American Journal of Aquaculture and Animal Science (AJAAS)

ISSN: 2835-8945 (ONLINE)

VOLUME 4 ISSUE 2 (2025)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Aquaculture and Animal Science (AJAAS)

Volume 4 Issue 2, Year 2025
ISSN: 2835-8945 (Online)
DOI: https://doi.org/10.54536/ajaas.v4i2.5304
https://journals.e-palli.com/home/index.php/ajaas

Influence of *Dracaena arborea* Extracts Used as Milt Diluents on the Reproductive Performance of *Clarias gariepinus* During Artificial Propagation

E. S. Akinnagbe[1*], O. T. Adebayo[2], S. B. Makinde[3], N. F. Ogunkunle[4]

Article Information

Received: May 14, 2025

Accepted: June 16, 2025

Published: July 05, 2025

Keywords

Clarias Gariepinus, Dracaena Arborea, Fertility, Milt Diluents, Milt Quality

ABSTRACT

This study assesses the use of *Dracaena arborea* extract as a diluent during artificial propagation of *Clarias gariepinus*. Apparently healthy male and female African catfish *(Clarias gariepinus)* broodstock with average weight of 2.5kg were used for this study. The male fish was dissected and the milt collected into a dry vial. The milt was assessed at different dilution ratios, specifically 0.1 ml of milt to 1 ml (D1), 2 ml (D2), 3 ml (D3), and 4 ml (D4) of *Dracaena arborea* extract, while the control was 0.1 ml of undiluted milt. The experiment was laid out in a complete randomized design (CRD) involving 4 treatments and a control, each replicated 3 times. Results showed no significant (P>0.05) difference in the milt percentage motility and milt count. The highest milt percentage motility occurred in D2 (57.11%) while the lowest (40.67%) was observed in the control group. There was significant difference (P<0.05) in the milt motility duration between the treatments and the control which ranged from 3.22±0.05mins to 2.05±0.03mins. Significant decreased was observed in the milt motility duration with increasing concentration of *Dracaena arborea* extract. The result of reproductive performance shows significant (P<0.05) difference in the percentage hatchability of eggs withthe highest in D1 (93.78%) and the lowest in D4 (47.01%). No significant (P>0.05) difference was recorded in water temperature, pH and dissolved oxygen, however, *Dracaena arborea* extract significantly (P>0.05) impacted water conductivity which increased as the concentration of the extract increased. The result of the study indicates that *Dracaena arborea* extract could serve as milt diluent during artificial propagation of *Clarias gariepinus* which can be exploited to improve reproductive performance in fish seeds production.

INTRODUCTION

The African Catfish *(Clarias gariepinus)* is highly valued among fish species cultivated in tropical and subtropical areas (Al-Khalaifah *et al.*, 2020). It is recognised as the most important aquaculture fish species in Nigeria due to its resistance to diseases (Oladosu *et al.*, 1993), ability to survive in hypoxic conditions, acceptance of pelleted feed, rapid growth in captivity, and high market value (Adewolu & Adoti, 2010). The African catfish is a durable species ideal for aquaculture, widely embraced in tropical regions and holding considerable commercial value (Oguntuase & Adebayo, 2014). Due to its limited ability to breed in captivity throughout the year, artificial seed production using hormones is necessary to ensure a consistent supply (Zamri *et al.*, 2022). In order to elevate fish production to a level that can adequately cater for the protein requirements of the population, it is imperative to engage in large-scale fish reproduction activities both during and outside the typical breeding season to maintain a consistent supply (FAO, 2022). The contemporary advancements in science and technology have popularised artificial reproduction and selective breeding as efficient strategies for ensuring the extensive production of fish seeds throughout the year (Azra *et al.*, 2022; Andrian *et al.*, 2024).

The market demand for African catfish in Nigeria is experiencing a rapid increase, driven by the growing necessity for sustainability in the country's aquaculture industry (Ndimele & Owodiende, 2012). Despite this, the consistent availability of fast-growing fish fingerlings throughout the year remains a significant challenge for farmers seeking to achieve high yields. The scarcity of fish fingerlings acts as a hindrance to the promotion and growth of aquaculture in Nigeria (Ajayi *et al.*, 2018). The introduction of high-quality fingerling fish and the establishment of optimal conditions that promote swift growth and early harvesting are essential for the success of aquaculture (Ogunremi *et al.*, 2022). The process of induced breeding involves the breeding of mature fish in a restricted water setting, with the aid of both endogenous and exogenous hormone administration to stimulate the process. In Africa, a variety of hormonal substances, such as carp and frog pituitary extracts, human chorionic gonadotropin, and ovaprim, have been utilised to induce breeding in fish, resulting in varying levels of success (Okoro *et al.*, 2007; Chowdhury *et al.*, 2010; Karami *et al.*, 2011).

The focus on utilising medicinal plants as a fertility enhancer in aquaculture has gained considerable attention (Dada & Ebhodaghe, 2011). As the trend moves away from synthetic drugs, the use of plants to enhance growth

[1] National Biotechnology Research and Development Agency, Oka-Akoko, Ondo State, Nigeria
[2] Department of Fisheries and Aquaculture Technology, School of Agriculture and Agricultural Technology, The Federal University of Technology, Akure, Ondo State, Nigeria
[3] Department of Crop, Soil and Pest Technology, School of Agriculture and Agricultural Technology, The Federal University of Technology, Akure, Ondo State, Nigeria
[4] Department of Food and Animal Sciences, Alabama A&M University, Normal, AL, USA
[*] Corresponding author's e-mail: akinnagbeevelynsade@gmail.com

and reproductive performance in animals and fishes is increasingly being embraced (Adeparusi *et al*., 2010; Dada & Oviawe, 2011). Researchers have provided evidence to substantiate assertions regarding the medicinal properties of various plants and their extracts (Ogunkunle *et al*., 2024; Egbeyale *et al*., 2015). Bioactive compounds in plants are believed to possess antioxidants which can potentially improve fertility (Oluyemi *et al*., 2007; Ashamu *et al*., 2010; Oke *et al*., 2019; Ganiyu *et al*., 2025). Medicinal plants and plant products continue to be the primary choice for improving fertility due to their accessibility, availability, and affordability (Fonge *et al*., 2012; Ahmadifar *et al*., 2021). The resurgence of interest in medicinal plants is attributed to the search for naturally occurring antioxidant, antibacterial and anti-inflammatory properties that could improve reproductive performance especially in fish (Sepehrfar *et al*., 2023). Several plant extracts such as pawpaw seed extract (Radwan *et al*., 2023), and curcumin (Sallam *et al*., 2024) have been reported for their stimulatory effects on the reproductive function of fish. The quest for a safe and potent plant-derived remedy without any negative repercussions is becoming more prevalent.

