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Possibility of using quinoa (Chenopodium quinoa) as an alternative energy source in the goldfish (Carassius auratus auratus) diet

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Research Article

Abstract − The present study was carried out to investigate the effect of using quinoa instead of 50(T2), 75(T3), and 100(T4) % of oat grain in goldfish rations on their performance. Ninety-six young goldfish, aged about 5 months were randomly divided into four similar groups, twenty-four goldfish in each group. The performances of goldfish were investigated by adding 0%, 50%, 75%, and 100% quinoa grains instead of oat grain in the feed (T1), (T2), (T3), and (T4), respectively. The Total live weight gains for fish fed by the T1, T2, T3, and T4 diets were 7.56±0.70, 7.48±0.38, 7.97±1.20, and 7.32±0.68 g day-1, respectively, during the trial. In this study, Insignificant (P>0.05) differences in specific growth rates (% / d) in experimental groups were observed during all experimental periods (60 days). The specific growth rates (%/d) were higher in goldfish fed with the T2 ration than in goldfish fed with T3 and T4 and T1 diets (2.88%, 11.03%, and 11.71%; P> 0.05), respectively. Furthermore, there were no significant differences between the control group and the groups that received quinoa on body length, body height, head highs, or head widths. The performance of all goldfish fed quinoa rations showed as similar to goldfish fed by oat ration. Based on the results obtained in this study, quinoa grain can be successfully used in the goldfish ration without any negative effect on goldfish performance.

Keywords − *Carassius aerates auratus Chenopodium quinoa, energy source, goldfish, quinoa*

1. Introduction

Aquarium fish hobby is increasing in the world. It is estimated that the entire industry, including aquarium equipment, feed, and pharmaceutical production, is worth more than 18-20 billion dollars worldwide (Dey, 2016). The goldfish (Carassius auratus auratus) belongs to the Cyprinidae family and is one of the most loved aquarium fish due to its color, body shape, and simple of breeding that can be seen in ponds and aquariums in the world (Değirmencioğlu, 2021). Structural differences in plant flora have also emerged due to changes in the ecosystem, along with global warming. In recent years, the use of drought-resistant plants as a source of alternative feed has been on the agenda in animal husbandry. Examples of such grains are quinoa. Quinoa (Chenopodium quinoa (Willd.) is a C3 annual dicotyledonous pseudo-cereal belonging to the Amaranthaceous family (Bilalis et al., 2019). Quinoa can grow in soil with a wide pH range (4.5-9). Didier et al. (2016). Unlike other grains, quinoa has versatile properties such as gluten-free, high protein and antioxidant content, and heat resistance. These features have made it recognized in global agriculture (Martínez et al., 2009; Pulvento et al., 2010; Bilalis et al., 2012; Kakabouki et al., 2014; Lavini et al., 2014; De Santis et al., 2016). The crude protein (CP) content varies between 7% and 22% in quinoa grains. (Cardozo and Tapia, 1979; Wright et al., 2002).

It is richer in essential amino acids than cereals. In addition, it is an important food source for animals in their developmental period due to its Lysine (5.1–6.4%) and Methionine amino acids (0.4–1.0%) content. Quinoa also contains mineral substances such as calcium, iron, and phosphorus. (Repo-Carrasco et al., 2003; Vega-Gálvez et al., 2010). The starch ratio of quinoa varies between 51% and 61% (Atwell et al., 1983; Koziol, 1992). In addition, starch is preferred in the food industry due to its high particle size (3 μ) and high viscosity

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(Galwey et al., 1990). The hesitation to use quinoa grain is due to the belief that quinoa is an antinutrient substance (saponin, phytic acid, and trypsin inhibitor) and its bitter taste could affect feed intake when administered at high levels. Therefore, before giving quinoa to animals; pre-treatments such as soaking, heat treatment, peeling, or selection of sweet quinoa varieties are required (Gül & Tekce, 2016). Interest is growing in starting to use it, as many studies show that quinoa provides significant opportunities to improve the fascination of animal feeds without losing animal performance. Quinoa can be used as an alternative energy source in livestock rations in terms of nutrient content (Angeli et al., 2020). Similarly, it is recommended that sweet quinoa species be added to animal rations as an alternative feed source, as it is stated that they give much better results than bitter quinoa and all other grains (barley, corn, and oats) (Pate et al., 2006; Bazile et al., 2015; Gül & Tekce, 2016). Constipation and bloating can be seen in sensitive fish due to the excessive use of gluten-containing grains in some fish rations. The use of quinoa in animal nutrition may become more attractive over time due to reasons such as the low protein content, high gluten content, and water requirement of the oat grain. Although numerous studies evaluated the use of quinoa, Research data are not available on evaluating its use in goldfish. This study aimed to investigate the effect of quinoa addition on growth performance, body form, and feed composition in goldfish diets.

