Effects of Dietary Palm Oil on the Whole-Body Mineral Composition of African Catfish, *Heterobranchus longifilis* (Teleostei, Clariidae)

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Abstract

A 50-day feeding trial was carried out to determine the effect of the graded incorporation of crude palm oil on the whole-body mineral composition of African catfish juveniles *Heterobranchus longifilis*. Six diets were formulated to contain from 3–21% crude palm oil (CPO). Whole-body macromineral composition represented by calcium (Ca), potassium (K), sodium (Na), phosphorus (P) and magnesium (Mg) showed significant variations ($p < 0.05$) with the different dietary palm oil levels. The same trend was observed in whole-body micromineral composition in iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu). Regardless of the micromineral, the increase in the body was related with increasing dietary palm oil levels between 3 and 9%. In summary, the results of this study suggest that an incorporation of palm oil into the fish diet modifies the mineral body composition without major effects on health and nutritional quality of fish.

Keywords: *Heterobranchus longifilis*, palm oil, feeding, whole-body mineral composition, nutritional quality

1. Introduction

Fish plays an important role in human nutrition. It represents an important source of proteins and lipids. In terms of nutrition, fish provides high-value proteins and long-chain (omega-3) polyunsaturated fatty acids that are beneficial to human health [1]. According to the Food and Agriculture Organization (FAO) of the United Nations [2], world consumption of fish per capita has increased from 5.2 kg in 1961 to 20 kg in 2014. In sub-Saharan Africa, fish represents on average 22% of dietary animal protein [3]. Fish consumption is therefore constantly increasing in relation to the growth of world population.

Currently, aquaculture is the main activity likely to meet the need for fish due to the reduction of capture fisheries and the depletion of natural stocks associated with overfishing. Among the factors of production, food represents more than 50% and constitutes one of the major constraints to the development of aquaculture. To maintain aquaculture yields at a satisfactory level, the intensification of production with significant use of compound feed is achieved [4]. In aquafeeds, fish meal and fish oil represent the main ingredients because of their good nutritional quality. Fish oil provides dietary lipids that are an important source of essential fatty acids for growth, health and reproduction [5]. However, the availability of fish oil remains limited by higher price and the decline in fisheries' catches [6]. The use of alternative dietary oil sources such as vegetable oils is being considered and their ability to meet the nutritional requirements of fish has been studied for some years [7].

Among the vegetable oils, palm oil is the one whose world production has increased rapidly in recent years [5, 8]. The oil palm tree (*Elaeis guineensis*) from which crude palm oil (CPO) is extracted is native to West Africa. Palm oil is the richest natural source of the antioxidants ß-carotene and vitamin E. In addition, CPO contains 48.8% of saturated fats, especially 16:0, 37% of monounsaturated fats, mainly 18:1 n-9, and has low concentrations of polyunsaturated fats (9.1% n−6 and 0.2% n−3) with 9.1% linoleic acid [8]. Several studies using palm oil-based diets showed an improvement of growth performance [8–11]. Dietary lipids play important roles of the fish diet as a source of energy and have a sparing action on dietary protein [12]. However, high dietary lipid intake can affect carcass composition and reduce the utilization of other nutrients [13].

Minerals are among the nutrients that fish need to live. Minerals are essential constituents of skeletal structures and play an important role in the maintenance of osmotic pressure. Minerals serve as essential components of many enzymes, vitamins, hormones and respiratory pigments or as cofactors in metabolism, catalysts and enzyme activators.

Fish can satisfy their mineral needs by absorbing minerals dissolved in water or through the diet [14]. Biological factors such as trophic levels, dietary habits and nutritional status, dietary factors such as diet composition, availability and nutrient interactions and environmental factors such as water mineral concentration and temperature of the rearing system can affect dietary levels of minerals and trace elements in fish [14]. The aim of this study was to evaluate the effect of graded incorporation of crude palm oil on the mineral composition of African catfish *Heterobranchus longifilis*, fingerlings.

2. Materials and methods

2.1. Fish and experimental design

This study was conducted at the hatchery of the Oceanological Research Center in Abidjan, Côte d'Ivoire. The fingerlings of *H. longifilis* used during the experiment had an average weight of 0.80 ± 0.7 g. Before the start of the trial, the fish were stored in glass tanks and acclimated to the experimental conditions for a 2-week period during which they were fed with a control diet (CD). After this step the fish were randomly distributed in the glass (50 L) containing 30 fish. The flow of water in the glass tank was ensured at all times by an electric motor pump allowing a flow of 1.5 liter/min. The filtration was carried out by settling and water renewal of 30% was performed daily. During the experimental period the water temperature, pH and dissolved oxygen were considered favorable in fish culture tanks according to Boyd [15].

