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ORIGINAL ARTICLE

Evaluation of a mixture of local feed ingredients for Nile tilapia juveniles reared in the south-east of Algeria

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Abstract
In order to reduce the cost of fish feeds, eight-week feeding study was conducted to assess the effect of partial substitution of fishmeal (FM) by a mixture of other locally available dietary protein sources, duckweed meal (DWM) and mealworm larvae meal (WLM), on growth, nutritional efficiency and profitability of *O. niloticus* juveniles (average initial weight, 3.87±0.63g). In total of 180 fish were reared in 12 glass aquariums of 80 L, i.e. 15 fish per aquarium, thus forming for four treatments each corresponding to one diet. The experimental diets were formulated to be isonitrogenous (35.35±0.04%, CP) *viz*; control diet (D_0) and three test diets (D_1, D_2 and D_3) containing a combination of different ratios (1:5, 2:4 and 4:2) on DWM and WLM, respectively. There were no significant differences (P>0.05) on the growth and feed utilization parameters in fish fed on the tested diets. While, the carcass compositions of the experimental fish and their profitability were showed a significant differences (P<0.05). The obtained results also proved that the inclusion of these neglected products in aquafeed could maintain *O. niloticus* juveniles growth performance, not negatively affect them, and reduce the use of FM by one third. Consequently, reducing feed production costs and making fish farming more sustainable in the country.

Keywords: Alternative protein, Growth, Nile tilapia, Profitability

INTRODUCTION

Currently, aquaculture contributes substantially to global food security, as evidenced by the increase in production from 7.5% per year in 1970 to 46.0% per year in 2018 (FAO 2020). Fish feed play a central and essential role in aquaculture and accounts for approximately 60% of total production costs (Asche & Smith 2018). From an economic point of view, the cost of aquaculture feed seems to be one of the main constraints for the expansion of aquaculture. Animal proteins are the main and most expensive component in fish feed, especially fishmeal (FM) which has been used for decades (Ogello et al. 2014). Therefore, controlling the cost of producing fish is one of the priorities to support the sustainable growth of aquaculture. It is necessary to find cheap and easily available alternative protein sources that can partially or completely replace FM while obtaining similar or higher growth performance. Alternative feed ingredients must be readily available and contain minimum levels of fiber and anti-nutritional factors (Gatlin et al. 2007).

In Algeria, aquaculture production has been significantly booming during the last few years, following a clear new policy, which consists in continuing efforts to reorganize and sustainably develop fishing and aquaculture activities, particularly by promoting the utilization of the continental water bodies for fish farming, with the objective of doubling the national production (DGPA 2018). This is particularly relevant because of the availability of a large potential for geothermal water in the south of country, favorable for continental fish farming (including tilapia), which is the most promising fish in low-input freshwater fish farming, with the Nile tilapia being the most appreciated species (FAO 2014). However, the lack of adequate local feed and the high cost of imported feed pose significant challenges for the development of this activity. Thus, developing diets from locally available raw materials has become imperative. Many previous studies have evaluated the use of

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plant by-products as a source of dietary protein, either alone or in combination with other feed ingredients in the formulation of fish diets. But the major drawback of the use of vegetable proteins is the presence of anti-nutritional factors, and deficiency in one or more essential amino acids (Gatlin et al. 2007). This issue necessitates the additional use of certain food processing techniques to reduce the effect of these anti-nutritive factors. In addition, most animal-derived ingredients are insufficient to fully replace fishmeal, due to the deficiency in indispensable amino acids (Agbo et al. 2015). Therefore, the combination of different alternative protein sources with varied amino acids profiles that complement each other has been highly recommended to overcome these drawbacks (Luo et al. 2011).

