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EFFECT OF FEED ADDITIVES, *Allium sativum* AND *Argana spinosa* OIL ON THE GROWTH OF RAINBOW TROUT FINGERLINGS (*Oncorhynchus mykiss)* IN MOROCCO

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Abstract

The present study aimed to evaluate the effect of garlic (*Allium sativum*) and Argan oil (*Argania spinosa*) on the growth of Rainbow trout (*Oncorhynchus mykiss*) fingerlings at the Ras El Ma (Azrou) salmon farming station during the 2023 production period. Fingerlings were distributed into seven tanks, each containing 1000 fingerlings. The control tank (B0) received only the feed without additives. Tanks B1, B2, B3, and B4 received garlic as a feed additive at rates of 1%, 1.5%, 2%, and 2.5%, respectively. Fingerlings in tanks B5 and B6, in addition to 2.5% garlic, received 5 mL and 10 mL Argan oil, respectively. During the two-month experiment, fingerling weight growth and the water's physico-chemical parameters (pH, temperature, dissolved oxygen, and electrical conductivity) were monitored. Fingerlings receiving garlic showed positive weight growth (mean weights: 4.95 g, 5.43 g, 5.13 g, and 5.06 g) compared to control fingerlings (mean weight: 3.88 g). The highest average weight was achieved with 1.5% garlic (5.43 g). Adding 5 mL and 10 mL of Argan oil resulted in a slight weight increase for B5 fingerlings (5.37 g) compared to the B4 control (5.06 g), but a minor decrease for B6 fingerlings (4.73 g). The results indicate that using these feed additives positively affected growth and yield, regardless of the quantities used.

Key words: argan oil, feed additive fry, garlic, Oncorhychus mykiss, weight growth

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1. Introduction

Moroccan waters contain a fish biodiversity dominated by cyprinids. In addition to this family, the salmonids family characterised by 3 endemic species, *salmo trutta macrostigma* which colonize the waters of high mountains at the level of small streams and the headwaters of large rivers, as is the case of Oum Er Rabia, *Salmo viridis* endemic to Lake Isli located in the eastern High Atlas, and *Salmo multipunctata,* an endemic fluvial species found in the Draa basin in southern Morocco (Abba et al. 2012; Bergstedt and Vilhelm Skov, 2023; Doadrio et al., 2015). In addition to endemic salmonids, introductions have been made, namely rainbow trout (Oncorhynchus mykiss) introduced to Morocco since 1925 and brook trout (*Salvelinus fontinalis*) recently introduced in 2016. At the National center of Hydrobiological and Pisciculture, brown trout (*salmo trutta macrostigma*) and rainbow trout (*Oncorhynchus mykiss*) are bred and released into different environments to maintain the populations of these salmonids, which are affected by a number of factors on a global scale (Handisyde et al., 2017). Indeed, climate changes, which have increased, water temperature, this fundamental parameter leads to increased fish mortality (Huang et al., 2021; Lam et al., 2020), habitat degradation following various anthropogenic activities (Abba et al., 2023) and

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poaching. All of these factors increase the stress of fish, especially in their natural environment. To face up the unfavourable conditions and the abusive exploitation of fish stocks, and ensure increased demand for fish as sources of animal protein (Jia et al., 2022; Merino et al., 2012) and omegas, which protect against cardiovascular diseases, intensive aquaculture remains an alternative for fish production, but the feeding of farmed fish constitutes a more important link from a qualitative and quantitative point of view.

Intensive salmonids farming requires optimal conditions including water quality on the one hand, and on the other hand a diet which varies quantitatively and qualitatively depending on the breeding stage (Abba et al., 2021). Several trials of food additives have been added to the food ration for certain species of farmed fish, generally non-salmon farming, the objectives of which are varied such as increasing the immune system and consequently reducing antibiotics (Melguizo-Rodríguez et al., 2022; Mohebbi et al., 2012; Valenzuela-Gutiérrez et al., 2021), improvement in the quality of the flesh and significant output. The overall aim of this work is to study the effect of garlic, whose bioactive compounds have antimicrobial, antiviral, antioxidant and antiparasitic properties that have a positive impact on biological properties and animal health, and Argan oil (*Argania spinosa L*) on the growth of Rainbow trout fry (Oncorhynchus mykiss) raised at the Ras El Ma salmon farming station (Azrou) during the 2023 production period.