2. Materials and Methods

2.1. Animals, treatments, and experimental design

As the animal material of the experiment, a total of 96 - goldfish (the age of about 5 months) were used. The fish were randomly divided into four groups with the same live body weight (g). Twins aquarium, a commercial pet store located in the Bursa-sehreküstü district was chosen as the experimental area. The experiment was conducted between September and November 2021 and lasted 60 days. In the research, four different rations were prepared, one for control and 3 for trial.

Table 1 The composition of feed mixtures used in the researche

Feed	Diet			
	T_1 0.0 Qkg^{-1}	T_2 100 g Q kg^{-1}	$T_3$150 g Q kg^{-1}	$T_4$200 g Q kg^{-1}
Fish meal	150	150	150	150
Wheat gluten	60	60	60	60
Krill meal	200	200	200	200
Soya meal	180	180	180	180
Wheat bran	20	20	20	20
Oat	200	100	50	-
Quinoa	-	100	150	200
Wheat germ	150	150	150	150
Spirulina	15	15	15	15
Molasses	5	5	5	5
Vitamin+Mineral*	5	5	5	5
Probiotic**	10	10	10	10
Beta-xylanase +Phytase***	4	4	4	4
Garlic powder	1	1	1	1
TOTAL	1000	1000	1000	1000
Nutrient composition				
DM	95.85	96.21	93.18	95.56
OM	88.62	88.67	85.66	88.2
CP	38.20	38.62	38.04	38.39
EE	8.51	8.75	8.66	9.17
CEL	2.86	3.00	3.05	3.01
CA	7.23	7.34	7.52	7.36
NFE	39.05	38.3	35.91	37.63
ME Kcal kg^{-1} DM****	4563.545	4579.205	4439.940	4578.425

*Trace minerals and vitamins (per kg): Dicalcium phosphate, Sodium chloride, Magnesium oxide, Calcium carbonate Analyse: Calcium 17.90 %, Fosfor 10.80%, Natrium 5.5%. Retinol palmitate (Vitamin A) 2000.000 IE, Cholecalciferol (Vitamin D3) 200.000 IE, α Tocopherol acetate (Vitamine E) 8.000 mg, Ascorbıc acıd (Vitamin C) 20.000 mg, Thiamine (Vitamine B1) 2.000 mg, Riboflovine (Vitamine B2) 4500 mg, Pyridoxine (Vitamine B5) 1500 mg, Nicotinamide (Vitamine PP) 5000 mg, Calcium-D-pantothenate 1500 mg, Foliumzuur 400 mg, Menadione (Vitamine K3) 250 mg, Vitamin B12 30.000 mcg, Biotin (Vitamin H) 25.000 mcg, Magnesium oxide 22.000 mg, Zinkoxide 50.000 mg, Nikkel (II)- Sulfate 10 mg, Natrium fluoride 50 mg, Borax 100 mg, Calcium iodide 110 mg, Natrium bromide 100 mg, Mangan (II)-sulfate 500 mg, Aluminium sulfate 500 mg, Lithium carbonate 500 mg, Calcium sulfate 5000 mg, Lizer (II)-Sulfate 1500 mg and Cooper (II)-Sulfate 400 mg. ** (Saccharomyces cerevisiae) and (lactobacillus acidophilus) *** 4a1617 Endo-1.4-beta-xylanase (EC 3.2.1.8) was obtained from Trichoderma citrinoviride Bisset (IM SD 135) 1.100.000 EPU/kg, 4a12 6-Phytase (EC 3.1.3.26) was obtained from Trichoderma reset (CBS 122001) 83.400 PPU/Kg. ****DM: Dry Matter, OM: Organic Matter, CP: Crude Protein, EE: Ether Extract, CELL: Cellulose, CA: Crude Ash, NFE: Nitrogen Free Extract, and ME: Metabolizable Energy

The performances of goldfish were investigated by adding 0%, 50%, 75%, and 100% quinoa grains instead of oat grain in the feed (T1), (T2), (T3), and (T4), respectively. Care was taken to prepare the diets equally in terms of energy and protein content. The structure of the concentrate feed mixtures used in the research, and the nutrient content of quinoa, oatmeal, and diets are presented in (Table 1). Quinoa (Q) proceeded at a size of 3 mm. Feed raw materials were mixed in a blender for 10 minutes. Then, the feed mixture was ground into a dough with a mixture of water and molasses and passed through a meat grinder. They were left to dry in an oven at 65 C^{o}. The length and diameter of the pellet were adjusted to 1-1.5 inches so that the fish could easily eat the prepared food mixture. Body weights, feed consumption, and body forms of the fish were determined every 20 days throughout the experiment. Scales capable of measuring 0.001 g were used to determine fish weights.

