

ROLE OF PHYTOESTROGENS FOR SUSTAINABLE TILAPIA AQUACULTURE IN NIGERIA

Abstract

The study investigated the control of prolific reproduction in *Oreochromis niloticus* culture using *Jatropha curcas* seed meal (JCSM). A total of 360 *Oreochromis niloticus* juveniles were used for the study in a 6 x 3 completely randomized design, using six dietary treatments (D1, D2, D3, D4, D5 and D6) with varied inclusion levels of treated and raw JCSM as control. The study indicated significant differences ($p < 0.05$) for both processed (toasted and soaked) and raw *Jatropha curcas* seed meal on the reproduction of *O. niloticus*. The treated and raw JCSM at 10% and 20% inclusions suppressed reproduction in *Oreochromis niloticus* juvenile for 12 weeks. The best reproduction control was observed at 10% inclusions for toasted and soaked JCSM with the soaked group performing better than the toasted group. The highest significant ($p < 0.05$) growth performance of juvenile *O. niloticus* with respect to final body weight (FBW), mean weight gain (MWG) and specific growth rate (SGR) (54.01g, 42.44g and 4.38% day⁻¹ fish⁻¹ respectively) were observed in the fish fed control diet (D1). The group of fish fed with 10% soaked JCSM (D4) diet performed significantly ($P < 0.05$) better than other treatments. The best feed utilization efficiency of the fish in terms of feed conversion ratio (FCR) and feed efficiency ratio (FE) were observed in the control treatment (D1) and D4 (10% soaked JCSM) with 2.38 and 3.35 for FCR, 0.42 and 0.30 for FE respectively. Using K-value of FCF the study inferred that the well-being of the fishes fed control diets (D1), 10% (D4) and 20% (D5) soaked *Jatropha curcas* seed meal were intact while fishes in other groups; 10% (D2) and 20% (D3) toasted *Jatropha curcas* seed meal and 10% (D6) raw *Jatropha curcas* seed meal were

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impaired but the survival rate (SR) of all the treatments were not significantly different ($p>0.05$). The control group (D1) had the highest value (55.40×10^6) of white blood cells (WBC) and the least value (26.16×10^6) was recorded from the group fed unprocessed JCSM. From the study, it can be concluded that 10% and 20% inclusion levels of processed and unprocessed JCSM suppressed reproduction in *Oreochromis niloticus* juvenile for 12 weeks which also adversely affected their growth performance and nutrient utilization, hence lower inclusion levels of JCSM, other methods of processing of *Jatropha curcas* and other phytoestrogenic plants should be investigated.

Keywords: *Oreochromis niloticus*, *Jatropha curcas*, Phytoestrogens, sustainable aquaculture, 17-alpha-MT

I. INTRODUCTION

Globally, the tilapias have been recognized as very good aquaculture candidates and presently the second most economically important fish in the world (FAO, 2020). Despite the widely reported production and progress of the tilapias in the global aquaculture, the common challenge of all the known commercial strain is their early maturation in sub-tropical and tropical climatic conditions which leads to prolific or excessive breeding and subsequent overcrowding in culture systems, resulting in stunting and poor yields of unacceptable market size fishes (Gabriel *et al.*, 2015). Existing methods to produce monosex (all-male) tilapia population encompass technical limitations that make them inappropriate for small aquaculture farms. The use of synthetic hormones, especially 17-alpha-methytestosterone (17-alpha-MT), has been responsible for the tremendous progress recorded in global tilapia growth. These synthetic hormones have a lot of associated problems such as bureaucratic impediments and cost of obtaining hormones for sex reversal, expertise requirements to handle the hormone and other problems such as environmental and public health concerns (Nwangwu *et al.*, 2015). These have been identified as some of the major reasons for the low popularity of commercial tilapia culture in Nigeria. There is also, a global concern of the residual effect of synthetic steroids on the fish flesh, producers, consumers and the environment (Dauda *et al.*, 2014); hence the need to explore other affordable, environmentally friendly and appropriate alternative technology. This has led to search for alternative approaches including the use of natural (organic) reproduction inhibitors found in plants (Ugoala *et al.*, 2014).

