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Effects of Jerusalem artichoke-enriched diet on water quality, growth performance, feed utilization, proximate body composition, and hematology and biochemical parameters in common carp fingerlings

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Abstract

The purpose of this research was to evaluate the impact of Jerusalem artichoke tubers (*Helianthus tuberosus* L.), a natural prebiotic, on the growth performance, proximate body composition, feed utilization, hematology, and biochemical parameters in common carp (*Cyprinus carpio*) fingerlings. Four JA-supplemented diets were formulated at 0.0% (control), 0.5%, 1%, and 2%. Fish were reared for ten weeks in cages placed in concrete ponds. Based on the results, an increase in the levels of JA supplementation led to significant improvements in growth and feed parameters ($P<0.05$), while the proximate body composition exhibited significant differences ($P<0.05$) between JA-supplemented-fed fish and the control-fed fish. The hematological profile showed that red blood cells, white blood cells, lymphocytes, hematocrit, hemoglobin, and mean corpuscular volume were significantly enhanced by supplementing dietary with JA at varying levels ($P>0.05$). However, the fish fed with a JA-supplemented diet exhibited significantly lower levels of red cell distribution width, red cell distribution, monocytes, granulocytes, mean corpuscular hemoglobin in fL, and mean corpuscular hemoglobin concentration ($P<0.05$). Biochemical indices revealed that fish in the experimental groups had significantly higher total protein, globulin, albumin, lipase, high-density lipoprotein, and amylase than the control-fed fish ($P<0.05$). The creatinine, glucose, triglyceride, cholesterol, urea, alanine transaminase, aspartate aminotransferase, and low-density lipoprotein were significantly decreased in JA dietary treatments than control diet ($P<0.05$). It was also found that dietary JA supplements promoted growth parameters, proximate body composition, hematology, and serum biochemical in common carp fingerlings.

Keywords: Common carp fingerlings, Growth parameters, Haematology and biochemical parameters, Jerusalem artichoke powder, Proximate body composition

1. Introduction

Global aquaculture and capture fisheries production is estimated to have reached 177.8 million tonnes in 2020. The aquaculture sector produced 87.5 million tonnes of aquatic animals, of which 27,581 million tonnes belonged to the Cyprinidae family, including 4.24 million tonnes of common carp (*Cyprinus carpio*), contributing 8.6% of the world's total fish aquaculture production [1]. Global fish consumption will require a rise of close to 80% in the following decades to meet the needs of the expanding population [2]. The space constraint requires high-density, intensive farming to realize this projected growth; however, it is often accompanied by numerous technical challenges, including decreased growth, immune system depression, husbandry-related stress, oxygen depletion, diseases, and increased mortality [3, 4]. Restrictions in certain nations on the utilization of antibiotics as feed supplements have prompted the adoption of a range of beneficial dietary additions, including prebiotics, probiotics, and synbiotics [5, 6].

Natural prebiotics have been described as potential compounds for preventing fish infections in aquaculture [7] since they are produced naturally and are environmentally friendly. A prebiotic is a food ingredient that is non-digestible and boosts the growth and/or function of beneficial microflora in the colon, thereby contributing to the host's health [5]. Prebiotics are frequently employed as a preventive measure rather than a treatment, diminishing the reliance on antibiotics [8]. Among foods that contain prebiotics are Jerusalem artichokes (JA), soybeans, leeks, asparagus, onions, garlic, oats, chicory, and wheat [9].

Jerusalem artichoke tubers (*Helianthus tuberosus*) are root vegetables that are native to tropical regions, cultivated extensively throughout the year, and are rich in inulin and fructooligosaccharides (FOS), which are two prevalent types of prebiotics. *Helianthus tuberosus* was found to contain 502 g/kg dry matter of total fructans [10]. The JA tuber contains 120-150 g/kg FOS and 160-200 g/kg inulin [11], as well as natural antioxidants, such as phenolic compounds with the potential ability to scavenge free

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radicals [12, 13]. These antioxidants could help regulate the excessive production of reactive oxygen species during infections and enhance immune function [14, 15]. A few studies have demonstrated that adding JA directly to the diets, such as prebiotic JA supplementation in juvenile tilapia, can improve growth performance, disease resistance, and hematological and immunological indices [10]. Furthermore, Tiengtam et al. [16] reported that JA supplementation in the feed of fingerling tilapia resulted in improved hematological and immunological activity, growth performance, survival rate, and disease resistance. Ali et al. [17] reported that JA-supplemented diets, especially at a 2% level, positively impacted the immunological, biochemical, and disease-resistance traits in Asian seabass juveniles. Trullas et al. [18] discovered that administrating JA in the diet led to a significant increase in the growth performance, the expression of antioxidant-related genes, the amount of intestinal mucous cells, and resistance to *Aeromonas veronii* infection in juvenile red tilapia.

