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Transforming Invasive Pterygoplichthys spp. Skin into Leather

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Abstract:

The South American Armoured Suckermouth Catfish (ASCF) (Pterygoplichthys spp.) is an invasive species that poses significant ecological and socio-economic threats to freshwater ecosystems in India. This study explores a sustainable approach to mitigate its adverse impacts by converting ASCF skin into value-added leather. Efficient skin recovery methods and a specialised tool for damage-free skinning have been developed. Microscopic analysis confirmed the presence of rigid bony plates with sharp tooth-like structures embedded within the skin, which critically influence processing behaviour. The dorsal and ventral skin of Pterygoplichthys showed markedly different ash contents (H”52% and 6.5%, respectively), with SEM-EDX confirming calcium & phosphorous rich mineral phases. FTIR and XRD analyses further validated the presence of characteristic P–O functional groups and crystalline HAP/â-TCP phases, reflecting the influence of the skin’s bony dermal plate architecture. A pit-based pretanning followed by a pickle-free tanning system was identified as the most suitable method, ensuring preservation of the skin’s structural integrity. In contrast, drum-based pre-tanning caused substantial abrasion due to the interaction with bony elements. Notably, drum-based post-tanning and subsequent mechanical operations did not induce physical damage, and optimised conditions enabled the production of flattened crust leather. The resulting leather demonstrated excellent abrasion and bladecut resistance, although it had relatively lower tear and puncture resistance. The finished material was

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successfully utilised to manufacture functional prototypes, including footwear and leather goods, highlighting its potential for commercial adoption and environmental management .

Keywords: Pterygoplichthys spp. Hydroxyapatite, Pickle free tanning, Pit tanning, Drum Based tanning, Blade-cut resistance

1. Introduction:

The Invasive Alien Species, as defined by The International Union for Conservation of Nature (IUCN) and Convention on Biological Diversity (CBD), has been threatening ecosystems and human socioeconomic values through severe out-competition with native organisms, fast spread rates, and others by causing extreme harm in the ecosystems. Recently, the aquarium trade has grown as one of the main ways of introducing non-native fishes in India. Among these, one of the most problematic invaders is the South American Armoured Suckermouth Catfish, ASCF (Pterygoplichthys spp.). Extremely attractive and algae-scavenging, this fish has widely been kept in aquariums, though it is eventually released or often escapes into natural bodies of water and leads to rapid population dispersal.Characterized by rapid maturation, high fecundity, long life, ability to breathe air, and high tolerance of low oxygen and salinity, ASCFs outcompete indigenous aquatic fauna. Feeding and burrowing result in bank erosion, siltation, riverbed excavation, benthic habitat alteration, deterioration of water quality due to increased nitrogen and phosphorus, native fish egg predation, and interruption of nutrient cycling and food webs. Impacts have been reported to reduce native fish diversity, fisheries productivity, and ecosystem services. Currently, the ASCFs have invaded inland waters of almost 20 countries

across five continents, thus turning into a global environmental and socio-economic concern. While preventive measures of physical barriers and public awareness could restrict further dissemination, complete eradication is impracticable. In this light, research has recently been focused on the sustainable use of ASCF biomass for value-added purposes. Several international studies report the use of ASCFs for heavy-metal and fluoride removal using bone-derived biochar, fish silage for livestock feed, organic fertilizers, biodiesel production, natural coagulants for wastewater treatment, extraction of enzymes, gelatin, bioplastics, collagen, and potential applications in the bioremediation of polluted waters. Such approaches point out the possibility to valorize an ecological threat into a resource while supporting environmental management and circular bioeconomy

strategies.

2. Methodology :

The South American armoured suckermouth catfish (ASCF) were collected from ponds in Panchuria village, South 24-Parganas, West Bengal, India. The fish had an average length of approximately 20 cm and weighed around 300 g. The skins were removed without damaging them and preserved in -20°C. To identify optimal processing conditions, ASCF samples were treated according to three tanning methods: (i) drum pre-tanning followed by conventional chrome tanning, (ii) pit pretanning followed by conventional chrome tanning, and (iii) pit pre-tanning followed by pickle-free chrome tanning. Conventional chrome tanning of leathers was then followed by common post-tanning processes to produce crust leather. Hydrothermal shrinkage temperature values of raw skins and wet-blue leathers were measured using the shrinkage tester as per IS 5914 standard. Chemical analysis of wet-blue leathers and crust leathers involved chromium estimation in wet-blue leathers using the wet

