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Impact of plant protein and oil sources on hydrochemical and growth indicators of African catfish (*Clarias gariepinus*) reared in aquarium

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Abstract

Ali, M., Stoyanova, S. & Sirakov, I. (2025). Impact of plant protein and oil sources on hydrochemical and growth indicators of African catfish (*Clarias gariepinus*) reared in aquarium. *Bulg. J. Agric. Sci., 31*(5), 1053–1060

The African catfish is a promising species in Bulgaria. It stands out due to its high growth rate, tolerance to varying water quality, and relatively high market price. The future of the Aquaculture sector depends on the lower use of fish meal and oil in the feed of hydrobionts. For years, plant sources have been increasingly used as alternatives to fish meal and oil, which contain protein and lipids. The present study aims to investigate the effect of replacing fish meal and oil with alternative sources, specifically seaweed and Ω-3 FORPLUS™, on the hydrochemical and growth indicators in cultivating African catfish *(Clarias gariepinus)*. The trial continued for 60 days, and the following indicators were measured daily to determine the effect of feeding with alternative protein and oil sources: temperature (°C), dissolved oxygen mg/L) L^{-1} active reaction (pH), and electric conductivity ($\mu S.cm^{-1}$). Control catches were performed at the beginning and end of the experiment. Based on these observations, the survival rate, weight gain, and final live weight were recorded, and the dietary coefficient was determined at the end of the trial. The hydrochemical indicators varied within the allowed ranges for African catfish. The survival rate was highest in fish fed the NEO feed. The weight gain of NEO feed-fed fish was highest, and so was the final live weight. The specific growth rate (SGR%) was highest in NEO feed-fed fish, and the dietary coefficient was lowest in the same group of fish.

Keywords: aquaponic system; African catfish (*Clarias gariepinus*); hydrochemical indicators; growth performance

Introduction

The African catfish (*Clarias gariepinus*) is the second most widely cultivated freshwater species after tilapia in Africa, except in Nigeria, where its production exceeds that of tilapia and accounts for 70–80% of the total output in the country. The species of the *Clarias* genus are significant for aquaculture in Africa. Throughout the years, they have become increasingly popular in Europe (Zaykov, 2000). African catfish is commonly consumed by people in Southeast Asia (Taufek et al., 2016). It is a preferred aquaculture species due to its palatable meat, resistance to diseases, and high fertility. It grows fast when cultivated in high stocking density (Erondu et al., 1993). The hydrobionts of this species may move for hours on land until they find a suitable site for new settlement, which is why they are also called "walking fish" (Zaykov, 2000). The African catfish has a dorso-abdominal, flat-headed body and a laterally flat body. It is an omnivorous fish species that prefers a predatory lifestyle (Zaykov and Staykov, 2014). Its food preferences include insects, worms, gastropods, crustaceans, small fish, water plants, as well as seeds, fruit, and even birds and small mammals. The larvae and small fish are almost dependent on zooplankton during the first week of their exogenous feeding (Uys,1989). Adult individuals, thanks to the high number of their gill teeth, also use zooplankton as a food source. Despite their omnivorous character, they tend to digest a high-protein diet better than carbohydrates (Romanova et al., 2017). The removal of their whiskers reduces their feeding efficiency by 23%. They catch their prey by swallowing it with a rapid opening of the mouth and holding it with their gill or curved teeth located in the oral cavity (Romanova, 2018).