The concept of harnessing the potentials of phytoestrogenic plants as natural (organic) reproductive inhibitors in tilapia aquaculture is novel and recently gaining attention in the growing interest for smart aquaculture. Some of these plants have been studied and found to possess bioactive constituents that are structurally and/ or functionally similar to the synthetic hormones used in the tilapia industry and are capable of producing estrogenic effects in animals (Chakraborty *et al.*, 2012). Whereas some investigations have been tried with *Tribulus terrestris*, *Basella alba*, *Moringa oleifera*, *Azadirachta indica* and *Carica papaya*; there is dearth of information on many more of these phytoestrogenic plants including *Jatropha curcas*, *Eriosema psoreloides*, *Momordica charantia*, etc. and their potentials in controlling unwanted reproduction tilapia aquacultures. If given proper attention, many phytoestrogenic plants could replace the synthetic hormones used in the tilapia industry since they can be easily obtained and safer to the producer, consumer and environment (Wokeh and Orose, 2021). The study therefore aims to evaluate of the efficacy of processed and raw *Jatropha curcas* seed meal (JCSM) as a reproductive inhibitor and (or) sterility agent in the control of unwanted reproduction in tilapia culture.

II. METHODOLOGY

The study was conducted at the Hatchery Complex (9.8672° N, 4.5299° E) of National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Niger State, Nigeria. Mature seeds of *Jatropha curcas* were identified, collected from nearby Monai village and shelled. The seeds were prepared using two simple methods of detoxification i.e. toasting and soaking (48 hours) to obtain the processed *Jatropha curcas* seed meal (JCSM). Both processed and unprocessed JCSM were subjected to proximate and bio-active constituent screening.

A pair (1 male and 3 female) of pure strains of *Oreochromis niloticus* broodstock were conditioned in a 3m × 5m happa setup in a 5m × 10m concrete tank and supplied with water

from nearby Kigera reservoir. They were allowed to breed, and the offspring nursed, raised to juvenile stage using a commercial feed (Coppens®). From the pool, a total of 360 matured and healthy juveniles were selected, sexed and acclimatized for one week, after which they were distributed into six (6) treatments. In a 6 × 3 completely randomized design (CRD), twenty (20) fishes were stocked in each tank (2m × 2m × 1m) with male to female ratio of 1:3 in triplicates per treatment. The tanks were properly screened; water was supplied from Kigera reservoir and supported from the complex borehole.

Based on Nile tilapia nutritional requirements and ascertained proximate compositions of JCSM, six (6) isonitrogenous dietary treatments (D1, D2, D3, D4, D5 & D6) were formulated at 35% crude protein (CP) for the study. A control diet (D1) with zero (0) gram *Jatropha curcas* seed meal and five test diets (D2, D3, D4, D5 and D6) with *Jatropha curcas* seed meal incorporated into the basal diet at 10%, 20% of toasted, soaked and 10% of raw respectively to replace the cellulose and fish meal part of the control (Table 1). Fishes were fed at 5% body weight divided into two and given twice daily between 08:00 – 08:30 hrs and 17:00 – 18:00hrs for the duration of experiment while sampling for weight gain was carried out fortnightly. Fish response to feeding and mortality were observed and recorded. Observations were also made while feeding and sampling to know if spawning have occurred in any of the experimental tanks. During this period, water quality parameters were monitored and recorded. From the data collated during the experimental duration, growth performance and feed utilization efficiency were evaluated. The growth parameters used were specific growth rate (SGR), mean weight gain (MWG) and mean final weight gain (MFW) while the feed utilization parameters used were feed efficiency (FE) and feed conversion ratio (FCR). The survival rate (SR) and Fulton condition factor (FCF) were equally determined. As described by Workagegn *et al.* (2013), the following formulas were used in calculating the values for these parameters –

- Mean WG (grams per fish) = [(FBW - IBW) ÷ IBW].
- SGR (% per day per fish) = [(lnFBW - lnIBW) ÷ Dt] × 100.
- FCR = FI (gm) ÷ BWG (gm).
- FE = BWG (gm) ÷ FI (gm).
- FCF = BWG (gm) ÷ TL (cm)³ × 100.
- SR = (NFS - NDF) ÷ NSF × 100.