2.2. Growth performance

Specific growth rate (SGR) = [(Final live weight) – (initial live weight) / 60 day] × 100, Weight gain (WG) (g) = (End weighing) (g) - (First weighing) (g/20 day); Feed conversion Ratio (FCR) = Feed intake DM(g) / Weight gain (g)

Quality water and high protein feed positively affect the head and color development of fish. In essence, feed residues and fish excrement increase harmful gases such as ammonia, nitrate, and hydrogen sulfur in the water over time. 30% of the water was drawn from the aquariums with a bottom siphon 4 times a week to eliminate such formations; tap water was added to aquariums after resting for three days. Oxygen was supplied to the aquarium with a hose and an air stone assembly connected to the air motor. Daily feed consumption of fish was determined at the level of 2% of live weight. The feed was given by soaking in a small bowl so that bubbles do not form in the air sacs while the fish are eating. Experimental groups were fed three times a day at 8:00 a.m., 13:00, and 6:00 p.m. The individual feed consumption of the fish could not be determined as group feeding was carried out in the aquarium. The feed consumption was obtained by dividing the total fish number in each aquarium.

2.3 Chemical composition

The metabolizable energy (ME) value of the diet was calculated based on chemical analyses according to the National Research Council (NRC 1981) and Halver (1973). The following main ME formula was given.

Total ME (Kcal kg-1) = 5.65X(CP%)+9.45X(EE%)+4.10X(NFE)X10. The nutrient contents of the diet were analyzed according to the AOC method (1990).

2.4 Statistical analysisEquations

Data for growth performance and head development in the aquarium were tested by analysis of variance using the SPSS version15.0 Statistical Package (2006) and means were analyzed with the general linear model's procedure using the following model described by (Cochran & Cox, 1957):

Yijk=μ+Ti+Dj+Eijk where; Yijk – observation, μ – population mean, Ti – Dietaries (i= T1, T2, T3 or T4),

Dj – animals (k=1, 2, 3….95 or 96), Eijk – residual error. Means were separated by Duncan's multiple range test.

3. Results and Discussion

Data showed that quinoa determined a lower OM and ash compared to oat seeds (867.5 vs. 901.1 and 14.6 vs. 16.1 g/kg, respectively). The CP content in quinoa was higher than in oat (132.5 vs. 110.6 g/kg, respectively). The cell wall contents of quinoa were close to those recorded for oat (Table 2).

Table 2
Chemical compositions of quinoa*and oat**seeds DM (%)

DM	OM	CP	EE	CE	CA	NFE	ME (kcal kg^{-1})
88.21*	86.75	13.25	2.14	4.94	1.46	66.42	3674.05
91.72**	90.11	11.06	4.22	4.80	1.61	70.03	3894.88

DM: Dry Matter; OM: Organic Matter; CP: Crude Protein; EE: Ether Extract; CE: Cellulose; CA: Crude Ash; NFE: Nitrogen Free Extract; ME: Metabolizable Energy calculated according to the (NRC 1981).

3.1. The Live body weight

The results of the live weights at various growth periods and the increases in total live weight, the specific growth rate, and feed intake during the trial period are reported in (Table 3).

As seen in Table 3, Groups whose live weights were quite close to each other at the beginning of the trial. At the end of the 60-day trial, their live weights increased and ranged from 17.24±1.37 to 17.74±1.61 g. The highest live weight was determined in the 3rd group and the lowest live weight was determined in the 4th group. The live weights of the groups were similar to each other. The Total live weight gains for fish fed by the T1, T2 , T3 , and T4 diets were 7.56±0.70, 7.48±0.38, 7.97±1.20, and 7.32±0.68 g day-1, respectively, during the trial (Table 3). In this study, the total live weight gain of the group was not significantly affected by the application of quinoa. As a result of the research, it was found that adding up to 20% quinoa to goldfish rations does not adversely affect the live weight and was similar to the oat Mosquero (2009) reported that sweet quinoa can be added to broiler rations up to 25%. This value is significantly lower than the 25 % reported by Mosquero (2009). Similarly; Jacopsen et al., (1997) found that the live weight in broilers consuming 50 g kg -1 quinoa showed similarities compared to control group broilers. The observed response variance may be related to several factors, such as species differences and the quinoa variety used in the dietary.