2. Material and methods

2.1. Presentation of salmoniculture station

Ras Al Ma salmon farming station (Fig. 1) with geographical coordinates 33°27'5044N and 5°08'51"W, is located at an altitude of 1500m north of the town of Azrou where the National Center for Hydrobiology and Fish Culture to which it belongs. It was inaugurated in 1957 and aims to artificially reproduce two salmonids (*Salmo trutta macrostigma* and *oncorhynchus mykiss*) with a view to improving and maintaining populations of these two species and promoting sport fishing (Abba et al., 2013). This station is located in a region with high snow and rainfall and very cold temperatures, contains the structures needed for the development cycle of salmonids, namely brood stock ponds, stabling ponds, a hatchery and a fry rearing room, in addition to pre-growth and fish fattening.

2.2. Water quality of Ras Al Ma station

The station is supplied with water from sources called Ras Al Ma springs from which it takes its name. Measurements of the physicochemical parameters of the water were made on a daily basis, the aim of which is to monitor the quality of the water on the one hand at the level of the nursery room and on the other hand to determine the ration food of the fry which varies according to the temperature.

The key parameters monitored are water temperature, hydrogen potential, dissolved oxygen concentration and electrical conductivity. The measurements were made using the Hach case.

2.3. Biological material and fish feed

The experiment was carried out on 7000 rainbow trout fry, distributed in seven nursery tanks (B0, B1, B2, B3, B4, B5, B6), at a rate of 1000 fry per environment. The average size of the fry is 5.07 cm at the start of the experiment and an average weight of 1.62 g with an initial biomass of 1620g. Table 1, shows the quality of the food distributed during the study period.

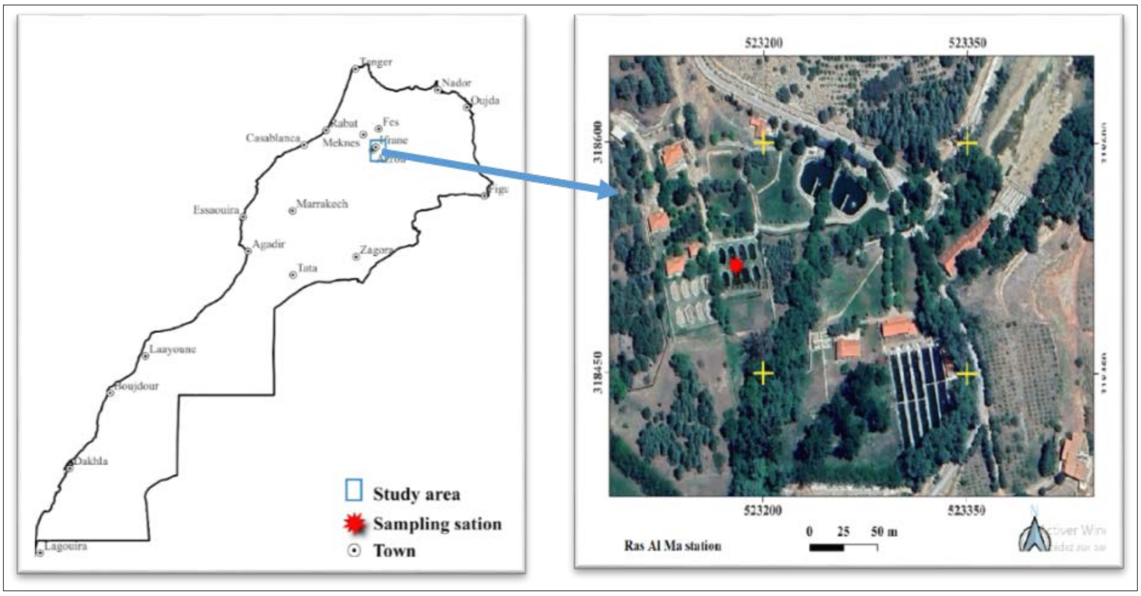

Fig.1. Location of the Ras Al Ma salmon farming station - Ifrane

Table 1. Composition (%) in 100g of feed distributed to fingerlings

Components	***Crude protein***	***Gross fat content***	***Cinder***	***cellulose***	***Calcium***	***Phosphate total***	***Sodium***	***Vit A***
Quantity %	52	17	9.98	2.17	1.58	0.71	0.64	10000 (UI/KG)