A subcosmopolitan food ingredient belonging to duckweed species is a small floating aquatic plant which, when grown under ideal conditions, can double in mass every 16 to 48 hours and accumulate a in crude protein levels of up to 43%, while fiber constitutes no more than 5% of its dry matter. It is devoid of indigestible matter, making it an ideal candidate for a sustainable protein (Leng et al. 1995). Based on its amino acid profile, studies have concluded that its protein quality is suitable for consumption by fish, poultry, cattle and humans (Appenroth et al. 2018; Sharma et al. 2019). Similarly, insect larvae, such as those of the yellow mealworm (*Tenebrio molitor*), are a food of choice for many domestic animals such as fish and poultry. Their popularity has grown as innovative sources of high quality protein and contributing to animal feed sustainability (Van Huis 2013; Makkar et al. 2014). Yellow mealworm (*Tenebrio molitor*) larvae offer a potential alternative source as an alternative animal protein source for sustainable aquaculture (Van Huis et al. 2013; Sánchez-muros et al. 2014) and provide adequate amino acid profiles for use in fish feed (Van Huis et al. 2013; Henry et al. 2015). Finally, the global production and import of animal feed raise various concerns. On the other hand, unconventional feed resources, as defined in this study, are products of plant and/or animal origin, which are little or not exploited in animal feed, which do not compete with human food and are unknown to most farmers. Duckweed meal and mealworms larvae meal are particularly suitable for this use. These two feed ingredients, available locally, are valuable sources of high-quality proteins. Their easy cultivation and rapid growth make them the ecologically sustainable feed resources on which aquafeed can rely.

Varying degrees of success have been achieved when trying to use a mixture of different animal and vegetable protein ingredients to replace fishmeal in Nile tilapia diets (El-Sayed 1998; Ribeiro et al. 2016; Djissou et al. 2017; Aziza et al. 2019; Alofa et al. 2020; Merah et al. 2022). And this study builds upon prior research and aims to assess the effects of partial replacement of fishmeal with a mixture of different ratios of two protein sources (duckweed and mealworm larvae) on growth, feed efficiency, nutritional quality and best economic performance in *O. niloticus* in stage II pre-growth under controlled laboratory feeding conditions.

MATERIALS AND METHODS

Experimental design and fish feeding: This study was conducted at the biophysical station of Oued Right (Touggourt) of the Center for Scientific and Technical Research on Arid Regions (Biskra, Algeria). Nile tilapia (*O. niloticus*) juveniles were produced in the hatchery of the experimental fish breeding station of the National Center for Fisheries and Aquaculture Research and Development (CNRDPA) in Hassi Benabdallah, Ouargla (south-east of Algeria). After acclimatization period (about 7 days), only fish with an average weight (3.87±0.63 g) were selected to the growth study. The Albian borehole water was used for the entire experiment with an average initial conductivity of 3.4 µS/cm, or a salinity of 1.6 ppt. Before the experiment, 15 fish were randomly selected and five additional fish also selected from each aquarium at the end of the experiment for analysis of carcass composition.

Table 1. The chemical composition of used ingredients in the formulation and preparation of the experimental diets.

	FM	SBM	WBM	DWM	WLM	CSM
Composition (% DM[1])						
Dry matter	93	92.48	90.73	92.23	92.37	89.6
Crude protein	75.39	45.98	13.88	29.71	51.47	2.49
Crude lipid	3.95	1.9	4.48	1.05	25.34	0.92
Crude fibre	1.55	6.5	13.59	12.21	11.69	4.2
Ash	11.05	6.84	8.79	25.28	3.26	0.33
NFE[2]	1.06	31.26	49.99	23.98	0.61	81.66
Calcium (g kg^{-1})	4.34	0.36	0.2	4.97	0.25	0.02
Phosphorus (g kg-[1])	2.8	0.71	1.1	0.51	0.76	0.13
Gross energy (kj g^{-1})[3]	19.03	16.67	13.48	11.35	21.60	14.93

[1]Results show the mean (n = 3) as % dry matter.
[2]Nitrogen-free extract = 100 - (% lipid + % moisture + % protein + % fiber + % ash).
[3]Calculated using the factors: carbohydrate, 4.1 kcal 100 g^{-1}; protein, 5.5 kcal 100 g^{-1} and, lipids, 9.1 kcal 100 g^{-1}, and transformed to kJ using the factor 4.184.
FM= fishmeal; SBM= soybean meal; WBM= wheat bran; DWM= Duckweed meal; WLM= mealworm larvae meal; CSM= corn starch.

