

Growth Performance, Body Composition, Haematology and Product Quality of the African Catfish (*Clarias gariepinus*) Fed Diets with Palm Oil

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Abstract: The replacement value of palm oil for codliver oil in diets for juvenile African catfish (initial weight 24.04 g) was investigated. For 8 weeks, fish were fed experimental diets in which there was either 9% codliver oil (Diet 1), 6% codliver oil, 3% palm oil (Diet 2), 3% codliver oil, 6% palm oil (Diet 3), or 9% palm oil (Diet 4). There were significant differences in body weight gain among all treatments, with fish fed diets 2 and 3 performing better. Fishes fed diets 3 and 4 had significantly higher survival than fish fed diets 1 and 2. Significant differences were recorded in carcass parameters of fish at the end of the feeding trial, with fish fed diets 3 and 4 having higher values. Fish fed diet 2 had higher blood parameters which decreased with increasing level of palm oil in the diet. There was no significant difference in the organoleptic properties of fish fed different dietary treatments and the end of the trial. The results of this study shows that diet with 3% codliver oil, 6% palm oil is nutritionally suitable for feeding the African catfish.

Key words: African catfish, palm oil, haematology, carcass quality, sensory evaluation

Introduction

Oil palm [*Elaeis guineensis* (Jacq.)] from which crude palm oil (CPO) is extracted, is native to West Africa. It is used to make foodstuffs, medicines, woven materials and wines (Casson, 2003). CPO is predicted to exceed soybean oil production within the next ten years making it the most abundant vegetable oil in the world (Gunstone, 2001).

Crude palm oil is the richest natural source of β -carotene and vitamin E, which function as natural antioxidants. These confer beneficial effects to growth and flesh quality when fish are fed high levels of palm oil in their diets (Lim *et al.*, 2001). Palm oil has been evaluated in fish diets for salmonids (Tortensen *et al.*, 2000; Bell *et al.*, 2002), catfishes (Legendre *et al.*, 1995; Lim *et al.*, 2001, Ng *et al.*, 2000) and tilapias (Ng *et al.*, 2001) Palm oil can meet the energy requirements of fish by providing easily oxidized fatty acids and at the same time, generate flesh fatty acid composition that are beneficial to the consumer both by maximizing retention of desirable fatty acids such as 22.6(n-3) and by minimizing deposition of undesirable fatty acids such as 18:2(n-6) (Bell *et al.*, 2002).

Good results have been reported on the use of palm oil in the diets of several catfishes: *Heterobranchius longifilis* (Legendre *et al.*, 1995), *Mystus memurus* (Ng *et al.*, 2000), *Clarias gariepinus* (Lim *et al.*, 2001; Ng *et al.*, 2003). The purpose of the present experiment was to evaluate the nutritive value of crude palm oil as a potential dietary lipid source for the African catfish, *Clarias gariepinus*. The effect of crude palm oil on the growth, carcass composition, some haematological

indices and organoleptic properties of fish flesh was examined.

Materials and Methods

Fish meal (Atlantic menhaden, *Brevoortia tyrannus*), mineral/vitamin premix and binder used in this study were obtained from a feed/feedstuff store in Akure. Bovine Blood meal, cassava starch and palm oil were obtained from Akure main market. Cod liver oil was obtained from a pharmacy shop at Akure. Triplicate samples of fish meal and blood meal were analyzed for proximate composition (moisture, crude protein, crude lipid, crude fibre, ash) according to AOAC (1990) methods. Crude protein was determined using a Kjeltac Auto 1003 Analyzer after digestion with concentrated H₂SO₄ in a digester. Crude lipid was estimated by extracting in chloroform: methanol (2:1) using a Soxtec extraction HT6 unit. Crude fibre was determined using a Fibretec System 1020 Hot Extractor and ash content was determined by igniting at 550°C in a muffle furnace for 12 hours. Gross energy content was determined using a ballistic bomb calorimeter (model OC-5182, Gallenkamp & Co. Ltd., Loughborough, England).