NOTE: IBW = Initial Body Weight; Dt = days experimental duration; FI = Feed Intake; TL = Total Length; NFS = Number of Fish Stocked and NDF = Number of Dead Fishes.

Table 1: Composition of experimental diets fed to juvenile *Oreochromis niloticus*.

Ingredients (g)	Experimental Diets					
	D1	D2	D3	D4	D5	D6
FM	336.30	269.10	224.30	273.90	233.90	276.90
SBM	100.00	100.00	100.00	100.00	100.00	100.00
GNC	100.00	100.00	100.00	100.00	100.00	100.00
Toasted JCSM	0.00	100.00	200.00	0.00	0.00	0.00
Soaked JCSM	0.00	0.00	0.00	100.00	200.00	0.00

Raw JCSM	0.00	0.00	0.00	0.00	0.00	100.00
MM	100.00	100.00	100.00	100.00	100.00	100.00
Millet	100.00	100.00	100.00	100.00	100.00	100.00
Starch	50.00	50.00	50.00	50.00	50.00	50.00
Vitamin premix	25.00	25.00	25.00	25.00	25.00	25.00
SBO	30.70	29.90	26.40	26.20	19.10	27.10
Cellulose	133.00	101.00	49.30	99.90	47.00	96.00
Mineral	25.00	25.00	25.00	25.00	25.00	25.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

- 1. Hematological Parameters Evaluated:** Fish blood samples were collected via the pectoral peduncle with the aid of 2 ml hypodermic syringes. The blood samples were immediately put into an anticoagulant EDTA container and taken to the laboratory where they were analyzed for the following parameters – Mean cell volume (MCV), Mean cell Hemoglobin (MCH), Mean cell Hemoglobin concentration (MCHC), Red blood corpuscles (RBC), total white blood corpuscles (WBC), packed cell volume (PCV) and Hemoglobin (Hb).
- 2. Phytochemical Screening:** Qualitative phytochemical screening was performed on the samples using standard methods as described by Trease and Evans (1989); Sofowora (1993) to test for the following bio-active constituents saponins, phenols, tannins, glycosides, oxalic acids, alkaloids and flavonoids.



Plate I: *Jatropha curcas* plant; Plate II: Fresh *Jatropha curcas* seeds; Plate III: *Jatropha curcas* kernel / seed

Plate IV: Dry *Jatropha curcas* seeds; Plate V: *Jatropha curcas* pods; Plate VI: Toasted *Jatropha curcas* seed

- 3. Statistical Analysis:** All data were subjected to statistical analysis using IBM SPSS® Statistics Ver. 20. One-way analysis of variance (ANOVA) was used and the significance

of differences ($P < 0.05$) between mean values were tested with Duncan Multiple Range Test (DMRT).

III. RESULTS

- 1. Proximate and Bio-active Component Analyses:** The results of proximate composition of *Jatropha curcas* seeds (processed and raw) are presented in Table 2. The results indicated that the processed seeds had a higher crude protein content (28% and 31.37% for soaked and toasted respectively) compared to the raw seeds (25.93%). The results of bio-active constituent analysis of *Jatropha curcas* seeds (processed and raw) are presented in Table 3. The results showed that alkaloids were not present in processed (toasted and soaked) seeds. Glycosides and oxalic acid were not present in the toasted seeds. Saponins, phenols, tannins and flavonoids were present in the processed and raw seeds but in low concentration for the toasted seeds.

