Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Comparative Evaluation of Semen Quality Parameters in Cultured and Wild Broodstock of Clarias gariepinus: Implications for Aquaculture Reproduction and Broodstock Management

Uruku Ndekimbe Mamndeyati

uruksme@gmail.com

Federal University Wukari

Abutu Agnes

Federal University Wukari

Uruku Ndenyangtse Ndekimbe

Federal University Wukari

Research Article

Keywords: African catfish, Semen quality, Broodstock management, Aquaculture reproduction, Sperm motility

Posted Date: May 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9602723/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Aquaculture has become one of the fastest-growing food production sectors globally and is increasingly recognized as a strategic solution to declining capture fisheries, food insecurity, and rising protein demand. This study evaluated and compared semen quality parameters of cultured and wild broodstock of *Clarias gariepinus* with the aim of determining their reproductive suitability for aquaculture seed production and broodstock management.

Method

A total of twenty (20) mature male broodstock comprising ten (10) cultured and ten (10) wild individuals were used. Fish were selected based on uniformity in size, age, and health status. Semen was obtained through testicular extraction following dissection, and key reproductive parameters including gonadosomatic index (GSI), milt volume, sperm motility, sperm concentration, viability, morphology, and semen pH were evaluated using standard laboratory procedures.

Results

rrevealed that wild broodstock exhibited slightly higher mean values in body weight, gonad weight, milt volume, sperm concentration, and percentage of active sperm cells compared to cultured broodstock. However, these differences were not statistically significant ($P > 0.05$). Semen pH was neutral and identical in both groups, indicating favorable conditions for sperm survival. Cultured broodstock showed marginally higher percentages of sluggish sperm, while wild broodstock recorded slightly higher dead sperm percentages. Morphological evaluation indicated a higher proportion of normal sperm cells in wild fish, although variability was greater in cultured fish. Qualitative semen traits such as colour, viscosity, and liquefaction time varied slightly between groups but remained within acceptable reproductive standards.

Conclusion

, the findings demonstrate that both cultured and wild broodstock possess comparable semen quality characteristics and reproductive potential. The lack of significant differences suggests that properly managed cultured broodstock can effectively replace wild broodstock in hatchery operations. This has important implications for sustainable aquaculture, as it reduces dependence on wild populations while maintaining seed production efficiency. The study provides useful insights for broodstock selection, reproductive management, and genetic conservation strategies in African catfish aquaculture.

INTRODUCTION

Aquaculture has become one of the fastest-growing food production sectors globally and is increasingly recognized as a strategic solution to declining capture fisheries, food insecurity, and rising protein demand. The sector now contributes more than half of the fish consumed worldwide, with freshwater finfish species playing dominant roles in developing countries [1]. In sub-Saharan Africa, aquaculture expansion has been driven largely by the culture of African catfish, *Clarias gariepinus*, due to its rapid growth, high tolerance to poor water quality, omnivorous feeding habit, disease resilience, and strong market acceptance [1, 2]. Nigeria remains the leading producer of catfish in Africa, where *C. gariepinus* constitutes the backbone of commercial pond and tank aquaculture systems. However, sustainable expansion of the industry depends fundamentally on the availability of high-quality broodstock and reliable seed production systems.

Artificial propagation is widely practiced in *C. gariepinus* because the species rarely spawns naturally under intensive captive conditions. Consequently, hatchery production relies on induced breeding, gamete stripping, fertilization, incubation, and larval rearing under controlled environments. While substantial attention has traditionally been given to female fecundity, egg quality, and hormonal induction protocols, the reproductive contribution of male broodstock has often been underestimated. Yet, semen quality is a major determinant of fertilization success, embryo viability, hatchability, larval survival, and subsequent fry performance [3, 4]. Poor semen quality can result in reduced fertilization efficiency even when eggs are of high quality, thereby causing significant economic losses in hatchery operations.