2.2. Experimental diets and methods

A control diet (containing no crude palm) and six experimental diets in which different palm oil levels were used were incorporated, and control diets were prepared using a 2 mm diameter pellet press and dried at 37°C. During the experiment, the diets were stored at 20°C. The composition and proximate composition of all diets are given in **Table 1** and mineral composition in **Table 2**. The diet was fed ad libitum, twice daily during 50 days. At the end of the experiment, all fish from the same tank were killed, weighed and individually measured and stored in the freezer at −20°C for the further analysis of whole-body composition.

2.3. Proximate analysis

The proximate composition of the experimental diets was determined according to the AOAC standard methods [16]. Gross energy (GE) contents of diets were calculated from the lipid and protein contents using the equivalents of 38.9 $KJ.g^{-1}$ crude fats, 22.2 $KJ.g^{-1}$ crude protein and 17.2 $KJ.g^{-1}$ carbohydrate (NFE) [17].

The mineral compositions were determined by atomic absorption spectrophotometry for calcium (Ca), phosphorus (P), potassium (K), sodium (Na), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) according to the AOAC standard methods [16].

2.4. Statistical analysis

All data were subjected to analysis of variance (ANOVA) using Statistica, statistical software for Windows (release 7.1). Comparisons among treatment means were carried out by a one-way analysis of variance followed by Duncan's test (0.05) [18]. Standard deviation (±SD) was calculated to identify the range of means.

2.5. Results and discussion

Lipids represent an essential component in the diet as they are a major source of energy and essential fatty acids [13]. However, an excess of dietary fat can affect the composition of the carcass due to increased lipid deposits and reduce the use of other nutrients [13]. On the other hand, dietary factor as feeding habits and nutritional status of fish can affect mineral and trace elements in fish. Minerals are inorganic elements that fish need for their different development stage, which they usually obtain through diet and water [19, 20]. In terms of minerals, dietary requirements in several fish distinguish two groups: macrominerals such as Ca, K, Mg, Na and P and microminerals such as Cu, Fe, I, Mn, Se and Zn, and several response

	Experimental diets						
	DC	D1	D2	D3	D4	D5	D6
Palm oil inclusion level	0%	3%	5%	7%	9%	15%	21%
Ingredients (g/100 g)							
Fish meal	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Soybean meal	19.00	19.00	19.50	20.00	21.00	22.50	24.50
Cottonseed meal	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Maize meal	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Wheat bran	29.00	26.00	23.50	21.00	18.00	10.50	2.50
Cassava starch	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Crude palm oil	00.00	3.00	5.00	7.00	9.00	15.00	21.00
Mineral mixture[1]	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Vitamin mixture[2]	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Proximate analysis							
Crude protein (%)	36.41	36.09	36.06	36.00	36.13	36.00	36.04
Crude lipid (%)	5.76	8.60	10.49	12.38	14.27	19.95	25.62
Ash (%)	8.94	8.89	8.88	8.87	8.88	8.85	8.84
Crude fiber (%)	3.73	3.63	3.58	3.52	3.48	3.31	3.15
NFE (%)	43.81	41.41	39.62	37.82	35.84	30.46	24.88
Digestible energy (kJg^{-1})[3]	13.97	14.71	15.21	15.71	16.22	17.73	19.25

NFE: Nitrogen free extract.[1]Composition for 1 kg of premix: Vitamin A 1.760000 IU, Vitamin D3 880,000, IU Vitamin E 22.000 mg, Vitamin B1 4400 mg, Vitamin B2 5280 mg, Vitamin B6 4400 mg, Vitamin B1236 mg, Vitamin C 151000 mg, (Vitamin K) 4400 mg, Vitamin PP 35200 mg, folic acid 880 mg, choline chloride 220,000 mg, Pantothenic acid D-14080 mg.

[2]Composition for 1 kg of premix: cobalt 20 mg, Iron 17,600 mg, Iodine 2000 mg, Copper 1600 mg, Zinc 60.000 mg, Manganese 10000 mg, Selenium 40 mg.

Table 1. Formulation and composition of the experimental diets (% dry weight).

criteria have been used to determine mineral requirements in different fish species [14]. In this study, the effect of the gradual incorporation of oil palm in the diet of juveniles *H. longifilis* was investigated.

