Food and Nutrition Sciences, 2021, 12, 526-543
https://www.scirp.org/journal/fns
ISSN Online: 2157-9458
ISSN Print: 2157-944X

Effect of *Zingiber officinale* and *Allium sativum* Powders as Natural Feed Additives Promoting Growth, Feed Utilization and Whole-Body Composition in *Clarias gariepinus* Fry

Paulin Nyadjeu*, Doriane Divine Mane Yemdjie, Noël Arlette Tamko Ndjuissi, Ghislain Nguimdop Nguenang, Nesrine Yolande Chamsy Dedou, Minette Eyango Tabi-Tomedi

Department of Aquaculture, Institute of Fisheries and Aquatic Sciences of Yabassi, University of Douala, Douala, Cameroon
Email: *epauka@yahoo.fr

How to cite this paper: Nyadjeu, P., Yemdjie, D.D.M., Ndjuissi, N.A.T., Nguenang, G.N., Dedou, N.Y.C. and Tabi-Tomedi, M.E. (2021) Effect of *Zingiber officinale* and *Allium sativum* Powders as Natural Feed Additives Promoting Growth, Feed Utilization and Whole-Body Composition in *Clarias gariepinus* Fry. *Food and Nutrition Sciences*, **12**, 526-543.
https://doi.org/10.4236/fns.2021.126040

Received: May 15, 2021
Accepted: June 15, 2021
Published: June 18, 2021

Abstract

Nutrition is the main factor determining the potential of farmed fish to exhibit their growth capacity as a function of the protein content and certain additives contained in their diet. Thus, the present study was conducted to assess dietary supplementation effects of ginger and garlic as feed additives on growth, feed utilization and whole-body composition in *Clarias gariepinus* fry. Following a 24 h fasting, 525 fry weighing 1.2 ± 0.01 g were randomly divided in triplicate into five treatments of 105 fish each and fed for 56 days. In treatment T0, fry was fed with control basal diet, in treatments T1 and T2, fry was fed with basal diet containing 1% and 2% ginger, while in treatments T3 and T4, fry was fed on basal diet supplemented with 1% and 2% garlic. Fish were fed at the rate of 10% of their body weight and every 14 days, intermediate fish sampling was done during which fry per treatment was counted, measurements taken on a representative sample and the feeding rate adjusted. Main water parameters were recorded daily before feeding. After the feeding trial, fish fed 1% (T3) garlic had the best growth performance in term of final weight (33.01 ± 2.99 g), weight gain (WG) (31.81 ± 0.99 g), specific growth rate (SGR) (5.86 ± 0.16%/d) and feed conversion ratio (FCR) (1.25 ± 0.11) which was significantly different from other treatments, particularly T0 which had the lowest growth performances (final weight (17.02 ± 0.27 g), WG (15.81 ± 0.28 g), SGR (4.73 ± 0.03%/d) and FCR (2.03 ± 0.01)). Similar trend to growth parameters was found with whole-body composition (moisture, crude protein, crude lipid, ash, and energy) and nutrient retention. In conclusion, *C. gariepinus* fry fed 1% dietary inclusion level of garlic has had better growth, feed utilization and body composition, which has been more attributed to its physiological and pharmacological properties than its nutritional effects.

Keywords

Clarias gariepinus, Ginger, Garlic, Growth

1. Introduction

Fish is highly nutritive and is the main source of animal protein for around one billion people worldwide [1]. Its demand for human consumption has grown exponentially in Africa, due to the rapid increase in the population size [2]. Unfortunately, this high demand is struggling to be met only by fishing due to the decline in wild stocks observed in most fisheries. Although aquaculture was introduced in sub-Saharan Africa and in Cameroon in particular since the years 1948, its development is still timid despite a slight increase in aquaculture production estimated at 3% [3]. Despite this slight increase in production observed, the national contribution to African aquaculture production, whose share in world production, estimated in 2017-18 at 18%, is very negligible; yet climatic and environmental conditions as well as the availability of a vast hydrographic network are major assets for the development of all forms of aquaculture [4]. Among the species commonly encountered in Cameroon's fish farms, African catfish, *Clarias gariepinus*, is the most prominent and cultured species, either in polyculture with Nile tilapia and/or Common carp in fertilized ponds, or in monoculture in concrete tanks or fastanks mounted, in closed or open circuit and supplied with borehole water. *Clarias gariepinus* exhibits numerous advantageous characteristics for cultivation such as rapid growth, good survival in high density culture, tolerance to low oxygen levels as well as pH fluctuations, and resistance to diseases [5]. It however requires high quality feeds with high protein content and some additives or dietary supplements to keep fish healthy and to enhanced growth [6] [7]. Among products used as feed additives in animal feeding in general and aquaculture in particular, are medicinal plants (phytobiotics), which properties have been widely recognized to enhance growth, feed utilization, and aquaculture productivity, performances and sustainability [8]. Phytogenic feed additives, also called phytobiotic products are natural biodegradable products of plant origin whose integration in the diets of several fish species improves performances through amelioration of feed properties, promotion of production performances and improving the quality of the product intended for the final [9]. Also, ginger as well as garlic being natural and readily available additives, has been reported to promote various activities like anti-stress, immunostimulation, appetite stimulation, and growth promotion in fish [10] [11] [12]. Their inclusion in fish diet might be a possible solution to the inadequacy of table fish supply in Cameroon in general, hence increasing the

African catfish market in particular.