This research investigated the effects of dietary inulin and JA on juvenile Nile tilapia. The impact of prebiotics was examined on growth performance, body composition, and feed efficacy. In addition, the health effects of natural prebiotic supplementation on the fish were further explored by studying their hematological activity and serum blood chemistry.

2. Materials and Methods

2.1. Preparation of Jerusalem artichoke (JA)

The Jerusalem artichoke (*Helianthus tuberosus* L.) purchased from a local market in Erbil, Kurdistan Region, Iraq, was transported to the laboratory in plastic bags. Any dust and other unwanted substances were removed from the tubers by washing them with tap water. The tubers were cleaned and sliced into small slices before being dried at 50 °C for 48 hours. Following that, they were powdered with a grinding device (FOSS, KnifetecTM 1095, Sweden) and placed in sealed polyethylene bags. To avoid moisture absorption, the powdered JA was kept in a dry container at room temperature, for further use.

2.2. Diet formulation

The control diet and experimental diets were prepared to supplement the 0.5%, 1%, and 2% JA diet. Diets were formulated based on isonitrogenous 32% and isolipidic 8%. An electrical grinder was used to pulverize all ingredients and JA powder supplements, which were then filtered using a 0.5 mm sieve. Having added the additives and homogenized thoroughly the mixture in an electric blender, water was added to transform the diet mix into a soft dough. All ingredients were homogenized and mixed. Diet pellets were extruded by cold pressing with a SUNRRY extruder (model: SYMM12, China) using a 2-mm aperture die, followed by air-drying at room temperature. The resulting pellets were then stored in individual plastic packs until needed. The ingredients of the diets and analyzed composition are tabulated in Table 1.

2.3. Experimental fish

One hundred and eighty healthy common carp (*Cypri-*

Table1. Formulation and proximate composition of control and experimental diets.

	Control diet	Experimental diets		
Ingredients [a] (g)				
Soybean meal [a]	570	570	570	570
Corn [b]	122	122	122	122
Fishmeal [c]	100	100	100	100
Soya oil	45	45	45	45
Wheat flour [d]	100	95	90	80
Wheat bran [e]	20	20	20	20
Vitamin premix [f]	20	20	20	20
Mineral premix [g]	23	23	2	2
Jerusalem artichoke [h]	-	5	10	20
Proximate composition (%)				
Moisture (%)	6.70	6.43	5.97	6.39
Protein (%)	30.97	31.02	31.34	31.73
Lipid (%)	10.86	9.42	9.62	10.99
Ash (%)	16.23	15.87	17.39	16.04

[a]Soybean obtained from the Kosar local company and originally sourced in Brazil. [b]Corn: (Dry mater=92%, MEn=1,525 kcal/kg, protein=19.2%, crude lipid=2.1%, crude fiber=14.4%, total phosphorus 0.65%). [c]Fish meal obtained from Norway: (Dry mater 90%, protein=65%). [d]Wheat flour: (Dry mater=87%, MEn=2,900 kcal/kg, protein=14.1%, crude lipid=2.5%, crude fiber=3%, total phosphorus=0.37%). [e]Wheat bran: (Dry mater=89%, MEn=1,300 kcal/kg, protein=15.7%, crude lipid=3% crude fiber=11%, total phosphorus=1.15%). [f] Vitamin premix sourced in Kosar Company and originally sourced in BAF in Turkey and consists of: Vitamin D3 (300,000 IU/kg), Vitamin K3 (1,600 MG/kg), Vitamin A (2,000,000 IU/kg), Vitamin C (150,000 MG/kg), Vitamin E (40,000 MG/kg), Vitamin B1 (2,000 MG/kg), Vitamin B2 (3,000 MG/kg), Vitamin B6 (2,000 MG/kg), Niacin B3 (8,000 MG/kg),), Biotin (2,000 MG/kg)Pantothenic acid B5 (20,000 MG/kg), Folic acid (800 MG/kg), Cholin (45,000 MG/kg. [g] Mineral premix consists of: 1-trace minerals consisting of Selenium (60 MG/kg), Manganese (3,000 MG/kg), Iodine (200 MG/kg), Cobalt (20 MG/kg), Copper (30,000 MG/kg), Zinc (6,000 MG/kg), Calcium carbonate 41%, Salt 1 g/kg, Limestone 14 g/kg. [h]Jerusalem Artichoke tuber: obtained from Erbil local market, Kurdistan region, Iraq.

nus carpio L.) fingerlings were obtained from Ankawa hatchery station, Erbil, Kurdistan Region, Iraq. The healthy fish were transported to the aquaculture unit located at the Grdarasha station, Salahaddin University, Erbil. The fish were placed in 12 cages (0.2 m^3) and fed with commercial diets (32% protein and 8% lipid). The fish were randomly placed in cages (n=15 in each cage, initial mean weight=16.81±0.09 g) and reared for 10 weeks. The fish were stocked into 12 cages (0.2 m^3), acclimatized to the cage system for 14 days, and received commercial diets (32% protein and 8% lipid). For 6 days a week, common carp fingerlings were subjected to one of the experimental diets twice daily, making up 3% of their live body weight. Fish biomass was weighed every week, and the daily feeding of each experimental group was adjusted every week.

