WATER QUALITY IN CARP FARMING SYSTEMS WITH DIFFERENT LEVEL OF INTENSIFICATION

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KVALITET VODE U SISTEMIMA GAJENJA ŠARANA SA RAZLIČITIM STEPENOM INTENZIFIKACIJE

Apstrak

Cilj ovog istraživanja je bila procena kvaliteta vode na osnovu fizičko hemijskih parametara u sistemima gajenja šarana u kojima je prisutan različit stepen intenzifikacije. Eksperimenti su rađeni u različitim sistemima za proizvodnju konzumnog šarana *(Cyprinus carpio L.)*. Sistemi uzgoja se razlikuju po geografskoj lokaciji, tipu sistema za gajenja (zemljani bazeni, akumulaciona jezera, kavezi), stepenu intenzifikacije (polu intenzivno, intenzivno i veoma intenzivno gajenje). Određen je kvalitet vode u 9 proizvodnih sistema za konzumnog šarana u kojima se razlikuju: stepen intenzifikacije, tip ribnjaka i izvor vodosnabdevanja. U odnosu na 9 primarnih fizičko hemijskih parametara sva voda je bila usaglašena sa tehnološkim normama za gajenje šarana. Na kvalitet vode u ispitivanim sistemima najviše je uticala temperatura, te sadržaj mineralnih i biogenih materija u vodi za vodosnabdevanje.

Ključne reči: kvalitet vode, šaran, proizvodni sistemi, fizičko hemijski parametri
Keywords: quality of water, carp, production systems, physico-chemical parameters

INTRODUCTION

The share of warmwater fish culture in freshwater fish production in Bulgaria is substantial. This is related to the favourable climatic conditions in the country water basins and the traditions in this type of fish farming. One of the main freshwater fish species produced in Bulgaria is the carp (*Cyprinus carpio* L.). The annual carp production for human consumption in the period 2003-2012 was between 1091 and 1288.4 tonnes. Carp is farmed either independently (monoculture) or together with other fish species (polyculture) in various production systems (earthen ponds, dam lakes, net cages). Regardless of the used production system, methods and technologies, the quality of water in aquaculture facilities is dependent on a number of abiotic (physical and chemical) and biotic factors. Physico-chemical parameters of water are of primary importance in the evaluation of its quality for aquaculture purposes, as water temperature, dissolved oxygen, content of biogenic elements, organic matter load etc. are essential for optimisation of the environment in aquaculture farms. All this creates preconditions for production of high-value fish. Its flavor, nutritional qualities become more and more important for consumer preferences in the purchase of fish and retail trade (Pieniak et al., 2007; Bauer and Schlott, 2009). That is why the monitoring of water quality at fish farms is a mandatory element of the good production practices in aquaculture (Hadjinikolova, 2013). The purpose of the present study was to evaluate the quality of water in carp production systems with different level of intensification on the basis of physico-chemical indicator parameters.

MATERIAL AND METHODS

The experiments were carried out in carp (*Cyprinus carpio* L.) production systems for human consumption, differing by their geographical location, types of farming system (earthen ponds, dam lakes, net cages), level of intensification (semi-intensive, intensive, super-intensive). Semi-intensive systems (SemiIS) were as followed: The Tri Voditsi/10 Experimental base (SemiIS-1), and Tsarimir 1 Dam Lake (SemiIS-2), free aquatory of Bistritsa Dam Lake (SemiIS-3), Budak dere dam lake (SemiIS-4). The intensive systems (IS) were the Tundzha 73/ 4 fish farm (IS-1), the Tundzha 73/ 5 fish farm (IS-2), and Tsarimir 2 Dam Lake (IS-3). Super-intensive systems consisted of net cages of Bistritsa Dam Lake (SuperIS-1) and net cages in Kardzhali Dam Lake (SuperIS-2). The 40 Izvora Dam Lake intended for amateur fishing only and no organised farming activities was used as control aquatic ecosystem (CAES). Carps were fed diets of different composition and structure: grain feeds, high-protein meals, specialised pelleted and extruded feeds (Table 1).