Garlic (*Allium sativum L.*), used as spice and in traditional medicine since ages belong to family Liliaceae. It is one of the natural immuno-stimulants used to control pathogenic infections in animals, including fish [13]. Phytochemical and nutritional analyses revealed that garlic contains at least 33 sulphur compounds, 17 amino acids, several enzymes, minerals and vitamins. It has been reported to be antibacterial, antiviral, antifungal, antioxidant, antiprotozoal and an effective immuno-stimulant, growth promoter and improves flesh quality owing to the presence of various organ sulphur compounds [14]. Allicin (dially thiosulfinate), responsible for most of the pharmacological properties of garlic is the most abundant compound representing about 70% of all thiosulfinates present, or formed in crushed garlic [15]. It is the most powerful organ sulphur component present in garlic that actively kills parasites and pathogenic bacteria and has been found to regulate oxidative stress and immune responses by enhancing immuno-competence, improving gastrointestinal motility and modulating the secretion of various enzymes to improve digestion and nutrient absorption. It also improves digestion by promoting the performance of the intestinal flora, thereby enhancing the utilization of energy and improving growth [16] [17].

Ginger (*Zingiber officinale*), a flowering plant whose rhizome is commonly used as spice and flavouring agent, belongs to the family Zingiberaceae [18]. Ginger is also considered as a safe herbal medicine used in diseases treatment in many countries worldwide [19]. It contains compound such as alkaloids, flavonoids, polyphenols, saponin, steroids, tannin, fiber, carbohydrate, vitamins, carotenoids and minerals [20] [21] and natural antioxidants as gingerols, shogaols and zingerone [22]. Ginger is reported antiplatelet, antibacterial, antifungal, antiviral, antiworm, anti-inflammatory, antihyperglycemic, antilipidemic, anti-oxidative activity and is also known to be effective as an immuno-modulatory agent in human and animals, including fish [23]. Supplementing ginger in fish diets has been reported to enhance growth survival and body composition [24] [25].

Although it has been reported in previous studies that garlic and ginger have been found to strengthen immunity and uplift health status, enhance growth and flesh quality in freshwater fish like common carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) [7] [26] [27], studies in respect to their efficacy in African catfish in general and during nursery operations in particular are inadequate. Hence, the aim of the present study was to evaluate the effect of garlic and ginger powders as feed additive on growth criteria, feed nutrients utilization and whole-body composition in African catfish fry.

2. Materials and Methods

2.1. Experimental System

The study was carried out from April to May 2020 in the technical facilities (hatchery unit) of a small-scaled private farm named "Massoma fish farm" at Bojongo-Bonaberi, Wouri Division, Littoral Region of Cameroon. The experiment was conducted in fifteen (15) circular plastic tanks of 10 litres each, filled at two-third (6.5 litres) with water. All the tanks were mounted in an open circuit connected by a pressurized piping system of diameter 25 mm and supplied with borehole water by the means of a pump.

2.2. Preparation of the Feed Additives

Fresh ginger (*Zingiber officinale*, cameroonian yellow ginger) and fresh garlic bulbs (*Allium sativum*, cameroonian white garlic) were procured from a local market. The dry skin of both fresh garlic and ginger was removed before use; they were peeled and cut into small pieces then dried in oven at 60˚C for 24 hours in the department of Processing, Quality Control of Aquatic Products of the Institute of Fisheries and Aquatic Sciences. The dried ginger and garlic were crushed into powdered form mechanically and sieved with a hand sieve to obtain 500 g of each of the powders which were then stored in airtight containers till formulation and preparation of experimental diets.

2.3. Experimental Diets

Five isonitrogenous (45% CP) diets were formulated using the Pearson's square method and distributed to *C gariepinus* fry divided into five treatments. Dietary treatments included T0 (0%AS/ZO) in which fry fed basal diet or control diet, T1 (1%ZO) and T2 (2%ZO) in which fry was fed with basal diet containing 1% and 2% ginger powder respectively, T3 (1%AS) and T4 (2%AS) in which fry fed basal diet supplemented with garlic powder at 1% and 2% respectively. Feed ingredients used for the experimental diets include: ginger powder, garlic powder, fish meal, soya bean cake, peanut cake, maize meal, Wheat bran, vitamin/mineral premix and bone meal. The formulation was based on the percentage composition of the ingredient (Table 1). To prepare the diets, the dried and grinded ingredients of each diet were weighed and mixed thoroughly in a bowl, palm oil and warm water were then added slowly along to the mixture and mixed manually for about 30 minutes to achieve a proper consistency. The resulting mixture was pelletized (2 mm) using an electric pelleting machine and allowed to dry for 24 h by air circulation before being packed into airtight containers and stored at room temperature to be crumbled before use. Formulated diet samples (10 g) were analysed following the procedures of AOAC [28]. Moisture was analysed by drying the sample in an air convection oven at 105˚C overnight. Crude protein was analysed by the Kjeldahl method after acid digestion ((%) crude protein = nitrogen (%) × 6.25) while crude lipid was determined by extraction with petroleum ether using the Soxhlet method. The ash content in the diet was analysed by combustion of samples in a muffle furnace at 550˚C for 12 h (Table 1).