Table 3
Results on goldfish performance growth

Groups / Parameters	1st Group (T_1) n	1st Group (T_1) $\bar{X} \pm S_{\bar{x}}$	2nd Group (T_2) n	2nd Group (T_2) $\bar{X} \pm S_{\bar{x}}$	3rd Group (T_3) n	3rd Group (T_3) $\bar{X} \pm S_{\bar{x}}$	4th Group(T_4) n	4th Group(T_4) $\bar{X} \pm S_{\bar{x}}$
İnitial live weight (g/fish)	24	9.69±0.64	24	10.05±0.62	24	9.76±0.64	24	9.95±0.73
20. day	24	13.26±1.00	24	13.41± 0.75	24	13.95± 0.46	24	14.20± 0.80
40. day	24	16.10±1.12	24	16.22±0.86	24	16.69±1.55	24	15.96±1.14
60. day	24	17.26±1.32	24	17.53±0.94	24	17.74±1.61	24	17.24±1.37
Total live weight gain	24	7.56±0.70	24	7.48±0.38	24	7.97±1.20	24	7.32±0.68
Specific growth rate (%/d)	24	11.45±0.88	24	11.79±0.56	24	12.87±1.28	24	12.97±1.11
Daily live weight gain (g/fish)								
0-20.day	24	0.182±0.201	24	0.170±0.179	24	0.212±0.197	24	0.214±0.129
20-40 day	24	0.144±0.018	24	0.142±0.174	24	0.138±0.028	24	0.089±0.027
46-60. day	24	0.058±0.145	24	0.067±0.119	24	0.055±0.007	24	0.067±0.013
Mean		0.128±0.121		0.126±0.157		0.135±0.098		0.123±0.068
Feed intake (g/fish)								
0-20. day		1.38		1.53		1.55		1.43
21-40 day		182		1.74		1.87		1.70
41-60. day		0.87		0.85		0.86		0.80
Mean		1.35		1.37		1.42		1.31
FCR *		10.54		10.87		10.56		10.65

*FCR; Feed conversion ratio

3.2. The specific growth rate

In this study, the specific growth rate (SGR) was not affected significantly by quinoa supplementation (Table 3). However, a partially insignificant increase (2.88%, 11.03%, and 11.71; P> 0.05) in the SGR (% / d) was observed in the goldfish groups fed by T2 with 100 g quinoa, T3 with 150 g quinoa and with T4 200 g quinoa diets feed compared to the control group.

Also, insignificant differences were observed in average daily gain during 0-20 days. The highest daily value of live weight gains on fish was obtained from the T4 diet with 0.214±0.129 g day-1. This was followed by the T3 diet, the T1 diet, and the T2 diet with 0.212±0.197, 0.182±0.201, and 0.170±0.179, respectively. The differences between the means of the group were found statistically insignificant (P>0.05). The same trend was obtained throughout the trial period (0-60 days). Group's daily live weight gain showed similarity with each other (Table 3). This can be explained by the fact that the protein and energy contents of the trial rations are close to each other (Abo-Eid et al., 2021).

3.3. The Feed intake

Feed consumption and FCM values of the experimental fishes are presented in (Table 3). The average daily feed consumption of fish showed a continuous increase during the trial period. It ranged from 1.31–1.42 g. The highest feed consumption was determined in the 3rd group fed by T3 with 150 g quinoa and the lowest feed consumption was determined in the 4th group fed by T4 with 200 g quinoa. The average daily feed consumption of the group was not significantly affected by the application of quinoa. This may be due to the palatability of quinoa grain being similar to that of oats. Similarly, Jacobsen et al., (1997) reported that feed intake did not affect broilers fed with quinoa. The different results might be due to the differences in animal, quinoa variety, and processing technology

3.4. The feed conversion

The average FCR; (Feed Conversion Ratio) of the experimental fish was determined to vary between 10.54–10.87, respectively during the trial. (Table 3). The highest FCR was determined in the first group and the lowest FCR was determined in the second group. During the period (60 days), the average FCR ranged from 17.24±1.37 to 17.74±1.61 g. for T1, T2, T3, and T4 respectively. These results are also supported by a previous study (Abo-Eid et al., 2021). This may be due to the close values of feed intake parallel to the average daily gain values (El Sayed, 2016). Since only the total feed intake was determined in each group, statistical analyses of the results obtained data of feed intake and FCR could not be performed.