The mineral proximate composition of the experimental diets in **Table 1** showed that, for the same mineral element, the contents were different according to the diets. As regards macrominerals, it should be noted that dietary Ca contents ranged from 72.8 to 231.3 g.kg^{-1}, with the highest level found in control diet and the lowest in diet D4. These calcium contents are widely higher compared to the dietary calcium requirements of channel catfish that were between 5 and 20 g.kg^{-1} [13]. P contents in diet ranged from 5.5 to 8.6 g.kg^{-1} and were in accordance with the fish P requirements which ranged from 0.5 to 0.9% of the diet [21]. Ca and P are

	Experimental diets						
	CD	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**
Palm oil inclusion level	0%	3%	5%	7%	9%	15%	21%
Mineral composition							
Ca ($g.kg^{-1}$)	231.34	136.8	105.42	108.68	140.47	72.82	140.88
P ($g.kg^{-1}$)	8.66	5.83	12.00	5.50	8.16	6.00	6.16
K ($g.kg^{-1}$)	66.02	78.95	100.25	86.18	82.54	33.56	68.9
Na ($g.kg^{-1}$)	82.36	75.39	78.31	99.41	61.56	45.36	59.09
Mg ($g.kg^{-1}$)	2.43	1.40	2.44	2.23	2.41	2.21	2.51
Fe ($mg.kg^{-1}$)	647.97	225.5	560.25	542.7	680.13	949.14	590.51
Zn ($mg.kg^{-1}$)	940.02	51.00	267.01	440.01	855.02	609.01	950.02
Mn ($mg.kg^{-1}$)	651.38	37.83	218.84	309.98	568.05	320.73	667.51

Table 2. Mineral composition of experimental diets (dry weight basis).

the two structural components that play an important role in the body of fish. Ca is involved in bone formation, muscle contraction and enzymatic activation and is also involved in bone development and fish growth [19, 21]. Phosphorus is the most important mineral element in fish. Because of the limited contribution from the aquatic environment, the fish is obliged to satisfy the needs through diet. A phosphorus deficiency results in decreased skeletal growth and bone deformation [21, 22]. The other macrominerals determined in the diets were K, Na and Mg. The diets showed fairly variable contents of K with a higher value (100.2 $g.kg^{-}1$) in diet D2 and the lowest (33.5 $g.kg^{--1}$) in diet D5. Dietary Na and Mg contents did not vary considerably and ranged from 45.3–99.4 and 1.4–2.5 $g.kg^{-}1$.

The microminerals analyzed in the experimental diets were Fe, Zn and Mn. Here too, it appeared that the contents were variable from one diet to another. Dietary Fe contents ranged from 225.5 to 949.1 $mg.kg^{-1}$ with the higher level obtained in diet D5 and the lowest in diet D1. Zn contents were between 51.0 and 950.0 $mg.kg^{-}1$ when Mn contents ranged from 37.8 to 667.5 $mg.kg^{-}1$. For these last two minerals, the highest levels are obtained in the D6 diet and the lowest in the D1 diet. The minimal and maximal requirements for fish reported in other studies were: Fe (65–493 $mg.kg^{-}1$), Zn (36–330 $mg.kg^{-}1$) and Mn (4.4–226 $mg.kg^{-}1$) [19].The values recorded in this study were in excess than dietary requirements mentioned for fish.

Whole-body macromineral composition of fish is presented in **Figure 1**. Body composition in calcium (Ca), potassium (k), sodium (Na), phosphorus (P) and magnesium (Mg) showed significant variations ($p < 0.05$) with the different dietary palm oil levels. The Ca content of whole body increased with increasing dietary palm oil levels at 5 and 9%. The highest value of Ca (168.49 ± 8.01 $g.kg^{-1}$) was recorded in fish fed with diet containing 9% of palm oil. Incorporation of palm oil at 3, 5, 7, 15 and 21% in diet increased fish whole-body K content and the highest value (98.54 ± 1.30 g.kg^{-1}) was obtained in the flesh fish fed with 9% dietary palm oil level. The same trend was observed for whole-body Na content, with the marked increase (87.50 ± 0.73 g.kg^{-1}) in fish fed with the diet containing 9% of palm oil. Change in dietary palm oil levels had significantly affected P on whole-body content of fish. Whole-body P content decreased with increasing palm oil levels in the diet, with the lowest value (6.68 ± 0.34) recorded in fish fed diet containing a 15% palm oil level. These values are generally higher than those reported by other works. For instance, Anthony Jesu Prabhu et al. [14] reported for Rainbow trout and Common carp the following values: for Ca, 5.2 ± 1.2 and 7.1 ± 0.8 g.kg^{-1}; Mg: 0.3 ± 0.2 and 0.25 ± 0.05 g.kg^{-1}; P: 4.8 ± 1 and 4.9 ± 0.7 g.kg^{-1}. In another study, Bogard et al. [23] obtained in Common carp Ca: 0.37 g.kg^{-1}, Mg: 0.26 g.kg^{-1} and P: 1.8 g.kg^{-1}.