African catfish is sensitive to temperature. When cultivating this fish in basins in the autumn-winter season, additional capital expenditures are required to maintain optimal temperature (Vlasov, 2014). Miles and Chapman (2007) claim that African catfish are demanding about the content of essential amino acids in the provided rations. The protein content must range between 40 and 42% during the various growth stages of the fish (Ov and Hecht, 1989). Ovie and Eze (2010) recommend the content of methionine to range between 29–32 grams per 1 kg of protein. Fish meal and fish oil are sources of protein and lipids in aquaculture. The digestibility of fish meal in fish is 89%, while in pigs, it is 85%, and in chickens, it is 94% (Barlow, 2003). The quantity of industrially caught fish used to feed hydrobionts decreases annually due to quotas imposed by the EU and stricter controls on illegal fishing (Tacon et al., 2011). In 2016, the share of fish meal and fish oil used in aquaculture dropped by 12% (Corino, 2018). In recent years, interest in plant protein has grown significantly, as the nutritional value of seaweed remains largely unknown. Seaweed has a wide range of applications in the global economy. Various species have been used in medicine, human nutrition, and agriculture (Corino et al., 2019). These plants have significant habitats in seawater, and some are even found in freshwater (O'Sullivan et al., 2010). Seaweed, which is used in aquaculture, may contribute to the sustainable development of the sector. Moreover, extensive research is required to demonstrate that they are a suitable alternative to the protein present in fish meal when preparing combined fodder for cultivating hydrobionts (Hardy, 2010; Ghosh et al., 2018). Some authors, such as Güroy et al. (2013), Khalafalla et al. (2015), Abdel-Aziz and Ragab (2017), and Davies (2021), have shown that the use of seaweed meal increases the growth indicators of experimental fish compared to those fed traditional fodder containing fish meal and oil. Abdel-Warith et al. (2016) and Serrano et al. (2021) believe that the use of seaweed meal as an alternative protein and oil source reduces the growth parameters of hydrobionts. While reviewing the scientific research in this area, we have found that the total replacement of fish meal and oil with an alternative source – seaweed is very contradictory, and more studies will be needed to prove whether they are a real alternative to the aforementioned nutrients.

The present study aims to establish the effect of replacing fish meal and oil with an alternative source – seaweed and Ω-3 –FORPLUS™ on the hydrochemical and growth indicators in cultivating African catfish (*Clarias gariepinus*).

Materials and Methods

The experiment lasted 60 days. The trial initially started with 90 fish in good health condition, without visible injuries, supplied by Aquafish Pazardzhik OOD.

The trial was conducted in the following experimental variants:

SUP (Supreme) – feed in which fish oil is replaced with Ω-3 – FORPLUS™, which is a replacement of fish oil, containing a high quantity of omega-3 fatty acids, and especially DHA.

NEO (NEOGREEN) – feed in which fish meal and oil are replaced by seaweed and Ω-3 – FORPLUS™.

ULT (Ultra) – control feed without fish meal and oil replacements, containing only as an additive mannan-oligosaccharide Bio-MOS.

The trial was conducted in two rounds. The average initial live weight of the fish from double repeats in the different experimental variants was the following:

- ULT – 25±0.52 g.
- NEO – 25.5±0.77 g.
- SUP – 24.5 ±0.76 g.

The stock density was 15 fish in an aquarium with a volume of 0.1 m^3.

For experimental purposes, we utilized the hatching facility of the Aquaculture Base at the Faculty of Agriculture, Trakia University. The hatching facility is equipped with an electric heater, which allows for the maintenance of a higher temperature to provide optimal conditions, close to the temperatures ideal for the African catfish. On a metal rack, we placed six aquariums. Prior to the experiment we filled each aquarium with water, and for 24 hours the aquariums were left with open lids to allow the chloride in the tap water we used from the university supply network to evaporate. Afterwards, each aquarium was equipped with a heater for additional water warming and an air pump. The tanks were cleaned daily. One third of the total water content of the aquariums was replenished with water from a container (with a pump fitted at the bottom) (Figure 1).

The trial was preceded by a 7-day adaptation period following the transportation of the fish. During the preparation of the experimental setting, all catfish were weighed individually with precision of up to 0.1 g. on the technical scales (Elicom S300PM). During the trial period of the experimental setting the number of dead fish was controlled daily and at the end of the trials we determined the survival rate (%) of each of the experimental variants. The dietary coefficient and the weight gain of the African catfish from each experimental variant were determined using the following formulas:

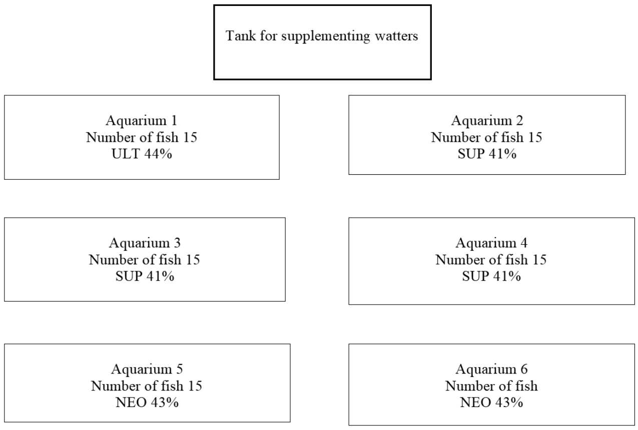

Fig. 1 Experimental seting

$$Weight\ gain = \frac{(Wf - Wi)}{n} \times 100$$

Wf – final average weight
Wi – initial average weight
n – interval (number of days)