Table 1.Characteristics of the studied production systems

Produc-tion systems	**Semi-intensive**				**Intensive**			**Super-inten-sive**		**Control aquatic ecosystem**
	Semi IS-1*	**Semi IS-2**	**SemiIS-3**	**Semi IS-4**	**IS-1**	**IS-2**	**IS-3**	**Super-IS-1**	**Super-IS-2**	**CAES**
Typeof feed	grain / meal	grain / meal+ CEF**	grain / grain screenin-gs + CEF	grain	CPF	CEF	CEF	CEF	CEF	for an-gling
Ratioof feed,%	50:50	73:16:11	70:30	100	100	100	100	100	100	-
area										
dka	45	500	204	250	750	200	40	-	-	489
m^3	-	-	-	-	-	-	-	80	156	-

(SemiIS-1**)- TriVoditsi/ 10 Experimentalbase; (**SemiIS-2**) -Tsarimir 1 damlake; (**Semi-IS-3**) - thefreeaquatoryoftheBistritsadamlake;(**SemiIS-4**) –Budakdere dam lake; (**IS-1**) -Tundzha 73/ 4 fishfarm; (**IS-2**) - Tundzha 73/ 5 fishfarm; (**IS-3**) -Tsarimir 2 damlake; (**SuperIS-1**) - netcagesinBistritsadamlake; (**SuperIS-2**) - netcagesintheKardzhalidamlake; (**CAES**) - the 40 Izvoradamlake*
*****CEF**- extruded feed; **CPF**- pelleted feed*

The systems also differed with respect to the stocking structure, which consisted mainly of one-year-old carps (K_1) from 70 to 200 ind.dka^{-1} in semi-intensive and intensive systems, two-year-old carps (K_2) – 140 ind.dka$^{-1,}$ one-year-old bighead carp (T_1) from 8 to 30 ind.dka^{-1}, two-year-old bighead carp (T_2) – 30 ind.dka^{-1}, two-year-old grass carp (A_2) from 3 to 10 ind. dka^{-1}. In intensive systems (IS-1 and IS-2), European catfish and pikes were periodically added. Super intensive systems were stocked with one-year-old carp (K_1) at 14-18 ind.m^{-1}. The control ecosystem (CAES) were periodically (every2-3 year) stocked with carp, grass carp and bighead carp, and the ichtyofauna included also common ruds (*Scardinius erythrophthalmus*), Danube bleaks (*Alburnus alburnus*), carassius (*Carassius carassius*) etc.

The different farming systems were supplied with water by various sources: karst springs (SemiIS-3, SuperIS-1), drilling water wells (SemiIS-1), dam lakes and irrigation facilities (SemiIS-2, IS-1, IS-2, IS-3, SuperIS-2), rivers (SemiIS-4), underground springs and rivers (CAES).

During the experimental period (2012–2014) between May and October, physicochemical parameters of waters in surveyed carp farming ponds were analysed monthly. The analysis of water included instrumental and analytical measurements of: water temperature (T, ^0C) – by means of microprocessor oximeter type WTW 315/SET (BSS 17.1.4.01-77); electric conductivity – by means of microprocessor conductivity meter type WTW 315/ SET (µS.cm^{-1}); water pH – with pH-meter type WTW 315/SET (BSS 3424-81, ISO 10523, 1994); dissolved oxygen content mg.l^{-1} – by means of microprocessor oximeter type WTW

315/SET (BSS EN 25814-2002); chemical oxygen demand (permanganate), mg $O.l^{-1}$ – by a standard analytical method (BSS EN ISO 8467, 2001); ammonia nitrogen N-NH4, $mg.l^{-1}$ – spectrophotometrically by the method of Nessler (BSS 3587-79, ISO 5664); nitrate nitrogen N-NO3, $mg.l^{-1}$ – spectrophotometrically (ISO 7890-3, 1998); orthophosphate content P-PO_4, $mg.l^{-1}$– spectrophotometrically (BSS EN ISO 6878-1:2004). Water temperature and dissolved oxygen were determined in-situ.