Dracaena arborea was identified as one of the plants studied by Etuk and Mohammed (2009) and Watcho *et al*., (2009). *Dracaena arborea*, originating from West Africa, is a plant that has been traditionally used in medicine for the treatment of venereal diseases and is also known for its aphrodisiac and genital stimulating properties (Watcho *et al*., 2009). The traditional applications of this plant in promoting sexual health and managing infections highlight its potential significance in the treatment of male infertility. The fish farming sector has predominantly concentrated on the quality of eggs and larvae, often overlooking the importance of milt quality from male broodstock, which is crucial for producing healthy larvae (Rurangwa *et al*., 2004; Hajirezaee *et al*., 2010; Odo *et al*., 2018). Milt quality, or potency, is defined by the sperm's capability to fertilize an egg successfully. The effectiveness of this capability is determined by a range of qualitative factors, including the characteristics of seminal fluid, the amount of milt, sperm density, and motility (Rurangwa *et al*., 2004). Various fertilization strategies have made use of normal saline, with the dry method being the most commonly adopted. This technique involves the addition of a small volume of physiological or normal saline to enhance the mixing process (Ankakali *et al*., 2011). The amount or rate of saline used varies among different researchers (Adebayo & Popoola, 2008).

It is essential to assess the effectiveness and viability of various milt diluents in order to optimize fish production. Therefore, the objective of this research is to determine the effect of *Dracaena arborea* plant extracts used as milt diluent on sperm motility with the goal of elucidating the fertilization process in the artificial propagation of African catfish.

MATERIALS AND METHODS

Experimental Area

This study was carried out at the Teaching and Research Farm of the Department of Fisheries and Aquaculture, The Federal University of Technology, Akure, Ondo State, Nigeria.

Experimental Plants

Fresh leaves of *Dracaena arborea* was obtained at FUTA Research Farm and identified at FUTA Herbarium with voucher number FUTA/0405 in the Department of Crop, Soil and Pest at The Federal University of Technology, Akure, Ondo State, Nigeria.

Extraction of plant materials

Fresh leaves of *Dracaena arborea* was rinsed, sliced into small pieces and subsequently blended using an electric blender (Pebepc 4500Bt Sc-1589) to extract the liquid. The plant extract was poured into a test tube of 30ml. Following this, a total of 60ml of the plant extract was centrifuged for 10 minutes. The extract was then stored at 16^{o}C in a refrigerator till further use.

Experimental Fish

Apparently healthy male and female African catfish *Clarias gariepinus* brood stock with average weight of 2.5kg were purchased from a fish breeding farm in Akure. They were acclimatised for 3 days in well-aerated plastic tanks. The fish were not fed for 24 h before the treatment, spawning, and organ harvesting.

Experimental Procedure

The Broodstocks were selected as described by Olaniyi and Omitogun (2014). Female broodstocks received an administration of Ovaprim at a dosage of 0.5 ml per kg of body weight, following the procedure outlined by Egwenomhe and Obi (2012). The male broodstock was humanely euthanized, then the gonads were obtained via abdominal dissection. Following this, any blood clots and surrounding tissues were meticulously removed from the gonads, which were then carefully incised using a sterilized surgical blade to gather the milt into a sterile container. This milt was then diluted with a predetermined volume (1-4 ml) of plant extracts. Ovulated eggs were retrieved in a clean bowl by softly pressing the abdomen of the female from the pectoral fin to the genital opening. The primary collection of freely released eggs was made for the study, with 1 gram of these eggs set aside for each treatment application.

Experimental Design

A completely randomized design was used for the experiment, involving 4 treatments and a control, each replicated 3 times. The milt was assessed at different dilution ratios as follows

Control: 0.1ml of Milt (Dry fertilization)

Treatment D1: 0.1ml of milt diluted with 1ml of *Dracaena arborea* extract

Treatment D2: 0.1ml of milt diluted with 2ml of *Dracaena arborea* extract

Treatment D3: 0.1ml of milt diluted with 3ml of *Dracaena arborea* extract

Treatment D4: 0.1ml of milt 4ml diluted with of *Dracaena arborea* extract

Evaluation of milt quality diluted with *Dracaena arborea* extract

A laboratory analysis was carried out on the milt extracted from the testes focusing on milt volume, motility, duration, and cell count.

Milt volume

A small incision was performed on the lobes of the testes, allowing the milt to be extracted and collected in a petri dish. The volume of the milt was subsequently measured using a plastic syringe in milliliters (mls).

Motility Duration

1 ml of milt from each diluted sample was placed on a Neubauer hemocytometer. After which, a drop of distilled water was introduced, and the sample were covered with a slip. The milt was examined under an Olympus microscope at a magnification of 100x to determine the moment when all sperm movement was ceased (Mims 1991).

Percentage Motility

Each sample was analysed using a light microscope at a magnification of 400x immediately following the addition of 20 ml of distilled water, which serves as the activating solution. During the activation process of the spermatozoa, the number of immotile sperm cells (ISC) was recorded. Once the activation ceases, the total number of whole sperm cells (WSC) were counted (Canyurt *et al*., 2008). The motile sperm cells (MC) were determined using the formula:

MC = WSC – ISC

% MC = (MC/WSC) × 100

Milt Count

Sperm concentration was evaluated by counting the spermatozoa in a sample that had been diluted with distilled water (100x) in a Burker haemocytometer under 400X magnification (Rainis *et al*., 2003).

Evaluation of Reproductive Performance

Calculation of Number of Eggs Released

The number of eggs released during the experiment was determined by subtracting the weight of the broodstock after stripping (Wb, grams) from the weight of the broodstock before stripping (Wa), and then multiplying the resulting difference by 700 (1 g = 700 eggs). This method is supported by research conducted by Viveen *et al.* (1985), Davies *et al.* (2006), and Ndimele *et al.* (2011).

The formula for calculating the number of eggs released is represented as:

Number of eggs released = (Wb-Wa)g×700,

Where Wa denotes the weight of the brood stock before stripping, Wb denotes the weight of the brood stock after stripping, g represents grams, and 700 is a constant.

Percentage fertility

Prior to the hatching process, the total number of fertilised and unfertilised eggs were physically tallied for each treatment. Fertilised eggs display characteristics of being green, transparent, and flattened, whereas unfertilised eggs appear white in color and thick.