Survival rate (Sr, %) $Sr \frac{NF}{NI} \times 100$

NI = initial number of fish
NF = final number of fish

Specific growth rate per day:

$$SGR\%.d^{-1} = \frac{\log Final\ weight - \log initial\ weight}{Experimntal\ periods\ in\ days} x100$$

Feed conversion ratio (FCR):

$$K = \frac{total\ quality\ of\ fed\ feed\ (g)}{weight\ quality\ gain\ of\ fish\ (g)}$$

where K – feed conversion ratio (FCR).

Fish were fed manually five times a day at 9:00, 11:00, 13:00, 15:00, and 16:00. The daily ration, which the catfish received, was 2% of their live weight. Three types of feed were used, produced by Alltech Coppens (Germany). The size of the food pellets was 3 mm, and the nutritional value and content of the fodder used during the current trial are presented in Tables 1, 2, and 3. The hydrochemical parameters were measured using the portable laboratory measuring device HQ-30D (Hach).

Table 1. Control fodder ULTRA

Nutritional content	Value
Protein(%)	44%
Oils(%)	25%
Crude fiber(%)	1.6%
P	0.84%
Gross energy (MJ kg^{-1})	23.4
Digestible energy (MJ kg^{-1})	21.3
Vitamin A (IE/ kg^{-1})	10.000
Vitamin D (IE/ kg^{-1})	1.240
Vitamin E (mg/kg^{-1})	200
Vitamin C (stabilizer) (mg/kg)	250

Table 2. Experimental fodder Supreme

Nutritional content	Value
Protein (%)	41%
Oils(%)	22%
Crude fiber (%)	2.00%
Ash(%)	8.00%
P	0.87%
Gross energy (MJ kg^{-1})	23.2
Digestible energy (MJ kg^{-1})	19.2
Vitamin A (IE/kg^{-1})	8936

Table 3. Experimental fodder Neogreen

Nutritional content	Value
Protein(%)	43%
Oils(%)	28%
Crude fiber(%)	1.7%
Ash	7.4%
P	1.20%
Gross energy (MJ kg^{-1})	23.2
Digestible energy (MJ kg^{-1})	21.2
Vitamin A (I kg^{-1})	10.000
Vitamin D (IE kg^{-1})	1.330
Vitamin E (mg kg^{-1})	200
Vitamin C (stabilizer) (mg kg^{-1})	

Results and Discussion

Temperature is the limiting factor in cultivating African catfish. The data analysis (presented in Figure 2) shows that the temperature in the aquariums used to cultivate the hydrobionts fed with SUP feed has the highest mean value: 28.53±2.16°C, which is 4% higher than the control variant (ULT), however, without any statistically significant differences ($p>0.05$). The difference between the experimental variants SUP and NEO regarding this indicator was 2.2% in favor of the tanks in which the fish were fed with SUP feed, without any statistically significant difference ($p > 0.05$).