A totalof 180 fish were weighed individually and randomly distributed in 12 glass aquariums of 80L useful volume, i.e. 15 fish per aquarium, thus forming for four treatments each corresponding to one diet. Fish were fed on the experimental diets four times a day (8:00, 11:00, 14:00, and 17:00h), six days a week. The rearing water was renewed daily at 30%, before the first feeding, and after the siphoning of aquariums to eliminate excrement and rest of the food and the aquariums were carefully cleaned and rinsed thoroughly at each control fishing, as for the oxygenation, it was provided by an oxygen pump, which diffused the air with perforated stones. The ratio was fixed at 5% of body weight per day. Every seven days, fish were counted, weighed to the nearest 0.1g and measured to the nearest 0.1cm per aquarium to determine the biomass and adjust the ratio. The physic-chemical parameters of water quality such as Temperature (°C), Dissolved Oxygen (mg/L), pH and Salinity (ppt) were measured by the Hanna's HI 9829 multiparameter portable meter. The sampling was done three times a day and seven days a week. As for, the concentration of ammonium (NH^+_4), nitrite (NO^-_2) and nitrate (NO^-_3) were carried out at weekly intervals before each feeding operation by spectrophotometry on the same day of water sampling. A photoperiod of 12h light, 12h dark (8:00-20:00h) was used.

Experimental ingredients: The proportion (%) of ingredients in the composition of the experimental diets is presented in Table 1. The feed ingredients used in this study were *Sardinella aurita* fishmeal (FM) prepared as described by Tarhouni et al. (2015), soybean meal (SBM), wheat bran (WBM) and corn starch (CSM) which were obtained from the local market. Duckweed *L. minor* was harvested from the rearing basins of the study station and the freshly harvested quantities were dried, crushed and stored immediately. As for the mealworm larvae, it was performed according to Siemianowska et al. (2013); after *T. molitor* was successful reared at the study station.

Diets formulation and preparation: The dry ingredients were finely ground and sieved using a 400 µm sieve. For each diet, the ingredients were weighed and mixed until a homogeneous powder was obtained, to which soybean oil and VMC (vitamin and mineral complement), were added. Hot distilled water was then added at a rate of 45% of the dry matter, in order to obtain a malleable paste which, when passed through a meat grinder die (Clatronic FW3506), given filaments of 3mm in diameter (spaghetti). These filaments were subsequently dried in the oven (BINDER, Germany) at 45°C for 48h, fragmented to the desired size, bagged and stored at 4°C until distribution. Four iso-protein feed treatments (35.35±0.04%, CP) with balanced nutritional values, intended for the feeding of Tilapia in the pre-growth satge, were elaborated from conventional and unconventional raw materials (Table 2).

Table 2. The formulation (g kg^{-1} as fed) and composition (%) of experimental diets.

Ingredients used in diet (g/kg)	D_0 (Control)	D_1	D_2	D_3
Duckweed meal	0	50	100	200
Mealworm larvae meal	0	250	200	100
Fishmeal	230	80	110	160
Soybean meal	300	300	300	300
Wheat bran meal	250	150	120	80
Corn starch	130	130	120	110
Baker's yeast	10	10	10	10
CMV[1]	20	20	20	20
Soybean oil	60	10	20	20
Ratio[*]	0 : 0	1 : 5	2 : 4	4 : 2
Biochemical composition (% DM)				
Dry matter	92.16	91.9	92.65	92.18
Crude protein	35.38	35.3	35.39	35.32
Crude lipid	8.76	9.62	9.58	7.48
Crude fibre	6.31	8.29	7.93	7.5
NFE[2]	23.02	29.55	28.52	28.23
Calcium (g kg^{-1})	1.16	0.8	1.16	1.84
Phosphorus (g kg^{-1})	1.15	0.83	0.87	0.94
Gross energy (kj g^{-1})[3]	15.42	16.86	16.68	15.82
Diet cost (DZD kg^{-1})[4]	200	110	130	140

[1]Vitamin premix (mg or $UI.kg^{-1}$) : Vit A, 400000 UI, Vit D3, 14000; Vit E, 75000 ; B1, 83.30 mg;Vit K3, 119.85 mg; Choline, 12000UI. Mineral premix ($mg.kg^{-1}$) : Fe, 1.7g ; Cu, 0.1g ; Mn, 3.2g ; Zn, 1.35g ; I, 0.06g; Se, 0.0067g; Co, 0.0020g ; P, 0.091g ; Ca, 0.27g ; N, 0.36g.
[2]Nitrogen-free extract = 100 - (% lipid +% moisture +% protein +% fiber +% ash).
[3]Calculated using the factors: carbohydrate, 4.1 kcal 100 g^{-1}; protein, 5.5 kcal 100 g^{-1} and, lipids, 9.1 kcal 100 g^{-1}, and transformed to kJ using the factor 4.184.
[4]The price estimate was based on the cost of conventional raw materials.
[*]Ratio between Duckweed meal and Mealworm larvae meal.