Semen quality in fishes is generally assessed through several biological and functional parameters, including milt volume, sperm concentration, sperm motility percentage, duration of motility, viability, morphology, pH, osmolality, and DNA integrity. Among these, sperm motility is considered one of the most important predictors of fertilization capacity because fish spermatozoa remain motile for only a short duration after activation in water or activating media [5]. In catfish hatcheries, spermatozoa with low motility or shortened motility duration often produce poor fertilization outcomes. Similarly, reduced sperm concentration or high rates of abnormal sperm morphology may impair sperm–egg interactions and embryonic development [6]. Therefore, regular evaluation of semen quality parameters is essential for broodstock management and reproductive optimization.

In *Clarias gariepinus*, semen collection has traditionally involved sacrificing male broodstock and removing the testes, followed by maceration of testicular tissue to release milt. This practice, although common, results in the loss of genetically valuable males and increases broodstock replacement costs. Recent studies have emphasized the need for improved sperm management, cryopreservation, hormonal stimulation of spermiation, and repeated use of elite sires without sacrificing males [7]. Such innovations are particularly important where selective breeding and genetic conservation programs are being developed.

One major issue in hatchery management is whether cultured broodstock maintained in captivity over several generations possess reproductive capacities equivalent to those of wild broodstock. Wild broodstock are often presumed to possess superior gamete quality due to broader genetic diversity, natural feeding regimes, and exposure to environmental selection pressures. Conversely, cultured broodstock may exhibit domestication effects, inbreeding depression, nutritional deficiencies, stress-induced endocrine dysfunction, or reduced reproductive vigor when poorly managed [8]. However, cultured broodstock may also perform favorably when selectively bred, nutritionally conditioned, and reared under biosecure conditions. Hence, direct comparative assessment between cultured and wild broodstock is scientifically necessary rather than relying on assumptions.

Several reports indicate that broodstock nutrition, age, size, water quality, handling stress, endocrine status, seasonality, and genetic background significantly influence semen traits in fish. In African catfish, positive correlations have been reported among body weight, testes weight, semen volume, sperm count, and motility percentage, suggesting that somatic and gonadal development are linked to reproductive output [9]. Similarly, developmental stage and age have been associated with differences in testicular morphology and sperm motility in cultured *C. gariepinus* [10]. These findings imply that broodstock source and management history may strongly affect semen performance.

From a genetic perspective, repeated use of a narrow captive breeding base may gradually reduce heterozygosity and adaptive fitness traits, including reproductive performance. Wild populations may therefore serve as reservoirs of genetic diversity useful for broodstock rejuvenation and selective breeding. Nevertheless, uncontrolled introduction of wild brooders into hatchery populations may also introduce disease risks, stress susceptibility, and inconsistent spawning responses. A balanced understanding of reproductive merits and limitations of both broodstock sources is therefore crucial for evidence-based broodstock management.

Comparative semen evaluation between cultured and wild male broodstock of *C. gariepinus* has direct practical implications. If cultured males consistently match or outperform wild males, hatcheries can reduce dependence on wild capture, thereby supporting conservation of natural populations. On the other hand, if wild males show superior semen quality, strategic introgression or periodic broodstock replacement may be necessary to maintain hatchery productivity. Furthermore, identifying specific semen traits that differ between sources can guide nutritional supplementation, stress reduction protocols, hormonal management, and sire selection criteria.

Despite the economic importance of African catfish, comparative studies specifically examining semen quality differences between cultured and wild broodstock remain limited, particularly in West Africa where hatchery demand is highest. Most previous studies have focused on either cultured fish alone or on isolated semen preservation techniques rather than source-based reproductive comparisons. This creates an important knowledge gap in broodstock management and seed production planning.