Four isoproteic diets (40% crude protein) were formulated as shown in Table 1. The control diet (diet 1) contained 9% cod liver oil, which was replaced by palm oil in diets 2, 3, and 4 at 33.3%, 66.7% and 100%, respectively. Each of the diets had 3% fish oil as a residual of the fish meal component of the diet. The feedstuffs were thoroughly mixed in a Hobart A-200 (Troy, Ohio, USA) pelleting and mixing machine to obtain a homogenous mass. The diets were passed through

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Table 1: Ingredient and proximate composition of diets with palm oil for the African catfish, *Clarias gariepinus*

Ingredients (g.100g ⁻¹ DM)	Diets			
	Diet 1	Diet 2	Diet 3	Diet 4
Fish meal (61% cp)	40	40	40	40
Blood meal (82% cp)	21	21	21	21
Starch	25	25	25	25
Fish (cod liver) oil	9	6	3	0
Palm oil	0	3	6	9
Vitamin/mineral premix	3	3	3	3
Carboxyl methyl cellulose	2	2	2	2
Proximate				
Moisture (%)	4.41±0.33	4.65±0.25	4.33±0.29	3.77±0.13
Ash (%)	17.00±0.04	16.21±0.15	14.47±0.14	14.58±0.09
Crude protein (%)	39.88±0.21	40.05±0.81	40.15±0.66	40.24±0.58
Crude lipid (%)	12.79±0.02	13.65±0.25	12.26±0.17	12.67±0.31
Crude fibre (%)	0.72±0.02	0.63±0.00	0.65±0.02	0.53±0.09
Nitrogen free extract (NFE) (%)	25.21±0.78	19.32±0.96	22.78±0.46	22.76±0.89
Gross Energy (Kcal/kg)	4564.52±7.85	4542.72±6.42	4499.44±5.2240	516.18±5.10

a mincer with die of 0.8 mm and milled, blended, moistened, pelleted (1mm lengths) using the pelleting machine referred to above. The diets were then sun-dried at ambient temperature of 30°C for three days and stored in airtight plastic at 26°C. Proximate composition of the diets was conducted in triplicates according to AOAC (1990) methods as described above. The study was conducted in twelve circular plastic tanks. Each of the four treatments was replicated in triplicates. Fingerlings of the African catfish, *Clarias gariepinus* were obtained from the Ondo State Agricultural Development Programme (ADP) Fish Farm at Alagbaka, Akure, Nigeria and transported in oxygen bags to the laboratory. The fish were then acclimated to laboratory conditions and fed with a commercial fish feed (35% cp) for 14 days. After acclimation, groups of ten *Clarias gariepinus* fingerlings (mean weight 24.03 g) were randomly stocked into the 12 circular plastic tanks (21 litre volume) containing 15 litres of water each for growth trials.

Each of the diets was fed to the fishes in triplicate containers at 4% body weight twice daily (9.00-10.00 h and 16.00-17.00 h) for 56 days. The weight of each group of fish was taken fortnightly using a Triple Beam Balance (700 series, Ohaus Florham park, N.J. 07932, USA), and the feed adjusted accordingly.

The water quality parameters of Dissolved oxygen, temperature and pH were monitored on alternate days. Early in the morning (6.00-7.00 am) on the days when the water quality parameters were taken, the oxygen meter (Jenway model 9071, QA, UK) was used to take the Dissolved oxygen and temperature, while the pH was also taken using a digital/electronic pH meter (Mettler Toledo 320 model, serial No. M 5970, UK). The tanks were aerated throughout with Aquarium Air-pumps (Resun AC-9802, Guangdong Risheng Group Co. Ltd., China).