The control diet (D_0) consists mainly of soybean meal and fishmeal as the main protein sources, while the other three diets (D_1, D_2 and D_3) were formulated to evaluate the effectiveness of a maxture of DWM and WLM constituted respectively of different ratios (1:5, 2:4 and 4:2) to partially substitute fishmeal.

Chemical analysis: Proximate analysis and mineral contents were carried out in triplicate according to AOAC (2000), to feedstuffs samples, experimental diets and fish carcasses (Table 2 and 6). Briefly, the samples were dried for 24h at 105°C in an oven to estimate the moisture and dry matter contents. The ash content was determined after incineration at 550°C for 16 h. The crude protein content was determined by measuring the nitrogen content (N×6.25) by Kjeldahl analysis (FoodALTY IR-600P, Analyzer). The crude lipid content was measured by Soxhlet method (Velp Scientifica, SER-148). The crude fiber content was determined using the Weende extractor method (Velp Scientifica, FIWE-6). The NFE content was then determined by the subtraction method.While the High- Performance Liquid Chromatography (HPLC, Nexera - XR, Shimadzu, IL, Japan) Post-Column derivatization method (Fiogbe 2009) was used to analyze the amino acid composition providing with standard of all types of essential amino acids (Table 3).

Growth parameters and feed utilization: Fish growth performance and feed conversion were determined in terms of survival Rate (SR), Daily Weight Gain (DWG), Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Feed Intake (FI), Protein Efficiency Ratio (PER), Condition factor (K), and Economic Conversion Ratio (ECR) were evaluated according to Merah et al. (2022).

Statistical analysis: The statistical analysis of the obtained results was carried out using SPSS 22 software (IBM, USA) using a one-way ANOVA followed by Tukey's HSD test ($P<0.05$). Three independent replications were used for each treatment, and the error bars were presented as mean values± standard deviations.

Table 3. Essential amino acids (EAA) composition of the experimental diets (% of dry diet) after analysis*.

EAA	D_0	D_1	D_2	D_3	*O. niloticus* requirement**
Lysine	1.73	1.77	1.8	1.76	1.43
Valine	1.88	1.48	1.18	1.14	0.78
Leucine	3.04	3.05	3.19	3.25	0.95
Histidine	1.1	0.96	0.98	1.16	0.48
Arginine	2.71	2.47	2.56	2.51	1.18
Threonine	1.7	1.42	1.76	1.92	1.05
Iseulocine	1.38	1.43	1.41	1.32	0.87
Methionine+Cysteine	0.98	0.86	0.82	0.87	0.91
Tryptophane	0.76	0.71	0.86	0.84	0.28
Phenylalanine	1.74	1.72	1.69	1.63	1.56

*Number of sampling Analysis (n= 3)
**AAE requirement, according to Santiago & Lovell (1988).

Table 4. Range and average values of water quality parameters during the experiment.

Items	T °C	DO mg/L	Salinity ppt	pH	NH_4 mg/L	NO_3 mg/L	NO_2 mg/L
Ranged	28.18-28.57	4.98-5.8	2.04-2.12	6.95-7.22	0.02-0.11	0.29-0.52	0.02-0.08
Average	28.37±0.04	5.5±0.07	2.08±0.01	7.11±0.04	0.06±0.007	0.43±0.006	0.03±0.004

RESULTS & DISCUSSION

Water quality parameters: The evolution of the main physico-chemical parameters of the rearing water according to various dietary treatments during the experimental period is presented in Table 4.

In general, the mean values of the water parameters underwent little change throughout the study period and these values are regrouped in Table 4. However, the mean values of all water quality parameters recorded during the experiment were not significantly different (P>0.05) and remained within the favorable limits for good growth of this species (Djissou et al. 2017). These parameters play an important role in the survival of aquatic organisms, growth performance and feed utilization efficiency. Therefore, their effects on growth of the experimental fish were ignored in evaluating the efficiency of feed. Hence their effects on growth of the experimental fish were disregarded in the evaluation of feed efficiency.