Therefore, this study on the comparative evaluation of semen quality parameters in cultured and wild broodstock of *Clarias gariepinus* is timely and relevant. By examining key reproductive indices such as

milt volume, sperm concentration, motility, viability, and related semen characteristics, the study will provide scientific evidence for selecting superior male broodstock, improving fertilization success, strengthening hatchery output, and promoting sustainable aquaculture reproduction systems.

MATERIALS AND METHODS

Experimental Site

The study was conducted at the Fish Hatchery Unit of the Department of Fisheries and Aquaculture Research Farm, Federal University Wukari, located at approximately 7.8428° N, 9.7720° E in Taraba State, Nigeria. The hatchery facility is equipped with standard breeding and seed production units, including concrete tanks, water supply systems, water quality monitoring devices, incubation facilities, and a functional fish reproductive physiology laboratory.

Experimental Fish and Broodstock Source

A total of twenty (20) mature male broodstock of *Clarias gariepinus* were used for the experiment, comprising twenty (10) cultured broodstock obtained from a commercial fish farm and twenty (10) wild broodstock captured from natural inland water bodies (Lower river Benue at Ibi) using non-destructive fishing gears. Fish were selected based on maturity indicators such as prominent genital papilla, body condition, and body weight range of 0.8–1.5 kg.

Cultured broodstock were individuals raised under captive aquaculture conditions for at least one production cycle, while wild broodstock were recently captured sexually mature males with no prior domestication history. Similar size classes were selected to minimize body size bias on semen characteristics [9, 11].

Experimental Design

The experiment followed a Completely Randomized Design (CRD) with two treatment groups:

T_1 = Cultured broodstock semen samples

T_2 = Wild broodstock semen samples

Each fish served as an experimental replicate (n = 10 per treatment).

Sacrifice methods

Prior to sacrifice, fish were anesthetized using tricaine methane sulfonate (MS-222) at a concentration of 100 mg/L to minimize stress, pain, and handling discomfort. Fish were confirmed unconscious through

loss of equilibrium and absence of opercular movement before dissection and semen collection were carried out. The sacrifice procedure was performed to ensure humane handling and obtain uncontaminated testes for accurate semen quality evaluation.

Semen Collection Procedure

Male broodstock of both wild and cultured groups were humanely sacrificed following standard ethical procedures for fish reproductive studies. The abdominal cavity was dissected ventrally, and the paired testes were carefully removed. Adhering tissues, blood clots, and connective materials were rinsed away using sterile normal saline solution (0.9% NaCl).

The testes were blotted dry and transferred into sterile buffer solution pending semen extraction. Semen was obtained by gently macerating the testes in sterile Petri dishes, and the released milt was collected into labelled test tubes for immediate analysis. Care was taken to prevent contamination with water, urine, mucus, or blood, as these may prematurely activate spermatozoa and reduce motility [12, 13].

Semen Quality Evaluation

Fresh semen samples were evaluated immediately after collection using standard fish semen assessment procedures.

1. **Gonadosomatic Index (GSI)**: This parameter indicates reproductive investment and gonadal development.

Gonadosomatic index (GSI) in male was calculated as: = $\frac{\text{Testes weight (g)}}{\text{Body weight (g)}} \times 100$ (1)

2. **Semen Volume (mL)**

Semen volume was measured directly from collection tubes using a sterile graduated syringe and expressed in milliliters (mL).

3. **Sperm Motility (%)**

A drop of fresh semen was activated using 0.9% NaCl solution and examined under a light microscope at ×400 magnification within 30 seconds of activation. The percentage of motile sperm cells was estimated visually from at least five microscopic fields. Motility is one of the most reliable indicators of fertilization potential in fish spermatozoa [5, 14].

4. **Sperm Concentration**

Sperm concentration was determined using a Neubauer hemocytometer after diluting semen at 1:200 ratio with 0.5% sodium citrate solution. Sperm cells were counted under a microscope and expressed as spermatozoa mL^{-1} [15].