oxidation method, while solvent extractable matter analysis used Soxhlet extraction with petroleum ether. The drying rate of wet-blue and crust leathers has been tested gravimetrically. The moisture loss of cuttings of 5 g of each type of leather has been tested with time intervals of 1 hour at 45°C.The mechanical parameters of tensile strength and abrasion resistance were tested after conditioning of the specimens as per IUP norms. Morphological and microstructural transformations occurring during various stages of processing were analysed with a handheld optical microscope and with a scanning electron microscope after gradual dehydration of samples.

3. Results and Discussion :

Dorsal skin of ASCF has a weight of ~80-150g (approx. 15-20% of the weight of the skin), skin area of 0.2-0.5 sq-ft, thickness of 2.0-3.0mm, whereas the ventral skin has less thickness (1.0-1.2mm) contributing a small portion of the skin weight and area (Figure 1a,1b). The Hydrothermal shrinkage temperature of dorsal skin, as well as ventral skin, lies in the range of ~57-58°C, similar to other fish skin. Morphological studies show uneven, “tooth-like” skin structures for dorsal skin, whereas more homogeneous structures for ventral skin. As a result of having overlapping bony plates (scutes) that are aligned in a straight line through the dorsal and lateral sides, the skin of the South American Armored Suckermouth Catfish (ASCF) differs significantly from normal freshwater fish. The skin has a keratinized epidermic surface provided with sharp tooth-like structures. Although it has bony plates, it also has a thin dermal layer, thus giving it a protection afforded by an armor. The skin on the ventral side lacks bony plates. It is soft. Due to the hardness of these bony plates and thin skin layers, it requires expertise to skin (Figure 1c, 1d).

Figure 1: (a) Lateral view of ASCF, (b) Ventral view of ASCF, (c) Dorsal skin (d) Ventral skin

Due to the presence of hard bony plates and a thin dermal layer, recovery of ASCF skin without damage requires specialized cutting tools and trained personnel (Figure 2). The physical characteristics of ASCF skin are summarized in Table I. The dorsal skin weighs 80– 150 g per piece, contributing ~20% of the total body weight, with an area of 0.2–0.5 sq ft and a thickness of 2.0–3.0 mm. In contrast, the ventral skin is thinner

Table I Characteristics of the ASCF’s skin

S.No Description Characteristics

1. Color Dark brown to Black

2. Weight (gram) 80-150

3. Area (Sq.ft) 0.2-0.50

4. Thickness of the dorsal skin (mm)

5. Thickness of the ventral/belly skin (mm) 1.0-1.2

6. % of the skin weight to the whole body weight 15-20

7. % of the ventral skin weight to the whole skin 3-5

8. % of the ventral skin area to the whole skin 10-12

9. Hydrothermal shrinkage temperature of dorsal skin (°C) 57±1

10. Hydrothermal shrinkage temperature of ventral skin (°C) 57±1

(1.0–1.2 mm) and accounts for ~12% of the total skin

area. The hydrothermal shrinkage temperature of both

dorsal and ventral skins is ~57 °C, comparable to other

fish species. Surface and cross-sectional images (Figure

3) show that dorsal skin contains two types of sharp

tooth-like structures (thin and thick), whereas ventral

skin exhibits uniformly distributed tooth-like structure.

@ Anterior @ Posterior

2.5 to 3.0 2.0 to 2.2

Figure 2: Cutting tool and steps involved in the recovery of ASCF's skin

Figure 3: (a & b) Microscopic images showing the surface morphology of dorsal and ventral skin, respectively;

Figure 3: (c & e) SEM images showing the magnified view of tooth-like structure on the surface of dorsal and ventral

skin, respectively (d & f) SEM images showing the cross-sectional view of dorsal and ventral skin, respectively.