Growth performance and feed utilization: The fish did not show any pathological signs, nor were there high mortality rates. The mean survival rates at the end of the experiment ranged between 99.36±0.92 and 100%, with the statistical analysis showing no significant differences (P>0.05) between the different treatments, allowing the recorded mortality to be attributed to the handling during biometric controls rather than to the composition of the diets, knowing that this occurred on the day following the growth controls. Our results were very satisfactory compared to the rate (80%) obtained by Mohapatra and Patra (2013) who reported that 15% of *L. minor* could partially replace FM in the diet of *Cyprinus carpio* fry. Additinally, Medard et al. (2018) obtained a survival rate of less than 90% in *O. niloticus* juveniles fed on diet of earthworms and maggots. However, they were lower than the rates (100%) obtained by Ali et al. (2015) when FM was replaced by maggot meal in the diet of *O. niloticus* fry.

The growth and efficiency of feed utilization of *O. niloticus* in pre-growth phase are indicated in (Table 5 and Fig. 1). The latter illustrates the growth curves obtained for the various treatments.

The zootechnical parameters at the end of the experiment showed that the average final weights of the fish varied between 7.42±1.94g for the batch fed on D_1 and 8.33±1.01g for that which received D_0 (control). Tukey's test showed that there were no significant differences (P>0.05) between the mean final weights of the different diets (Table 2).

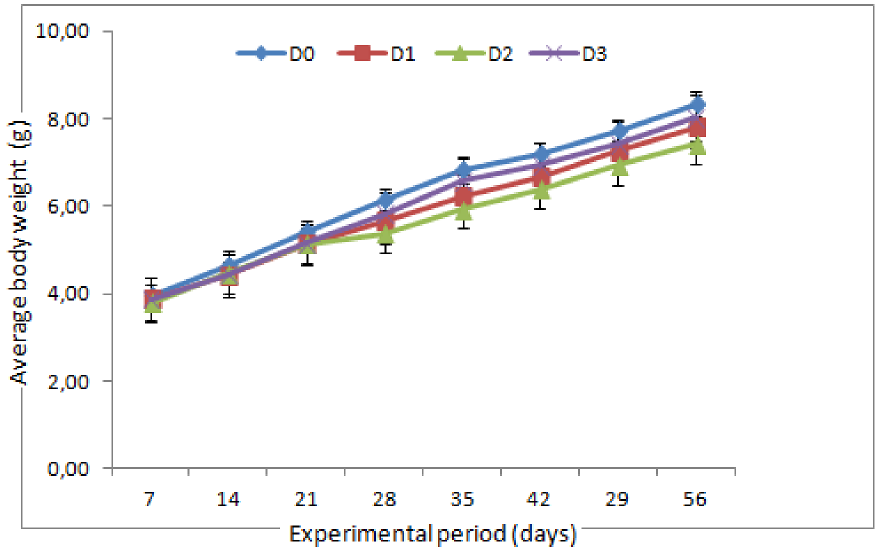

Fig.1. Growth performance of *O. niloticus* juveniles fed on experimental diets.

Table 5. Growth performance parameters of *O. niloticus* juveniles fed with four diets during 56 days of experimentation. (Mean values ±SD, *n*= 3).

	Diets			
Variables	D_0	D_1	D_2	D_3
IBW (g)	3.96±0.41	3.88±0.64	3.79±0.74	3.86±0.73
FBW (g)	8.33±1.01	7.81±1.47	7.42±1.94	8.02±2.59
SR (%)	99.68±0.54	100	99.36±0.92	99.68±0.54
DWG (g/day)	0.1±0.02	0.09±0.01	0.09±0.02	0.1±0.02
SGR (%)	1.77±0.58	1.67±0.37	1.6±0.53	1.74±0.54
FCR	1.7±0.62	1.69±0.36	1.45±0.6	1.67±0.61
FI (g/day)	0.98±0.02	0.98±0.01	0.98±0.02	0.98±0.02
PER	4.83±1.76	4.79±1.02	4.12±1.69	4.75±1.74
K	3.04±0.35	2.76±0.32	3.1±0.32	3.01±0.34
ECR	$3.78±0.68^{c}$	$2.03±0.2^{ab}$	$1.94±0.59^{a}$	$2.89±0.69^{b}$

IBW, inital body weight; FBW, final body weight; SR, survival rate; DWG, daily weight gain; SGR, specific growth rate; FCR, feed conversion ratio; FI, feed intake; PER, protein efficiency ratio; K, condition factor; ECR economic conversion ratio;
^{a,b} Mean values within each row not sharing common superscripts are significantly different (P<0.05, one-way ANOVA).