The percentage fertility was determined by utilising the formula:

% Fertility = (Number of fertilised eggs)/(Total number of eggs counted.)× 100 .

Percentage hatchability

After the eggs have hatched, a precise count of the larvae within each experimental trough was carried out, enabling the determination of the hatchability rate following the FAO (1996) guidelines.

The formula utilised for this calculation is:

% Hatchability = (Number of eggs hatched)/(number of eggs incubated) × 100

Percentage survival

The determination of the percentage survival at the end of the experiment (14 days) was conducted in accordance with the formula outlined by FAO (1996), represented as:

% survival = (Final number of fry at the end of the experiment)/(Initial number of fry at the beginning) × 100.

Determination of water quality

Water quality parameters such as temperature, pH and dissolved oxygen concentration were assessed during the experiment using mercury-in-glass thermometer, pH meter (Hanna H198106 model) and dissolved oxygen meter (JPP-607 model) respectively as described by APHA (1987).

Statistical Analysis

The data collected from the experiment were analysed as one-way analysis of variance with mixed model in SAS 9.4. Significant results were separated with Turkey posthoc using an alpha of 5%. All values were recorded as mean ± standard error.

RESULTS AND DISCUSSIONS

Effect of *Dracaena arborea* extracts used as milt diluents on the milt quality of *Clarias gariepinus*

The milt quality parameters observed when *Dracaena arborea* extract was used as a diluent is shown in Table 1. There was no significant difference (P>0.05) observed between the treatments and the control. The control treatment had the highest milt count of 2 ± 0.03 x 107-ml, followed by the treatment with *Dracaena arborea* extract (D4) of 1.98± 0.04 x 107-ml. The extracts at D3 – D4 recorded milt count values of 1.92 ± 0.04, 1.93 ± 0.03 and 1.95 ± 0.04 x 107-ml, respectively. There was a significant difference (P<0.05) in milt motility, the milt motility duration ranged from 3.22±0.05mins to 2.05±0.03mins, control had the highest value of

3.22±0.05mins while D4 had the lowest milt motility of 2.05±0.03mins. A significant decrease was observed in the milt motility duration with increasing concentration of *Dracaena arborea* extract.

There was no significant difference in percentage motility, it ranged from 40.67±3.54% in control to 57.11±3.55% in D2. *Dracaena arborea* extract had numerically higher percentage motility than the control. Dilution of the milt with *Dracaena arborea* extractsignificantly (P<0.05) affected the milt pH. Milt pH ranged from 6.65±0.03 to 7.04±0.01, the pH in the control was significantly (P<0.05) lower in the control than the treated group. However, the *Dracaena arborea* extract diluted milt did not differ in pH. The pH values increased with increasing concentration of *Dracaena arborea* extract in the milt.

Table 1: Effect of *Dracaena arborea* extracts used as milt diluents on milt quality of *Clarias gariepinus* during artificial propagation

Parameters	Treatments					Pvalue
	Control	D1	D2	D3	D4	
Milt count ($x10^7$ ml)	2 ± 0.03	1.93±0.03	1.92±0.04	1.95±0.04	1.98±0.04	0.46
Milt motility (Mins)	3.22±0.05^a	2.44±0.03^b	2.17±0.04b^c	2.13±0.03^c	2.05±0.03^c	0.0006
% Motility	40.67±3.54	51.64±3.54	57.11±3.55	54.83±3.55	55.08±3.55	0.09
pH	6.65±0.03^b	6.90±0.01^a	6.96±0.01^a	7.01±0.01^a	7.04±0.01^a	<0.0001
% Deformity	3.32±0.50	6.91±0.65	6.94±0.65	7.01±0.65	7.05±0.65	0.65

**Data is expressed as mean ± SE; ^{a,b}mean with different superscript within the same row are significantly different (p<0.05); D1: 0.1ml of milt diluted with 1ml of Dracaena arborea extract, D2: 0.1ml of milt diluted with 2ml of Dracaena arborea extract, D3: 0.1ml of milt diluted with 3ml of Dracaena arborea extract, D4: 0.1ml of milt 4ml diluted with of Dracaena arborea extract*

Effect of *Dracaena arborea* extracts used as milt diluents on reproductive performance of *Clarias gariepinus*

The reproductive performance of *Clarias gariepinus* exposed to varying concentrations of *Dracaena arborea* extract as milt diluent is presented in Table 2. The percentage fertility, hatchability, survival and hatching time were assessed across the experimental groups. There was no significant (P>0.05) difference in the percentage fertility, hatchability values are 96.67 ± 1.36% for control, 94.06±1.35%, 96.05±1.60%, 94.26±1.35% and 95.60±1.36% for D1, D2, D3 and D4 respectively.

The percentage hatchability of eggs ranged from 47.01 ± 4.90 to 93.78 ± 3.02 with a significant (P<0.05) difference between the control and *Dracaena arborea* extract treated groups. The highest hatchability of 93.78%was recorded in D1 which was similar to control (92.93%) while the lowest was observed in D4 with 47.01±0.9%. A significant decrease was recorded in the percentage hatchability with increasing concentration of *Dracaena arborea* extract. No significant (P>0.05) difference was observed in the hatching time, it ranged from 22 hrs 38 mins in D2 to 22 hrs 78 mins in control. There was no significant (P>0.05) difference in the percentage survival of larvae, control group has 59.75±6.37% survival while treatment D1, D2, D3 and D4 had 72.65±6.37%, 63.18±6.37%, 46.37±6.37% and 51.97±6.37% respectively. There was a numerical increase in D1 (72.65%) and D2 (63.18%) when compared with the control (59.75%) and D4 (51.97±6.37).