At the beginning and end of the feeding trial, six *Clarias gariepinus* fingerlings randomly selected from the initial pool, were homogenized, packed in air-tight polythene bags and stored in a deep freezer (-20°C), prior to analysis. For the carcass analysis at the end of the study, two fish were pooled together for each replicate (glass tank), homogenized in a blender and the proximate composition determined. Moisture was determined by oven-drying using oven (Gallenkemp LCO N53 CF, model 94 M003, Gen Lab. Widnes, England) Crude protein was determined using Kjeldahl method (AOAC, 1990). Crude lipid was determined by extraction with dimethyl ether for six hours on a soxhlet apparatus; ash was determined from weighed moisture-free samples in a porcelain crucible placed in a muffle furnace at 550°C for 6 hours.

The fish, from which blood for haematology was collected, were anaesthetized with 150 mg/l solution of tricaine methane sulphonate (MS-222, Sigma Chemical co. St. Louis, MO, USA). (Wagner *et al.*, 1997). Blood samples were taken with 2ml heparinized syringes and 21swg needles from the caudal vein of a set of three *Clarias gariepinus* fingerlings from each treatment and put separately in 2ml heparinized tubes and taken to the laboratory for determination of haematocrit (Hct), haemoglobin (Hb), erythrocyte sedimentation rate (ESR), white blood cells (WBC), and red blood cells (RBC) using the methods of Svobodova *et al.* (1991).

The haematological indices of mean cell haemoglobin concentration (MCHC), mean cell haemoglobin (MCH) and mean cell volume (MCV) were calculated using the total red blood cell count (RBC), haemoglobin concentration (Hb), and hematocrit (Hct) according to the following formulae (Dacie and Lewis, 2001):

$$\begin{aligned} \text{MCHC (g l}^{-1}\text{)} &= [\text{Hb (g dl}^{-1}\text{)} \times 10] / \text{Hct} \times 100 \\ \text{MCH (pg)} &= [\text{Hb (g dl}^{-1}\text{)} \times 10] / \text{RBC (} 10^6 \mu\text{l}^{-1}\text{)} \\ \text{MCV (fl)} &= \text{Hct} / \text{RBC (} 10^6 \mu\text{l}^{-1}\text{)} \end{aligned}$$

Sensory evaluation to assess fish quality was performed on the day the trial ended. The fish fillets were assessed by a panel of trained panelists of 4 individuals selected for their interest, availability and sensorial capacities of memorizing stimuli or discriminating intensities (Regost *et al.*, 2003). The samples were evaluated using a 9-point hedonic scale, with 1 being the lowest and 9 the best. Both fresh and cooked samples were assessed. Fresh samples attributes assessed were general appearance and colour; while the attributes of cooked samples assessed were texture, aroma, taste and juiciness.

Growth, haematological, carcass analysis and sensory evaluation data collected from the experiment were subjected to one way analysis of variance (ANOVA) test USING the SPSS (Version 10.0) FOR WINDOWS ON PC, and where significant differences were indicated, means were tested using Least Significant Difference (LSD) test at the 5% level of significance (Zar, 1984).

Results

The diets used in the feeding trial, the ingredients composition as well as proximate composition are presented (Table 1). The proximate analysis shows that there is no significant difference between diets. Water quality condition in the experimental tanks showed very little variation throughout the duration of the trial (Table 2). The performance in terms of survival of fish on different diets is shown (Table 3). Mortality during the growth trial was fairly high (40%) in two treatments and fairly low in two treatments (20%). The higher the cod-liver oil content in the treatment, the higher was the percentage mortality recorded for that treatment. Diets 3 and 4 with the lowest cod-liver oil inclusion and no codliver oil component respectively recorded the highest survival of fish. The growth responses in all the treatments are presented in Table 3. The percentage weight gain recorded in catfish fed diets with palm oil substitution, with the exception of Diet 4, was not significantly inferior to that of catfish fed the control diet (Diet 1). The performance of catfish fed Diet 3 (with cod-liver oil: palm oil ratio being 1:2) performed better than fish fed the control diet (Diet 1). The same trend was observed for the specific growth rate (SGR), and feed conversion ratio (FCR). There was no significant difference in these indices ($p < 0.05$), except percentage weight gain (PWG) and protein efficiency ratio (PER) that showed significant difference between treatments.