2.4. Fish and Experimental Design

Five hundred and fifty-five (555) *Clarias gariepinus* fry with mean weight of 1.2

Table 1. Formulation and proximate composition of experimental diets (g/100 g dry weight).

Ingredients	T0: 0%ZO/AS	T1: 1%ZO	T2: 2%ZO	T3: 1%AS	T4: 2%AS
Fish Meal	46	46	46	46	46
Soybean cake	20	20	20	20	20
Peanut cake	19	19	19	19	19
Maize meal	6.5	6.5	6.5	6.5	6.5
Wheat bran	4.5	4.5	4.5	4.5	4.5
Ginger	0	1	2	0	0
Garlic	0	0	0	1	2
Premix	1	1	1	1	1
Bone meal	1	1	1	1	1
Palm oil	2	2	2	2	2
Biochemical composition (%)					
Protein	45.18 ± 0.31	45.37 ± 0.4	45.42 ± 0.52	45.69 ± 0.92	45.79 ± 0.16
Lipid	8.18 ± 0.01	8.54 ± 0.00	8.95 ± 0.03	8.11 ± 0.03	8.58 ± 0.03
Ash	4.85 ± 0.14	5.05 ± 0.07	5.101 ± 0.18	5.35 ± 0.07	5.21 ± 0.07
Moisture	5.73 ± 0.04	4.69 ± 0.03	4.83 ± 0.04	5.69 ± 0.01	4.20 ± 0.28
Dry matter	94.27 ± 0.04	95.31 ± 0.03	95.70 ± 0.04	94.43 ± 0.01	95.8 ± 0.28
Energy (kJ/100 g DW)	1763.56 ± 0.64	1767.74 ± 0.28	1775.44 ± 0.85	1750.10 ± 0.42	1765.65 ± 0.42

± 0.01 g resulting from an artificial reproduction carried out in the farm hatchery were randomly distributed in 15 breeding tanks and allowed to acclimatize for 7 days before the beginning of the treatment regime. During the acclimatization period, fish were fed with a commercial feed (Coppens 0.2 mm, the Netherlands). The fish were starved for 24 hours before the start of the experiment after which, thirty fish (2 per breeding thank) were randomly pick up for initial determination of the carcass composition. The remaining fry (525) distributed into 15 breeding tanks of 35 fish each were divided in triplicate into five dietary treatments named T0 (0%AS/ZO), T1 (1%ZO), T2 (2%ZO), T3 (1%AS) and T4 (2%AS). Fish were hand-fed four times daily (08:00 a.m, 11:00 p.m, 14:00 p.m and 17:00 p.m respectively) with different diets at a rate of 10% of their body weight (BW) during the first 28 days of feeding and 5% for the rest of the feeding period, with feeding ration being adjusted in accordance to weight gain of fish after random sampling at 14 days interval. Every day before feeding, the physico-chemical parameters such as temperature (T˚C) was measured using a Maximum-minimum thermometer, dissolved oxygen (D.O), using JBL Test Kits, pH, nitrite (NO_2^-) and nitrate (NO_3^-), using Test strips (JBL Easy Test 6in1) (Table 2). During intermediate samplings, fifteen fish from each tank were randomly harvested to record growth in terms of total body length (TBL) and body

Table 2. Water quality parameters (Mean ± SD) during 56 days of the experimental period.

Parameters	Rearing period (days)				
	1	14	28	42	56
T (˚C)	27.80 ± 0.00	28.90 ± 0.00	28.70 ± 0.00	27.50 ± 0.00	27.30 ± 0.00
pH	6.80 ± 0.20	6.80 ± 0.20	6.70 ± 0.20	6.80 ± 0.20	6.70 ± 0.20
D.O (mg/l)	7.30 ± 0.22	7.50 ± 0.11	7.50 ± 0.01	7.3 ± 0.06	7.30 ± 0.06
NO_2^- ($mg \cdot l^{-1}$)	0.0 ± 0.00	0.20 ± 0.01	0.30 ± 0.02	0.30 ± 0.01	0.30 ± 0.02
NO_3^- ($mg \cdot l^{-1}$)	0.00 ± 0.00	5.00 ± 0.03	6.00 ± 0.01	6.00 ± 0.01	6.00 ± 0.04

weight (BW). At the end of the feeding trial, fish were harvested and then weighed as total fish weight of each replicate within dietary treatment and counted for calculation of both the growth and feed efficiency parameters. Fifteen fish (five fish per tank) from each treatment were selected to analyse the final proximal composition of the carcass according to the method of Association of Official Analytical Chemistry AOAC [28].

