Aquaculture Studies, 23(2), AQUAST850
http://doi.org/10.4194/AQUAST850

RESEARCH PAPER

Effects of Potassium Diformate (KDF) on Growth Performance and Some Physiological Parameters of Cultured Rainbow Trout (*Oncorhynchus mykiss*) in Commercial–scaled Net Cages

Serhat Engin[1,*], Özgür Altan[1]

[1]Ege University, Faculty of Fisheries, Department of Aquaculture, İzmir, Turkey

How to Cite

Engin, S., Altan, Ö. (2023). Effects of Potassium Diformate (KDF) on Growth Performance and Some Physiological Parameters of Cultured Rainbow Trout (*Oncorhynchus mykiss*) in Commercial–Scaled Net Cages. *Aquaculture Studies*, *23(2), AQUAST850*. http://doi.org/10.4194/AQUAST850

Article History
Received 15 December 2021
Accepted 09 August 2022
First Online 25 August 2022

Corresponding Author
Tel.: +902323433815
E-mail: serhat.engin@ege.edu.tr

Keywords
Rainbow trout
Growth performance
FCR
Potassiumdiformate

Abstract

This study was conducted to evaluate the feed utilization and protein effect ratios of combined and single diet administration of potassium di formate (KDF) in juvenile rainbow trout (*Oncorhynchus mykiss*). 600.000 trout fry were stocked as 50.000 in each cage and were fed 3 meals a day in the range of 25-80 grams and two meals a day up to 80-250 grams (until harvest time) and fed with commercial feeds until satiation. 3 kg/ton (T1), 5kg/ton (T2) and 7 kg/ton (T3) KDF were added to the diets and given to fish for 11 months. In the study, when the specific growth rates (SGR) of fish were compared, the results obtained in the T1, T2 and T3 groups were generally higher than in the control group. While no significant difference was found between T1 and T2 groups ($p>0.05$), there is a significant difference between T3, the other experimental groups and the control ($p<0.05$). In the study, a significant difference was found between the feed conversion rate (FCR of all groups, ($p<0.05$)). When the protein efficiency ratio (PER) was compared to the control group and the other groups, a significant difference was detected, while the same situation was found among the KDF supplemented groups ($p<0.05$). While the survival rate (SR) was significantly different between the control and experimental groups ($p<0.05$), there was no statistical difference between the experimental groups ($p>0.05$). The results of the study showed that the application of 7 kg/ton KDF can be considered a useful feed additive and a growth promoter for rainbow trout juveniles.

Introduction

Rainbow trout is one of the most important freshwater fish species for aquaculture in the world. The most important features of this species are that it is extremely resistant to stress factors, the feed conversion ratio can be reduced to almost 1:1, the broodstock maturation and larval stage periods are shorter and easier than most marine fish, nutrient content, particularly it can be considered as a species-rich in unsaturated fatty acids (Camire, 2001) With the total world fisheries production being close to 1.6 million tons, it has gained an important place in aquaculture in Turkey and the annual production has reached the limit of 127.905 tons. Considering that the total amount of fisheries produced by aquaculture in Turkey is 421 thousand tons, how important is trout production for the country's fisheries (TUIK, 2020).

Published by Central Fisheries Research Institute (SUMAE) Trabzon, Türkiye.

The origin of many additives used in the feed industry is based on the nutrition of terrestrial animals. As is known, the digestive system of trout is different from thatof terrestrial animals. Crude protein, which is present at the rate of 48% in the feed of carnivorous fish such as rainbow trout, from the larval stage onwards, decreases to 42% in the later life periods of the fish. This ratio in the feed content is obtained from raw protein-rich animal origin fish meal, vegetable origin soybean meal and raw materials such as corn gluten (Rodehutscord., 1997) Fish meal is a raw material obtained from South American countries such as Peru and Chile and Northern European countries such as Norway and Denmark. In the supply of fishmeal containing 65-71% crude protein, a very limited amount of products can be found due to the laws in the mentioned countries for environmental protection and the development of natural fish populations. These difficulties in the supply of raw materials have deepened the search for solutions both by researchers dealing with fish nutrition and by fish producers looking for ways to reduce feed costs (Engin, 2020).