Carcass composition of fish at the end of the feeding trial was significantly different from the initial composition in crude protein and crude lipid contents (Table 4). The crude protein of the experimental fish in all the treatments had a significantly higher protein value than the initial fish. For crude lipids, significant differences existed in the values obtained in the initial fish and those obtained for fish fed diets 1, 2 and 4, but

no significant difference between the initial fish value and that for fish fed diet 3. The viscerosomatic index (VSI) of the initial fish (prior to the feeding trial) was not significantly different from the values for all the other treatments. The gonadosomatic index (GSI) was significantly different ($p < 0.05$) between treatments, with the value for initial fish, fish fed diets 1, and 2 significantly higher than those of fish fed diets 3 and 4. But with the exception of diet 3, the hepatosomatic index (HSI) decreased with increasing palm oil substitution. There was a significant difference in all the haematological parameters measured both between dietary treatments and between the control and dietary treatments (Table 5). Apart from fish fed diet 1 whose blood parameters did not follow the observed trend, all the fish fed other dietary treatments showed a common trend, namely the higher the palm oil substitution level, the lower the blood parameters. There was no significant difference between the initial (pre-treatment) values of erythrocyte sedimentation rate, white blood cells and red blood cell and those of fish fed diets 2 and 3. The Hct and Hb of the pre-treatment fish were not significantly different from those of fish fed diet 2, but were significantly better than those for fish fed all the other diets. MCHC values were not significantly different between all the treatments, except the value for fish fed diet 1 which were significantly lower than the values for all other treatments as well as that for the pre-treatment fish. MCV values were significantly different between treatment groups, with values decreasing with increasing palm oil level in the diet.

For sensory evaluation, fish fed different diets did not present any significant difference in the mean score for either the attributes of the raw fish (general appearance and colour) or attributes of the cooked fish (texture, aroma, taste and juiciness) (Table 6). Not only was there no significant difference between sensory attributes of fish fed different dietary treatments, but even the overall mean score between treatments was not significantly different

Discussion

Palm oil appears to be a promising ingredient to partially replace fish (codliver) oil in feeds for the African catfish, since growth performance were similar among fish fed the different diets, except those fed diet 4 that performed significantly poorer than all the rest. There were no significant differences in weight gain among all treatments, except those fed diet 4 (Table 3.). Fish mortality throughout the feeding trial was relatively high for diets 1 and 2 (40%) but relatively low for those fed diets 3 and 4 (20%). A survival of 80% recorded for diets 3 and 4 is very close to that obtained by Piedecausa *et al.* (2006) who obtained a survival of 85% in a study with soybean oil in diets for sharpnose sea bream. The mortality appeared to be independent of dietary

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Table 2: Water Quality parameters of culture tanks during feeding trials of *Clarias gariepinus* fed diets with palm oil

Diet	Temp. range (°C)	Mean Temp. (°C) ± S.E.	pH range	Mean pH ± S.E.	Dissolved Oxygen (DO) (mg/l)	Mean DO (mg/l) ± S.E.
1	23.0 - 25.0	24.11±0.07 ^a	5.78 - 6.86	6.39±0.04 ^a	5.3 - 6.5	5.80 ±0.04 ^a
2	23.0 - 25.0	24.10±0.07 ^a	5.86 - 6.96	6.42±0.04 ^a	5.3 - 6.4	5.69±0.03 ^a
3	23.0 - 25.0	24.07±0.06 ^a	6.09 - 6.96	6.56±0.04 ^a	5.3 - 6.4	5.80±0.04 ^a
4	23.0 - 25.0	24.10±0.03 ^a	6.14 - 6.91	6.54±0.03 ^a	5.3 - 6.4	5.69±0.03 ^a

* Means with same superscript are not significantly different

Table 3: Growth performance of *Clarias gariepinus* fed diets with palm oil for 56 days, mean ± S.E. of three replicates