Table 2: Effect of *Dracaena arborea* extracts used as milt diluents on reproductive performance of *Clarias gariepinus* during artificial propagation

Parameters	Treatments					Pvalue
	Control	D1	D2	D3	D4	
Temperature (°C)	26.83±0.03	26.87±0.03	26.83±0.03	26.90±0.04	26.87±0.04	0.64
Conductivity(µS/cm)	170±1.16^c	181±1.33^b	186.33±1.46^b	191.33±1.50^{ab}	197.33±1.64^a	<0.0001
pH	6.97±0.18	6.92±0.18	6.97±0.18	6.97±0.18	6.98±0.18	0.18
DO(mg/L)	5.3±0.56	5.13±0.56	5.17±0.56	5.23±0.56	5.37±0.57	0.57

**Data is expressed as mean ± SE; ^{a,b}mean with different superscript within the same row are significantly different (p<0.05); HT: hatching time; D1: 0.1ml of milt diluted with 1ml of Dracaena arborea extract, D2: 0.1ml of milt diluted with 2ml of Dracaena arborea extract, D3: 0.1ml of milt diluted with 3ml of Dracaena arborea extract, D4: 0.1ml of milt 4ml diluted with of Dracaena arborea extract*

Effect of *Dracaena arborea* extracts used as milt diluents on water quality of *Clarias gariepinus*

Effect of Dracaena arborea extracts used as milt diluents on water quality of Clarias gariepinus is presented in Table 3. No significant (P>0.05) difference was recorded in the temperature, the temperature for control was 26.83±0.03°C while D1, D2, D3 and D4 were 26.87±0.03°C, 26.83±0.03°C, 26.90±0.04°C and

26.87±0.04°C respectively. All the temperatures were within the same range in both control and treated groups. However, *Dracaena arborea* extract significantly (P<0.05) increased the water conductivity which ranged from 170±1.16µS/cm in the control group to197.33±1.64µS/cm in D4.191.33µS/cm was recorded in D3, 186.33±1.46 in D2 and 181±1.33µS/cm in D1. The conductivity increased with increasing concentration of *Dracaena arborea* extract. There was no significant (P>0.05) in the pH and dissolved oxygen of the water. The pH value observed in the control group was 6.97±0.18, while D1 had 6.92±0.18, 6.97±0.18 in D2, D3 was 6.97±0.18 and 6.98±0.18 in D4. The Dissolved oxygen levels remained relatively stable across all groups, with mean of 5.3±0.56mg/L in the control, 5.13±0.56mg/L in D1, D2 with 5.17±0.56mg/L, 5.23±0.56mg/Lin D3 and D4 with 5.37±0.57mg/L.

Table 3: Effect of *Dracaena arborea* extracts used as milt diluents on water quality of *Clarias gariepinus* during artificial propagation

Parameters	Treatments					Pvalue
	Control	D1	D2	D3	D4	
% Fertility	96.67 ± 1.36	94.06 ± 1.35	96.05 ± 1.60	94.26 ± 1.35	95.60 ± 1.36	0.61
%Hatchability	92.93 ±3.02^{a}	93.78 ±3.02^{a}	79.87 ±3.80^{a}	61.87 ±4.08^{b}	47.01± 0.90^{c}	<0.0001
Hatching Time (Hrs)	22.78± 0.25	22.50 ± 0.25	22.38 ± 0.25	22.72 ± 0.26	22.68 ± 0.26	0.76
% Survival	59.75 ± 6.37	72.65 ± 6.37	63.18 ± 6.37	46.37 ± 6.37	51.97 ± 6.37	0.10

**Data is expressed as mean ± SE; ^{a,b}mean with different superscript within the same row are significantly different (p<0.05); HT: hatching time; D1: 0.1ml of milt diluted with 1ml of Dracaena arborea extract, D2: 0.1ml of milt diluted with 2ml of Dracaena arborea extract, D3: 0.1ml of milt diluted with 3ml of Dracaena arborea extract, D4: 0.1ml of milt 4ml diluted with of Dracaena arborea extract*

Discussion

This research utilized *Dracaena arborea* extract at inclusion level of 1, 2, 3, and 4 mls as milt diluent to enhance the fertility of *Clarias gariepinus* during artificial propagation. The effectiveness of the reproductive process relies on a consistent supply of high-quality gametes, this makes availability of viable milt an important step for the success of fish production (Crus-Casallas *et al*., 2005). This study has demonstrated that the extract of *D. arborea* positively influences some milt quality parameters in *C. gariepinus*, including sperm counts, motility percentage, motility duration, and the pH level of the milt. This corroborates the report of Watcho *et al.* (2021) and Tchatat Petnga *et al.* (2021) who observed that D. arborea positively influences testicular and epididymal weights, along with enhancing sperm parameters and antioxidant enzyme levels in rats with varicocele. Previous studies have identified sperm count and motility as key indicators of fertility (Al-Sa'aidi *et al*., 2009; Etuk & Muhammad, 2009). Furthermore, the fertilizing capacity of sperm remains the most definitive measure of sperm quality (Tanga *et al*., 2021; Pamungkas *et al*., 2025). The antioxidant properties could be responsible for enhancing fertility by reducing oxidative stress in the milt thereby improving the sperm quality and survivability. This resulted in a notable increase in motility in the *Dracaena arborea* extract treated groups relative to control, with the highest motility percentage recorded in D2.

Sperm motility serves as a primary indicator of milt quality, as elevated motility is essential for successful fertilization and is closely associated with fertilization rates (Kowalski & Cejko, 2019; Blackburn *et al*., 2022). The motility percentages observed in this study align with findings of Watcho *et al.* (2021), who demonstrated that aqueous extract of *D. arborea* at a dosage of 500 mg/kg significantly enhanced testis and epididymis weight, as well as sperm viability and motility in rats. The extract of *D. arborea* did not impact milt count across the treatments, this lack of significant differencescould be linked to the concentration of *D. arboreautilized* in this research. In contrast, the study conducted by Ekere *et al.* (2013) demonstrated that the use of methanolic leaf extract from *Dracaena arborea* produced a significant and dose-dependent increase in the sperm count of rats. In comparison with ginger, Olaniyi *et al.* (2020) reported that ginger-based diet led to higher sperm motility and sperm livability. Similarly, Eissa *et al.* (2024) reported that nano curcumin improved the reproductive performance of red tilapia by increasing the number of fries per female. In another study, Doğu *et al.* (2023) reported curcumin to improve sperm motility in cryopreserved trout sperm when curcumin was used as extender. Furthermore, the authors reported high antioxidant genes in the semen which suggest the protective effects of plant bioactive compounds.

