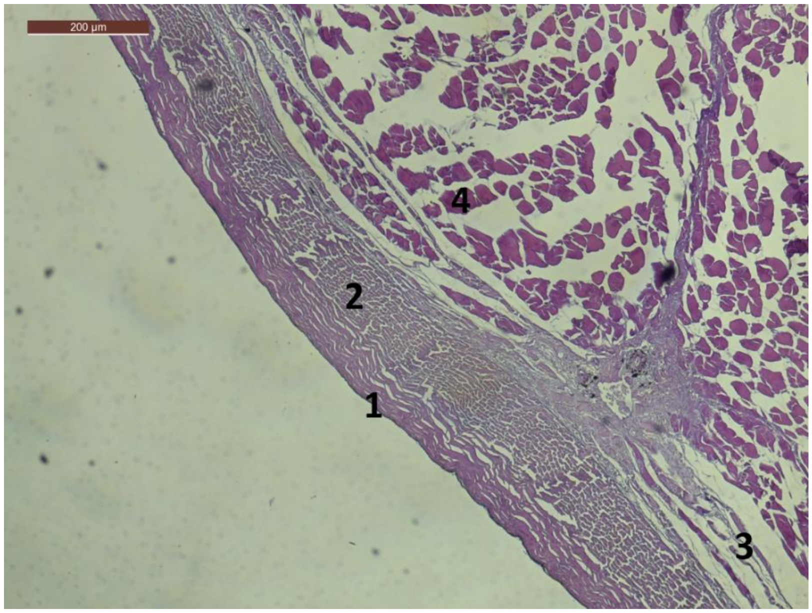

Fig. 5. Histological slide catfish skin identifying the following structures: **1)** Epidermis; **2)** Dermis; **3)** Hypodermis; **4)** Muscles. H&E stain

DISCUSSION

The current study investigated the histological features of the skin of the common carp (*Cyprinus Carpio*) and catfish (*Silurus Triostegus*), revealing similarities and differences that reflect their respective adaptations to their lifestyles and habitats. The skin structure has been investigated in most species of fish. However, despite having similar cytological organization, there are some differences in the structural organization.

The findings indicated that the morphological characteristics of the common carp (*Cyprinus Carpio*) and catfish (*Silurus Triostegus*) skin, with and without scales, were similar to those of other species. The skin of the common carp and catfish consists of the epidermis, dermis, and hypodermis layers, as described in previous research **(Whiter *et al*., 1981; Burkhardt *et al*., 1997; Pinky *et al*., 2000)**. **Patel *et al*. (2019)** highlighted the multifunctionality of fish skin, emphasizing its protective, communicative, and regulatory roles. Their research detailed the composition of teleost skin, which includes an outer epidermis, an inner dermis, and a mucus layer that serves as the first line of defense against pathogens. The distribution of goblet cells throughout different body regions suggests that specific skin structure and function adaptations are related to various environmental and biological needs.

A notable difference observed in the studied specimens was the presence of scales of various sizes and shapes covering the epidermal layer in the common carp. These bony structures are specialized for protection against external threats. In contrast, catfish lack scales, relying on the underlying skin structures for flexibility and sensory functions.

The epidermal layer of the common carp skin is thick, with a prominent stratum corneum composed of keratinocytes. This adaptation is essential for preventing water loss in freshwater environments. On the other hand, the skin of catfish has a thinner epidermal layer and lacks a stratum corneum. Instead, mucus cells provide a mucous layer, essential for protection and lubrication. This mucus also acts as a barrier against pathogens and facilitates movement in dark environments **(Seo *et al*., 2020)**. Previous studies **(Sire & Akimenko, 2004; Pickering, 2006)** have outlined the roles of various epidermal cells in fish, including mucosal, granular, alarm, and epidermal cells.

Singh and Mittal (1990) compared the epidermis of the Indian common carp (*Cyprinus carpio*) with three Indian major carp species (*Catla catla*, *Labeo rohita*, and *Cirrhina mrigala*), revealing differences in epidermal cell distribution. The Indian common carp exhibited a higher number of mucus cells and fewer club cells in the deep epidermis layer. In contrast, the other three species had fewer mucus cells but a higher number of club cells. This variation suggests that a reduction in mucus cells leads to an increase in club cells, compensating to support the fish's defense system, which aligns with the findings of this study.

Recent research by **Ye *et al.* (2020)** focused on the common carp, which is known for its various breeds and colors. Their iTRAQ proteomic analysis revealed complex interactions between genetic features and factors involved in pigment synthesis, particularly pteridine and melanin. Their findings underscored the primary function of fish skin in the immune system and its role in producing mucosal components that contribute to immune function, maintaining internal equilibrium, and resisting external stressors. This aligns with the conclusions of the current study, highlighting the need for further research to understand the full function and importance of fish skin.

CONCLUSION

This study investigated the histological analysis of skin structure in two species including the common carp (*Cyprinus Carpio*) and catfish (*Silurus Triostegus*) to illustrate the differences and similarities of skin morphological features that respond to various environmental changes. The scales cover the skin in the common carp and provide both support and protection, whereas, the lack of scale in the catfish skin is compensated by the amount of mucus layer that is capable of the flexibility and sensory approach. Understanding these variations could contribute to conserving efforts of fish breeding in their aquatic environment. More studies could explain how these adaptations impact the understanding of survival fish strategies and responding to external factors.

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