	Diets			
	1	2	3	4
Initial Weight	25.17±1.99	24.20±0.90	23.94±1.08	22.81±0.81
Final Weight	38.94±1.14	39.02±2.20	8.96±5.77	32.41±2.23
Mean Weight Gain	13.77±1.97	14.82±2.71	15.02±5.46	9.60±1.96
Percentage Weight Gain	54.87±7.84 ^{a,b}	61.98±13.35 ^b	62.55±23.46 ^b	42.10±8.23 ^a
Feed Conversion Ratio ¹	3.77±0.58	3.46±0.61	4.66±1.86	4.94±0.82
Protein Efficiency Ratio ²	0.70±0.06 ^b	0.77±0.04 ^b	0.78±0.09 ^b	0.53±0.05 ^a
Specific Growth Rate ³	0.78±0.09	0.85±0.14	0.83±0.26	0.62±0.10
Survival (%)	60.0±2.52 ^a	60.0±3.44 ^a	80.0±5.56 ^b	80.0±6.72 ^b
Apparent Digestibility	0.6138±0.07 ^{a,b}	0.7082±0.03 ^b	0.7235±0.01 ^b	0.5483±0.06 ^a
Coefficient of protein ⁴				

* Means with same superscript are not significantly different

FCR¹ (Feed conversion ratio) = TF/(Wf - Wi). TF is the average total feed fed to a fish.

PER² (Protein efficiency ratio) = Wet weight gain (g)/protein fed (g)

SGR³ (Specific growth rate) = 100 x (ln Wf - ln Wi)/rearing period (days), where Wf is Final weight and Wi is Initial weight.

ADC⁴ (Apparent digestibility coefficient of protein) = 10⁻² 10² (% AIA in feeds x % protein in faeces) / (% AIA in faeces x % in protein in feed) (Nwana, 2005).

Table 4: Carcass composition VSI, GSI and HSI of *Clarias gariepinus* (on a DM basis) fed diets with palm oil for 56 days, mean ± S.E. of three replicates

Trt	Moisture	Crude protein	Crude lipid	Ash	VSI	GSI	HSI
Initial	5.44±0.74 ^a	63.40±1.19 ^a	6.57±1.40 ^b	4.84±0.44 ^b	9.50±1.29 ^a	4.97±0.05 ^a	2.37±0.08 ^b
Diet 1	7.51±1.78 ^b	65.70±0.81 ^b	5.67±0.27 ^a	3.73±0.29 ^a	9.42±0.07 ^a	5.16±0.39 ^a	2.95±0.11 ^b
Diet 2	8.91±1.49 ^c	66.19±0.50 ^b	5.64±0.22 ^a	3.92±0.44 ^a	9.47±0.05 ^a	5.15±0.12 ^a	2.73±0.09 ^b
Diet 3	7.89±0.92 ^{b,c}	65.36±0.70 ^b	6.40±0.28 ^b	4.10±0.11 ^a	10.01±0.11 ^a	4.50±0.22 ^a	1.93±0.19 ^a
Diet 4	5.75±0.33 ^a	65.30±0.32 ^b	5.28±0.60 ^a	4.69±0.26 ^{ab}	9.79±0.75 ^a	4.85±0.02 ^a	2.06±0.32 ^a

* Means with same superscript are not significantly different. Trt = Treatment

Table 5: Haematology of *Clarias gariepinus* fed diets with palm oil for 56 days, mean ± S.E. Blood Parameter