3.1. Process Optimization of the ASCF Skin :

ASCF skin has been found difficult to process because of its brittle and low flexibility characteristics of armored bony plates and sharp tooth-like structures on its surface. The preliminary attempts made on ASCF skin with drum type pre-tanning and chrome tanning processes have caused serious mechanical damage during the liming and other operations mainly due to high abrasion between

pieces, low mechanical strength, and damage due to toothlike projections. Drum type pre-tanning has been found to be unsuitable for ASCF skin. The pit-based pre-tanning system helped prevent physical damage; but penetration of acid, alkali, and chromium was limited because of the hard bony plates. To overcome this problem and to simplify processing and liquor reuse, a pit-based salt-free high pH chrome tanning technique was developed. The technique

includes deliming and partial pickling (pH 5.0) and tanning with basified chrome liquor (pH 4.5). The extended tanning time (50 hours) minimized brittleness of bony plates and increased flexibility. Microscopic examination showed that there was incomplete chromium diffusion in the dorsal bony areas and equal diffusion in ventral skin due to the high calcium-phosphorus content and low porosity of the bony plates. Drum post-tanning did not damage skin and

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Figure 4: Optimization of conditions to flatten the crust leather

Figure 5: Drying pattern of wet-blue and crust leather

enabled effective elimination of surface tooth-like formations from dorsal skin, whereas chemical diffusion, including dyes, was still incomplete in bony areas. Controlled flattening of crust leather by staged roller plating (40 °C, 15-bar then 50-bar pressure) prevented damage to leather. In overall processing of ASCF skin, pit pretanning and high pH chrome tanning and drum post-tanning were found to be the most effective methods Figure 4.

3.2. Drying Pattern:

Previous results suggest that dorsal and ventral regions exhibit different compositions and chemical absorption, which may vary in drying behavior. Therefore, dorsal and ventral wet-blue and crust leathers were dried under the same conditions, at 45 °C; their moisture contents were measured every 60 minutes. Figure 5 illustrates that approximately 45% and 60% of moisture were initially concentrated on dorsal and ventral leathers, respectively, in both wet-blue and crust forms. Drying data were fitted to an exponential decay model to get the time constant t1, where t1 is inversely related to the rate; higher t1 represents slower drying rate. Although the rates of drying of dorsal and ventral wet-blue leathers are similar, the ventral side of crust leather (t1 = 54.7) showed ~57% slower drying rate compared to the wet-blue leather (t1= 34.8). Such slow drying could be attributed to the water-retention effect of post-tanning auxiliaries, which can hinder moisture evaporation.

3.3. Chemical characteristics:

The chemical characteristics of ASCF wet-blue and crust leathers were analysed. Both dorsal and ventral regions showed similar volatile matter (~45%), while the ventral region exhibited higher Cr2 O3 content due to greater collagen reactivity and chromium uptake. The dorsal region showed lower solvent extractable substances, indicating

Figure 6: Different products fabricated from ASCF’s leather

limited post-tanning chemical penetration, likely due to mineral-rich bony plates. Cr (VI) was below the detection limit, confirming leather safety.

3.4. Physical Strength Characteristics:

Due to the limited area of the ventral region, physical strength tests were conducted only on the dorsal leather. ASCF leather exhibited moderate abrasion resistance, withstanding 12,800 cycles, corresponding to a performance level >4 under the EN 388 standard. The leather also showed good blade cut resistance (factor 10–11; level 4). However, tear and puncture resistance were comparatively low, indicating limited resistance to sharp-point loads. The leather demonstrated a maximum elongation at break of ~17%, reflecting moderate flexibility. Overall, the results suggest that ASCF leather is a promising raw material for specialized protective wear where abrasion and cut resistance are prioritized.

3.5. Product fabrication:

The finished ASCF leathers were successfully fabricated into various products, including shoes and sandals (Figure 6). The fabrication process was smooth, with no operational difficulties, and needle penetration was comparable to that of conventional leather.

4. Conclusions:

This work shows the successful recovery, characterization, and process optimization of South American armoured suckermouth catfish skin for value-added leather production and its use as a potential alternative raw material for the leather industry. The significant morphological and chemical differences between dorsal and ventral skins had a pronounced effect on their processing behaviour and resulting properties. Among the different methods, pit-based pre-tanning in combination with high-pH pickle-free chrome tanning and drum-based

post-tanning produced structurally intact leather, featuring good chromium uptake, diminished bony-plate brittleness, and well-preserved grain integrity. The matured leather that was produced exhibited adequate resistance to abrasion and cuts; it also presented slower drying kinetics due to post-tanning auxiliaries and good processability into footwear products, thus being suitable for applications related to protective use in niches. In general, the valorization of the invasive ASCF skin represents a sustainable, circular-economy approach with a low ecological impact that produces functional leather products.