Table 2: Proximate composition of *Jatropha curcas* seeds (processed and raw)

Sample	Moisture (%)	Ash (%)	C P (%)	C F (%)	C. Fat (%)	NFE (%)	Energy (K/Cal)
S – JC	8.33	2.30	28.00	3.29	49.35	8.73	591.07
T – JC	4.92	3.21	31.37	3.42	40.40	16.68	555.80
R – JC	7.45	2.42	25.93	3.09	42.50	18.61	560.66

Where: S-JC = Soaked *Jatropha curcas*, T-JC = Toasted *Jatropha curcas*, R-JC = Raw *Jatropha curcas*,

CP = Crude Protein, CF = Crude Fibre, C. Fat = Crude Fat and NFE = Nitrogen Free Extracts

Table 3: Phytochemical constituents of *Jatropha curcas* seeds (processed and unprocessed)

Samples	Saponins	Phenols	Tannins	Glycosides	Oxalic acid	Alkaloids	Flavonoids
S – JC	++	++	++	+	+	-	++
T – JC	+	+	+	-	-	-	+
R – JC	++	++	++	++	++	+	+

Where: S-JC = Soaked *Jatropha curcas*, T-JC = Toasted *Jatropha curcas*, R-JC = Raw *Jatropha curcas*,

“-” = Not Present, “+” = Present and “++” = Highly Present

- 2. Growth Performance and Feed Utilization Efficiency:** Growth performance and feed utilization efficiency of *Oreochromis niloticus* juveniles fed 0% (control), 10%, and 20% of toasted, soaked and 10% of raw *Jatropha curcas* seed meal is presented in Table 4. The highest significant growth performance ($P < 0.05$) of juvenile *Oreochromis niloticus* with respect to SGR, BWG and FBW were noticed in fish fed with control diet (D1). The group

of fish fed diet with 10% soaked JCSM (D4) performed significantly ($P < 0.05$) better than the other groups fed diet with processed and unprocessed JCSM in terms of growth parameters. The best feed utilization efficiency of the fishes with respect to FE and FCR was noticed in fish that fed on the control diet (D1) and diet with 10% soaked JCSM (D4).

Table 4: Growth performance and feed utilization of *Oreochromis niloticus* juveniles fed diets with processed and raw *Jatropha curcas* seed meal (12 weeks)

Parameters	Experimental Diets (Treatments)					
	D1	D2	D3	D4	D5	D6
MIW (g / fish)	11.57 ^a ±3.38	11.93 ^a ±3.44	12.32 ^a ±4.13	9.66 ^a ±3.05	9.24 ^a ±3.28	12.13 ^a ±2.06
MIL (cm / fish)	8.73 ^a ±0.27	9.01 ^{ab} ±0.11	9.67 ^b ±0.85	9.0 ^{ab} ±0.30	8.60 ^a ±0.36	9.07 ^{ab} ±0.35
MFW (g / fish)	54.01 ^c ±6.15	22.47 ^{ab} ±2.61	21.18 ^{ab} ±3.69	29.67 ^b ±5.39	20.18 ^a ±2.06	22.12 ^{ab} ±5.36
MWG (g / fish)	42.44 ^c ±8.28	10.53 ^a ±3.31	8.86 ^a ±0.73	20.01 ^b ±2.86	10.94 ^a ±1.76	9.99 ^a ±6.74
SGR (% day ⁻¹ fish ⁻¹)	4.38 ^c ±0.14	3.33 ^{ab} ±0.13	3.24 ^a ±0.20	3.67 ^b ±0.20	3.21 ^a ±0.11	3.28 ^a ±0.32
FI (g)	101.00 ^a ±5.32	59.60 ^c ±2.36	59.46 ^c ±2.72	67.04 ^b ±4.81	50.72 ^{cd} ±3.42	57.53 ^c ±2.10
FCR (g/g)	2.38 ^a ±2.12	5.66 ^a ±1.63	6.71 ^c ±1.34	3.35 ^b ±2.11	4.64 ^c ±2.09	5.76 ^d ±1.32
FE (g/g)	0.42 ^a ±2.04	0.18 ^d ±1.42	0.15 ^d ±1.60	0.30 ^b ±1.73	0.22 ^c ±2.08	0.17 ^d ±2.06

Values with the same superscript in the same row are not significantly different ($P > 0.05$).

Where: MIW = mean initial weight, MIL = mean initial length, MFW = mean final weight, MWG = mean weight gain, SGR = specific growth rate, FI = Feed Intake, FCR = Feed Conversion Ratio and FE = Feed Efficiency.