Dietary acidifiers have shown to be effective in increasing growth performance and nutrient availability in various aquatic species. They reduce the pH of digestion of the stomach and foregut, which stimulates pepsin activity, and improves protein digestibility and mineral absorption (Lückstadts, C. 2007; Jun-sheng et al., 2006). The addition of citric acid/formic acid to the diet increases the bioavailability of minerals such as phosphorus, magnesium, calcium and iron in rainbow trout (*Oncorhynchus mykiss*), fangri (*Pagrus major*) and Indian carp (*Labeo rohita*) (Jun-sheng et al., 2006; Vielma et al., 1997). Today, some studies have reported that graded KDF levels affect the growth of aquatic organisms, feed use efficiency and protein retention efficiency (Zhou et al., 2009; Nermeen et al., 2015). Abu Elala and Ragaa (2013) stated that the addition of 2 or 3 g kg^{-1} KDF to Nile tilapia (*Oreochromis niloticus*) diets significantly affected growth performance and feed use efficiency. However, oral administration of KDF significantly improved feed intake, body weight gain, feed conversion rate and protein productivity rate of various tilapia species (Liebert et al., 2010; Cuvin-Aralar et al., 2010).

To the best of our knowledge, the effects of potassium di formate on rainbow trout have not been found in the experimental setting except for a few studies. This study aims to reveal the results of potassium di formate application on some growth parameters and FCR in rainbow trout in a commercial enterprise.

Materials and Methods

Fish stocking and feeding

The study was carried out in a commercial trout cage system with three replicates which were located in Karkamış Dam Lake, Gaziantep - Turkey. A total of 600,000 rainbow trout juveniles were used in the study. The fish with an average live weight of 25±0.5 g were stocked in a total of 12 net cages, with 50,000 in each cage. The fish were fed three meals a day in the range of 25-80 grams, and 2 meals a day until the harvest time of 80-250 grams. The feed was provided by Kilic Fish Feed Company and the nutrient contents of the feeds are given in Table 1. In the study, the feeds produced with KDF (Assay:98%, Moisture: ≤2.0%, sigma Commerce Corporation, Germany), (3kg, 5kg, 7 kg KDF / ton feed) and without KDF additive (Control Group) were given to the fry until the end of the study. The feeding of fish was done in triplicate. The feed amount given to the fish was recorded. Once every 15 days, 50 fish were taken from the net cages by random sampling method and stunned with tricaine methanesulfonate (MS-222,100 mg/L,

Table 1. Nutritional composition of starter feed for trout.

Ingredients	Control diet	T1	T2	T3
Moisture (%)	7.9	8.3	8.2	8.3
Protein (%)	48	48	48	48
Fat (%)	12	12	12	12
Ash (%)	7.8	7.8	7.7	7.9
Crude Fiber (%)	1.97	1.94	2.07	1.96
Brut Energy (kcal/kg)	4.900 max.	4.900 max.	4.900 max.	4.900 max.
Digestable energy (kcal/kg)	4.360	4.360	4.360	4.360
DP/DE (mg/kj)	29.50	29.50	29.50	29.50
KDF (kg/t)	0	3	5	7

Table 2. Growing parameters of Rainbow trout.

Trials	Initial weight(g)	Final weight(g)	FCR	SGR (%)	IFC (g)	WG (g)	PER	SR (%)	CF
Control	25±1.25	250±15.2	1.43±0.03^d	1.54±0.03^c	309.16^b	275.0±1.18^d	1.98±0.28^d	80.79±0.12^b	1.150±0.12^c
T1	25±1.35	250±22.7	1.35±0.08^c	1.58±0.02^b	308.82^b	287.5±0.96^c	2.07±0.23^c	81.27±0.01^a	1.02±0.01^b
T2	25±1.28	250±33.4	1.22±0.01^a	1.58±0.02^b	290.61^c	300.6±0.76^b	2.30±0.21^a	81.33±0.01^a	1.00±0.01^b
T3	25±1,30	250±33.9	1.28±0.02^b	1.60±0.05^a	311.72^a	306±1.32^a	2.20±0.18^b	81.30±0.01^a	0.91±0.08^a