The reproductive performance results indicate that the percentages of fertilization, hatchability, and survival were marginally elevated in the treatment groups when compared to the control group. The findings of Dada (2012) and Dada and Ajilore (2009) reported enhanced hatchability and fertilization rates in *Clarias gariepinus* fed Garcinia kola seed meal and ethanol extracts of *Garcinia kola*, respectively. Notably, treatment D1 exhibited superior outcomes in terms of hatchability and survival. The presence of flavonoids, phenolics and saponins within this plant may elucidate its role as a fertility

enhancer (Watcho *et al.*, 2007). Studies have demonstrated that flavonoids in plant extracts possess numerous pharmacological attributes, including antioxidant activities, suggesting that these compounds may also play a significant role in enhancing fertility (Okwu & Josiah, 2006; Doğu *et al.*, 2023). In comparison with plants rich in bioactive compounds, Maryam *et al.* (2024) observed high survival rate of fingerlings when ginger and garlic powder was supplemented to fingerlings. Similarly, Nyadjeu *et al.* (2020) reported that ginger and garlic mixture enhance the survival of catfish fries. In another study, Gabriel *et al.* (2019) reported aloe vera increased the survival of catfish fingerlings at low pH. This elucidates the beneficial effects of naturally occurring bioactive compounds in plants in improving reproductive performance of fish.

The water quality parameters observed in the study were within the acceptable range for fish culture, demonstrating that extracts from *D. arborea* did not adversely affect the temperature, dissolved oxygen levels, or pH of the water. Fish experience daily stress due to various factors such as alterations in the culture system, water quality, environmental conditions, fish physiology, and social dynamics contribute to stressors that disrupt the delicate internal equilibrium, or homeostasis (Imam *et al.*, 2019). This disruption can lead to negative consequences by impacting their behavior, survival, immune response, and disease resistance (Mugwanya *et al.*, 2022; Zhang *et al.*, 2025). The temperature recorded in this study ranged from 26.83°C to 27.57°C. This finding is consistent with Adebayo (2006), who stated that the ideal temperature for the hatching of *C. gariepinus* falls within the range of 23°C to 29°C. Additionally, these results align with the findings of Amaechi and Solomon (2015), who noted that the optimal temperature range for fertilization and hatchability is between 26°C and 27°C. The average water pH level of 6.76 to 6.92 recorded in this study is consistent with the research conducted by Santhosth and Singh (2007), who reported the appropriate pH range for fish breeding lies between 6.7 and 9.5. The present study recorded dissolved oxygen within the acceptable levels, low dissolved oxygen concentrations can be fatal, leading to acute anoxia in fish, which adversely affects the growth of embryos and juveniles which could result in their death (Ali *et al.*, 2022; Abdel-Tawwab *et al.*, 2019). The result corroborates the result of Bhandari *et al.* (2025) who reported that ginger rhizome extract had no significant effect on water quality in fish. The extracts of *D. arborea* resulted in increased conductivity, water conductivity can influence egg and larval survival and development, small body size with increased mortality has been recorded with high conductivity (Brown *et al.*, 2025). This could be the reason why hatchability and survival decreased with increasing conductivity in this study. Understanding the role of plant extracts in fish hatching is important because it improves our knowledge of the positive and negative effects the bioactive compounds can pose on the success of hatchery operations.

CONCLUSION

The findings of this research indicate that the use of *Dracaena arborea* extract as milt diluent during the artificial propagation of *Clarias gariepinus* significantly enhances milt motility, viability, and overall fertilisation success without any detrimental effect on water quality. The study confirms the potential of *Dracaena arborea* extract as a fertility enhancer for *Clarias gariepinus* broodstock, suggesting its adoption to reduce reliance on traditional and synthetic milt diluents for fertility enhancement. The incorporation of *Dracaena arborea* extracts into the artificial propagation of *Clarias gariepinusis* a significant step toward sustainable aquaculture, it reduces the reliance on artificial diluents and embraces the use of naturally occurring bioactive compounds in plant to improve reproductive performance by serving as antioxidants, antibacterial as well as diluent during propagation. The findings of this study offer foundational data for future studies. As research progresses, it becomes evident that these natural milt diluent may be crucial in shaping the future of aquaculture, fostering systems that are more sustainable, productive, and resilient.

REFERENCES

Abdel-Tawwab, M., Monier, M. N., Hoseinifar, S. H., & Faggio, C. (2019). Fish response to hypoxia stress: growth, physiological, and immunological biomarkers. *Fish physiology and biochemistry, 45*(3), 997–1013. https://doi.org/10.1007/s10695-019-00614-9

Adebayo, (2006). Reproductive performance of African Clariid Catfish Clarias gariepinus broodstocks on varying maternal stress. *Journal of Fisheries and Aquatic Science, 1*(1-2):17-20.

Adebayo, O. T., & Popoola, O. M. (2008). Comparative evaluation of efficacy and cost of synthetic and Non-synthetic hormones for artificial breeding of African Catfish (Clarias gariepinus, Burchell 1822). *Journal of Fisheries and Aquatic Science, 3*(1), 66-71.

Adeparusi, E. O., Dada, A. A., & Alale, O. V. (2010). The effects of medicinal plant (Kigelia Africana) on sperm quality of African catfish Clarias gariepinus (Burchell, 1822) Broodstock. *Journal of Agricultural Science, 2*(1), 193-199.

Adewolu, M. A., & Adoti, A. J. (2010). Effect of mixed feeding schedules with varying dietary crude protein levels on the growth and feed utilization of Clarias gariepinus fingerlings. *Journal of Fisheries and Aquatic Science, 5,* 304–310. https://doi.org/10.3923/jfas.2010.304.310

Ahmadifar, E., Pourmohammadi Fallah, H., Yousefi, M., Dawood, M. A. O., Hoseinifar, S. H., Adineh, H., Yilmaz, S., Paolucci, M., & Doan, H. V. (2021). The Gene Regulatory Roles of Herbal Extracts on the Growth, Immune System, and Reproduction of Fish. *Animals; 11*(8), 2167. https://doi.org/10.3390/ani11082167

Ajayi, B. B., Ogunsola, J. O., Olatoye, O. I., Richard E.

A., & Agbede, S. (2018). Effects of pituitary extract, ovaprim, and bitter leaf (Vernonia amygdalina) on the histopathology of African catfish (Clarias gariepinus). *Aquaculture and Fisheries, 3*(6), 232- 237.

Akankali, J. A., Seiyaboh, E. L., & Abowei, J. F. N. (2011). Fish hatchery and management in Nigeria. *Advance Journal of Food Science and Technology, 3*(2), 144-154.