3. **Unwanted Reproduction Control in *Oreochromis Niloticus* Juveniles Fed *Jatropha Curcas* Seed Meal:** The results of the fecundity and spawning of *Oreochromis niloticus* juveniles fed processed and raw *Jatropha curcas* seed meal as observed during the study is presented in table 5. Within the duration of study, spawning did not occur across the treatment tanks, but the control tanks witnessed spawning under same duration.

Table 5: Fecundity of *O. niloticus* juveniles fed processed and raw *Jatropha curcas* seed meal (12 weeks)

Experimental Duration (Weeks)	Mean Number of Fry / Spawned Eggs per Treatment Tanks					
	D1	D2	D3	D4	D5	D6
1 – 2	-	-	-	-	-	-
2 – 4	750	-	-	-	-	-
4 – 6	-	-	-	-	-	-
6 – 8	803	-	-	-	-	-
8 – 10	1105	-	-	-	-	-
10 – 12	1350	-	-	-	-	-

Note: Values indicated are mean number of fry / spawned eggs per treatment tanks

Effect of processed and raw *Jatropha curcas* seed meal on the survival, well-being of *Oreochromis niloticus* juveniles and their haematological parameters are presented in Figures 1, 2 and table 5, respectively.

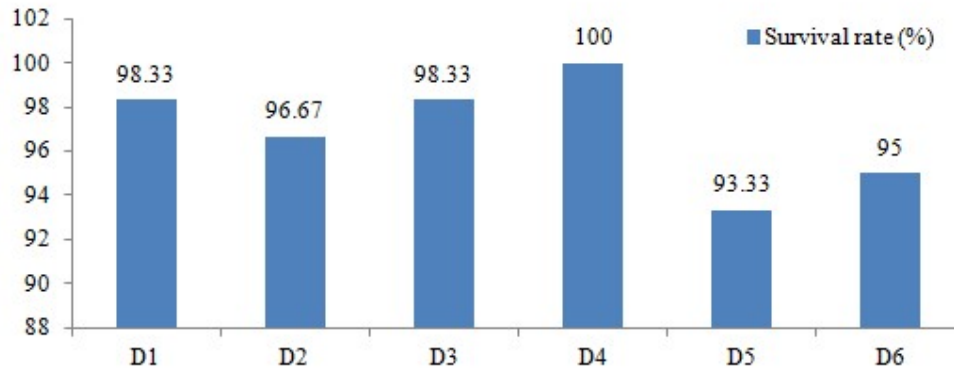


Figure 1: Percentage survival of *O. niloticus* juveniles fed processed and unprocessed JCSM (12 weeks.)

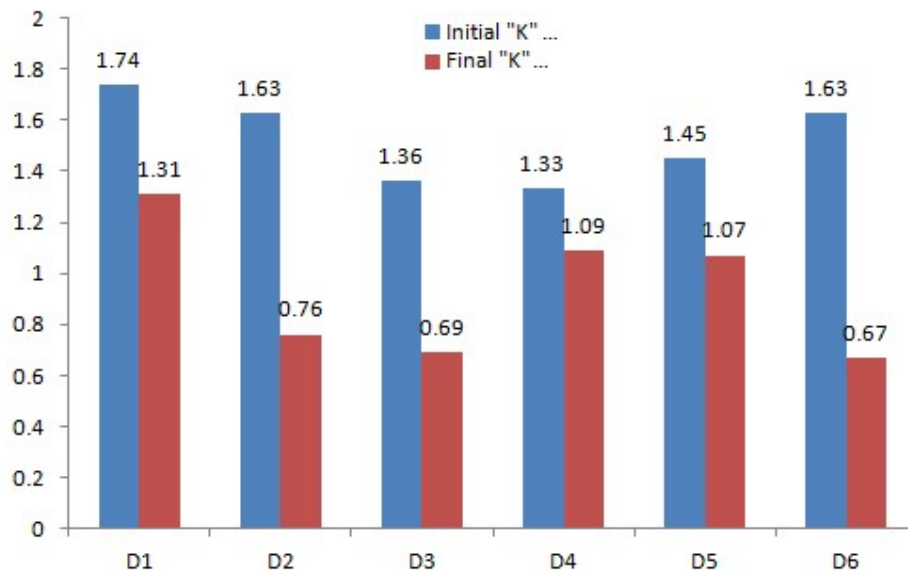


Figure 2: FCF (K- value) of *Oreochromis niloticus* juveniles fed diets with processed and unprocessed *Jatropha curcas* seed meal (12 weeks).