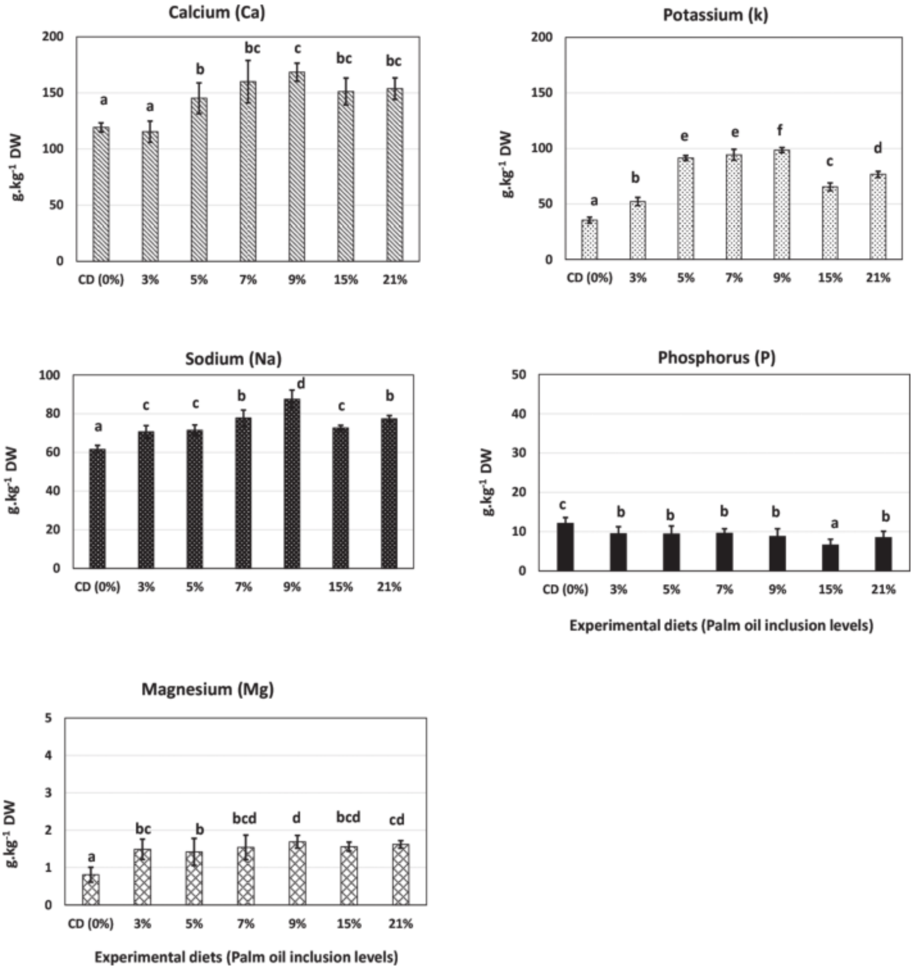

Figure 1. Whole-body Ca, k, Na, P, and Mg contents (wet weight basis) of *H. longifilis* fed graded levels of dietary palm oil for 50 days.

Fish whole-body micromineral composition in iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) was significantly affected ($P < 0.05$) by dietary palm oil levels, with different variations according to the mineral (**Figure 2**). Regardless of the mineral, the increase in the body was related with increasing dietary palm oil levels between 3 and 9% and the highest value was obtained in fish fed diet containing a 9% palm oil level. The highest value was: body Fe with 536.88 ± 38.74 ppm and that of Zn, Mn and Cu were 246.43 ± 4.09 , 48.24 ± 4.07 and 22.63 ± 0.91 mg.kg^{-1}, respectively.