buffered to pH 7.4). These fish were individually weighed on a balance with an accuracy of 0.1 g (Sartorius BSA224S-CW electronic balance) and their length (total) was determined using a 1mm partitioned measuring board. Against any fish diseases, commercial vaccination was applied. Water temperature, dissolved oxygen and pH were controlled throughout the study period (temperature 15±1, dissolved oxygen 7.7±0.28.3±0.1 mg $L^{-,1}$ and pH 7-7.8). Ammonia, nitrate, and nitrite concentrations in water are not between deadly impact levels as the quality of the water resource was drinking water quality.

Growth performance indicators were calculated using the following formulas (Ricker, 1975):

Specific growth rate (SGR,%day-1)= ln (final weight in grams) – ln (initial weight in grams) x100) / t (in days).

Mean Daily Weight Gain (MDWG) = 100 x [(Total final weight – Total initial weight)/Days of the experiment]

Survival (%) = 100 x (Total number of harvested fish / Total number of initial stock)

Condution factor (K) = W (weight) /L^3 (length) × 100

Protein efficiency ratio (PER) =wet weight gain (g) /total protein given (g).

Feed conversation ratio (FCR) = Weight of feed given (g) / Fish WG (g)

Dead fish in all experimental groups were immediately collected and removed daily from the cages and the number of dead fish was recorded.

Statistical analysis

The data obtained were statistically assessed by the analysis of variance (ANOVA, through the general linear model procedure of the SPSS14.0 software). The values were expressed as means ±standard error. Duncan's multiple range tests were used to test the significance of the difference between means by considering the differences significant at $p < 0.05$.

Results

When the FCRwas examined in the study, a significant difference was found when the control group was compared with the KDF added groups (p<0.05). The FCR of fish fed with KDF-added feeds provided better results than the control. When the experimental groups were compared among themselves, a significant difference was found in all three groups (p<0.05). Accordingly, the best FCR was seen in the T2 with a value of 1.22±0.01, followed by the T3 with 1.28±0.02 and the T1 with 1.35±0.08.

When comparing specific growth rates in fish, in general, fish fed with all KDF added feeds had a higher SGR than feeds without KDF added. While no significant difference was found in the T1 and T2 (p>0.05), a significant difference was found in the T3 with other groups and the control group (p<0.05). Accordingly, the highest SGR ratio was found in the T3 with 1.60±0,05.

The fish whose average initial live weight of 25±0.7 g in the study achieved higher individual weight gain as a result of the 160-day feeding-raising period compared to the feeds without KDF added. When the control group and other groups were compared, a significant difference was detected, while the same situation was also detected among the KDF supplemented groups (p<0.05). According to the results obtained, the highest individual weight gain was found in the T3 with 306±1.32 g (Figure 1).

The protein efficiency ratio was best seen in the groups fed with KDF added feeds compared to the groups fed with feeds without KDF addition. When the