Teat-ment	HCT (%)	HB (g dl ⁻¹)	ESR (mm/hr)	WBC (x10 ³ /µl)	RBC (x10 ⁹ /µl)	MCH (pg)	MCHC (g l ⁻¹)	MCV (fl)
Initial	22.00±2.65 ^c	7.53±0.92 ^c	10.67±0.88 ^{ab}	4.40±0.41 ^c	2.27±0.20 ^{b,c}	33.10±0.14	34.20±0.21 ^c	96.62±0.37 ^{b,c}
Diet 1	12.00±0.58 ^a	3.60±0.06 ^a	12.33±0.33 ^b	2.50±0.06 ^a	1.20±0.12 ^a	30.60±0.03	30.17±1.78 ^a	102.46±1.39 ^c
Diet 2	21.33±0.33 ^{b,c}	6.83±0.03 ^{b,c}	10.33±0.03 ^a	4.80±0.06 ^c	2.40±0.06 ^c	28.50±0.01	32.07±0.34 ^{b,c}	89.05±0.35 ^b
Diet 3	17.67±0.33 ^b	6.13±0.03 ^b	11.00±0.58 ^{ab}	3.73±0.03 ^b	2.00±0.06 ^b	31.03±0.01	34.73±0.59 ^c	88.56±0.40 ^b
Diet 4	13.33±0.33 ^a	4.40±0.06 ^a	12.00±0.00 ^{ab}	2.70±0.06 ^a	1.40±0.06 ^a	31.50±0.12	33.00±0.49 ^{b,c}	83.49±1.33 ^a

* Means with same superscript are not significantly different

treatment. Fish fed diets 2 and 3 performed better in weight gain than fish fed diets 1 and 4. The implication of this is that the African catfish requires a balance between the n-3 PUFA found in fish oil and the n-6 PUFA present in palm oil in its diet. This result agrees with the result obtained by Lim *et al.* (2001) that up to 8% of refined, bleached, deodorized, palm olein (RBDPO) or crude palm oil CPO can be included in diets for the African catfish with improved performance, protein retention and fillet vitamins E concentration of this fish. Ng *et al.* (2000) also reported that up to 90% of dietary

fish oil could be replaced by crude palm oil without compromising growth or feed utilization efficiency of a tropical catfish, *Mystus nemurus*. Increased substitution level of palm oil in the diets did not cause any significant increase in any of the above components of the body. Lim *et al.* (2001) found a significantly higher whole body protein in fish fed diets with 12% or 16% refined, bleached, deodorized, palm olein (RBDPO) or 16% crude palm oil (CPO). Their result differ from this probably because they used a higher level of palm oil and some of their diets had RBDPO, but it was CPO that

was used in this study. There was no significant difference between fish fed the control diet (diet 1) and those fed diet 4 (no codliver oil inclusion) in their percentage weight gain, SGR, FCR and PER. But when these growth parameters are considered in conjunction with the survival of the fish at the end of the trial, then palm oil diet performed significantly better than the control. The result of this study shows that palm oil can effectively substitute for fish (codliver) oil without adverse effect on growth. Fish fed diet 1 that had not palm oil substitution showed a slight, but not significant depression in growth when compared with fish fed diets 2 and 3. Particularly, fish fed diet 3 combined better increases in weight gain and survival. Xue *et al.* (2006) found that up to 50% of fish oil can be replaced in diets for the Japanese sea bass without adverse effect on growth. From the human nutritional point of view, it is considered important that a balance in n-3 and n-6 PUFA be present in the fish to be consumed (Tichelaar, 1993). Other studies involving soybean oil where similar results have been obtained include feeding canola oil or soybean oil to Atlantic salmon, rainbow trout and grey mullet without negative effect on growth, feed conversion ratio or survival (Greene and Selivonchick, 1990; Argyropoulou *et al.*, 1992; Bell *et al.*, 2001). Similar results as the present study were reported where the replacement of 42.7% fish oil by soybean oil and corn oil did not show significant difference on SGR and PER. Hoffman and Prinsloo (1995) obtained a similarly better growth of this species with sunflower lipid diet than he had with catfish fed codliver oil as lipid source. The high linolenic acid concentration (5.2%) he used which is even less than the quantity used in this study (9%) may have been responsible for the slight retardation in growth experience in both this study and that of Hoffman and Prinsloo (1995). It has been reported that when linolenic acid concentration approaches 1% in diet, it retards the growth of channel catfish (Stickney and Hardy., 1989). Legendre *et al.* (1995) obtained highest growth when the related African catfish species, *Heterobranchus longifilis* was given diets with palm oil or copra oil compared with when cotton seed, peanut or codliver oil was given.