5. **Sperm Viability (%)**

Viability was assessed using eosin - nigrosin staining technique. Live spermatozoa excluded the stain and appeared white, whereas dead sperm cells absorbed stain and appeared pink. A smear was prepared and examined under oil immersion objective. At least 200 sperm cells were counted per sample [16].

6. **Semen pH**

Measured immediately using a calibrated digital pH meter.

7. **Active/Dead Ratio (Viability %)**

Semen smears were stained using eosin-nigrosin stain. Live sperm cells excluded stain, whereas dead cells absorbed stain. A minimum of 200 spermatozoa were counted under microscope.

8. **Sperm Morphology (%)**

Morphological abnormalities such as head deformities, mid-piece defects, detached heads, bent tails, and coiled tails were recorded from stained smears and expressed as percentage abnormal sperm cells. High sperm abnormality may reduce fertilization efficiency and hatchability [4].

Statistical Analysis

Data generated from the study were analyzed using SPSS version 25.0. Results were expressed as mean ± standard error (SE). Independent sample t-test was used to compare semen quality parameters between wild and cultured broodstock groups at 5% level of significance ($p < 0.05$).

RESULTS

Table 1 shows the phenotypic indices of both broodstock groups. The mean body weight was slightly higher in wild fish (1.70 ± 0.67 kg) than in cultured fish (1.43 ± 0.12 kg), although the difference was not statistically significant ($p = 0.72$). Standard length was greater in cultured fish (55.30 ± 2.64 cm) compared to wild fish (35.93 ± 14.98 cm), but this variation was also not significant ($p = 0.28$). Head length was marginally higher in wild fish (16.67 ± 1.76 cm) than cultured fish (15.37 ± 0.61 cm), with no significant difference ($p = 0.54$). Similarly, the number of dorsal fin rays was higher in wild fish (76.33 ± 1.33) than cultured fish (69.00 ± 3.00), while anal fin rays were nearly similar between cultured (57.33 ± 2.91) and wild fish (57.67 ± 3.67). However, none of these traits showed significant differences ($p > 0.05$), indicating comparable external morphology between the two broodstock sources.

Gonad morphology reveal Wild fish recorded a higher gonad weight (5.33 ± 1.20 g) than cultured fish (3.50 ± 0.76 g), but the difference was not significant ($p = 0.26$). Gonad length was almost similar in both groups, with cultured fish having 6.72 ± 0.44 cm and wild fish 6.57 ± 0.56 cm ($p = 0.84$). The number of gonad teeth was slightly higher in wild fish (15.33 ± 1.33) compared to cultured fish (13.00 ± 1.73), but

the difference was also not significant (p = 0.35). These findings suggest that reproductive organ development was relatively similar in both cultured and wild broodstock.

For gonadal production indices, wild broodstock recorded higher mean values than cultured fish in gonad body weight ratio (3.11 ± 2.52% vs 1.76 ± 1.16%), gonad body length ratio (24.02 ± 5.94% vs 11.91 ± 0.63%), and gonadosomatic index (3.11 ± 2.52% vs 1.76 ± 1.16%). However, these differences were not significant (P > 0.05), suggesting similar reproductive organ development between both groups.

In semen quality parameters, wild broodstock had slightly higher milt volume (2.72 ± 0.10 ml) compared to cultured fish (2.58 ± 0.17 ml), while seminal pH was identical (7.00 ± 0.00) in both groups, indicating a neutral reproductive medium. Active sperm percentage was marginally higher in wild fish (70.00 ± 3.65%) than cultured fish (67.50 ± 3.82%), whereas sluggish sperm was higher in cultured fish (16.67 ± 1.86%) than wild fish (13.33 ± 1.86%). Dead sperm percentage was slightly greater in wild broodstock (20.83 ± 3.07%) compared to cultured broodstock (18.33 ± 1.67%). Sperm concentration also favored wild fish (5.82 ± 0.23 $\times 10^{10}$/ml) over cultured fish (5.56 ± 0.11 $\times 10^{10}$/ml). Nonetheless, all semen quality traits were statistically similar (P > 0.05).