2.5. Growth and Feed Efficiency Parameters

Growth performances, survival rate, feed utilization and nutrients retention were assessed for each treatment by determination of weight gain (WG), length gain (LG), specific growth rate (SGR), survival rate (SR), condition factor (K), Feed intake (FI), feed conversion ratio (FCR), feed efficiency ratio (FER), protein efficiency ratio (PER) and nutrients retention (NR). Calculations were carried out using the following formulae:

1) $\text{WG}(\text{g}) = \text{Wf} - \text{Wi}$;

2) $\text{LG}(\text{cm}) = \text{Lf} - \text{Li}$;

3) $\text{SGR}(\%/\text{day}) = \frac{\ln \text{Wf} - \ln \text{Wi}}{\text{T}} \times 100$;

where: Wf = final weight; Wi = initial weight; Lf = final length; Li = initial length; T = number of days in the experimental period;

4) $\text{SR}(\%) = \frac{\text{final number of fish}}{\text{initial number of fish}} \times 100$;

5) $\text{K} = \frac{\text{Weight}}{\text{Length}^3} \times 100$;

6) $\text{FI}(\text{g/fish}) = \frac{\text{total dry feed distributed}}{\text{number of fish}}$;

7) $\text{FCR} = \frac{\text{feed intake}}{\text{Fish weight gained}}$;

8) $\text{FER} = \frac{\text{Fish weight gained}}{\text{feed intake}}$;

9) $\text{PER} = \frac{\text{Fish weight gained}}{\text{protein fed}}$,

where, $\text{Protein fed} = \frac{\text{Total feed consumed} \times \text{Crude protein in feed}}{100}$;

10) $$\text{NR}(\%\ \text{dry feed intake}) = \frac{\text{Final carcass composition} - \text{Initial carcass composition}}{\text{Amount of nutrient fed}} \times 100.$$

2.6. Statistical Analysis

The data obtained were tested for normality and homogeneity of variances and analysed by one-way analysis of variance (*ANOVA*-1) repeated measure followed by Tukey's multiple comparison test. Results are expressed as mean ± Standard Deviation (SD). The statistical analysis was performed using *GraphPad Prism* version 6.0. Treatment effects were considered significant at $p < 0.05$; n = 3 replicates of 35 fry each.

3. Results

3.1. Growth Performances

Clarias gariepinus fry was observed to feed voraciously on all dietary diets all over the feeding period. The results are shown in **Figure 1** and indicated that weight gain (A) and length gain (B) were increased with the increase of time, but independently to the inclusion level of ginger and garlic powders. Fish fed with diet T3 have presented at the end of the experimental period a value of the weight gain of 31.81 ± 0.99 g, significantly ($P < 0.05$) higher by 50.30%, 31.47% and 33.92% compared to T0 (15.81 ± 0.28 g), T1 (21.80 ± 0.80 g) and T2 (21.02 ± 0.58 g) respectively.

Specific growth rate of *Clarias gariepinus* fry fed with different dietary diets for 56 consecutive days is presented in **Figure 2**. It is noted that whatever the treatment, fry growth which is faster during the first weeks of feeding, gradually decreases with the increase of the experimental period. At the end of the culture period, fish fed on diet T3 containing 1% of garlic powder have presented a specific growth rate value of 5.86 ± 0.16%g/d), significantly high ($p < 0.05$) by 19.28%, 10.10%, 11.10% and 6.82% as compared to treatments T0 (4.73 ± 0.04%g/d), T1 (5.27 ± 0.14%g/d), T2 (5.21 ± 0.21%g/d) and T4 (5.46 ± 0.11%g/d)

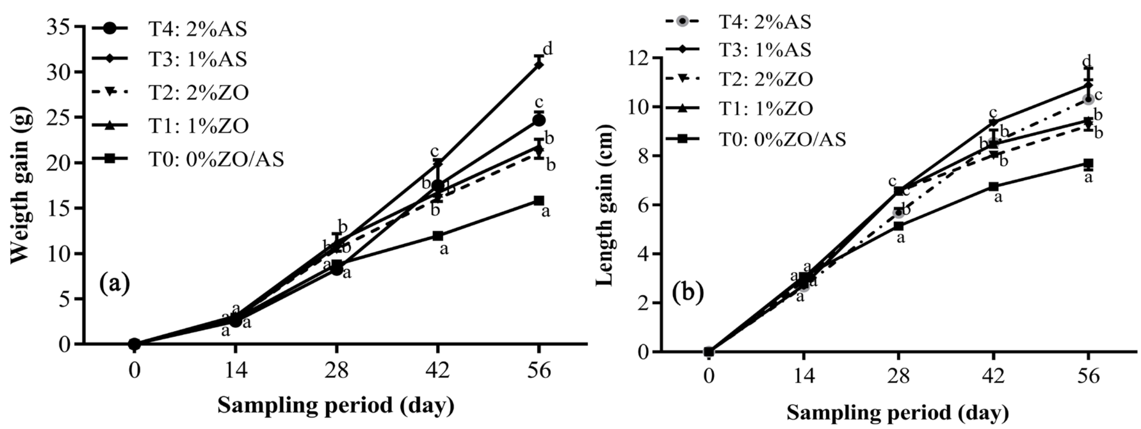

Figure 1. Weight gain (a) and length gain (b) of *Clarias gariepinus* fry fed with different diets for 56 days. Means on the same sampling period carrying different superscripts are significantly different from each other at $p < 0.05$.

respectively.