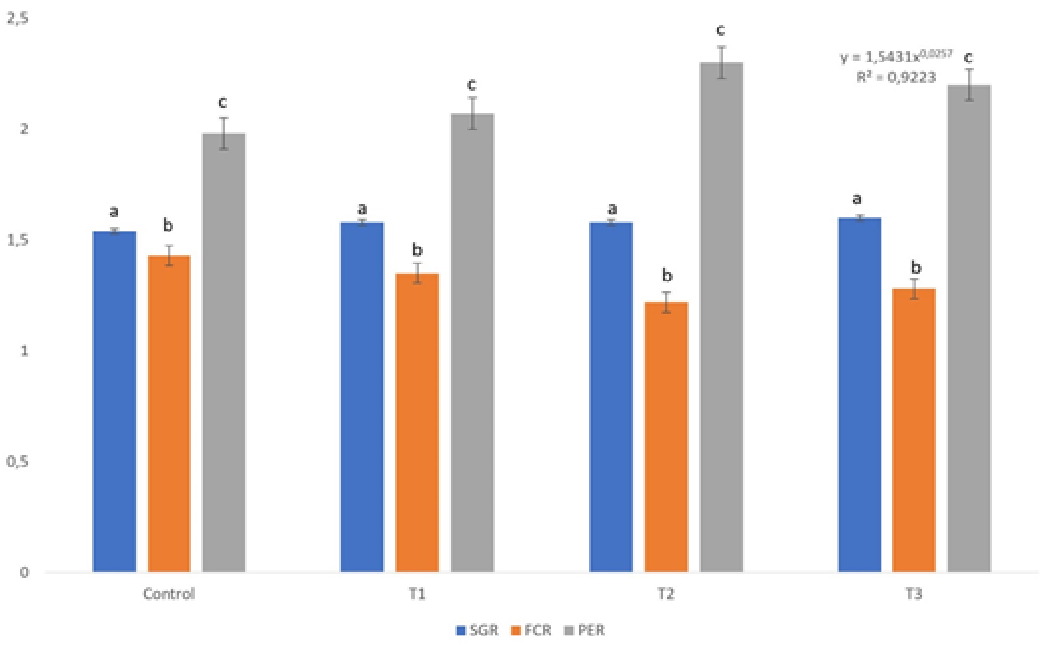

Figure 1. Variations of SGR; %, FCR and PER of the experimental fish during the trial period.

control group and other groups were compared, a significant difference was detected, while the same situation was also detected among the KDF supplemented groups ($p<0.05$). According to the results obtained, the best PER was found in the T2 group with 2.30±0.21.

When the survival rates of the fish were compared, a significant difference was found between the control and experimental groups ($p<0.05$), while there was no statistical difference between the experimental groups ($p>0.05$). Accordingly, the highest survival rate was found in the T2 group with 81.33%.

While no significant difference was observed in the condition factor T1 and T2 groups ($p>0.05$), a significant difference was found in the control and T3 groups ($p<0.05$).

The highest fillet meat wastage rate was found in the control group, and the experimental groups gave better results than the control group (Table 2).

Discussion

In aquaculture, the use of fish feed additives such as probiotics, organic acids and their salts has been attracting attention recently, both to increase growth performance and to control diseases (Lückstadt, 2006). All these compounds have been reported to increase the survival rate and growth performance in aquatic species by improving the function of digestive enzyme activity and immune responses (Guardiola et al., 2016).

In the study, parameters such as specific growth performance (SGR), FCR, Individual live weight gain (GR), Protein efficiency rate (PER), Survival rate (SR), Condition factor (CF) and meat waste rate were determined by adding potassium di formate to trout feeds. . Studies on feed additives in trout show that the results of issues related to probiotic additives are mostly revealed (Park et al., 2016; Zorriehzahra et al., 2016). It is seen that a few studies in which there are almost no studies on potassium di formate are carried out in experimental environments and with a low number of individuals (Farsani et al., 2020).

Some studies have been carried out on the subject in different species and it has been revealed that the growth of fish can be increased by using some organic acids. Recently, effects of KDF on *Oreochromis niloticus* (Nermeen et al., 2015), *Salmo salar* (Morken et al., 2012) and *Sciaenops ocellatus* (Castillo et al., 2014) have been reported. Vielma and Lall, (1997) reported that formic acid supplemented diet led to better absorption of P, Mg and Ca in rainbow trout. Luckst et al., (2008) noted no significant improvement in intestinal pH in KDF-fed Atlantic salmon (*Salmo salar*), although improved digestibility of protein, dry matter and gross energy was observed. Farsani et al., (2020) reported that KDF had positive effects on SGR, FCR and SR in their study on rainbow trout. These results are in parallel with our results.

It is striking that the studies on the subject focus on tilapia species. It is seen that the studies are conducted on low populations in low-scale production or experimental environments, and low doses of KDF are used in parallel with this (Ramli et al., 2005; Lim et al., 2010; Cuvin-Aralar et al., 2010). In this context, various factors such as species and physiological age of experimental fish, type and level of organic acids, diet composition and culture conditions can all influence the manifestations of potential growth-promoting effects of dietary organic acids in aquaculture (Wing-Keong et al., 2009). The results we obtained showed parallelism with the previous studies, moreover, in the study, not only the SGR and FCR results but also the parameters such as GR, PER and CF were revealed. However, the study differs from other studies in that it was carried out on a high number of individuals in a commercial mesh cage business.