Table.2. Quantity (%) of feed additives added to the feed distributed to oncorhynchus mykiss fry

Nursery tanks	B_0	B_1	B_2	B_3	B_4	B_5	B_6
% of garlic added the feed ration	0	1%	1,5%	2%	2,5%	2,5%	3%
Volume of Argan oil added: mL	0	0	0	0	0	5	10
B_0 : Control tray for B1, B2, B3 and B4: Control tray for B5 et B6							

The feed ration is determined according to the rationing table given by the manufacturer and which varies according to the water temperature and fry weight according to the following Eq. (1).

$$DFR = \left(W * IN * FR\right) / 100 \quad (1)$$

where: *DFR*, daily food ration; *Pm*, average weight of the fry, *NI*, number of individuals in the tank and *FR*, feeding rate given by the manufacturer and which varies as a function of water temperature and average fry weight.

2.4. Zootechnical parameters

According to several authors (Haria et al., 2004, Okomoda et al., 2022) the zootechnical parameters used in breeding are as follows: (Eqs. 1-5)

Mean Weight Gained (MWG): This parameter is used to monitor weight growth over the experimental period and is calculated as follows (Eq. 2):

$$MWG\,\% = (FW\,(g) - IW\,(g)) \quad (2)$$

where: *FW*, *IW*: Final Weight and Initial Weight (g)

Growth rate (*GR*), this parameter is used to monitor daily weight growth (Eq. 3).

$$GR\,(g)) = (FW\,(g) - IW\,(g)) \;\; / RP\,(days) \quad (3)$$

where: *FW*, *IW*: Final and Initial Weight (g), and *RP*: Rearing period (days)

Specific growth rate (*SGR*): A term used in aquaculture to estimate fish production after a certain period. It is given by Eq. (4):

$$SGR\,(\%)) = ([In\,(FW) - In\,(IW)] * 100) / E\,D\,(days) \quad (4)$$

where: *FW*, *IW*: Final and Initial Weight (g), Experiment duration in days (4);

Survival rate (*SR*): the survival rate is calculated from the total number of fish at the end of the experiment and the number at the start of the rearing period, and is evaluated using the following formula (Eq. 5):

$$SR\,(percentage\,\%) = (FNF * 100) / INF \quad (5)$$

where: *FNF*, *INF*: Final and Initial Number of fish.

3. Results and discussion

3.1. Water quality parameters

Water temperature influences the behavior of fish more than any other nonliving variable (Beitinger and Fitzpatrick, 1979) Water parameters such as temperature, dissolved oxygen, hydrogen potential and electrical conductivity are in the following order: the mean temperature during the study period was 11.91°C ± 0.10928. The maximum and minimum temperatures recorded were 12.24°C and 11.71°C respectively. According to Bal et al. (2011), Jiang et al. (2021) and Abba et al. (2022), water temperatures are very favorable to the development of rainbow trout fry. For dissolved oxygen, the average concentration recorded was 6.867mg/L ± 0.127591. The maximum and minimum concentrations of dissolved oxygen (6.87 and 6.86mg/l) were the concentrations recorded fall within the range required for salmonids (Abba et al. 2022; Jiang et al. 2021).

Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, phosphate and sodium. The average measured in Ras Al Ma station was 599.85 µS/ cm ± 6.6. For potential Hydrogen, the average recorded was 6.86 ± 0.0040, according to Thalund-Hansen et al. (2023). Therefore, the water quality parameters at the Ras Al Ma salmon farming station are favourable for salmonids biology.