3.2. Survival Rate and Feed Nutrients Utilization

Table 3 presents the survival rate and feed nutrients utilization in *C. gariepinus* fry at the end of the feeding period. It is noticed that, even though no significant difference is observed amongst treatments, mortalities occurred in all treatments

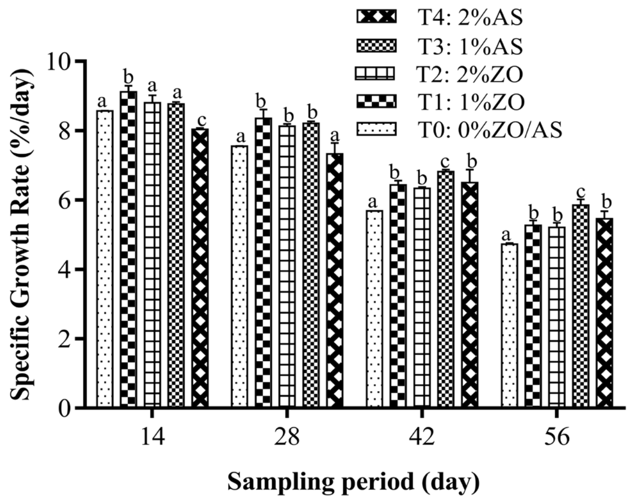

Figure 2. Specific growth rate of *Clarias gariepinus* fry fed with different diets for 56 days. Means on the same rearing period carrying different superscripts were significantly different at $p < 0.05$.

Table 3. Survival and feed utilization of *Clarias gariepinus* at the end of the feeding study.

Parameter	T0: 0%ZO/AS	T1: 1%ZO	T2: 2%ZO	T3: 1%AS	T4: 2%AS	p
Ni	105	105	105	105	105	
Nf	68	74	72	71	77	
Wi (g)	1.21 ± 0.01	1.20 ± 0.01	1.20 ± 0.01	1.20 ± 0.01	1.21 ± 0.01	ns
Wf (g)	17.02 ± 0.27^{a}	23.02 ± 1.79^{a}	22.30 ± 1.59^{a}	33.01 ± 2.99^{b}	25.90 ± 2.90^{a}	*
Li (cm)	5.03 ± 0.005	5.10 ± 0.04	5.02 ± 0.015	5.04 ± 0.01	5.03 ± 0.00	ns
Lf (cm)	12.73 ± 0.27^{a}	13.93 ± 0.42^{ab}	14.24 ± 0.16^{ab}	15.92 ± 0.69^{c}	15.33 ± 0.8^{bc}	*
FI (g/fish)	30.69 ± 0.74^{a}	36.08 ± 0.48^{b}	36.67 ± 0.64^{b}	37.45 ± 0.48^{b}	33.03 ± 0.42^{a}	**
PI (g/fish)	13.81 ± 0.33^{a}	16.14 ± 0.10^{b}	16.50 ± 0.74^{b}	16.86 ± 0.21^{b}	14.86 ± 0.46^{a}	**
SR (%)	65.00 ± 4.56	70.00 ± 4.04	69.00 ± 2.52	68.00 ± 1.73	73.00 ± 1.73	ns
K	0.83 ± 0.04^{a}	0.84 ± 0.01^{a}	0.77 ± 0.03^{ab}	0.79 ± 0.03^{ab}	0.72 ± 0.03^{b}	*
FCR	2.03 ± 0.01^{a}	1.70 ± 0.00^{b}	1.79 ± 0.05^{b}	1.25 ± 0.11^{c}	1.36 ± 0.00^{d}	***
FER	49.38 ± 0.74	58.96 ± 1.34	55.90 ± 0.62	80.61 ± 0.70	73.28 ± 1.07	***
PER	1.10 ± 0.01^{a}	1.31 ± 0.01^{b}	1.24 ± 0.01^{b}	1.79 ± 0.01^{c}	1.63 ± 0.01^{d}	***

Values are mean ± standard deviation of three replicates of 35 fish each. Mean within the row with different superscripts are significantly different each other at $p < 0.05$. ns, $p \geq 0.05$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. Ni, initial number of fish; Nf, final number of fish; Li, initial length of fish; Lf, final length of fish; FI, feed intake; PI, protein intake; K, condition factor; FCR, feed conversion ratio; FER, feed efficiency ratio; PER, protein efficiency ratio.

with the lowest value of survival rate of 65.00% ± 4.56%, obtained with control diet T0 (0%AZ/AS) and the highest value of 73.00% ± 1.73% obtained in fry with fed the experimental diet T4 (2%AS). the determination of feed nutrients utilization parameters indicate that fish fed with diet T3 (1%AS) have expressed better feed utilization characteristics with significant differences as far as feed intake (37.45 ± 0.48 g/fish), protein intake (16.86 ± 0.21 g/fish), Feed conversion ratio (1.25 ± 0.11) and protein efficiency ratio (1.79 ± 0.01) are concerned compared to other diets especially the control diet T0 (0%AZ/AS) with the significant differences in term of percentage variation of 18.13%, 18.10%, 38.42% and 8.55% respectively to feed intake (30.69 ± 0.74 g/fish), protein intake (13.81 ± 0.33 g/fish), feed conversion ratio (2.03 ± 0.01) and protein efficiency ratio (1.1 ± 0.01).