Conclusion

As a result, in this study, which lasted approximately 11 months, it was revealed that the addition of 7 kg/ton KDF to rainbow trout feeds had a positive effect on growth performance and FCR rate. This study provides encouraging evidence for the use of such additives in aquaculture. In the future, the development of studies on different cultured fish and increasing the trials will make significant contributions to improving the aquaculture industry and potentiate fish welfare.

Ethical Statement

No fishes were harmed during this experimentation.

Funding Information

This study was supported by the 1501 – Industrial R&D Projects Grant Programme (Project no: 3130021).

Author Contribution

All the authors contributed equally in carrying out the study and drafting the manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

Acknowledgements

The authors thank the efforts of Kilic Deniz Company Inc., the owner of the trout farm and particularly Mr. Taner Seker, the general manager of the farm. This study was supported by the 1501 – Industrial R&D Projects Grant Programme (Project no: 3130021).

References

Abu-Elala, N., Marzouk, M., & Moustafa, M. (2013). Use of different Saccharomyces cerevisiae biotic forms as immune-modulator and growth promoter for Oreochromis niloticus challenged with some fish pathogens. Int J Vetrinary Sci Med 2013;1:21–9.

Camire, M.E., 2001. Extrusion and nutritional quality. In: Guy, R. (Ed.), Extrusion Cooking, Technologies and Applications. Woodhead Publishing Limited, Cambridge, pp. 108–129.

Castillo, S., Rosales, M., Pohlenz, C., & Gatlin, D. M. (2014). Effects of organic acids on growth performance and digestive enzyme activities of juvenile red drum Sciaenops ocellatus. Aquaculture 433:6– 12. https://doi.org/10.1016/j.aquaculture.2014.05.038.

Cuvin-Aralar, M., Kühlmann, K. J., Schroeder, K., & Lückstadt, C. (2010). Effect of potassium diformate (KDF) on growth performance of male Nile tilapia (Oreochromis niloticus). In: XIV international symposium on fish nutrition and feeding, Qingdao, China, Book of Abstracts; 2010. p. 187.

Farsani, M. N., Gorji, S. B., Hoseinifar, S. H., Rashidian, G., & Doan, H. V. (2020). Combined and Singular Effects of Dietary PrimaLac® and Potassium Diformate (KDF) on Growth Performance and Some Physiological Parameters of Rainbow Trout (Oncorhynchus mykiss). Probiotics and Antimicrobial Proteins https://doi.org/10.1007/s12602-019-9523-2 (2020) 12:236–245.

Engin, S. (2020). The First Commercially-Scaled Study on the Influence of Long Dark and Light Photoperiod Manipulation on the Egg and Larvae Performance of Rainbow Trout (*Onchorhynchus mykiss*). Journal Of Coastal Research, 38, 10.2112/jcoastres-d-21-00056.1.

Guardiola, F. A., Porcino, C., Cerezuela, R., Cuesta, A., Faggio, C., & Esteban, M. A. (2016) Impact of date palm fruits extracts and probiotic enriched diet on antioxidant status, innate immune response and immune-related gene expression of European seabass (Dicentrarchus labrax). Fish Shellfish Immunol 52:298–308. https://doi.org/10.1016/j.fsi.2016.03.152.

Jun-sheng, L., Jian-lin, L., & Ting-ting, W. (2006). Ontogeny of protease, amylase and lipase in the alimentary tract of hybrid Juvenile tilapia (Oreochromis niloticus X Oreochromis aureus). Fish Physiol Biotechnol 2006;32:295–303.

Liebert, F., Mohamed, K., & Lückstadt, C. (2010). Effects of diformates on growth and feed utilization of all male Nile Tilapia fingerlings (Oreochromis niloticus) reared in tank culture. In: XIV International symposium on fish nutrition and feeding, Qingdao, China, Book of Abstracts; 2010. p. 190.