Ali, B., Anushka, & Mishra, A. (2022). Effects of dissolved oxygen concentration on freshwater fish: A review. *International Journal of Fisheries and Aquatic Studies. 10*(4), 113-127. 10.22271/fish.2022.v10.i4b.2693

Al-Khalaifah, H. S., Khalil, A. A., Amer, S. A., Shalaby, S. I., Badr, H. A., Farag, M. F. M., Altohamy, D. E., & Abdel Rahman, A. N. (2020). Effects of Dietary Doum Palm Fruit Powder on Growth, Antioxidant Capacity, Immune Response, and Disease Resistance of African Catfish, Clarias gariepinus (B.). *Animals, 10*(8), 1407. https://doi.org/10.3390/ani10081407

Al-Sa'aidi, J. A. A., Al-Khuzai, A. L. D., & Al-Zobaydi, N. F. H. (2009). Effect of alcoholic extract of Nigella sativa on fertility in male rats. *Iraqi Journal of Veterinary Sciences, 23,* 123-128.

Amaechi, C., & Solomon, J. R. (2015). Calculation of the physiochemical parameters of catfish (Clarias gariepinus) fed locally formulated feeds (earthwarm). *International Journal of Bioassays, 4*(16), 3941-3947.

Andrian, K. N., Wihadmadyatami, H., Wijayanti, N., Karnati, S., & Haryanto, A. (2024). A comprehensive review of current practices, challenges, and future perspectives in Koi fish (Cyprinus carpio var. koi) cultivation. *Veterinary world, 17*(8), 1846–1854. https://doi.org/10.14202/vetworld.2024.1846-1854

APHA. (1987). *Standard Method for the Examination Water and Wastewater* (17th ed., pp. 1268). Washington D.C.

Ashamu, E. A., Salawu, E. O., Oyewo, O. O., Alhassan, A. W., Alamu, O. A., & Adegoke, A. A. (2010). Efficacy of vitamin C and ethanolic extract of Sesamum indicum in promoting fertility in male Wistar rats. *Journal of Human Reproductive Science, 3*(1), 11-14.

Azra, M. N., Okomoda, V. T., & Ikhwanuddin, M. (2022). Breeding Technology as a Tool for Sustainable Aquaculture Production and Ecosystem Services. *Frontiers in Marine Science. 9*. 679529. 10.3389/fmars.2022.679529.

Bhandari, R., Shrestha, K., & Bastola, D. (2025). Effect of ginger (Zingiber officinale) rhizome extract on growth performance, survival and gut flora of common carp (Cyprinus carpio). *International Journal of Agriculture and Food Science, 7,* 111-116. 10.33545/2664844X.2025.v7.i4b.343

Blackburn, H., Torres, L., Liu, Y., & Tiersch, T. R. (2022). The Need for a Framework Addressing the Temporal Aspects of Fish Sperm Motility Leading to Community-Level Standardization. *Zebrafish, 19*(4), 119–130. https://doi.org/10.1089/zeb.2022.0006

Brown, R., Kaunert, M., Johnson, K., Roosenburg, W., & Popescu, V. (2025). Assessing the effects of conductivity on egg development and survival of Eastern Hellbenders (Cryptobranchus a. alleganiensis). *Scientific Reports, 15*, 6821. https://doi.org/10.1038/s41598-024-82969-5

Canyurt, M., A., & Akhan, S. (2008). Effect of Ascorbic Acid Supplementation on Sperm Quality of Rainbow Trout (Onchorynchus mykiss). *Turkish Journal and Aquatic Sciences, 8,* 171-175.

Chowdhury, M., Chatterjee, A., Mondal, A., & Chatterji, U. (2010). Ovaprim abrogates expression of GnRH receptor-II in the Indian catfish. *International Journal of Biology, 2,* 189–198.

Cruz-Casallas, P. E., Lombo-Rodriguez, D. A., & Velasco- Santamaria, Y. M. (2005). Milt quality and spermatozoa morphology of captive Brycon siebenthalee (Eigenmann) broodstock. *Aquaculture Research, 36*, 628-688.

Dada A. A. (2012). Effects of Garcinia kola seed meal on egg quality of the North African catfish, Clarias gariepinus (Burchell, 1822) broodstock. *African Journal of Food, Agriculture, Nutrition and Development, 12,* 6447-6459.

Dada, A. A., & Ajilore, V. O. (2009). Use of ethanol extracts of Garcinia Kola as fertility Enhancer in female catfish Clarias gariepinus (Burchell, 1822) broodstock. *Journal of Fisheries Aquaculture, 1,* 1-5.

Dada, A. A., & Ebhodaghe, B. E. (2011). Effect of Garcina kola seed meal on egg quality of the African catfish (Clarias gariepinus) (Burchell) broodstock. *Cameroon Journal of Experimental Biology, 7*(1), 1-8.

Dada, A. A., & Oviawe, N. E. (2011). The use of bitter kola (Garcinia kola) dry seed powder as a natural growth-promoting agent for African sharptooth catfish Clarias gariepinus fingerlings. *African Journal of Aquatic Science, 36*(1), 97-100.

Davies, A. O., Inko-Tariah, M. B., & Amachree, D. (2006). Growth response and survival of Heterobranchuslongifilis fingerlings fed at different feeding frequencies. *African Journal Biotechnology, 5,* 778-780.

Doğu, Z., Aral, F., Şahinöz, E., Temiz, E., & Koyuncu, İ. (2023). Impact of Curcumin Supplementation on Sperm Characteristics and Gene Expression in Fish Sperm Freezing Medium. *Genetics of Aquatic Organisms, 7*(4), GA729. https://doi.org/10.4194/GA729

Egbeyale, L. T., Ayo-Ajasa, O. Y., Ayoola, A. A., Ogunkunle, N. F., & Okuboyejo, O. A. (2015). Performance of broiler chickens fed neem (Azadirachta indica) leaf meal as an alternative to antibiotics. *Bulletin of Animal Health and Production in Africa, 63*(4), 403-410.

Egwenomhe, M., & Obi, A. (2012). The cost and effectiveness of using two Gonoadotropin releasing hormone Anologue, Ovaprim and Ovatide and fresh pituitary extract in the induced breeding of the African Catfish (Clarias gariepinus). *Nigeria Journal of Fisheries, 3,* 555-559.

Eissa, E. S. H., Hendam, B. M., Dighiesh, H. S., Abd Elnabi, H. E., Abd El-Aziz, Y. M., Eissa, M. E. H., Abdelnour, S. A., & Ghanem, S. F. (2024).

Comparative effects of curcumin, nano curcumin and their combination on reproductive traits and spawning performance of red tilapia (Oreochromis Niloticus X O. Mossambicus). *Veterinary Research, 20,* 427. https://doi.org/10.1186/s12917-024-04257-8

Ekere, S. O., Okoye, C. N., & Udoumoh, A. F. (2013.) Fertility enhancing effects of methanolic leaf extract of Dracaena arborea in albino rats (Rattus norvegicus). *Czech Journal of Animal Science, 11,* 520–524.