3.3. Whole-Body Composition and Nutrient Retention

Whole-body composition of African catfish juveniles produced at the end of 56 days of culture is recorded in Table 4. As compared to fish body composition at the beginning of the study, it is noted that apart from the moisture rate that dropped down significantly ($p < 0.05$) in juveniles obtained after feeding with either the control diet T0 or the experimental diets T1, T2, T3 and T4, opposite effects were observed regarding other macro-elements that constitute the whole-body biochemical composition such as ash, protein, lipid and therefore energy that increased significantly ($p < 0.05$), particularly in fish of the experimental treatments. Moreover, whole-body composition of fish within treatments revealed that T3 has induced the highest effects compared to other treatments,

Table 4. Proximate composition (% or kJ/g WW) of the carcass and nutrient retention in juvenile of *Clarias gariepinus* produced after 56 days of feeding.

Parameters	T0: 0%ZO/AS)	T1: 1%ZO	T2: 2%ZO	T3: 1%AS	T4: 2%AS	p
Carcass composition[IBC] (% or kJ/g WW)						
Moisture	65.34 ± 0.03[b]	63.97 ± 0.02[bc]	64.97 ± 0.01[b]	60.30 ± 0.04[c]	63.70 ± 0.03[bc]	***
Ash	1.33 ± 0.01[b]	1.42 ± 0.01[b]	1.56 ± 0.01[a]	2.21 ± 0.06[c]	1.48 ± 0.01[b]	**
Protein	21.63 ± 0.13[b]	23.60 ± 0.06[c]	22.80 ± 0.08[b]	27.10 ± 0.06[d]	24.60 ± 0.06[e]	***
Lipid	2.89 ± 0.01[a]	3.73 ± 0.02[b]	3.46 ± 0.08[b]	3.52 ± 0.01[b]	3.61 ± 0.01[b]	**
Energy	6.21 ± 0.04[b]	6.57 ± 0.01[c]	6.47 ± 0.02[bc]	6.98 ± 0.01[d]	6.57 ± 0.01[c]	***
Nutrient Retention (% dry feed intake)						
Protein	24.90 ± 0.15[a]	31.80 ± 0.08[a]	29.10 ± 0.10[a]	49.40 ± 0.10[b]	40.60 ± 0.09[c]	***
Lipid	18.30 ± 0.03[a]	28.30 ± 0.15[b]	23.50 ± 0.56[b]	34.30 ± 0.05[c]	30.60 ± 0.01[c]	***
Ash	13.80 ± 0.13[a]	15.80 ± 0.07[b]	17.10 ± 0.57[b]	36.20 ± 0.11[c]	21.50 ± 0.14[d]	**
Energy	18.75 ± 0.01[a]	23.13 ± 0.03[b]	21.64 ± 0.56[b]	33.00 ± 0.01[c]	28.68 ± 0.02[c]	***

[IBC]initial body composition, on % wet weight basis, was: moisture: 69.78 ± 0.02[a]: ash: 1.69 ± 0.01[a]; protein: 19.80 ± 0.06[a]; lipid: 2.83 ± 0.01[a]; energy: 5.30 ± 0.04[a] kJ/g WW. Values are mean ± standard deviation of three replicates of 35 fish each. Mean within the row with different superscripts are significantly different each other at $p < 0.05$. **$p < 0.01$; ***$p < 0.001$.

especially T0. Ash (2.21% ± 0.06%), protein (27.10% ± 0.06%), lipid (3.52% ± 0.01%) and energy (6.98 ± 0.01 kJ/g) contents in fish carcass of T3 are significantly ($p < 0.05$) high by 39.82%, 20.18%, 17.90% and 11.03% as compared respectively to the content in ash (1.33% ± 0.01%), protein (21.63% ± 0.13%), lipid (2.89% ± 0.01%) and energy (6.21% ± 0.04%) determined of fish carcass fed with diet T0. The results also revealed the influence of different treatments on protein, lipid, ash and energy retention. Once more, diet T3 has induced the highest and most significant retention in protein (49.40% ± 0.10%), lipid (34.30% ± 0.05%), ash (36.20% ± 0.11%) and energy (33.00% ± 0.01%) compared to other experimental diets, particularly diet T0 (protein = 24.90% ± 0.15%, lipid = 18.30% ± 0.03%, ash = 13.80% ± 0.13% and energy = 18.75% ± 0.01%).