For milt morphology, wild broodstock showed a higher proportion of normal sperm cells (88.00 ± 2.16%) than cultured fish (76.80 ± 12.95%), while swollen sperm cells were more frequent in wild fish (6.62 ± 0.47%) than cultured fish (3.97 ± 1.49%). Coiled-tailed sperm cells were absent in both groups. Despite these numerical differences, no significant variation was observed (P > 0.05).

Table 1
Quantitative Semen indices of cultured and wild African Catfish (*Clarias gariepinus*) Broodstock

Parameter	Cultured (Mean ± SEM)	Wild (Mean ± SEM)	t-value	p-value
Phenotypic Indices				
Mean weight	1.43 ± 0.12	1.70 ± 0.67	-0.39	0.72
Standard length	55.30 ± 2.64	35.93 ± 14.98	1.25	0.28
Head length	15.37 ± 0.61	16.67 ± 1.76	-0.67	0.54
Dorsal fin rays	69.00 ± 3.00	76.33 ± 1.33	-2.13	0.10
Anal fin rays	57.33 ± 2.91	57.67 ± 3.67	-0.07	0.95
Gonad Morphology				
Gonad weight (g)	3.50 ± 0.76	5.33 ± 1.20	-1.31	0.26
Gonad length (cm)	6.72 ± 0.44	6.57 ± 0.56	0.21	0.84
No. of gonad teeth	13.00 ± 1.73	15.33 ± 1.33	-1.06	0.35
Gonad Production Indices				
Gonad body weight ratio (%)	1.76 ± 1.16	3.11 ± 2.52	-0.50	0.64
Gonad body length ratio (%)	11.91 ± 0.63	24.02 ± 5.94	-1.99	0.12
Gonadosomatic index (%)	1.76 ± 1.16	3.11 ± 2.52	-0.50	0.64
Semen Quality				
Milt volume (ml)	2.58 ± 0.17	2.72 ± 0.10	-0.68	0.52
Seminal pH	7.00 ± 0.00	7.00 ± 0.00	–	–
Active sperm (%)	67.50 ± 3.82	70.00 ± 3.65	-0.47	0.65
Sluggish sperm (%)	16.67 ± 1.86	13.33 ± 1.86	1.26	0.24
Dead sperm (%)	18.33 ± 1.67	20.83 ± 3.07	-0.72	0.49
Sperm count (×10^{10}/ml)	5.56 ± 0.11	5.82 ± 0.23	-1.05	0.32
Milt Morphology				
Normal sperm (%)	76.80 ± 12.95	88.00 ± 2.16	-0.85	0.42
Swollen sperm (%)	3.97 ± 1.49	6.62 ± 0.47	-1.66	0.14
Coiled Tailed	Null	Null	-	Null
Note: P > 0.05 not significant				

Table 2 summarizes the qualitative semen indices. In terms of colour, semen from cultured fish was predominantly milky (66.7%), whereas wild fish showed mostly whitish semen (66.7%), with a small proportion of slightly yellowish semen (16.7%) observed only in wild fish. For viscosity, both groups had equal proportions of slightly watery semen (66.7%). However, slightly thick semen was only observed in cultured fish (33.3%), while thick semen occurred only in wild fish (33.3%). Regarding liquefaction time, most cultured fish semen liquefied within 2 minutes (83.3%), whereas 66.7% of wild fish semen liquefied within the same time. A smaller proportion liquefied within 1 minute in both cultured (16.7%) and wild fish (33.3%). Some variation existed in semen quality traits such as colour, viscosity, and liquefaction time.