The results of the present study also revealed that all the experimental diets were accepted by *O. niloticus* juveniles. This implies that the different experimental feed ingredients did not affect the palatability of the diets. This could confirm the suitability of chosen nutritional composition for tilapia. In fact, the substitution of FM by the mixture of DWM and WLM in such proportions does not in any way affect growth performance and feed utilization of experimental fish and therefore, no significant differences (P>0.05) were recorded. This confirms the observation made by De Almeida Bicudo and Cyrino (2014) that fish do not have a specific requirement for crude protein per se, but rather need the right combination of EAA. Therefore, meeting the EAA requirements of the species is of utmost importance in preparing a balanced diet, which is probably now confirmed. Furthermore, growth is closely linked to feed intake and the ability of fish to utilize it (Carter & Houlihan 2001), especially at low levels of anti-nutritional factors (ANFs). The calculated SGR varied between 1.6±0.53% in fish fed on D_2 and 1.77±0.58% on D_0. The feed conversion (FCR) were between 1.45±0.6 and 1.7±0.62 respectively for diets D_2 and D_0. But without significant differences (P>0.05) between the different treatments. Also for daily weight gain (DWG), feed intake (FI) and protein efficiency ratio

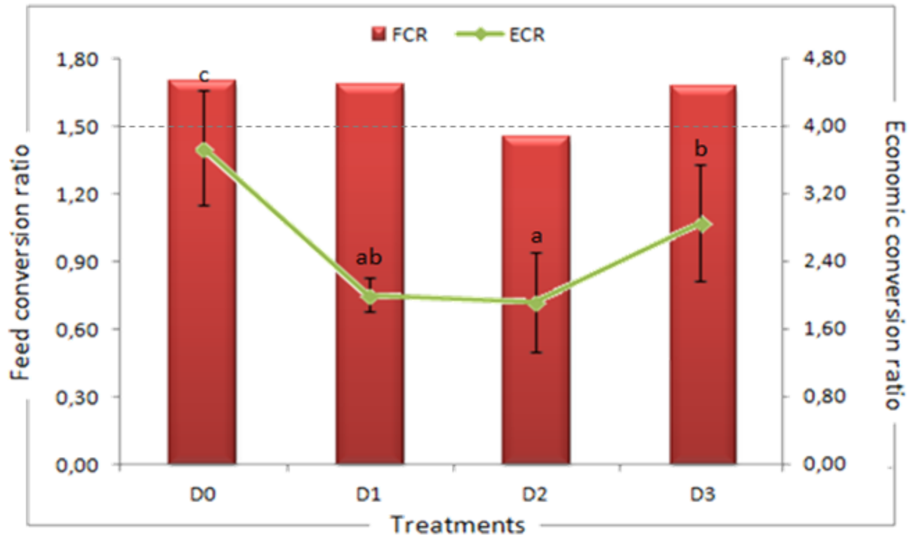

Fig.2. Feed conversion ratio and economic conversion ratio of *O. niloticus* juveniles fed with four diets during eight weeks of growth. Bars that cross the dotted line indicate good growth. Mean values±SD; *n*= 3. Different lower-case letters represent significant differences at *P*<0.05.

(PER) were recorded a similar trend across all diets. Although, the best SGR were recorded in fish fed on D_0 and D_3 with a value of (1.77 and 1.74%). These values in the present study were comparable to those obtained by Muin et al. (2017). Indeed, these authors did not observe any differences (P>0.05) in SGR of *O. niloticus* fingerlings fed on diets one of which contained fishmeal, and the other containing varying levels of maggot (*Hermetia illucens*) meal. The FCR values, ranging from 1.45 to 1.7 observed in among treatments, showed that the fish utilized the feed well unlike feed D_2 (Figure 2). It is know that FCRs between 1.5 and 2.0 are considered "good" growth for most fish species (Carter & Houlihan 2001). The mean value of FCR (1.6) obtained in the mixture of this study was slightly better than those reported by El-Sayed (1998) (1.86-2.48). On the other hand, our values were consistent with reported ranges in *O. niloticus* of 1.43 to 2.3 (Opiyo et al. 2014). As for the obtained values, FI did not show any significant differences (P>0.05) in terms of feed consumption. In appearance, none of tested diets exhibited any repellent character (inappetence). Regarding the protein efficiency coefficient, which is an indicator of the quality of the protein content of animal feed and high PER values are generally required for better feed utilization of fish. PER ranged between 4.12 and 4.83, higher than those reported by Ogunji et al. (2008) in tilapia feed, where FM was replaced by a diet of maggot flour. This was probably dependent on the type of feed used (in nugget form) and not in powder form, as noted by Campbell (1978). The powder form increases not only the possibilities of quantitative losses but also of qualitative imbalances due to disentangling and leaching of water-soluble compounds. Essentially, the PER values in all experimental diets were greater than 2.00. This indicates efficient utilization of dietary protein.