Table 5: Hematology of *Oreochromis niloticus* juveniles fed processed and raw (unprocessed) *Jatropha curcas* seed meal for 12 weeks.

Parameters	Experimental Diets (Treatments)					
	D1	D2	D3	D4	D5	D6
PCV (%)	12.82	6.98	5.00	14.81	4.87	6.25

HB (g/dl)	4.27	2.33	1.67	4.94	1.63	4.17
RBC x 10 ⁹	3.18	2.65	3.91	2.29	1.98	2.94
WBC x 10 ⁶	55.4	51.12	37.32	43.60	40.52	26.16
MCV (fl)	4.03	2.63	1.28	6.47	2.43	2.13
MCH (pg)	13.43	8.79	4.27	21.57	8.23	7.09
MCHC	33.31	33.38	33.40	33.36	33.47	33.36

Where: PCV (%) = Packed Cell Volumes, HB (g/dl) = Heamoglobin, RBC = Red Blood Corpuscles, WBC = White Blood Corpuscles, MCV (fl) = Mean Cell Volume, MCH (pg) = Mean Cell Heamoglobin and MCHC = Mean Cell Heamoglobin Concentration

IV. DISCUSSION

The results obtained for proximate and phytochemical analyses of the *Jatropha curcas* seeds in this study agreed with reported values from other authors (Magu *et al.* 2018; Nabil *et al.* 2011 and Ojo *et al.* 2015). This indicated that seeds from west and north Africa could be same in nutrients. The moisture contents of the processed and unprocessed *Jatropha curcas* seed samples were basically low with values below the 15% moisture content needed as safe limit for short and long-term storage of plant food materials (Guru and Mridula, 2021; Deepak and Prasanta, 2017). The variations in processed seeds (soaked and toasted) can be attributed to the processing technique where high moisture content (8.33%) in the soaked seeds is likely due to absorption of water molecules and lower moisture content (4.92%) in toasted seeds implies loss of water content due to heat.

Processing by soaking and toasting increased the crude protein value of the seeds (28.00% and 31.37% respectively) compared to the unprocessed seeds (25.93%). For the soaked seeds, it could be as a result of hydrolysis during soaking which increases the crude protein content (Yarlina, *et al.* 2023), a process commonly associated with activities of microorganisms (Muhammad, *et al.* 2022) while the increase in protein contents of toasted sample might be attributed to an increase in the free nitrogen content (Cong *et al.* 2020) after toasting provided they are not toasted to a degree that denatures the protein (Muhammad, *et al.* 2022). The crude fat of the raw seeds reduced slightly with toasting and increased with soaking. A decline in lipid contents of Parkia seed with increasing period of toasting and increase with increased period of soaking has also been reported (Abegunde *et al.* 2022). The reduction in value of lipid as seen in the toasted JCSM may be attributed to loss of volatile essential fatty acids and denaturing effect of heat (Muhammad, *et al.* 2022). Mean water quality parameters recorded in all treatments from the study were not significantly different ($P > 0.05$) and are within the optimum range for aquaculture and normal growth of *Oreochromis niloticus* as stated (Azzaza *et al.*, 2008). The good water quality parameters can be attributed to the unpolluted source of water supply, screened inlet pipes.