3.5. The Effects of Quinoa on the developmental body of Fish

When the effects of the use of quinoa on the development body of fish were examined, it was determined that the mean body lengths of the experimental animals varied between 6.29±0.124 - 6.43±0.132, respectively at the beginning of the trial. (Table 4). The body lengths of fish increased at the end of the 60-day trial. and it ranged from 6.95±0.131 to 7.29±0.212 cm.

As seen in Table 4, the head highs of fish according to the groups are; It was determined that it varied between 2.00±0.059 - 2.20±0.061 cm at the beginning of the study ($p>0.05$). At the end of the 60-day trial, the head highs of fish were partially positively affected in goldfish fed by T2. In fish fed by diet T2 with 100 g quinoa increased head high by 0.15 cm and Similarly, this increment was only 0.02 cm in fish fed by diet T3 with 150 g quinoa. In the present study, the head highs and head widths of the fish were not significantly affected by quinoa.

There was no statistical difference between the rations in terms of criteria. Based on the data obtained in Table 4, shows that the qinoa ration does not have a negative effect on fish. The performance of all goldfish-fed quinoa rations was similar to that of goldfish fed oats rations. However, these study results were not similar to the previous study results. (Pate et al., 2006; Gutierrez-Espinosa et al., 2011; Bazile et al., 2015; Gül &Tekce, 2016; Marino et al., 2018; Angeli et al., 2020) which stated that quinoa gives much better results than all other grains (barley, corn, and oats).

Table 4
Results on the developmental body of goldfish

Groups Parameters	1st, Group n	$\overline{X} \pm S_{\overline{x}}$	2nd Group n	$\overline{X} \pm S_{\overline{x}}$	3rd Group n	$\overline{X} \pm S_{\overline{x}}$	4th Group n	$\overline{X} \pm S_{\overline{x}}$
İnitial body lengths (cm)	24	6.43±0.132	24	6.29±0.124	24	6.32±0.167	24	6.29±0.134
20. day	24	6.74± 0.148	24	6.80± 0.182	24	6.62± 0.138	24	6.63± 0.130
40. day	24	6.80±0.184	24	6.89±0.116	24	6.63±0.186	24	6.83±0.166
60. day	24	7.29±0.156	24	6.95±0.131	24	7.29±0.212	24	7.02±0.198
İnitial body height (cm)	24	2.94±0.071	24	2.86±0.080	24	3.00±0.046	24	3.00±0.060
20. day	24	3.10±0.076	24	3.13±0.067	24	3.23±0.066	24	3.19±0.061
40. day	24	3.30±0.078	24	3.30±0.055	24	3.32±0.065	24	3.31±0.071
60. day	24	3.42±0.095	24	3.48±0.067	24	3.47±0.074	24	3.55±0.083
İnitial head highs (cm)	24	2.20±0.061	24	2.12±0.046	24	2.15±0.036	24	2.00±0.059
20. day	24	2.35±0.055	24	2.36±0.044	24	2.42±0.047	24	2.27±0.055
40. day	24	2.45±0.058	24	2.53±0.042	24	2.53±0.061	24	2.43±0.052
60. day	24	2.60±0.055	24	2.75±0.065	24	2.62±0.064	24	2.58±0.048
İnitial head widths (cm)	24	1.55±0.039	24	1.61±0.034	24	1.55±0.044	24	1.51±0.040
20. day	24	1.68±0.041	24	1.74±0.034	24	1.77±0.044	24	1.61±0.036
40. day	24	1.78±0.038	24	1.84±0.030	24	1.83±0.044	24	1.73±0.034
60. day	24	1.91±0.050	24	1.98±0.053	24	1.95±0.044	24	1.83±0.034

4.Conclusion

A well-chosen quinoa can positively affect goldfish performance growth and development body in diets when an energy grain was limited or replaced by an oat grain as a concentrate energy source and can be included up to 20% in goldfish diets without losing performance. However, considering the head development of 0.15 cm in fish and long-term use in the diet, it is thought that the most optimal dosage of quinoa to a diet of goldfish was 100 g/kg on a DM basis. Quinoa, which has a rich nutrient content and does not contain gluten can play a very important role in terms of the recognition of this feed in the sector for reasons such as ease of pelleting and being substituted for oats. No blood sample was taken because the fish were small. There was no loss of death from the trial animals.

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Author Contributions

Taşkın Değimencioğlu Designed and conducted most of experiments, statistical analyses of the result and writing. Also involved in choosing the sample of animals and collecting data.

Conflicts of Interest

The author declares no conflict of interest.

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