2.4. Water quality

Water samples were gathered in 1.5L acid-washed polypropylene containers and transported to the laboratory to undergo analysis. Water samples were tested for pH (potential hydrogen ion concentration), Temp (temperature), electrical conductivity (EC), conductivity, turbidity, total hardness, total alkalinity, total dissolved solids (TDS), salinity, sodium, sulphate, chloride, potassium, calcium, and magnesium. A field kit (Hach Chemical Co., Loveland, CO, USA) was employed to evaluate total ammonia, nitrite, and nitrate; a portable device (Hanna, HI98129, CE; Made in Mauritius) to assess temp, pH, TDS, EC, and conductivity parameters directly in the field; and a portable DO meter (model AZ 8403; electrometric method) to measure dissolved oxygen (DO).

A HACH. 2100N Turbidimeter was utilized to measure turbidity and the argentometric method to assess chloride. A flame photometer (Jenway PFP7) was utilized to measure sodium, calcium, magnesium, and potassium. Temp, pH, water temperature, and DO were measured daily. The titration method with 2Na-EDTA was employed to determine the total hardness, the Ultraviolet Spectrophotometric Screening Method (model: Cecil instruments, CE 7200) was used for nitrate measurement, the titrimetric method was utilized for sulfate determination, and alkalinity was assessed using the titration method.

An electrical aerator (Prefix manufacturing, Submersible water pump, Veronella, Italy) supplied daily routine aeration and operated in the cement pond from 10:00 pm to 7:00 am. The water in the cement pond was replaced daily between 9:00 am and 11:00 am. Having measured the levels of total ammonia-nitrogen, nitrate, and nitrite levels by a field kit (Hach Chemical Co., Loveland, CO, USA) every two weeks, they were maintained within acceptable limits for optimum fish performance.

2.5. Growth performance

Growth performance and feed efficacy were measured by weight gain (WG), feed conversion ratio (FCR), total feed intake (TFI), feed conversion efficiency (FCE), protein intake (PI), specific growth rate (SGR %), protein efficiency ratio (PER), and survival rate (SR). The performed calculations are as follows:

WG (g/fish) = FBW−IBW;

SGR% = [ln FBW−ln IBW]/t×100, where FBW is final body weight (g); IBW is initial body weight (g); ln = natural logarithmic; t = time in days.

FCR = TFI / WG, where TFI is total feed intake (g);

FCE = 100 [Live weight gain (g)/Total feed intake (g)];

PER = WG / PI (g);

SR = 100% (final number of fish) / (initial number of fish).

Proximate composition

AOAC (2012) standard methods were used to analyze test diets and fish samples (nine fish per treatment) [19]. Each sample was examined in triplicate. Having reached a constant weight by drying the material at 105°C in a fan-assisted oven, the moisture level was determined. The samples underwent a 24-hour burning process in a muffle furnace set at 550 °C to determine their ash content. After acid digestion, the automated Kjeldhal method (Kjeldahltherm microsystem 40, C. Gerhardt GmbH, KG, Germany) was utilized for crude protein (N6.25) extraction. The measurement of lipid content was made by employing a soxhlet gravimetric technique with petroleum ether (1356, Parr Instrument Company, IL, the USA).

2.6. Blood sample collection

After ten weeks, 12 fish in each treatment were euthanized and their blood samples were taken. Buffered tricaine methane sulfate (MS222, Phamaq, Norway) at a concentration of 200 mg/L was used to anesthetize fish before destroying their brain. The fish were starved for 24 hours prior to sampling. A 25-gauge heparinized needle and a 1-ml syringe were used to collect blood samples from the tail vein [20]. After dividing the blood samples into two equal portions, the first half of each sample was transferred to heparinized vials for hematological analysis. The remaining halves of the blood samples were put in clot activator and sun-val tubes, and promptly after being chilled on ice underwent centrifugation at 3,500 rpm for 15 minutes. The supernatant serum was gathered and kept at -20 °C for further use.

2.7. Hematology parameters

The heparinized blood samples were subjected to the analysis of their hematological parameters. Red blood cell count (RBC), white blood cells (WBC), lymphocyte (LYM), monocyte (MON), granulocyte (GRA), hemoglobin, (Hb), hematocrit (Hct), red cell distribution width (RDW), mean platelet volume (MPV), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), mean corpuscular hemoglobin (MCH), and red cell distribution in fL (RDW-SD) were assessed by a fully-auto hematology analyzer (MCL-3800, China) in the fish physiology laboratory, Fish Resources and Aquatic Animals, College of Agricultural Engineering Sciences, Salahaddin University, Erbil.