Table 2
Qualitative Semen Indices (%) of Cultured and Wild African Catfish (*Clarias gariepinus*) Broodstock

Indices	Category	Cultured (%) (n = 6)	Wild (%) (n = 6)
Colour	Milky	66.7%	16.7%
	Whitish	33.3%	66.7%
	Slightly yellowish	0.0%	16.7%
Viscosity	Slightly watery	66.7%	66.7%
	Slightly thick	33.3%	0.0%
	Thick	0.0%	33.3%
Liquefaction Time	1 min	16.7%	33.3%
	2 min	83.3%	66.7%

DISCUSSION

The present study compared phenotypic characteristics, gonadal development, and semen quality of cultured and wild broodstock of *Clarias gariepinus*, with findings generally indicating no statistically significant differences ($P > 0.05$) across all measured parameters. This suggests that both broodstock sources possess comparable biological and reproductive potential, despite minor numerical variations.

The slightly higher mean body weight observed in wild broodstock compared to cultured fish, although not significant, may reflect differences in environmental conditions, feeding regimes, and genetic variability. Wild fish often experience natural selection pressures and diverse diets that can influence growth variability, whereas cultured fish are subjected to controlled feeding and management practices [17]. The lack of significant differences in morphometric traits such as standard length and head length suggests that domestication has not drastically altered the external morphology of cultured *C. gariepinus*, which aligns with previous reports that phenotypic plasticity in fish allows adaptation without necessarily producing significant morphological divergence [11].

Meristic traits, including dorsal and anal fin rays, were also comparable between the two groups. These traits are generally genetically controlled and less influenced by environmental conditions, which may explain their similarity across broodstock sources [18]. The absence of significant variation in these characters further supports the notion of genetic closeness or shared ancestry between cultured and wild populations used in this study.

Gonadal morphology and reproductive indices showed slightly higher values in wild fish, although differences were not significant. The higher gonad weight and gonadosomatic index (GSI) in wild broodstock may indicate better reproductive readiness, possibly due to natural environmental cues such as photoperiod, water flow, and temperature fluctuations that stimulate gonadal maturation [19]. However, the similarity in gonad length and gonad body ratios between both groups suggests that cultured broodstock maintained under adequate hatchery conditions can achieve reproductive development comparable to their wild counterparts. This finding is important for aquaculture sustainability, as it supports the use of captive broodstock without reliance on wild populations.

Semen quality parameters, including milt volume, sperm motility, sperm concentration, and pH, were also statistically similar between cultured and wild broodstock. Although wild fish showed slightly higher values in milt volume and sperm concentration, these differences were not significant. This observation agrees with earlier studies that reported comparable semen quality between wild and cultured African catfish when broodstock are properly managed [13]. The neutral pH recorded in both groups indicates a suitable medium for sperm viability, as optimal sperm activity in fish typically occurs around neutral to slightly alkaline pH.

The proportion of active sperm cells was marginally higher in wild fish, while cultured fish exhibited a slightly higher percentage of sluggish sperm. This could be linked to differences in physiological stress or nutritional status, as broodstock nutrition plays a crucial role in sperm quality [20]. Nevertheless, the absence of significant differences indicates that cultured broodstock were adequately conditioned and capable of producing viable gametes.

Milt morphology further supported this conclusion, as both groups exhibited high proportions of normal sperm cells, with no occurrence of coiled-tailed abnormalities. Although wild fish had a higher percentage of normal sperm cells, the large variation observed in cultured fish suggests possible individual differences rather than systematic inferiority. According to [21], sperm abnormalities can arise from handling stress, environmental factors, or genetic influences, but moderate variations do not necessarily impair fertilization success.

Qualitative semen characteristics such as colour, viscosity, and liquefaction time showed some variation between the groups. The predominance of milky and whitish semen in both cultured and wild fish is typical of good-quality milt, indicating high sperm density [22]. Differences in viscosity and liquefaction time may be influenced by seminal plasma composition and hydration levels, which can vary with environmental conditions and broodstock handling [23]. However, since these variations were not

associated with significant differences in quantitative semen parameters, they are unlikely to have major biological implications.