The initial body weight of the fishes recorded at the onset of the study were not significantly different ($P > 0.05$); thus, the different performances of the fish among treatments groups was as a result of the inclusion of JCSM. The study revealed that inclusion of processed and unprocessed JCSM at different proportions to the diet of juvenile *Oreochromis*

niloticus exhibited unusual variation on feeding response, growth capacity and efficiency of feed utilization of the fishes. The results agree with the report of Workagegn *et al.*, (2013). Fish fed with control diets exhibited more active feeding response than fish fed the processed and unprocessed JCSM and performed significantly ($P<0.05$) higher in growth with better feed utilization efficiency. Amongst the fish fed JCSM, the group fed 10% toasted JCSM performed significantly ($P<0.05$) better than fish fed the rest of the treatments. This can be attributed to the palatable nature of the control diet with low content of anti-nutritional factors which affects the dietary taste as well as restricts nutrients availability in other experimental diets (Thakur *et al.* 2019). However, the average MFW of the fish increased reasonably from the initial value across all dietary treatments. The results of this study is similar with the previous works of Azzaza *et al.*, 2011 and Workagegn *et al.*, 2013 who adduced that higher concentration of anti-nutritional factors (ANFs) in feeds reduce nutrient availability, protein digestibility and minerals bioavailability especially Ca^{2+} and Fe^{2+} which in turn impairs growth performance of the fish and increase wastage of nutrients via faeces. Ojediran *et al.*, (2014) concluded that simple processing methods reduced the antinutrients with minimal effect on the saponin and phorbol esters present in the *Jatropha curcas* kernel meal, which adversely affected feed intake, final weight, weight gain and feed gain ratio in dietary treatments observed by the depressed growth rate and high mortality in birds fed JCSM (Ojediran and Emiola, 2018; Ojediranemiola *et al.* 2019).

Similarly, the same trend was observed in feed utilization efficiency of juvenile *O. niloticus* fed processed and unprocessed JCSM in terms of feed conversion ratio (FCR) and feed efficiency (FE) with fish fed the control diet having the best FCR and FE ($2.38^a \pm 2.12$ and $0.42^a \pm 2.04$ respectively) followed by fish fed 10% soaked JCSM. The remarkable values recorded for the FE can be attributed to practical constraints in experiments with fish, especially in outdoor facilities, it was not possible to ensure that all feed presented was ingested nor was it possible to collect uneaten food from the experimental tanks. Therefore, for calculation of FCR and FE, the amount of feed fed (instead of feed consumed/intake) was used without correction being made for any wastage. This could lead to overestimation of feed and underestimation of the ratios. Again, the number of female fishes in the control tanks carrying eggs at sampling time may have influenced the mean body weight (MBW) of the group and consequently the daily feed ration (DFR) for the subsequent weeks.

In the study, reproductions of *Oreochromis niloticus* was suppressed in all treatments with processed and unprocessed *Jatropha curcas* seed meal (JCSM) while the control treatments had free reproductive activities as evident in batches of spawning which occurred in the control tanks during the experiment. This observation implies that the JCSM (processed and unprocessed) rendered the treated fish incapable of successful reproduction within the experimental period. The results here are in conformity with the works of Ampofo-Yeboah (2013) using pawpaw and moringa seeds. The author reported that despite significant differences in biological parameters, female fish from the control treatment was noticed to be brooding eggs in her mouth while no reproductive activities were noticed all through the experimental duration of 60 days with the fishes (*Oreochromis mossambicus*) that fed on the respective treatments of pawpaw and moringa seeds. He further adduced that the treatments impaired the maturation of gonads thereby interfering in spawning. This view corresponds with the observation made in the study of Ekanem and Okoronkwo (2003) who worked with *Carica papaya* seed as anti-fertility agent in Nile tilapia. The authors reported that spawning did not occur in all replicates with the treatment for the experimental duration of 30 days

while spawning occurred with fish in the control experiment at two weeks into the period and five weeks after. Fish in the low dose category also spawned 21 days after the treatment was terminated. They attributed the reproductive inhibition to phytoestrogens in pawpaw seeds. Similar reports were given by other authors like Jegede, 2011, Abdelhak *et al.*, 2013 and Omeje, 2016 with *Carica papaya* as sterility-inducing agents adducing that phytoestrogens at higher dosage in the pawpaw seed meal (PSM) were destructive to testes and ovary tissues leading to disintegration of many cells, rendering the testes and ovaries devoid of spermatids and oocytes, respectively.