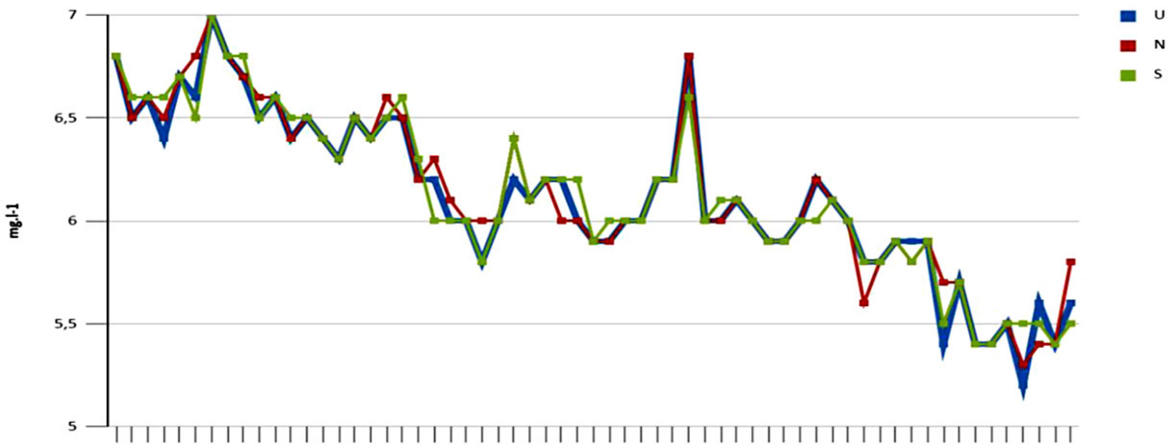

Fig. 2. Water temperature in control tank (U) experimental (N,S) tanks

According to Zaykov and Staykov (2014), the temperature range within which African catfish can be cultivated is between 12–14°C and 35°C, although it grows best at 28–30°C. Our results regarding temperature align with those of Suleiman and Solomon (2017). They think that the optimal temperature for cultivating African catfish is 24–28°C. According to Al-Deghayem et al. (2014), a temperature above 24°C is suitable for the intensive feeding of African catfish, which is also undemanding in terms of oxygen quality in the water. Our results regarding this indicator are presented in Figure 3.

The experimental data indicate that the mean oxygen value in the aquariums with hydrobionts, fed with NEO feed at 6.8±0.68 mg/L, is the largest, which is a 1.5% higher mean value of this indicator than the one detected in hydrobionts fed with SUP feed. However, the difference is not statistically significant ($p > 0.05$). The mean value of this indicator in fish fed NEO feed is 4.6% higher than that measured in the aquariums in the control variant ULT, without significant differences ($p > 0.05$). According to Zaykov and Staykov (2013), oxygen in intensive feeding of African catfish should not fall below 3 mg/L. Ajiboye et al. (2015) think that levels of dissolved oxygen over 3 mg/L are suitable for this species of hydrobionts. Conceição et al. (1998) can report that African catfish may survive at oxygen levels below 1 mg/L.

African catfish *(Clarias gariepinus)* is not sensitive to the active reaction of water. During the experiment (the data are given in Figure 4), the highest mean value of hydrogen ions is detected in the aquariums where hydrobionts from the SUP group are fed: 7.2±0.35, which is a 4.3% higher mean