2.8. Serum Biochemical

The level of the serum biochemical components in the blood was measured to examine whether JA-supplemented dietary could modulate fish nutritional status and health. The serum sample underwent testing for total protein, urea, globulin, albumin, creatinine, glucose, high-density lipoprotein (HDL), low-density lipoprotein (LDL), alanine transaminase (ALT), aspartate aminotransferase (AST), cholesterol (Cho), triglyceride, lipase, and amylase using Cobas c111 Accent 200 (CORMAY) in Alpha Laboratory for Disease Diagnosis at 100m street in front of East Emergency Hospital, Erbil.

2.9. Statistical analysis

The findings in this research are presented as mean ± standard deviations (SD). The hypothesis of normality and homogeneity for data was confirmed. Growth performance, proximate body composition, feed efficacy, hematology indices, and serum biochemical parameters underwent a one-way ANOVA test in SPSS software (version 26) to find whether the examined parameters were affected by JA levels. Any significant differences among the treatments were determined using Duncan's test at 0.05 levels.

3. Results

3.1. Water quality assessment

The findings of water quality are represented in Table 2. The water Temp was estimated at 25.14±1.24 °C, pH at 8.12±0.14, and DO at 7.76±0.36 ppm. The turbidity was measured at 5.79±1.23 NTU, conductivity at 278.16±21.56 mS.cm-1, EC at 0.30±0.02, total dissolved solid at 235±6.17 ppm, total alkalinity at 184±8.36 ppm, total hardness at 107±5.38 ppm, sulfate at 124.2±3.48 ppm, and salinity at 0.16±0.02 g/L. The results of chloride, sodium, potassium, calcium, and magnesium recorded in the current study were 32±2.26, 65±4.38, 0.73±0.8, 6.52±1.21, and 106±5.18 ppm, respectively. Generally, during the experiment, the mean ammonia, nitrate, and nitrite were obtained at0.59±0.04,10.6±2.93, and 0.01±0.002 ppm, respectively.

3.2. Growth performance

Common carp (*Cyprinus carpio* L.) fingerlings receiving JA-supplemented diets exhibited better growth performance and feed utilization efficacy than the fish in the control group, as presented in Table 3. A significant rise was observed in the final weight, SGR, and WG in JA-fed fish by a boost in the levels of JA, in comparison to the fish fed with the basal diet (P<0.05). Additionally, fish that were fed with JA diets demonstrated significant enhancements in TFI, FCR, FCE, PI, and PER compared to their control counterparts (P<0.05). There was no recorded mortality in any of the experimental groups.

3.3. Whole body composition

Table 4 presents the data regarding the whole-body composition of *C. carpio* fingerlings that received JA-supplemented diets. Accordingly, significantly higher levels of lipid content and moisture content were observed in the experimental fish than in the control fish (P<0.05). Nevertheless, the fish fed with 1% JA obtained significantly lower crude protein than the fish in the basal diet group (P<0.05). Among the experimental groups, the highest level of ash content was reported in the fish receiving supplemented diets with 2% JA, whereas the lowest level was observed in the fish fed with 0.5% JA.

3.4. Hematological parameters

The information about the hematological parameters related to common carp fingerlings in the experimental groups is provided in Table 5. Significantly higher levels of WBC, LYM, RBC, Hct, Hb, MCV, and PLT were observed in the experimental groups than in the control group (P>0.05). Moreover, fish fed with supplemented JA dietary exhibited a significantly lower MCH, MCHC MON, GRA, RDW, and RDWSD than the fish receiving the basal diet (P>0.05). Based on the findings, the highest PLT and MPV were obtained in fish fed with 0.5% JA, which were significantly better among dietary treatments (P>0.05).

3.5. Biochemical parameters

The data concerning serum biochemical parameters related to common carp fingerlings receiving JA-supplemented dietary are tabulated in Table 6. The experimental groups showed significantly elevated levels of total protein, albumin, and globulin compared to the control group (P<0.05). Significantly lower levels of glucose were exhi-

Table 2. Water quality parameter for common carp fingerlings reared in cage system fed with different levels of Jerusalem artichoke powder for ten weeks.

Parameters	Cement pond water
Temperature °C	25.14±1.24
pH	8.12±0.14
DO (ppm)	7.76±0.36
Turbidity (NTU)	5.79±1.23
Conductivity (mS.cm-1)	278.16±21.56
EC (mS.cm-1)	0.30±0.02
Salinity	0.16±0.02
TDS (ppm)	235±6.17
Sodium (ppm)	65±4.38
Chloride (ppm)	32±2.26
Calcium (ppm)	6.52±1.21
Magnesium (ppm)	106±5.18
Potassium (ppm)	0.73±0.8
Total alkalinity (mg.$CaCO_3$.l-1)	184±8.36
Total hardness (mg.$CaCO_3$.l-1)	107±5.38
Sulfate (ppm)	124.2±3.48
Ammonia (ppm)	0.59±0.04
Nitrate (ppm)	10.6±2.93
Nitrite (ppm)	0.01±0.002

Table 3. Growth performance, feed utilization, and survival rate among common carp fingerlings fed with diets supplemented with Jerusalem artichoke for ten weeks.