Despite the variations described above, the whole-body mineral composition of *H. longifilis* was generally increased with increasing dietary palm oil levels. In this study, the diets were formulated to contain from 3 to 21% crude palm oil with dietary lipid levels ranging from 8 to 25%. Wang et al. [24] reported that crude lipid contents in the whole body and muscles were not significantly influenced by the dietary lipid source. It may be thought that the effect of palm oil on body composition may be related to lipid metabolism. Several studies in fish have reported that dietary lipid sources could regulate gene expression. Qui et al. [25] reported that dietary lipid source could influence hepatic fatty acid synthetic gene expression, gene expression related to fatty acid β-oxidation and lipid deposition in the muscle and liver.

It appears in the light of various works that fish whole-body mineral contents are highly variable from one species to another and often for the same species. This may be partly attributable to sampling variability and methodological differences in analysis and fish species.

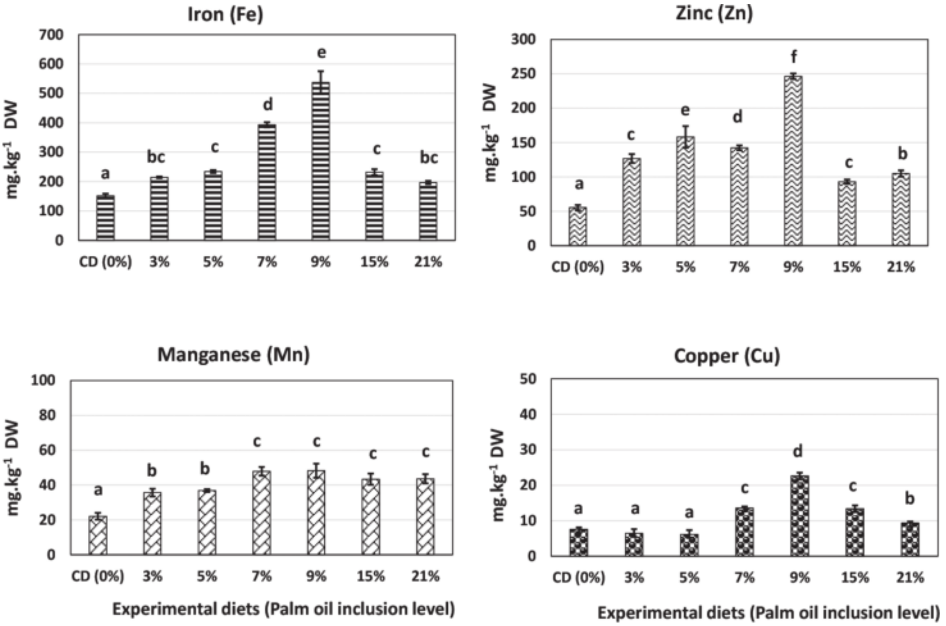

Figure 2. Whole-body Fe, Zn, Mn, and Cu contents (wet weight basis) of *H. longifilis* fed graded levels of dietary palm oil for 50 days.

However, the results obtained in this study are within the range of fish reported elsewhere [26]. Indeed, good results have been reported on the use of palm oil in the diets of several catfishes: *H. longifilis* [11, 27], *Mystus nemurus* [28] and *Clarias gariepinus* [9, 10, 29]. Other studies have also shown that inclusion of palm oil in the diet of tilapia did not affect hematology and organoleptic properties [30].

Although it has been proven that substantial quantities of palm oil can be used as energy substitutes in fish diets without negative effects on growth performance [11, 12, 28, 30, 31] it is important to determine the dietary level for optimal use that does not affect growth, whole-body composition and nutritional quality of fish. In Nile tilapia *Oreochromis niloticus*, [32] reported that 6% of dietary palm oil improved growth performance and fish recorded the highest level of whole-body docosahexaenoic acid (DHA). In view of the different studies on the incorporation of vegetable oils in fish feed, it appeared that palm oil, due to its fatty acid composition, is one of the best lipid sources that can be replaced by fish oil in aquafeed [5].

3. Conclusion

The results of this study showed that the incorporation of palm oil in the diet of juveniles of *H. longifilis* affected their whole-body mineral composition. Increasing the level of dietary palm oil from 3–9% resulted in increased whole-body macrominerals and micromineral contents. Previous studies have shown that dietary palm oil improved fish growth and feed utilization. This study suggests that palm oil modifies the whole-body mineral composition without major effects on health and nutritional quality of fish, confirming the interest of this oil as an ingredient for fish feed. Due to its nutritional value and relative low cost, palm oil is an interesting source of lipid to promote in the aquafeed manufacture for sustainable and profitable aquaculture.

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