Lim, C., Klesius, P., &Luckstadat, C. (2010). Effects of dietary levels of potassium diformate on growth, feed utilization and resistance to Streptococcus iniae of Nile tilapia, Oreochromis niloticus. In: Proceeding of the fourteenth international symposium on fish nutrition and feeding, Qingdao, China; 2010. p. 170.

Luckst, C. (2008). Effect of dietary potassium diformate on the growth and digestibility of Atlantic salmon Salmo salar. Proceedings of the thirteenth international symposium on fish nutrition and feeding; June 1–5. Florianopolis, Brazil, p 179.

Lückstadt, C. (2006). Use of organic acids as feed additives – sustainable aquaculture production the non-antibiotic way. Int Aquafeed 2006;9:21–6.

Morken, T., Kraugerud, O. F., Sørensen, M., Storebakken, T., Hillestad, M., Christiansen, R., & Øverland, M. (2012). Effects of feed processing conditions and acid salts on nutrient digestibility and physical quality of soy-based diets for Atlantic salmon (Salmo salar). Aquac Nutr 18:21–34. https://doi.org/10.1111/j.1365-2095.2011.00872.x

Nermeen, M., Elaa, A., & Ragaa, M. (2015). Eubiotic effect of a dietary acidifier (potassium diformate) on the health status of cultured Oreochromis niloticus. J Adv Res 6:621–629. https://doi.org/10. 1016/j.jare.2014.02.008

Park, Y., Lee, S., Hong, J., Kim, D., Moniruzzaman, M., & Bai, S. C. (2016) Use of probiotics to enhance growth, stimulate mmunity and confer disease resistance to Aeromonas salmonicida in rainbow trout (Oncorhynchus mykiss). Aquaclt Res 48:2672–2682. https://doi. org/10.1111/are.13099.

Ramli, N., Heindl, U., & Sunanto, S. (2005). Effect of potassium-diformate on growth performance of tilapia challenged with Vibrio anguillarum. Bali, Indone´ sia: World Aquaculture Society; 2005. p. 9–13.

Ricker, W. E. (1958). Handbook of computations for biological statistics of fish populations. Bulletin of Fisheries Research Board of Canada, 119, 1–300.

Rodehutscord, M., Becker, A., Pack, M., Pfeffer, E., 1997. Response of rainbow trout *Oncorhynchus mykiss* to supplements of individual essential amino acids in a semipurified diet, including an estimate of the maintenance requirement for essential amino acids. J. Nutr. 127, 1166–1175.

TÜİK (Turkish Statistical Institute) (2020). Fisheries and Aquaculture Statistics. http://www.tuik.gov.tr (Accessed November, 1, 2017).

Vielma, J., & Lall, S. (1997). Dietary formic acid enhances the apparent digestibility of minerals in rainbow trout, *Oncorhynchus mykiss* (Walbaum). Aquac Nutr 1997;3:265–8.

Zhou, Z., Liu, Y., He, S., Shi, P., Gao, X., Yao, B., & Ringo, E. (2009). Effects of dietary potassium diformate (KDF) on growth performance, feed conversion and intestinal bacterial community of hybrid tilapia (*Oreochromis niloticus* ♀ *O aureus* ♂). Aquaculture 291:89–94. https://doi.org/10.1016/j.aquaculture.2009.02.043.

Zorriehzahra, M. J., Delshad, S. T., Adel, M., Tiwari, R., Karthik, K., Dhama, K., & Lazado, C. C. (2016). Probiotics as beneficial microbes in aquaculture: an update on their multiple modes of action: a review. Vet Q 36:228–241. https://doi.org/10.1080/01652176.2016. 1172132.

Wing-Keong, N., Koh C. B., Sudesh, Kumar., & Siti-Zahrah, A. (2009). Effects of dietary organic acids on growth, nutrient digestibility and gut microflora of red hybrid tilapia, Oreochromis sp., and subsequent survival during a challenge test with Streptococcus agalactiae. Aquac Res 2009;40:1490–500.