3.2. Zootechnical parameters

The results of the zootechnical parameters of the fry according to the quantity of garlic alone (%) in the diet during the rearing period are recorded in Tables 3-4 and Figs. 2-4.

The average weight at the end of the experiment is significant at the level of B2, whose % of garlic in the diet is 1.5%. This average weight decreases by increasing or decreasing the % of garlic in the food ration. Compared to the control tank (0% garlic), the average weight of the fry is greater than 3.88g. These results show that the quantity of garlic added (%), positively impacts the weight growth of the fry during the experimental period. In terms of final biomass, we see the same results with a maximum for B2 (9473.8g) and respectively (8117.97g, 8090.7g and 8079.78g) at the level of the tanks (B3, B4 and B1: 2%, 2.5% and 1% garlic).

Compared to only 6795.85g for B0 fry (0% garlic), despite the survival rate which is important at the B0 level. This last result can be explained by a significant appetite due to garlic at the start of the experiment and which caused mortality of the fry at the start of the experiment. The same growth performance was observed in *Oreochromis niloticus* receiving a diet with 2.5% garlic in the diet (Guillaume et al., 2019; Jegede, 2012; Shalaby et al., 2006; Vigneshpriya and Krishnaveni, 2016).

The results (Table 4, Fig. 5) obtained by adding argan oil (mL) and a quantity of garlic (%) to the fingerling feed show that. The addition of 5mL of argan oil (Table 4 and Fig. 5) increased the average weight of fingerlings in (B5) to 5.37g compared to B4 (5.06g), in B6 the average weight decreased to 4.74g when 10mL of argan oil was added. Compared with the average weight (3.88g) recorded at B0 (0% garlic and 0mL argan oil), the results obtained at B4, B5 and B6 are significant. In terms of final biomass and mortality rate, there was a slight drop in mortality rate when argan oil was added to the garlic (from 90.5% to 90.9%) and from 8090.7g (B4) to 7635.6g (B6) for the final biomass. The decrease in the latter was observed during the first week after the addition of argan oil. In conclusion, these results clearly show that garlic and argan oil (Table 4) can act jointly and synergistically to improve the average weight and final biomass of fingerlings, but at very specific quantities.

These results clearly show that garlic and Argan oil (Table 5) can act jointly and synergistically to improve the average weight and final biomass of fingerlings, but at very specific quantities. The addition of 1.5% garlic, which gave the best results with a volume of Argan oil (mL) remains to be verified.

4. Conclusion

The increased demand for animal protein, the over-exploitation of fishery resources and the decline in stocks have led researchers to consider different ways of preserving natural resources on the one hand, and satisfying the increased demand for fish consumption through intensive farming at marine and continental level on the other. The use of feed additives in recent decades has shown satisfactory results in terms of yield and flesh quality, especially for garlic tested for non-demanding species such as Nile tilapia and others.

Table. 3. Zootechnical parameters of fingerlings of *Oncorhychus mykiss* according % of garlics in diet

	B 0	***B 1***	***B2***	***B 3***	***B4***
Average weight (g)	3.88	4.95	5.43	5.13	5 .06
Standard deviation	±1.6929	±2.3728	±2.6382	±2.381975	±2.4879
initial Weight	1.62	1.62	1.62	1.62	1.62
Final Weight	6.83	8.66	10.1	9.03	8.96
final number of fish	995	933	938	899	905
Survival rate %	99.5	93.3	93.8	89.9	90.5
Initial Biomass	1620 g				
Final Biomass (g)	6795.85	8079.78	9473.8	8117.97	8090.7