The welfare status of farmed fish was good, as indicated by the calculated condition factor (K>1) which did not appear to be affected (P>0.05) by the different diets (Table 5). In general, the factor obtained from this growth study was between (2.76-3.1) which should be close to or greater than 1 for farmed fish (Olufeagba et al. 2016). Our results are consistent with those of Medard et al. (2018) and Alofa & Abou (2020), respectively, regarding the substitution of FM in the feed of Nile tilapia a mixture of earthworm and maggot meal and by chicken viscera, housefly larvae and spirulina.

Table 6. Carcass composition of *O. niloticus* juveniles fed the experimental diets. Values (mean±SD) of triplicate groups[1].

Parametre (%)	Initial fish	Final contents of whole body (% DM)			
		D_0	D_1	D_2	D_3
Moisture	76.84	77.47±0.34^b	75.02±0.3^a	75.69±0.12^a	77.32±0.29^b
Crude protein	48.68	48.14±0.39^c	44.96±0.58^a	46.28±0.35^b	48.25±0.18^c
Crude fat	15.72	15.85±0.2^a	20.19±0.3^c	18.07±0.2^b	15.88±0.2^a
Ash	20.41	20.61±0.5^a	19.27±0.36^a	20.22±0.38^a	20.24±0.58^a

[1]On each line, the values (means±SD, n= 3) affected by different letters were significantly different (P< 0.05), Tukey's test. The absence of letters a, b and c on the same line indicates an absence of significant difference (P>0.05).

Chemical composition of fish carcass: The chemical compositions of fish at the end of the feeding experiment were presented in Table 6. The analysis showed that there were significant differences (P<0.05) between the carcass protein contents of fish fed on different experimental diets. Crude protein content was highest in the fish fed with D_0 and D_3 (48.14±0.39% and 48.25±0.18%, respectively), followed by the group of fish fed on D_2 (46.28±0.35%), while in the group fed with D_1, has had the lowest content (44.96±0.58%). On the other hand, carcass fat percentages seemed to be more clearly influenced by the WLM incorporation rate, the highest values were obtained in fish fed on D_1 (20.19±0.3%), while those of D_0 yielded lower values (15.85±0.2%). Whereas, the moisture content relative to the carcass of fish at the end of the experiment increased significantly (P<0.05) from 75.02±0.3% (D_1) to 77.47±0.34% (D_0). As for ash content, this do not appear to be statistically affected (P>0.05) by the treatments.

The present study showed variation in carcass compositions of Nile tilapia juveniles, which seemed to be related to the experimental diets. Among all carcass contents analyzed, only ash content was not affected. Thus, fish fed on D_0 and D_3 have retained more protein at the end of the experiment. This could suggest that the ratio (4:2 for DWM and WLM) used in D_3 represented the appropriate proportion. In fact, the confirmation of the quality could also be seen in the reduction of carcass fat content of fish fed on the same two diets compared to the initial lipid content. This might indicate that *O. niloticus* juveniles fed on D_1 and D_2, contained a high level of WLM, which was not effectively used for growth but would increase lipid deposition. Our results were corroborated by those of Medard et al. (2018) in tilapia fed on earthworm and maggot meal based diet. Moisture contents of carcasses were significantly (P<0.05) higher in fish fed on D_0 and D_3 than in those fed on D_1 and D_2. However, the opposite was true for body fat contents. Zhang et al. (2014) revealed that an inverse correlation between moisture content and total lipid of nine wild freshwater fish species, which was clearly demonstrated in the present study. Our results were generally consistent with those obtained by Younis et al. (2019) in *O. niloticus* fed on diets containing graded levels of seaweed (*Ulva lactuca*) and Duodu et al. (2018) in *O. niloticus* receiving diets included 30% of cottonseed meal (CSM) or groundnut meal (GNM).