Etuk, E. U., & Muhammad, A. A. (2009). Fertility enhancing effects of aqueous stem bark extract of Lophira lanceolata in male Spargue Dawley rats. *International Journal of Plant Physiology and Biochemistry, 1,* 1–4.

Fonge, B. A., Tchinda, A. T., Ngadjui, B. T., & Emmanuel, T. (2012). Medicinal plants used in the treatment of diseases in the South West Region of Cameroon. *Journal of Medicinal Plants Research, 6*(31), 4729-4743.

Food and Agriculture Organization. (2022). *The State of World Fisheries and Aquaculture 2022*. Towards Blue Transformation. Rome, FAO. https://doi.org/10.4060/cc0461en

Food and Agriculture Organization. (1996). Data base on Introduced Aquatic species, FAO, Rome Italy, pp. 46.

Gabriel, N. N., Wilhelm, M. R., Habte-Tsion, H.-M., Chimwamurombe, P., Omoregie, E., Iipinge, L. N., & Shimooshili, K. (2019). Effect of dietary Aloe vera polysaccharides supplementation on growth performance, feed utilization, hemato-biochemical parameters, and survival at low pH in African catfish (Clarias gariepinus) fingerlings. *International Aquatic Research, 11*(1), 57–72. https://doi.org/10.1007/s40071-019-0219-8

Ganiyu, A. O., Belewu, M. A., Ogunkunle, N. F., & Imam, R. O. (2025). Growth Performance and Digestibility of Red Sokoto Goat Fed Jatropha curcas Kernel Cake. *International Journal of Veterinary Medicine and Animal Science, 2*(1). https://doi.org/10.54536/ijvmas.v2i1.4195

Hajirezaee, S., Amiri, B. A., & Mirvaghefi, A. (2010). Fish milt quality and major factors influencing the milt quality parameters: A review. *African Journal of Biotechnology, 9*(54), 9148-9154.

Imam, T. S., Abdullahi, Z. D., & Sani, A. (2019). Effect of Different Water Qualities On Clarias Gariepinus Growth and Survival. *Journal of Veterinary and Biomedical Sciences, 1*(2), 78 - 84.

Karami, A., Christianus, A., Zoekaeifer, H., Saad, K. Z., Imraan, F. T. J., & Shakibazadeh, S. (2011). Ovaprim treatment promotes oocyte development and milt fertilization rate in diploid and triploid African catfish (Clarias gariepinus). *Aquaculture International, 19,* 1025–1034.

Kowalski, R. K., & Cejko, B. I. (2019). Sperm quality in fish: Determinants and affecting factors. *Theriogenology, 135,* 94–108. https://doi.org/10.1016/j.theriogenology.2019.06.009

Maryam, I., Suleiman, A., & Bako, H. (2024). Evaluation of Ginger (Zingiber officinale) and Garlic (Allium sativum) effect on growth performance and survival rates of Clarias gariepinus fingerlings. *Life Science, 1*(1). https://doi.org/10.13140/RG.2.2.36602.30402

Mims, S. D. (1991). Evaluation of activator solutions, motility duration and short-term storage of Paddle fish spermatozoa. *Journal of World Aquaculture Society, 22*(6), 224-229.

Mugwanya, M., Dawood, M. A., Kimera, F., & Sewilam, H. (2022). Anthropogenic temperature fluctuations and their effect on aquaculture: A comprehensive review. *Aquaculture and Fisheries, 7*(3), 223-243. https://doi.org/10.1016/j.aaf.2021.12.005

Ndimele, P. E., & Owodiende, F. B. (2012). Comparative reproduction and growth performance of Clarias gariepinus (Burchell, 1822) and its hybrid induced with synthetic hormone and pituitary gland of Clarias gariepinus. *Turkish Journal of Fisheries and Aquatic Sciences, 12,* 619–626.

Ndimele, P. E., Owodeinde, F. G., Kumolu-Johnson, C.A., Jimoh, A. A., & Whenu, O. O. (2011) Growth performance of the reciprocal hybrids of Clarias gariepinus (Burchell, 1822) and Heterobranchusbidorsalis (Valenciennes, 1840). *Current Research Journal of Biological Sciences, 3,* 137-140.

Nyadjeu, P., Ekemeni, R.G.M. & Tomedi, M.E.T. (2020). Growth Performance, Feed Utilization and Survival of Clarias gariepinus Post-larvae Fed with a Dietary Supplementation of Zingiber officinale-Allium sativum Mixture. *Journal of Aquaculture & Fisheries*. https://doi.org/10.24966/AAF-5523/100028

Odo, S. N., Alozie, E. C., & Anyanwu, E. D. (2018). Comparative assessment of milt quality of three populations of clariasgariepinus (burchell, 1822) broodstock. *African Journal of Agriculture and Food Science, 1*(1), 19-26.

Ogunkunle, N. F., Adeniyi, N. O., & Simpson, M. D. (2024). The Use of Pomace as Animal Feed: A Review ofGrape and Tomato Pomace. *Journal of Agricultural Science, 16* (10). https://doi.org/10.5539/jas.v16n10p1

Ogunremi, J. B., Igbani, F., Onimisi, M. M., & Shetur, C.Y. (2022). Assessment of Fish Farming Practices, Development and Constraints among Fish Farmers in Ibi Local Government Area, Taraba State, Nigeria. *Nigerian Agricultural Journal, 53*(1), 260-266.

Oguntuase, B, G., & Adebayo, O. T. (2014). Sperm Quality and reproductive performance of male Clarias Gariepinusinduced with synthetic hormones (Ovatide and Ovaprim). *International Journal of Fisheries and Aquaculture, 6*(1), 9-15. https://doi.org/10.5897/IJFA2013.0364

Oke, I. O., Dada, A. A., Saliu O. R., & Kuyoro, E. B. (2019). Dietary Effects of Desmodium (Desmodiumadscendens) Leaves on the Reproductive Indices in African Catfish (Clarias gariepinus) Broodstock. *Aquaculture Studies, 19*(2), 133-137.

Okoro, C. B., Nwadukwe, F. O., & Ibemere, I. (2007). The

use of Ovaprim in oocyte maturation and ovulation in Clarias gariepinus(Burchell, 1822). *African Journal of Applied Zoology and Environmental Biology, 9,* 83–84.

Okwu, D. E., & Josiah, C. (2006). Evaluation of the chemical composition of two Nigerian plants. *African Journal of Biotechnology, 5*(4), 357 -361.