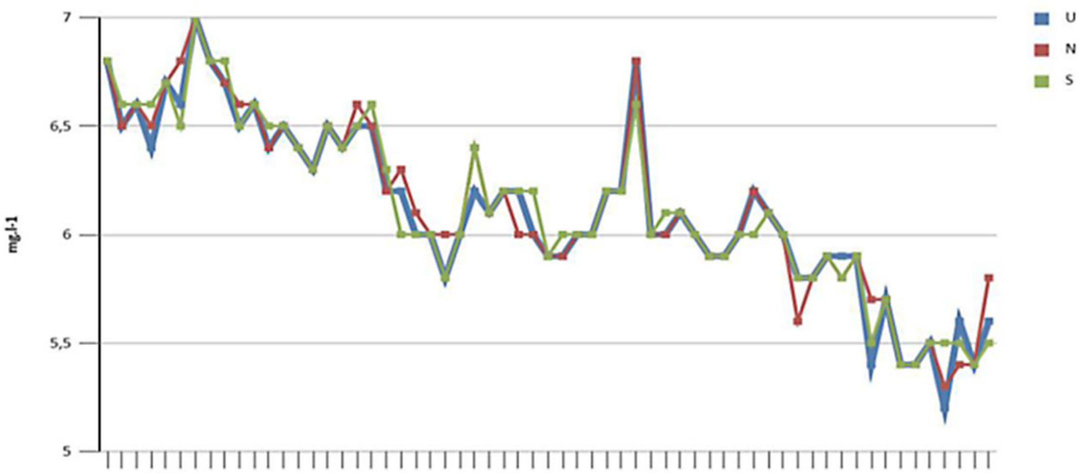

Fig. 3. Dissolved oxygen in control (U) experimental (N,S) tanks

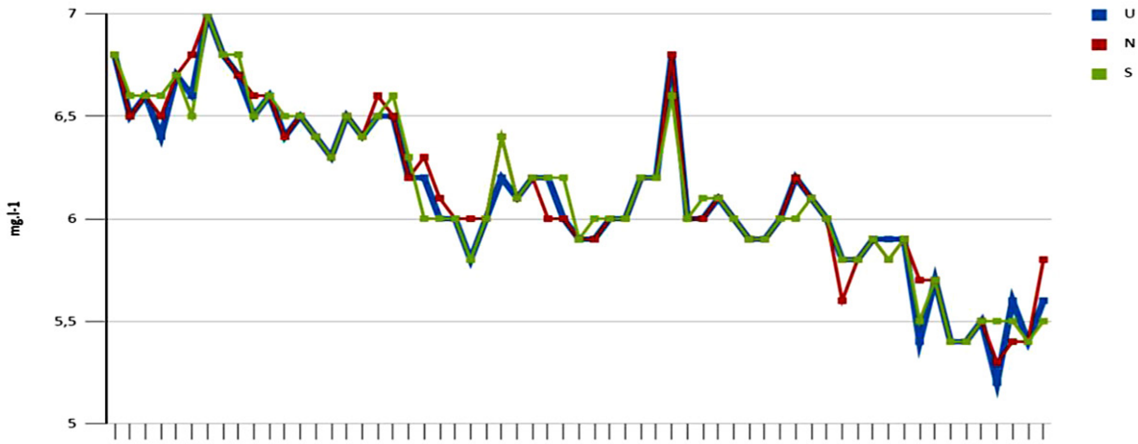

Fig. 4. pH in control (U) experimental (N,S) tanks

value than the one found in the tanks with fish fed with the NEO variant. The difference is minimal and not statistically significant ($p > 0.05$).

The difference in this indicator between the experimental variants SUP and ULT is a 1% higher mean value for SUP; however, this difference is not statistically significant ($p > 0.05$).

Ndubuis et al. (2015) inform that values below 2.3 pH and above 10 pH are lethal for this type of hydrobiont. Boyd et al. (1982) believe that African catfish cannot tolerate values of this indicator below 4 pH or above 10 pH. From the performed analysis, we have found that the obtained results for water pH during the trial fall within the allowed limits for the cultivated species.

During the trial (presented in Figure 5), the highest the mean value of the electric conductivity in the aquariums with fish from the NEO variant: 288±1.2 µS.cm^{-1}, which is 2.1% higher than the mean value of this indicator in the control variant ULT, but the difference is not statistically significant ($p > 0.05$). Between the trial groups NEO and SUP regarding this indicator, we note 1% higher value of the electric conductivity in the NEO tanks, yet the differences are minimal and statistically unproven ($p > 0.05$).

The initial live weight of fish fed with NEO feed is the highest, but there is no statistically significant difference compared to the obtained results in the ULT variant ($p > 0.05$).

The final average live weight of hydrobionts from the NEO group is the highest: 183.5±5.25 g, while the difference for this indicator in ULT-fed fish is 3.2% in favor of the NEO grup, but is statistically insignificant ($p > 0.05$). When the mean values for the final live weight are compared between the NEO and SUP variants, a 1.68% higher live weight of Af-

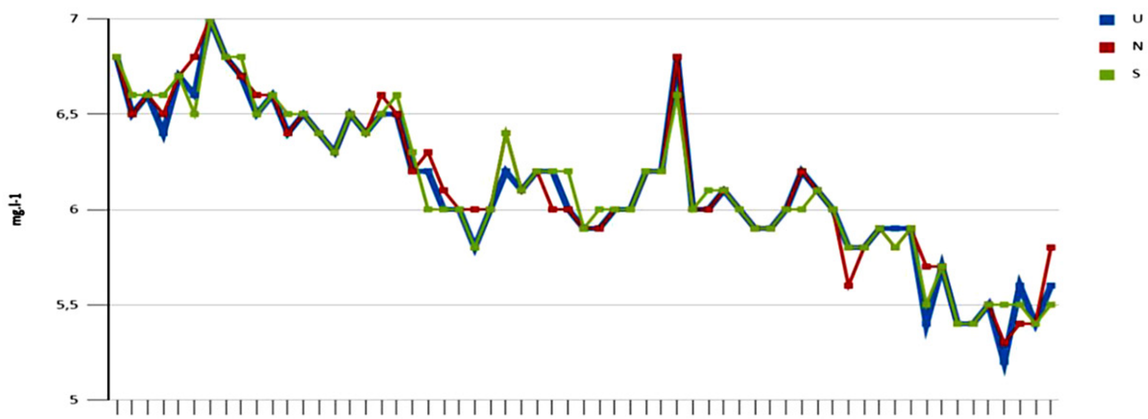

Fig. 5. Electric conductivity in control (U) experimental (N,S) tanks

Table 4. Survival rate and growth indicators in cultivating African catfish in aquariums. Control (U) experimental tank(N,S) tanks