The protein content of the carcass composition was not significantly different between treatments, although there was a significant difference between the values for fish fed different treatments and that of the initial fish which had a lower value. The lipid content of the initial fish was not significantly different from that of fish fed diet 3, but differed significantly from the relatively lower values obtained in fish fed diets 1, 2 and 4. The ash content did present any significant difference between treatment groups (Table 6). The VSI and GSI of fish fed different diets were not significantly different between groups. The HSI of the initial fish were not significantly different from those fed diets 1 and 2 but differed significantly

from those of fish fed diets 3 and 4. In general, the HSI of fish decreased with increasing palm oil level in the diet. Piedecausa *et al.* (2006) obtained higher HSI values for sharpnose sea bream fed soybean oil than those fed fish oil or linseed oil. In contrast, previous studies did not record significant HSI differences on other fish species when vegetable oils were used, including Atlantic salmon (Rosenlund *et al.*, 2001; Menoyo *et al.*, 2003; Bendiksen *et al.*, 2003; Ng *et al.*, 2004), turbot (Regost *et al.*, 2003), and European sea bass (Mourete *et al.*, 2005).

Results of analysis of the hematological parameters of *Clarias gariepinus* in this study showed significant difference between the treatment values and the Hct value obtained for the control (Table 5) other than fish fed diet 1 which showed the lowest Hct value in the trial, the Hct of fish fed other diets decreased with increasing level of palm oil substitution. The pre-treatment fish had significantly higher Hct values than the treated fish. Only fish fed diet 2 had an Hct value that was not significantly different from that of the pre-treated fish. Fish fed all other diets had Hct values that were significantly lower than those of the pre-treated fish. Other the fish fed diet 1 which had the least Hct value the trend observed for the other diets is that the higher the percentage of palm oil substitution, the lower the Hct value. Ekanem (2001) obtained similar value for haematocrit with the bagrid catfish, *Chrysichthys nigrodigitatus*. He also noticed the same degree of variation between treatments.

The Haemoglobin (Hb) content of fish fed different diet types exhibited a similar trend to that observed for the Hct. The Hb values are much higher than those obtained by Subhadra *et al.* (2006) for the largemouth bass with diets containing canola oil, chicken oil and menhaden fish oil, which ranged between 3.7-3.9 g dl⁻¹. The mean Hb value of 7.53±0.92 g dl⁻¹ for the initial (pre-treatment) *Clarias gariepinus* and the mean values of 6.83±0.32 obtained for fish raised on diet 2 (6% CLO, 3% CPO) were similar to the mean Hb values of 7.44% obtained by Etim *et al.* (1999) for *Chrysichthys nigrodigitatus* showing that the oxygen carrying abilities of the blood of these two catfishes are similar. The difference may be due to the fact that we used different species and the ability to utilize n-6 fatty acids present in the vegetable oils differs from species to species. There was no significant difference in the erythrocyte sedimentation rate (ESR) of fish different treatments, except that fish fed diet 1 had significantly higher value than those fed diet 2, but not significantly more than the values for those fed other diets. There was a significant difference in the white blood cells (WBC) of fish fed diets with no apparently defined trend. The RBC of fish fed different diets presented trend to that of WBC. The mean RBC values obtained in this study (1.20±0.12-2.40±0.06 x10⁶/μL) are similar to those obtained by Osuigwe *et al.* (2004) for *C. gariepinus*. The consistently lowest values

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Table 6: Sensory Evaluation of *Clarias gariepinus* fed diets with Palm oil diets for 56 days, mean \pm S.E of four replicates