Oladosu, G. A., Ayinla, O. A., Adeyemo, A. A., Yakubu, A. F., & Ajani, A. A. (1993). A comparative study of the reproductive capacity of the African catfish species Heterobranchusbidorsalis (Geoffery), Clarias gariepinus(Burchell) and their hydrid "Heteroclarias", 92, ARAC Technical Paper1–5.

Olaniyi, C., Atoyebi, M., Obafunmiso, H., & Salaam, K. (2020). Effect of ginger (Zingiber officinale) in the nutrition of african catfish-A cholesterol reducer and fertility enhancer. *International Journal of Aquaculture and Fishery Sciences, 6*(2), 021–028. https://doi.org/10.17352/2455-8400.000052

Olaniyi, W. A., & O. G. Omitogun (2014). Embryonic and larval developmental stages of African giant catfishHeterobranchusbidorsalis (Geoffroy Saint Hilaire, 1809) (Teleostei, Clariidae). *SpringerPlus, 3,* 677.

Oluyemi, K. A., Jimoh, O. R., Josiah, S. J., Olamide, A. A., Omotuyi, O. I., & Oyesola, T. O. (2007) Effects of crude Ethanolic Extracts of Garcinia cambogia on the Reproductive System of Male Wister Rats (Rattus novergicus). *African Journal of Biotechnology, 6*(10), 1236-1238.

Pamungkas, W., Arifin, O. Z., Subagja, J., Anggraeni, F., Astuti, D. N., Robisalmi, A., & Puspaningsih, D. (2025). Comparative Analysis of Sperm Quality and Fertilization Potential in Neomales (XX) and Normal Males (XY) of the Bonylip Barb (Osteochilus vittatus). *Egyptian Journal of Aquatic Biology & Fisheries, 29*(2), 2357–2369.

Radwan, M., Darweesh, K. F., Ghanem, S. F., Abdelhadi, Y., Kareem, Z. H., Christianus, A., Karim, M., Waheed, R. M., & El-Sharkawy, M. A. (2023). Regulatory roles of Pawpaw (Carica papaya) seed extract on growth performance, sexual maturity, and health status with resistance against bacteria and parasites in Nile tilapia (Oreochromis niloticus). *Aquaculture International, 31*(5), 2475-2493. https://doi.org/10.1007/s10499-023-01094-8

Rainis, S., Mylonas, C. C., Kyriakou, Y., & Divanach, P. (2003). Enhancement of spermiation in European sea bass (Dicentrarchuslabrax) at the end of the reproductive season using GnRHa implants. *Aquaculture, 19*, 873-890.

Rurangwa, E., Kime, D. E., Ollevier, F., & Nash, J. P. (2004). The measurement of sperm motility and factors affecting sperm quality in cultured fish. *Aquaculture, 234*(1-4): 1-28.

Sallam, G. R., Fayed, W. M., Elsawaf, M. A., Mabrouk, H. A., Al-Absawey, M. A., Henish, S., El Basuini, M. F., & Shehata, A. I. (2024). Phyto-additive fueling fertility: Nanocurcumin enhances red tilapia foundation stock breeding in saline waters. *Aquaculture, 592,* 741268. https://doi.org/10.1016/j.aquaculture.2024.741268

Santhosh, B., & Singh, N. P. (2007). Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region, Tripura Center, Publication no.29.

Sepehrfar, D., Sudagar, M., Paknejad, H., Yousefi S. S., & Norouzitallab, P. (2023). Role of phytochemicals in farmed fish reproductive performance: A review. *Iranian Journal of Fisheries Sciences, 22*(5), 1039-1068 https://doi.org/10.22092/ijfs.2023.130580

Tanga, B. M., Qamar, A. Y., Raza, S., Bang, S., Fang, X., Yoon, K., & Cho, J. (2021). Semen evaluation: methodological advancements in sperm quality-specific fertility assessment - A review. *Animal bioscience, 34*(8), 1253–1270. https://doi.org/10.5713/ab.21.0072

TchatatPetnga, Y. B., Tetsatsi Momo, A. C., Wankeu-Nya, M., MunyaliAlumeti, D., BonsouFozin, G. R., Deeh-Defo, P. B., Ngadjui, E., & Watcho, P. (2021). Dracaena arborea (Dracaenaceae) Increases Sexual Hormones and Sperm Parameters, Lowers Oxidative Stress, and Ameliorates Testicular Architecture in Rats with 3 Weeks of Experimental Varicocele. *Evidence-based complementary and alternative medicine*, 1378112. https://doi.org/10.1155/2021/1378112

Viveen, W. J. A. R., Richter, C. J. J., Van Odot, P. G. W. J., Janssen, J. A. L., & Huisman, E. A. (1985) Practical manual for the culture of the African catfish (Clarias gariepinus). Section for Research and Technology, Ministry for Development Co-operation. The Hague, Netherlands pp: 128.

Watcho, P., Wankeu-Nya, M., Nguelefack, T. B., Tapondjou, L., Taponno, R. B., & Kamanyi. (2007). Pro-sexual effect of Dracaena arborea (Wild) Link (Dracaenaceae) in sexually experienced male rats. *Pharmacology online, 1,* 1400–419.

Watcho, P., Ngadjui, E., Nkeng-Efouet, P., Nguelefack, T. B. & Albert, K. (2009). Reproductive Effects of Ficus asperifolia (Moraceae) in Female Rats. *African Health Science, 9*(1), 49-53.

Watcho, P., Tchatat, B. Y. P., Deeh, P. B. D., Georges Romeo BonsouFozin, G. R. B., & Wankeu-Nya, M. (2021). Dracaena arborea improves sperm characteristics and antioxidant enzymes in adult male rats with experimental varicocele. *JBRA Assisted Reproduction, 25*(3), 329-336. https://doi.org/10.5935/1518-0557.20200098

Zamri, A., Zulperi, Z., Esa, Y., & Syukri, F. (2022). Hormone Application for Artificial Breeding towards Sustainable Aquaculture - A Review. *Pertanika Journal of Tropical Agricultural Science, 45*(4). https://doi.org/10.47836/pjtas.45.4.11.

Zhang, K., Ye, Z., Qi, M., Cai, W., Saraiva, J. L., Wen, Y., Liu, G., Zhu, Z., Zhu, S. & Zhao, J. (2025). Water quality impact on fish behavior: a review from an aquaculture perspective. *Reviews in Aquaculture, 17*(1), e12985. https://doi.org/10.1111/raq.12985