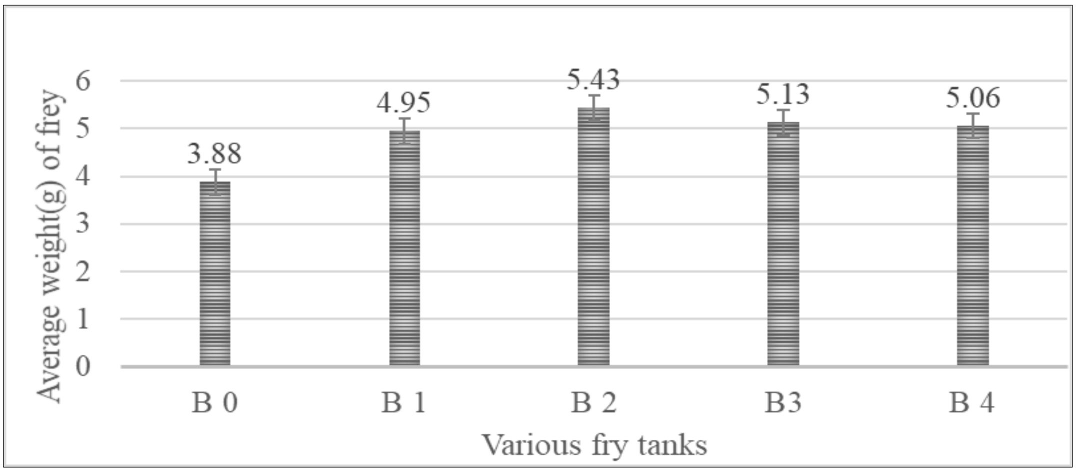

Fig. 2. Average weight of fingerlings over the trial period as a function of the percentage of garlic in the feed