4. Discussion

Fish growth depends not only on the quality of water and feed, but also to some extent on their physiological state which can be disturbed by pathogenic organisms or any other abiotic factor in the culture environment. Many findings have reported that addition of medicinal plant products or by-products to diet favour various activities like growth promotion, appetite and digestion stimulation, antistress, enhancement of tonicity and immune stimulation and antipathogen properties in fish and shrimp aquaculture [29] [30]. In the present study carried out to evaluate the effects of dietary inclusion of *Zingiber officinale* and *Allium sativum* powders on growth, feed utilization and whole-body composition of *Clarias gariepinus* fry raised under intensive farming condition, the physico-chemical parameters of the breeding medium such as temperature and dissolved oxygen were observed to be within the range recommended for freshwater fish culture [31]. Bhatnagar *et al.* [32] recommended 25˚C - 30˚C for culture of *C. gariepinus*. Dissolved Oxygen level greater than 5 mg/l is essential to support good fish production. The value of the acidity degree obtained during the study was around 6.7. Santhosh and Singh [33] reported that the ideal pH level is between 7.5 and 8.5 and any value above and below this could be stressful to the fishes particularly to fry. According to Molleda [34], a pH value below 7 slows the nitrification process. The nitrite concentration recorded in the present study shows a range between 0.0 mg/L and 0.3 mg/L. According to Boyd [35] concerning water quality for pond aquaculture and based on the conclusion from the study conducted on the water quality for the management of pond fish culture by Bhatnagar and Devi. [36], the nitrite threshold for freshwater fish fry is less than 0.2 mg/l. Excess nitrite compounds in water due to faeces and residual feed is considered as an invisible killer of fish because it oxidizes haemoglobin to methemoglobin in the blood, turning the blood and gills brown and hindering respiration. It also accumulates in liver, brain and muscle causing damage for nervous system, liver, spleen and kidneys of the fish [37] [38]. Nitrate being a transitional form between ammonia and nitrate (nitrification), and between nitrate and nitrogen gas (denitrification), is relatively less toxic. The results of the present study indicate that the nitrate concentration range between 0.00 mg/L and 6 mg/L [39] [40]. This concentration being less than 10 mg/L, still meet the proper range for optimum growth of catfish fry. According to the above observations, the mortalities recorded in all the treatments would be attributed more to the poor conditions of the breeding environment than to the diet. The absence of automatic siphoning of residual feed and faeces would be responsible for the acidity of the rearing environment and abnormal nitrite levels, thus causing disturbances of the general metabolism in the young fry, certainly due to an increase in the production of free radicals whose effects on vital functions are known to cause death. On the other hand, the reduction, although not significant, in the mortality rate observed in the fry of the experimental treatments compared to the control would be attributed to the antioxidant potential of ginger and garlic. According to Shahidi and Hossain [41], spices such as ginger and garlic are useful in aquaculture industry not only to improve the palatability of feed and as a flavouring agent but also because of their high antioxidative properties. The main bioactive compounds associated with spices comprise a diverse array of components such as terpenoid components, flavonoids, phenolic compounds, saponins, glycosides and other bioactive molecules [42]. So, the relative low mortalities observed in treated fry compared to control might be partially attributed to above mentioned bioactive molecules known to improve health by their ability to eliminate free radicals, prevent lipid peroxidation, promotion of endogenous cellular antioxidant defences like superoxide dismutase, catalase and reduced glutathione and thereby an improvement in fish health condition [43].

The findings of the present study on growth performances and feed utilization revealed that *C. gariepinus* fry fed with basal diet supplemented with either garlic powder or ginger powder showed better growth and feed utilization in term of weight gain, length gain, specific growth rate, feed intake, feed conversion ratio as well as protein efficiency ratio compared to control diet. On contrary to the results obtained by Mahmoud *et al.* [27] who found poor growth and feed utilization in term of specific growth rate and feed conversion ratio after feeding *Oreochromis niloticus* fingerlings for 60 days with 1.5% ginger and garlic compared to basal control diet, the results of the present study are in accordance with those obtained by Jahanjoo *et al.* [44] who recorded better growth performance and feed utilization in Sobaity Sea Bream (Sparidentex hasta) fry fed with basal diet containing 1% of garlic and ginger respectively for 8 weeks. In addition, the highest values of growth performance and feed utilization were observed in fish fry fed the basal diet containing 1% of both ginger and garlic compared to control diet and even diet with 2% of plant material. Iheanacho *et al.* [1] reported significant increases in weight gain, specific growth rate and final weight when *C. gariepinus* juvenile were exposed to varying concentrations (0.25, 0.50, 0.75 and 1.0 g/35 L) of ginger as compared to the control. The same trend was observed by Adewole [45] who also reported significant increases in growth parameters (final weight, weight gain, specific rate and relative growth rate) in *C. gariepinus* fed roselle supplemented diets when compared with the control. Therefore, the positive response to growth in treated fish, especially those receiving 1% inclusion level of ginger, could be attributed to the average proximate content of ginger which is a good source of mineral elements, vitamins and contains good number of phytochemical constituent that enhance growth and health of animals through actions as the stimulation of the secretion of pancreatic enzymes and the bile from the liver that induce fast feed digestion and helps to balance the intestinal bacteria [46]. Ginger roots also contain high levels of proteolytic enzymes and lipolytic which lead to improved digestion of dietary protein and lipid [47]. Moreover, the results of the present study revealed that the lowest level of feed conversion ratio as well as greatest values of growth performance were recorded in fish fry fed with the diet containing 1% of garlic compared to the rest of the treatments. These results are in contradiction with those reported by Mahmoud *et al.* [27] who found no significant difference between the growth performance and feed utilization of *O. niloticus* fingerlings fed on diet containing 1.5% ginger and garlic during 60 consecutive days. In addition, Jahanjoo *et al.* [44] after feeding Sobaity Sea Bream (*Sparidentex hasta*) fry with basal diet containing 1% of garlic and ginger respectively reported better growth performance and feed utilization. Sahu *et al.* [48] also showed that feed conversion ratio and specific growth rate were not significantly influenced in *Labeo rohita* fed on diet containing 0.5% and 1% garlic inclusion. The conflicting results of adding dietary garlic and ginger on growth performances and feed utilization of *C. gariepinus* fry may be attributed or depend on fish species differences, feeding program, period in which the supplemented diet was applied and the ambient culturing conditions. It may also be attributed to fish size, age, bioactive precursors present in feed additive and fish nutritional or physiological status. The best improvement of growth observed with the dietary inclusion of garlic might be due to the active materials in the herbal plant which increased the efficiency of utilization of feed nutrient, resulting in enhanced growth. Indeed, previous works suggested that these functions are attributable to the bioactive components of garlic which include allin and allicin. Allicin being the most abundant compound representing almost 70% of all present thiosulfinates [49]. Khalil *et al.* [16] reported that among the physiological properties of allicin, there is that which improves the performance of intestinal flora, thus improving digestion and consequently enhance the utilization of energy and leading to an increase in the speed of bodily development.