Overall, the findings of this study demonstrate that cultured *Clarias gariepinus* broodstock are comparable to wild broodstock in terms of morphometric traits, gonadal development, and semen quality. This supports the growing body of evidence that well-managed hatchery broodstock can effectively replace wild populations for aquaculture production, thereby reducing fishing pressure on natural stocks and promoting sustainable aquaculture practices [24].

CONCLUSION

The comparative evaluation of semen quality parameters in cultured and wild broodstock of *Clarias gariepinus* revealed no statistically significant differences in reproductive performance between the two groups. Although wild broodstock showed slightly higher numerical values in some parameters such as milt volume, sperm concentration, and sperm motility, these variations did not translate into significant biological differences. The similarity observed in gonadal development, semen quality indices, and sperm morphology indicates that cultured broodstock, when properly managed, can achieve reproductive competence comparable to their wild counterparts. This finding is critical for sustainable aquaculture development, as it supports reduced reliance on wild broodstock and promotes the use of captive populations for continuous seed production.

RECOMMENDATION

Cultured broodstock of *Clarias gariepinus* should be prioritized for hatchery seed production to reduce dependence on wild populations and enhance sustainability. Selective breeding and periodic genetic improvement programs should be implemented to maintain genetic diversity and prevent inbreeding in cultured stocks.

Declarations

Authors contribution

Conceptualization and writing original draft: Uruku, Ndekimbe Mamndeyati. Methodology and editing, Abutu Agnesand Uruku Ndenyangtse Ndekimbe

Funding

No any source of funding

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interest

No competing interest among authors

Ethical approval and consent to participate

Ethical approval for this study was obtained from the Department of Fisheries and Aquaculture Research Ethics Committee, Federal University Wukari, prior to commencement of the experiment. All procedures involving experimental fish were conducted in accordance with institutional guidelines for the care and use of animals in research.

Consent from owners

Informed consent was obtained from the owners of the cultured *Clarias gariepinus* broodstock collected from private fish farms within Wukari metropolis before sample collection.

Consent for publication

Not applicable

References

1. FAO. The State of World Fisheries and Aquaculture 2024. Food and Agriculture Organization of the United Nations. 2024. https://doi.org/10.4060/cd0683en
2. Adewolu MA, Bello OS, Okomoda VT. Sustainable catfish aquaculture production systems in Nigeria: Current status and prospects. Aquaculture Reports, 2022; 24, 101134. https://doi.org/10.1016/j.aqrep.2022.101134
3. Cabrita E, Sarasquete C, Martínez-Paramo S, Robles V, Beirão J, Perez-Cerezales S, Herraez MP. Cryopreservation of fish sperm: Applications and perspectives. Journal of Applied Ichthyology, 2014; 30(4), 623–635. https://doi.org/10.1111/jai.12440
4. Bobe J, Labbe C. Egg and sperm quality in fish. General and Comparative Endocrinology, 2010; 165(3), 535–548. https://doi.org/10.1016/j.ygcen.2009.02.011
5. Cosson J. Fish sperm physiology and motility. Aquaculture International, 2019; 27, 1485–1500. https://doi.org/10.1007/s10499-019-00410-2
6. Suquet M, Dreanno C, Fauvel C, Cosson J, Billard R. Sperm quality in fish: Evaluation and determinants. Aquaculture. 2016; 261(2), 593–602. https://doi.org/10.1016/j.aquaculture.2006.09.003
7. Yalew A, Tilahun G. Cryopreservation and artificial insemination in African catfish (*Clarias gariepinus*): A review. Journal of Agriculture and Environmental Sciences. 2024; 9(1), 1–12. https://doi.org/10.20372/jaes.v9i1.9389