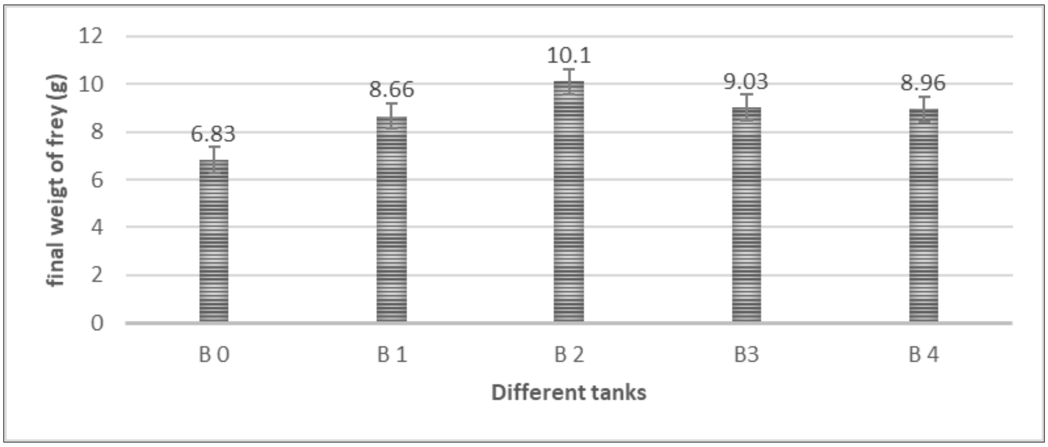

Fig. 3. Fingerling weight changes over the rearing period

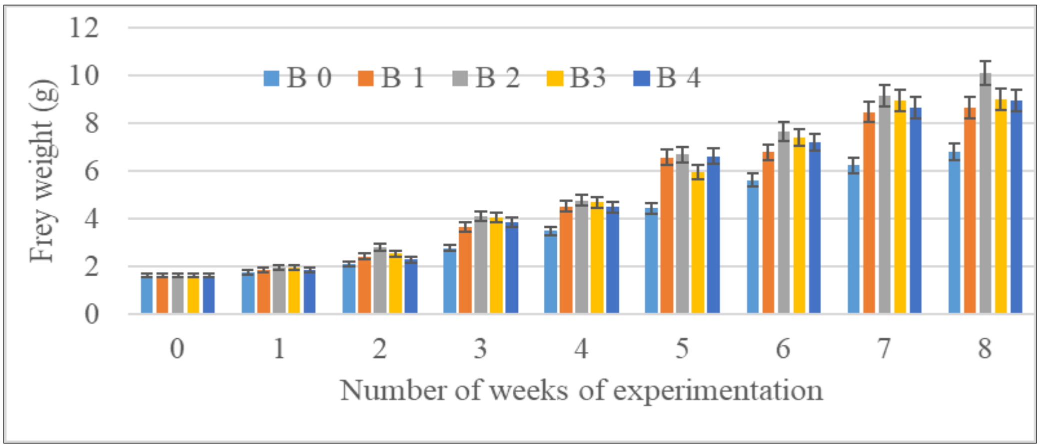

Fig. 4. Fingerling weight changes over the rearing period

Table 4. Zootechnical parameters with % feed garlic and argan oil

	B 0	***B4***	***B 5***	***B 6***
Average weight (g)	3.88	5 .06	5.37	4.74
Standard deviation	±1.6929	±2.4879	±2.3466	±2.258
initial Weight	1.62	1.62	1.62	1.62
Final Weight	6.83	8.96	8.86	8.4
final number of fish	995	905	906	909
Survival rate %	99.5	90.5	90.6	90.9
Initial Biomass	1620g			
Final Biomass (g)	6795.85	8090.7	8027.16	7635.6

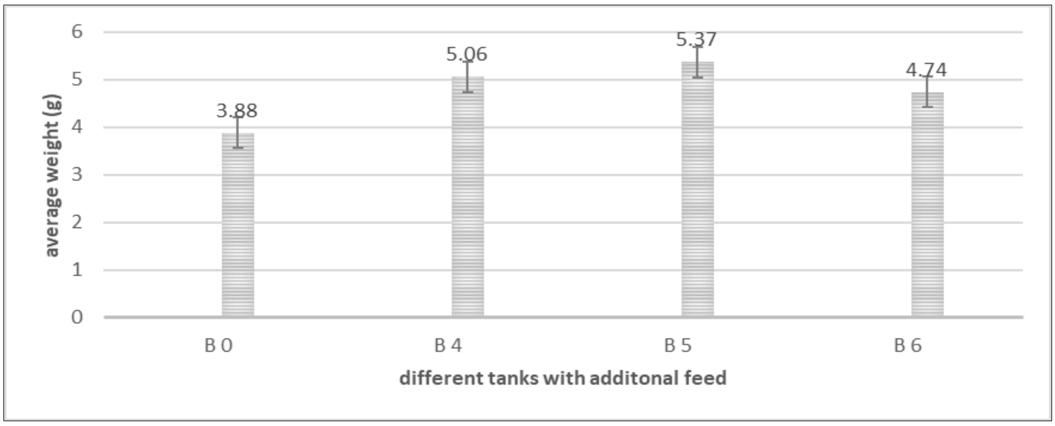

Fig. 5. Average weight of rainbow trout fingerlings after addition of Argan oil to garlic in B5 and B6

Table 5. Evolution in weight fingerlings (g) according the percentage (%) of garlic and Argan oil (mL) in the feed

	B 0	***B 1***	***B2***	***B 3***	***B4***	***B 5***	***B 6***
Average weight (g)	3.88	4.95	5.43	5.13	5 .06	5.37	4.74
Standard deviation	±1.6929	±2.3728	±2.6382	±2.3819	±2.4879	±2.3466	±2.258
Initial weight	1.62	1.62	1.62	1.62	1.62	1.62	1.62
Final weight	6.83	8.66	10.1	9.03	8.96	8.86	8.4
Final number of fish	995	933	938	899	905	906	909
Survival rate %	99.5	93.3	93.8	89.9	90.5	90.6	90.9
Initial biomass	1620 g						
Final biomass (g)	6795.85	8079.78	9473.8	8117.97	8090.7	8027.16	7635.6

Experimentation with garlic alone as a feed additive for rainbow trout fingerlings has been satisfactory, especially for a percentage of 1.5% garlic. The addition of Argan oil to well-defined volumes can also be beneficial in terms of the quantity and quality of fish flesh, based on the important role of this oil. Tests carried out at the Ras Al Ma station are encouraging for rainbow trout fingerlings. However, it is still important to monitor the growth and flesh quality of the other stages using garlic and Argan oil.

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