Parameters	Control	JA 0.5%	JA 1%	JA 2%
IBW (g)	16.80±0.07	16.76±0.07	16.82±0.14	16.87±0.14
FBW (g)	42.80±0.84^{d}	51.67±0.33^{c}	52.93±0.13^{b}	54.20±0.47^{a}
WG (g)	26.00±0.81^{d}	34.87±0.27^{c}	36.11±0.10^{b}	37.38±0.37^{a}
SGR (%)	1.34±0.026^{d}	1.60±0.004^{c}	1.64±0.010^{b}	1.67±0.008^{a}
TFI	785.46±16.52^{b}	888.78±17.48^{a}	895.44±5.10^{a}	910.74±12.62^{a}
FCR	2.01±0.02^{a}	1.70±0.02^{b}	1.65±0.01^{c}	1.62±0.01^{c}
FCE	49.65±0.51^{d}	58.85±0.71^{c}	60.49±0.41^{b}	61.58±0.47^{a}
PI	243.26±5.12^{c}	275.70±5.42^{b}	280.63±1.60^{b}	289.07±4.01^{a}
PER	1.60±0.02^{c}	1.90±0.02^{b}	1.93±0.01^{a}	1.94±0.01^{a}
Survival %	100 ±0.00	100±0.00	100±0.00	100±0.00

Data in the same row with different subscripts are significantly different (P≤0.05).
Data are expressed as mean ± SD.

Table 4. Proximate body composition of the common carp fingerlings fed with diets supplemented with Jerusalem artichoke for ten weeks.

Parameters	Control	SFP 0.3	SFP 0.6	SFP 0.9
Moisture (%)	78.66±0.29^{c}	81.60±0.49^{a}	79.59±0.67^{b}	79.42±0.30^{bc}
Crude protein (%) *	68.40±0.20^{a}	67.59±1.51^{ab}	66.23±0.38^{b}	69.11±0.03^{a}
Crude lipid (%) *	6.35±0.08^{c}	10.14±0.06^{ab}	10.41±0.49^{a}	9.61±0.35^{b}
Ash (%) *	16.61±0.22^{ab}	15.44±1.20^{b}	16.14±0.57^{ab}	16.96±0.01^{a}

Data in the same row with different subscripts are significantly different (P≤0.05).
Data are expressed as mean ± SD dry matter basis.

Table 5. Hematological parameters of the common carp fingerlings fed with diets supplemented with Jerusalem artichoke for ten weeks.

Parameters	Control	SFP 0.3%	SFP 0.6%	SFP 0.9%
WBC (×10^{9}/L)	80.37±0.91^{c}	101.27±1.80^{b}	102.79±0.52^{ab}	104.37±0.64^{a}
LYM# (×10^{9}/L)	67.23±1.65^{d}	89.63±0.49^{c}	92.90±0.95^{b}	97.43±0.87^{a}
MON# (×10^{9}/L)	10.63±0.61^{a}	8.70±0.20^{b}	7.40±0.15^{c}	6.43±0.25^{d}
GRA# (×10^{9}/L)	6.80±0.30^{a}	5.02±0.16^{b}	3.86±0.27^{c}	3.46±0.14^{c}
RBC (×10^{6}/L)	0.98±0.01^{d}	1.12±0.02^{c}	1.31±0.02^{a}	1.22±0.02^{b}
Hct (%)	19.43±0.11^{d}	22.73±0.08^{c}	28.80±0.46^{a}	24.90±0.30^{b}
Hb (g\dL)	9.31±0.04^{d}	10.24±0.02^{b}	10.59±0.08^{a}	9.73±0.06^{c}
MCV (fL)	198.41±3.10^{c}	202.54±3.43^{bc}	219.19±3.00^{a}	204.53±0.88^{b}
MCH (pg)	94.97±1.21^{a}	91.54±1.72^{b}	81.08±0.72^{c}	79.89±1.05^{c}
MCHC (g\dL)	47.96±0.28^{a}	45.50±0.61^{b}	37.81±0.83^{d}	39.15±0.74^{c}
RDW	9.50±0.14^{a}	7.85±0.30^{b}	6.44±0.25^{c}	6.11±0.18^{c}
RDWSD	181.69±2.17^{a}	160.36±3.80^{b}	130.83±2.34^{c}	128.73±1.91^{c}
PLT (×10^{9}/L)	22.97±1.91^{b}	27.07±3.16^{a}	23.99±1.30^{ab}	20.72±1.09^{b}
MPV (um)	6.08±0.16^{b}	6.41±0.16^{a}	5.74±0.08^{c}	5.85±0.12^{bc}

Data in the same row with different subscripts are significantly different (P≤0.05).
Data are expressed as mean ± SD.

bited in fish receiving diets supplemented with JA than in the control fish (P<0.05). A significant decrease was observed in ALT and AST in fish fed with JA-supplemented diets than in the control group. Cholesterol, triglyceride, and LDL showed a significant decline in the experimental groups than in the control group. A diet with 2% JA improved the HDL in the fish, compared to the basal diet. Significant decreases appeared in urea and creatinine among fish in the treatment groups in comparison to the control group (P<0.05). Lipase and amylase levels were significantly higher in the fish in the experimental groups than in their control counterparts (P<0.05).