Body development or growth of farmed animals, particularly fish, is one consequence of improving whole-body composition due to nutrients retention from distributed feed. The results of the present study revealed that whole-body composition of *Clarias gariepinus* at the end of the study compared to initial fish samples, in term of the levels of crude protein, crude lipid and ash were significantly affected by both experimental diets and control diet. These results also indicate that all diets used contain balanced nutrients that have been effectively converted and utilized by all fish samples for both flesh and bone development are in accordance with that of Lee *et al.* [12] who observed significant increase in crude protein, crude lipid and ash content in whole body composition of sterlet sturgeon juvenile fed on diet containing different inclusion levels of garlic extract. Similarly, Olaniyi *et al.* [9] showed that addition of increase levels of ginger in the diet of *C. gariepinus* juveniles increased significantly protein, lipid and ash contents in their body composition compared to initial fishes. Moreover, the results also revealed significantly higher values of body protein, lipid and ash in fish fed diets with ginger and garlic compared to fish fed the control diet. These results are partially in agreement with that of Mahmoud *et al.* [27] who observed increase in protein and ash content in the carcass of Nile tilapia fed with 1.5% ginger and garlic respectively compared to control diet. Knowing the phytochemical and nutritional composition of ginger and garlic, the improvement of biochemical composition of the experimental fish whole-body as compared to control is more attributed to physiological and pharmacological properties of bioactive molecules in supplemented plant products than to their nutritional effects. As previously observed with growth and feed utilization parameters, body content of protein, lipid, ash and energy as well as their retention were significantly high in carcass of fish fed 1% garlic powder supplementation in the diet compared to the rest of the treatments. These results are in agreement with the findings of Kaur and Ansal [17] who observed significant increase in chemical body composition in Major carp fingerlings compared to control diet after 6 months of feeding with inclusion levels of garlic powder (1% - 3%). These results also corroborate previous findings which established a direct link between the feed utilization efficiency by fish and their bodily level of retention [50] [51]. Knowing that body nutrient retention refers to feed nutrient proportion stored as nutrient in the body tissues of fish during rearing process, it is reflected on physical appearance by both weight increase and linear growth. The overall results of the present study in *C. gariepinus* fed with 1% garlic powder supplemented diet can therefore be justified by the fact that protein, lipid, ash and energy retention were significantly greater in comparison with fish fed the rest of the diets. According to Kaur and Ansal [17] and others, the beneficial effects of garlic on biochemical body content as well as their retention in *C. gariepinus* at the end of the study are attributed to biological activity of allicin that not only facilitate digestion process of feed, but also helps in a more efficient assimilation of dietary proteins and others macro-nutrients into the flesh, bones and some vital organs involved in feed metabolism.

5. Conclusion

The present study demonstrated that supplementation of ginger and garlic powder in the diet of *Clarias gariepinus* fry at inclusion levels of 1% and 2% have exhibited significant growth promoter effects and feed efficiency improvement as well as fishes whole-body content in protein, lipid, ash and energy additional to their bodily retention not depending on the level of inclusion as compared to control diet. Although, supplementation with ginger and garlic induced beneficial effects in *C. gariepinus* fry compared to control, dietary inclusion of 1% garlic powder had presented the best effects on growth performances, feed nutrient utilization and whole-body composition: attributed more to its physiological and pharmacological properties than its nutritional effects.

Acknowledgements

The authors would like to thank Mr. Tcheudjie Tchianga Joël for providing the necessary facilities for conducting the research work. Thanks also to Miss Junie Wandji Tchakoute and Dr. Gordon Ajonina for proofreading the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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