Diets	General Appearance	Colour	Texture	Aroma	Taste	Juiciness	Overall mean for attributes
Diet 1	8.00 \pm 0.71	8.00 \pm 0.41	7.50 \pm 0.50	7.25 \pm 0.85	7.00 \pm 1.35	6.25 \pm 1.44	7.33 \pm 0.48
Diet 2	7.50 \pm 0.50	7.25 \pm 0.25	7.50 \pm 0.29	7.75 \pm 0.63	8.25 \pm 0.48	7.50 \pm 0.87	7.63 \pm 0.36
Diet 3	7.25 \pm 0.75	7.50 \pm 0.65	8.50 \pm 0.29	8.00 \pm 0.41	8.00 \pm 0.41	8.50 \pm 0.50	7.73 \pm 0.50
Diet 4	7.25 \pm 0.48	7.50 \pm 0.29	7.75 \pm 0.48	8.00 \pm 0.41	8.50 \pm 0.29	8.75 \pm 0.25	7.73 \pm 0.37

of Hct, Hb, WBC, and RBC in fish fed diet 1 (with no palm oil inclusion), show clearly that the African catfish cannot effectively utilize n-3 PUFA without dilution with n-6 PUFA. The n-3: n-6 PUFA balance seems critical in the diet of the African catfish. The significantly poorer survival of fish fed diets 1 and 2 (60%) compared with the better survival of fish fed diets 3 and 4 (80%) lend credence to this thesis. It is highly likely that n-3 PUFA in the codliver oil may have significantly affected the white blood cells and other blood parameters, thereby compromising the immune system. This perhaps may explain the high mortality (40% recorded for diet 1 and 2 compared with 20% recorded for diets 3 and 4) (Table 3). The mean cell haemoglobin concentration (MCHC) differed between treatments and did not follow a clearly defined trend, but differ significantly between treatments and mean cell volume (MCV) decreased significantly with increasing level of palm oil in the diet. Fish on Diet 1 (CLO 9%, CPO 0%) showed significantly lower MCHC than fish raised all the other treatments, which were not significantly different, one from the other. Lane (1979) cited by Lie *et al.* (1989), reported that an increase in MCH and MCHC values reflect a preserving mechanism in rainbow trout activated at reduced water temperatures. There was no temperature variation in this study, hence no increase relative to the initial MCH and MCHC values were observed.

Sensory evaluation of fish is an important index in its overall assessment. This is because eating quality is an important determinant of the overall impression of a food (Rasekh *et al.*, 1970). A poorly tasting food is unlikely to enjoy future patronage. The sensory quality of fish is determined by its composition (Robb *et al.*, 2002). Kestin *et al.* (1995) showed that muscle lipid level significantly affected the eating quality of rainbow trout. General appearance and colour were assessed on fresh samples whereas texture, aroma, taste and juiciness were assessed on cooked samples. There was no significant difference between treatments for all the attributes assessed by the panelists. Consequently, the mean overall score ranged from 7.33 \pm 0.48 to 7.73 \pm 0.50 on a scale of 9.00. Increasing levels of dietary oil result in higher muscle lipid levels in the fish (Robb *et al.*, 1997), but because the lipid level in this study was controlled, it resulted in product quality with little or no variation in eating quality. Hence the use of CPO in rearing the African catfish does result in product with good eating quality.

In conclusion, the results obtained in the present study can be summarized as follows: (i) Replacement (up to 100%) of fish oil with palm oil in diets for the Nile tilapia did not significantly compromise growth performance and survival of the fish during an 8 week trial. (ii) Survival of catfish fed diets with 67% and 100% palm oil was significantly higher than that of fish fed any of the other two diets - diet 1 with 100% codliver oil and diet 2 with 2: 1 codliver oil: palm oil blend. (iii) Carcass quality of African catfish fed palm oil diets was not compromised. (iv) The viscerosomatic index (VSI) of fish fed palm oil diets was not adversely affected, but the gonadosomatic index (GSI) hepatosomatic index (HSI) decrease with increasing level of palm oil content in the diet. (v) The values of the blood parameters – Hct, Hb, WBC, and RBC - of fish different diets decreased with increasing level of palm oil in the diet. (vi) The sensory evaluation of the fish showed that palm oil in diets has no negative effect on the eating quality of fish produced. It is therefore recommended that *Clarias gariepinus* be fed with diets in which two-thirds of the lipid requirement is palm oil.

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