4. Discussion

To my knowledge, this was the first study dedicated to examining the effect of JA powder on growth performance, water quality, proximate body composition, and hematological and biochemical parameters in common carp (*C. carpio*) fingerlings. The results demonstrated that water quality had no effect on the health status and growth

Table 6. Serum biochemical parameters of the common carp fingerlings fed with diets supplemented with Jerusalem artichoke for ten weeks.

Parameters	Control	SFP 0.3%	SFP 0.6%	SFP 0.9%
Total protein (g/dL)	3.56±0.04^{d}	4.47±0.06^{c}	5.26±0.13^{b}	5.49±0.11^{a}
Albumin	1.01±0.06^{d}	1.43±0.06^{c}	1.84±0.10^{b}	2.00±0.06^{a}
Globulin (mg/dL)	2.53±0.04^{d}	3.05±0.06^{c}	3.38±0.03^{b}	3.52±0.08^{a}
Glucose (mg/dL)	83.16±1.16^{a}	69.39±0.38^{b}	63.48±1.37^{c}	61.96±1.51^{c}
AST (U/L)	68.82±0.39^{a}	61.15±0.67^{b}	56.59±0.37^{c}	55.61±1.04^{c}
ALT (U/L)	36.79±0.46^{a}	29.08±0.37^{b}	25.17±0.28^{c}	24.91±0.35^{c}
Cho (mg/dL)	159.87±4.01^{a}	138.83±2.78^{b}	135.60±2.92^{b}	136.300±5.67^{b}
TG (mg/dL)	147.31±1.74^{a}	131.77±3.41^{b}	122.06±2.30^{c}	117.79±1.38^{c}
HDL (mg/dL)	34.27±1.12^{b}	35.67±1.30^{ab}	36.07±0.75^{ab}	36.78±0.42^{a}
LDL (mg/dL)	35.49±0.84^{d}	44.20±0.64^{c}	48.82±0.71^{b}	52.96±0.62^{a}
Urea (mg/dL)	12.62±0.24^{a}	9.30±0.13^{b}	9.68±0.34^{b}	9.36±0.19^{b}
Creatinine (mg/dL)	0.92±0.03^{a}	0.77±0.01^{b}	0.71±0.01^{c}	0.70±0.01^{c}
Lipase (U/L)	35.81±0.42^{c}	39.10±0.30^{b}	39.62±0.65^{ab}	40.20±0.41^{a}
Amylase (U/L)	88.80±1.29^{d}	103.98±1.47^{a}	99.36±1.13^{b}	95.03±0.47^{c}

Data in the same row with different subscripts are significantly different (P≤0.05).
Data are expressed as mean ± SD.

performance of common carp. Water quality for aquaculture refers to the quality of a water system that allows suitable organisms to grow and reproduce. Different fish species depend on the water quality for their growth, survival, and production. The physicochemical parameters recorded for the fishpond were favorable for fish culture and were within the previously documented standard range.

The water Temp was kept at 25.14±1.24 °C, the ideal range (24-30°C) recommended for the optimal growth of common carp [21]. The pH and DO and pH were 8.12±0.14 and 7.76±0.36 ppm, respectively; the recommended range is a minimum DO of less than 5 ppm, with pH maintained between 6 and 9 [22]. The EC, TDS, turbidity, and conductivity were within a suitable range of common carp culture. Furthermore, conductivity, higher turbidity, and lower transparency are required in fish farms in the transition region to support the changes that occur due to fish rearing in cages [23]. Moreover, the results of a study by Yi and Yuan [24] demonstrated that there was a rise in total dissolved solids and a decline in transparency within the caged regions of Vietnam, demonstrating the correlation between fish farming feed and waste and the elevated levels of dissolved solids. The dissolved organic solids made up 36.6-48.9% of the total solids, implying the presence of organic particles originating from fish farming feed in the adjacent water. The concentrations of total alkalinity and total hardness were estimated at 107±5.38 and 184±8.36 in the current study, respectively, which were in the desirable range for fish farming as recommended by Bhatnagar et al. [25]. The salinity, chloride, sulphate, potassium, sodium, magnesium, and calcium were within the acceptable range suggested in two studies for common carp culture [26, 27]. The ranges of nitrite (0.01±0.002 ppm), nitrate (10.6±2.93 ppm), and ammonia (0.47±0.04 ppm) were determined were established according to the limits proposed by Balrian and Haller (1982), based on which ammonia was less than 12 ppm and nitrate was equal to 50 ppm. Omar et al. [28] and Goran et al. [29] found that the majority of water quality parameters (DO, Temp, pH, EC, TDS, chloride, potassium, sodium, calcium, sulfate, nitrate, and ammonia) of common carp reared in cages were appropriate for growth performance, body composition, hematology, feed utilization, and serum biochemistry.