This suppression in reproduction can also be attributed to the presence of one or more phytoestrogens inhering both processed and unprocessed *Jatropha curcas* seed meal which modulate the (in vivo) endocrine system of fish (Abaho *et al.* 2022), hence referred to as endocrine disrupting compounds (EDCs). Information on the mode of action of EDCs is insufficient but the general view held about the process by which EDCs distort endogenous hormones is to antagonize or mimic the actions of endogenous hormones. These effects may either be estrogenic or anti-estrogenic (Lehtinen and Tana, 2001; Ososki and Kennelly, 2003). Estrogenic potentials are able to act like endogenous estrogens and produce estrogenic actions, whereas, that of the anti-estrogenic potentials can interrupt or obstruct estrogen receptors (ERs) and hinder estrogenic activity, thus producing inverse estrogenic actions (Ososki and Kennelly, 2003; Matozzo *et al.*, 2008). Results from Blazer *et al.*, 2012; Sassi-Messai *et al.*, 2009; Cheshenko *et al.*, 2008; Manning, 2005; Mills and Chichester, 2005 and Damstra *et al.*, 2002 indicated that exposure of an organism to dosages of EDCs or natural hormones capable of interfering with the normal operation of the endocrine system could have severe effect on the reproductive endocrine system resulting in changes in the reproductive evolution (Ampofo-Yeboah, 2013). In addition, the present results agree with reports from other investigators to affirm the effects of JCSM as a sterility agent or reproductive inhibitor in fish and other animals. For instance, Nur and Sabrina (2013) concluded that *Jatropha curcas* has anti implantation effects on pregnancy of *Sprague Dawley* rats during early gestation period.

There is no significant difference in the survival rates of juvenile *O. niloticus* fed processed and unprocessed JCSM. Fish from all treatments survived well and the good survival rate can be attributed to careful experimental routines / handling, good water quality and adequate space in experimental tanks. This result on survival rate contradicts that of Workagegn *et al.*, 2013 who reported that fish fed control diets had significant higher survival rate as compared to the fish fed rest of the experimental diets with varying inclusion levels of *Jatropha curcas* kernel meal (JCKM). This contradiction may be due to difference in culture medium as well as the size/age of the fish at time of experiment since older fish are more likely to withstand rigors emanating from the dietary treatments or experimental routines. Again, while Workagegn *et al.*, 2013 reported that the Fulton's condition factor (FCF) K-value of all fish were intact, the present study revealed the well-being of the fish in terms of FCF K-value were impaired for the toasted (D2, D3) and raw (D6) treatments. This can be attributed to the residual toxic anti-nutritional components of *Jatropha curcas*. Chivandi *et al.*, 2006 and Tiurma *et al.*, 2010 both reported that dietary JCSM caused severe adverse effects in pigs and broiler chicken of 7-21 day old, respectively. They inferred that the detoxification procedure failed to completely remove and or neutralize the toxic anti-nutritional factors (ANFs) in the JCSM adding that some of the toxicity observed can be ascribed to the residual PEs in the JCSM.

The relatively low WBC (lymphocytes) values recorded in the group that fed on diet with 20% JCSM (toasted & soaked) and very low value recorded for the raw JCSM fed fishes can be attributed to residual and (or) un-tempered ANFs in JCSM when compared with the control group. The observation on lymphocyte values agreed with the findings of Ojediranemiola *et al.*, (2019) who investigated the response of finisher broiler chickens to various inclusion levels of processed-fermented *Jatropha curcas* kernel meal. Lymphocytes are notable to play vital roles in the immune defense system of both humans and animals.

V. CONCLUSION AND RECOMMENDATION

Toasted, soaked and raw *Jatropha curcas* seed meal at both 10% and 20% were able to suppress unwanted reproduction in juvenile *Oreochromis niloticus* for 12 weeks by impairment of fish gonads but with adverse effect on the performance in terms of growth, feed utilization efficiency and overall well-being of the fish.

From the study, it is recommended that lower inclusion levels of JCSM in tilapia feed as well as other processing methods for JCSM should be investigated in subsequent studies. Also, there is need for further studies in the area of incorporating other phytoestrogenic plants for control of prolific reproduction as alternative to synthetic hormones like 17 α MT for sustainable aquaculture.

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