Indicator	ULT *x* ±***SD***	NEO *x* ±***SD***	SUP *x* ±***SD***
Survival rate, %	70±0.85a	83±0.65b	76±0.82a
Initial weight, g.	24.5±0.52	26.2±0.77	25±0.76
Final live weight, g.	177.5±6.15	183.5±5.25	180.4±5.12
Weight gain, g.	153±14.1	157.3±12.8	155.4±12.4
Specific growth rate (SGR %)	2.55±0.08	2.62±0.04	2.58±0.09
Feed conversion ratio (FCR)	1.21	1.08	1.14

(P > 0.05).

rican catfish is determined in the NEO variant, as the noted difference is minimal and statistically unreliable ($p > 0.05$).

The weight gain of the NEO-fed group of fish is the highest: 157.3±12.8 g. The obtained results show that the difference with the ULT-fed grup, which show 2.73% higher gain is in favor of the NEO fed grup, but is statistically unreliable ($p > 0.05$). During a comparison between NEO grup and SUP fish, we found a 1.2% higher value of the results in favor of the NEO fish, but the difference is not statistically significant ($p > 0.05$).

The obtained values for the indicator related to the specific growth rate of fish show that the NEO grup have the fastest growth rate: 2.62±0.04, which is 2.67% higher compared to the ULT fish, however the difference is not statistically proven ($p > 0.05$). The difference in the specific growth rate between the NEO and SUP fish is also 1.52% in favor of the NEO group, yet it is not statistically proven ($p > 0.05$).

At the end of the experiment, the analysis shows that the NEO grup have utilized the feed most effectively. The feed conversion ratio in the experimental variant NEO is 1.08, which is 10.75% lower than the FCR from the established value for the control variant fish. However, the difference is not significant ($p > 0.05$). The difference between NEO and SUP is a 5.26% lower FCR in fish from the NEO trial variant compared to the fish from the control variant; however, the difference is not statistically significant ($p > 0.05$).

El-Boshy et al. (2014) confirm our results related to the positive impact of seaweed on the survival rate in feeding African catfish. Thépot et al. (2022) express a similar opinion to ours regarding the survival rate of fish. The authors think that seaweed meal feeding (*Asparagopsis taxiformis*) stimulates the survival rate of Atlantic salmon (*Salmo salar*). Enyidi (2017) supports our data for growth, specific growth rate, and lower feed conversion ratio in feeding African catfish (*Clarias gariepinus*) with partial addition of seaweed meal. However, Costa et al. (2013) share their results, which contradict ours. In the use of powder from the seaweed *Ascophyllum nodosum* as a partial replacement of protein in feeding tilapia (*Oreochromis niloticus*), the authors conclude that feeding with an alternative protein source does not increase the growth parameters of fish. Seong et al.(2022) use the seaweed *Schizochytrium* and rapeseed oil as a source of proteins and oils in feeding species of the *Carangida* family. The team believes that feeding fish with alternative sources of protein and oil reduces their growth indicators, which contradicts our data on growth.

Conclusion

Feeding with alternative sources of proteins and oils, as well as with control feed (NEO, SUP, ULT) does not have an impact of the hydrochemical parameters. The highest temperature value was the control feed SUP. The highest oxygen value was in the control feed NEO. The highest pH value was observed in the control feed SUP. The highest electric conductivity value was the control feed SUP. But feeding the fish with alternative sources of protein and oil showed no significant differences.

Feeding African catfish with alternative sources of proteins and oils resulted in increased values of observed growth indicators – survival rate, weight gain, final live weight, and dietary coefficient – compared to the values of these indicators in catfish fed with ULT control feed.

We recommend the usage of algae meal in fish feeding increases the sustainability in aquaculture, allowing for a decrease in fish meal and fish oil quantity used for fish feeding purposes.

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