The findings of the current study were indicative of the significant effects of varying levels of JA supplementation in diets on the final body weight, WG, SGR, FCR, TFI, FCE, PI, and PER. In the same vein, based on the findings reported by Van Doan et al. (2015), JA significantly enhanced SGR and FCR in catfish fed with the dietary treatment of JA than in fish receiving the control diet [30]. Trullas et al. [18] found a significantly higher WG, ADG, FCR, and SGR in fish on JA diets in comparison to control fish for 28 days. According to Tiengtam et al. [16], Nile tilapia fingerlings on diets supplemented with JA for 82 days exhibited significantly enhanced levels of FW, SGR, ADG, and FCR. In another study, Tiengtam et al. [10] indicated that different supplementing levels of JA significantly improved FW, SGR, FI, and FCR in Nile tilapia juveniles for 8 weeks. The positive effects of JA on feed utilization and growth performance may be attributed to various compounds, such as carbohydrates, protein, Vitamin C, FOS, inulin, and minerals [31]. Inconsistent with our results, Ali et al. [17] reported that the supplementation of JA at different levels (0.5%, 1%, and 2%) had a non-significant effect on growth performance (FW, SGR, and FCR) in seabass (*Lates calcarifer*) in comparison to fish on the control diet for 45 days. One of the reasons could be that the JA contains inulin and FOS (at a large percentage of 43%-52%) and [11, 32]; therefore, the superior impact of JA might be partially associated with its FOS content.

The proximate body composition of common carp fingerlings receiving diets supplemented with JA indicated significantly boosted levels of moisture and crude lipid, while fish fed with 1% JA exhibited a significant decline in crude protein content; however, no significant differences appeared between JA and control diets regarding crude lipid. Similar to current results, Ali et al. [17] reported a significant difference in crude ash, crude lipid, and moisture content in the carcass of seabass fed with JA supplemented

diet for 45 days. On the contrary, fish fed with experimental diets (0.5-1% JA) had lower levels of crude protein than those in the control group, and significant differences were detected in the fish fed with 1% JA-supplemented diets. Tiengtam et. al. [16] found that in Nile tilapia, the addition of JA exhibited no significant difference in crude lipid, crude protein, moisture content, and ash for an 82-day feeding trial. One of the common indicators employed to measure fish quality is the proximate composition. The nutritional properties of any food item, fish included, determine its nutritional quality. The biochemical composition of both freshwater and seawater environments varies in terms of the entire body and individual organs. Various factors contribute to these variations, including feeding, growth, maturation, spawning, and season [33].

Biochemical and hematological analysis is a cost-effective and valuable tool for assessing fish health and physiological status [34]. Nonetheless, contradictory results have been published regarding the impact of prebiotics on these measures. In the present study, JA supplementation significantly affected the hematology parameters. The levels of WBC, LYM, RBC, Hct, Hb, MCV, and PLT were significantly increased in the experimental fish than in the control fish, whereas the MCH, MCHC, MON, GRA, RDW, and RDWSD were significantly reduced in fish on JA-supplemented diets than in control fish. Moreover, the results showed that 1% JA supplementation of diets significantly increased PLT and MPV in common carp fingerlings. Tiengtam et al. [10,16] revealed that RBC levels in fish fed with JA increased significantly, whereas Hct and Hb showed no significant differences between dietary JA-supplemented and control diets in Nile tilapia juveniles and fingerlings, respectively. Ali et al. [17] demonstrated that JA dietary had no significant effect on RBC, WBC, Hb, MCV, and MCHC levels in Asian seabass, whereas MCV in the fish fed with 0.5% and 2% JA diets significantly increased, which was consistent with our findings. According to Ahmadifar et al.[35], WBC and LYM levels were significantly higher in beluga juveniles fed with 1% inulin-supplemented diets. An increase in the levels of inulin supplementation led to a rise in MCH and MCHC levels; however, WBC, RBC, Hb, PCV, and MCV levels marginally decreased compared to the control fish, which was in disagreement with our findings. These discrepancies might be due to the varying effects of inulin on the hematological indices in different fish species, duration of feeding, and level of inulin supplementation. Moreover, adding JA directly to fish feed did not improve the hematological parameters further [10]. Despite this, several factors, such as species, physiological status, age, size, environmental conditions, quality and quantity of food, dietary regime, dietary ingredients, vitamins, protein sources, and probiotics, have been reported to influence fish hematological parameters [36].