The costs per kilogram feed were 200, 110, 130 and 140 DZD, respectively for the control diet D_0 and the tested diets D_1, D_2 and D_3. These costs were relatively related to the cost of the total amount of feed intake to produce one kilogram of fish (Table 2). Feeding costs were significantly reduced with the partial replacement of fishmeal in diets. ECR followed the same trend as feed costs, and compared to control diet D_0 (3.78±0.68), ECR values of tested diets decreased significantly (P<0.05). These values varied between 1.94±0.59 to 2.89±0.69 (Table 5 and Fig. 2). In our study, the economic analysis showed that these protein sources were more economical than fishmeal. Consequently, the economic results that we obtained corroborate with the studies of Ali et al. (2015) and Medard et al. (2018) which demonstrated that the partial substitution of fishmeal with insect meal (maggots, earthworms) included in diet of

O. niloticus could reduce costs and maximize profits.

CONCLUSION

Overall, this study highlighted the importance of using local feed ingredients in the diet of Nile tilapia (*O. niloticus*) in a pre-growth phase. The diet enriched with a (4:2) ratio of duckweed meal (DWM) and water lentil meal (WLM), respectively, demonstrated zootechnical performance comparable to that of the control diet. Moreover, such a substitution could reduce FM inclusion to 30.43%, and above all contribute to a reduction in feed-related expenses by 23.5%. The feed developed in our study has the advantages of being locally available, efficient, and accessible to fish farmers. Further research will be necessary on the processing of these two feed resources to better utilize them and to maintain their long-term sustainability in aquafeed.

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مقاله کامل

ارزیابی ترکیبی از مواد غذایی محلی برای بچه‌ماهیان تیلاپیا نیل پرورش‌یافته در جنوب شرقی الجزایر

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چکیده: به‌منظور کاهش هزینه خوراک ماهی، مطالعه هشت هفته‌ای تغذیه برای ارزیابی اثر جایگزینی جزئی پودر ماهی (FM) با ترکیبی از سایر منابع پروتئینی محلی در دسترس، آرد عدسک آبی (DWM) و آرد لارو کرم (WLM) بر رشد و کارایی تغذیه *O. niloticus* (متوسط وزن اولیه، ۳/۸۷±۰/۶۳ گرم) به‌اجرا درآمد. در مجموع ۱۸۰ ماهی در ۱۲ آکواریوم شیشه‌ای ۸۰ لیتری پرورش داده شدند، یعنی ۱۵ ماهی در هر آکواریوم، بنابراین برای چهار تیمار هر کدام مربوط به یک رژیم غذایی تشکیل شدند. جیره‌های آزمایشی به‌صورت ایزونیتروژن (۳۵/۳۵ ±۰/۰۴٪، CP) فرموله شدند. رژیم غذایی کنترل (D0) و سه جیره آزمایشی (D1، D2 و D3) حاوی ترکیبی از نسبت‌های مختلف (۱:۵، ۲:۴ و ۴:۲) به‌ترتیب بر روی DWM و WLM بودند. تفاوت معنی‌داری (P>۰/۰۵) در پارامترهای رشد و استفاده از خوراک در ماهی‌های تغذیه شده با جیره‌های آزمایش شده وجود نداشت. در حالی‌که ترکیبات لاشه ماهیان آزمایشی و کارایی آنها تفاوت معنی‌داری نشان داد (P<۰/۰۵). نتایج به‌دست‌آمده همچنین ثابت کرد که گنجاندن این محصولات نادیده گرفته شده در غذای آبزیان می‌تواند عملکرد رشد *O. niloticus* نابالغ را حفظ کند، بر آنها تأثیر منفی نداشته باشد و استفاده از پورد ماهی را تا یک سوم کاهش دهد. در نتیجه کاهش هزینه‌های تولید خوراک و پایداری بیشتر پرورش ماهی در کشور را به‌دنبال دارد.
گرم).
کلمات‌کلیدی: پروتئین جایگزین، رشد، تیلاپیای نیل، سودآوری