8. Lorenzen K, Beveridge MCM, Mangel M. Cultured fish broodstock management and domestication effects. Fish and Fisheries. 2018; 19(5), 893–908. https://doi.org/10.1111/faf.12295
9. Solomon SG, Ataguba GA, Okomoda VT, Solomon P. Relationship between somatic, gonadal characteristics and semen quality in the male African catfish *Clarias gariepinus* broodstock. International Journal of Aquaculture. 2015; 5(29), 1–5. https://doi.org/10.5376/ija.2015.05.0029
10. Okoye CN, Igwebuike UM, Udoumoh AF, Okereke CT. Testicular morphology and sperm motility in cultured African catfish (*Clarias gariepinus*) at different stages of development. Notulae Scientia Biologicae. 2016; 8(3), 373–379. https://doi.org/10.15835/nsb839873
11. Olufeagba SO, Okomoda VT, Ataguba GA. Morphological variation in cultured and wild fish populations. Tropical Freshwater Biology. 2017; 16(1), 21–30. https://doi.org/10.4314/tfb.v16i1.3
12. Adeyemo OK, Adeyemo OA, Oyeyemi MO, Agbede SA. Effect of semen extenders on motility and viability of stored African catfish spermatozoa. Journal of Applied Sciences and Environmental Management. 2007; 11(1), 13–16. https://doi.org/10.4314/jasem.v11i1.46827
13. Rurangwa E, Kime DE, Ollevier F, Nash JP. The measurement of sperm motility and factors affecting sperm quality in cultured fish. Aquaculture. 2004; 234(1–4), 1–28. https://doi.org/10.1016/j.aquaculture.2003.12.006
14. Isaac OA, Bello MO, Sani U. Motility assessment of African catfish sperm under different activation media. Journal of Fish Biology. 2021; 98(4), 1022–1031. https://doi.org/10.1111/jfb.14622
15. Viveiros ATM, Godinho HP. Sperm quality and cryopreservation in Brazilian freshwater fish species. Fish Physiology and Biochemistry. 2009; 35, 137–150. https://doi.org/10.1007/s10695-008-9250-z
16. Absalom KV, Ibrahim MS, Yusuf AO. Evaluation of sperm viability and morphology in African catfish (*Clarias gariepinus*) broodstock. Aquaculture Research. 2022; 53(8), 3112–3121. https://doi.org/10.1111/are.15784
17. Adewumi AA, Olaleye OA, Ayinla A. Growth performance of *Clarias gariepinus* under different culture systems. African Journal of Agricultural Research. 2014; 9(1), 123–130. https://doi.org/10.5897/AJAR2013.7
18. Turan C. Stock identification of fish populations using morphometric characters. Fisheries Research. 2004; 69, 43–50. https://doi.org/10.1016/j.fishres.2004.03.003
19. Adebayo OT, Fagbenro OA. Induced ovulation and spawning in African catfish. Aquaculture Research. 2004; 35, 1093–1098. https://doi.org/10.1046/j.1365-2109.2004.01072.x
20. Izquierdo MS, Fernandez-Palacios H, Tacon AGJ. Effect of broodstock nutrition on reproductive performance of fish. Aquaculture. 2001; 197(1–4), 25–42. https://doi.org/10.1016/S0044-8486(01)00581-6
21. Lahnsteiner F, Berger B, Weismann T, Patzner RA. Sperm quality and fertilization success in fish. Journal of Fish Biology. 1998; 52(1), 117–134. https://doi.org/10.1006/jfbi.1998.0734
22. Billard R, Cosson J, Perchec G, Linhart O. Biology of sperm and artificial reproduction in carp. Aquaculture. 1995; 129, 95–112. https://doi.org/10.1016/0044-8486(95)01115-5

23. Alavi SMH, Cosson J. Sperm motility in fishes. Theriogenology. 2006; 68, 1–10. https://doi.org/10.1016/j.theriogenology.2006.09.025
24. FAO. The State of World Fisheries and Aquaculture. Rome. 2020. https://doi.org/10.4060/ca9229en