Biochemical parameters can help understand the blood metabolic response and nutritional status caused by dietary food additives. According to the findings of the present research, fish fed with JA-supplemented diets showed significantly higher levels of total protein, globulin, and albumin, whereas glucose levels decreased significantly with an increase in JA levels in the dietary treatments. In agreement with these findings, Tiengtam et al. [10] found that juvenile Nile tilapia fed with dietary 0.5-1% JA had significantly higher total protein and albumin levels, while glucose levels were lower, which was inconsistent with our results demonstrating a significant increase. In addition, a previous study on fingerling Nile tilapia found that the dietary supplement JA significantly increased total protein levels while not affecting albumin levels. However, the glucose levels were significantly elevated, which contradicted our findings. In contrast, Trullas et al. [18] found that the levels of albumin and total protein in the red tilapia fed with JA diets increased but not significantly; nevertheless, glucose levels were positively modulated. The dietary GOS and inulin (both components of JA) increased plasma protein in common carp, and dietary FOS (also a component of JA) had no effect on plasma protein [37], which could be due to the fact that varying prebiotic types affect different prebiotic metabolism.

The results demonstrated that as the levels of JA in the diets increased, there was a significant decrease in AST, ALT, TG, Cho, and LDL levels; however, a significant increase was observed in HDL levels among the fish fed with 2% JA diets. The JA dietary treatments significantly reduced ALT levels in red tilapia fingerlings while not affecting AST and TG levels. However, Cho levels were significantly increased in fish receiving a 1% JA diet, which was inconsistent with our findings [18]. In contrast to our study, Ali et al. [17] showed that the TG levels of Asian seabass fed with JA dietary significantly increased with a rise in the levels of JA in the diet. On the other hand, Cho levels fluctuated, being significantly lower in fish fed with 0.5% JA diets and significantly higher in fish fed with 2% JA diets. Furthermore, Tiengtam et al. (2015) found that AST, ALT, TG, and Cho levels were unaffected in Nile tilapia fingerlings fed with JA dietary [10]. Furthermore, Tiengtam et al. [16] demonstrated that supplementing JA in the diet of Nile tilapia fingerlings had no influence on ALT and AST levels. An elevated level of AST and ALT enzymes can indicate liver damage, degeneration, necrosis, and destruction as a result of cellular damage. Furthermore, these enzymes can be an indicator for determining the potential toxicity caused by diet treatments and experimental materials [38].

The levels of creatinine and urea were significantly reduced in the fish fed with JA-supplemented dietary. The results of the present research were in agreement with those of a study conducted by Ali et al. [17], demonstrating that the urea level was significantly lower in Asian seabass fed with 0.05% JA diets than in the experimental diets. A significant increase was observed in amylase and lipase activity among fish fed with JA-supplemented diets. Our findings were consistent with those reported by Abd El-Latif et al. [39], indicating that there was no significant difference between fish on FOS-supplemented diets and those on the basal diet in terms of activity. In contrast, the study found that turbot (*Scophthalmus maximus* L.) juveniles fed with FOS dietary treatments had significantly higher amylase and lipase activity [40]. According to Wu et al. [41], the amylase activity of blunt snout bream fingerlings did not change significantly with FOS in their diet at 0.05% and 0.2% levels, while dose levels of 0.4% and 0.8% significantly increased amylase activity in comparison to the control. This variation between the results could be explained by fish species, size, and dietary amount. Furthermore, according to Goran et al. [29], common carp treated with JA had higher levels of the enzyme amylase than the control group. Due to the fact that the digestive

tract absorbs carbohydrates, starch will be hydrolyzed into di- and trisaccharides by a significant amount of enzyme activity [42]. There is a significant variation in the amylase activity of intestinal contents and pancreatic tissue. In certain fish species, intestinal amylase activity in herbivorous and omnivorous fish positively correlates with the amount of carbohydrates in the diet and the intensity of feeding [43].

5. Conclusion

The findings of the current study demonstrated that the JA supplementation in the diets of common carp fingerlings significantly enhanced feed utilization and growth performance, and the highest benefit was reported in the 2% JA levels. It was also found that supplementing diets with JA led to significant improvements in hematological and serum biochemical parameters in *C. carpio*, with the most favorable results observed in fish diets containing 1-2% JA supplement.

The global demand for countermeasures to combat antimicrobial resistance and reduce antibiotic use in animal production, including aquaculture, deserves more attention. This study on common carp fingerlings provides evidence for the benefits of JA as a natural feed additive with numerous benefits for this species. Reducing chemotherapeutic and antimicrobial medicines for fish through prophylactic nutritional strategies provides long-term solutions. Yet, further detailed studies are required to investigate the raw contents of JA as one of the adopted strategies and examine the beneficial effects of its components in practical diets as a feed additive.

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Conflicts of interest

None.

Consent for publications

All authors read and approved the final manuscript for publication.

Ethics approval and consent to participate

Not applicable.

Informed Consent

Not applicable.

Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Authors' contributions

Samad S. Omar did all the work alone.

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