RESULTS AND DISCUSSION

The environmental conditions of carp farming systems with the respective physicochemical parameters of water are summarised in Table 2.

Water temperature. The average seasonal water temperature in SemiIS varied from 19.3 to 24.6^{0}C, in IS from 23.2 to 25.3^{0}C, in Super IS within 20.8-22.6^{0}C, and in CAES it was 25.7^{0}C. Maximum registered values were in July and august: between 24.2 and 29.7^{0}C, with exception of SemiIS-3 (21.3^{0}C). Lower water temperature values were measured in May-October, which was related to climatic characteristics and the seasonal character of the parameter. The lower mean seasonal and maximum water temperature values for production systems located in the aquatory of the Bistritsa dam lake were attributed to the fact that it is supplied with water by karst springs, whose average temperature for the season was 13^{0}C. Despite that, the water temperature was within the technological allowances for carp farming in SemiIS-3 and SuperIS-1. For other production systems, it was within the optimum range (Hadjinikolova, 2013, Privezentsev, 2000).

Electric conductivity. The average seasonal values of this ecological parameter varied between 327 and 705 $\mu S.cm^{-1}$. Data show that both minimum and maximum registered values for all production systems, regardless of intensification level and farming system type, were within the allowances for freshwater in ponds from the lake type, such as dam lakes (650 - 750 $\mu S.cm^{-1}$, Ordinance H-4/14.09.2012 of the Ministry of Environment and Water). The only exception was SemiIS-4, located in the aquatory of Budak dere dam lake, where water electric conductivity varied from 1301 $\mu S.cm^{-1}$ to 1385 $\mu S.cm^{-1}$, and average values for the season in the different stations were within 1328.67–1357.33 $\mu S.cm^{-1}$. All these values exceeded the allowances for freshwater lake-type ponds and indicated the presence of external contamination of dam waters from anthropogenic contamination of rivers supplying the dam.

Water pH. The average seasonal values of water pH of studied production systems varied from 7.57 to 8.40; i.e. were compliant with optimum technological values for carp farming. The same was true for minimum pH values. In some of water samples collected in July and August, water pH was within the range 8.68-9.10, which did not influence the overall water quality with respect to this parameter.

Dissolved oxygen content of water. The average for the season dissolved oxygen content of water was from 6.69 $mg.l^{-1}$ to 10.4 $mg.l^{-1}$, and maximum absolute values were from 8.8 $mg.l^{-1}$ to 13.7 $mg.l^{-1}$. All measurements were optimum for farmed fish species. An exception was demonstrated for station 1/pond 5 of Tundzha 73 fish farm in August, with in situ dissolved oxygen concentration of 3.4 $mg.l^{-1}$. Data indicate that with respect to water dissolved oxygen content, the conditions in studied production system were optimum which benefited the normal feeding and feed conversion ensuring good growth performance of fish and resistance to adverse environmental conditions (Hadjinikolova, 2013).

Table 2. Values (minimum, maximum and average) of primary physico-chemical parameters of water

Production systems / Parameter		Semi-intensive				Intensive			Super-intensive		Control Aquatic ecosys tem
		Semi IS-1*	Semi IS-2	Semi IS-3	Semi IS-4	IS-1	IS-2	IS-3	Super IS-1	Super IS-2	CAES
T,^{0}C	min	13.7	21.9	13.0	16.4	17.8	18.3	23.7	17.1	21.0	23.1
	max	27.8	27.1	21.3	29.7	26.8	27.6	26.4	25.0	24.2	28.5
	x	23.7	24.6	19.3	24.6	23.2	23.3	25.3	20.8	22.6	25.7
Electrical conductivit, $\mu S.cm^{-1}$	min	-	486	498	1301	679	630	458	480	324	469
	max	-	722	672	1385	733	719	647	673	330	586
	x	616	647	663	1343	705	690	552	666	327	526
pH, units	min	7.87	7.87	7.77	8.35	7.59	7.53	7.90	7.82	7.41	8.21
	max	8.65	8.53	8.15	8.45	8.68	8.69	9.10	8.37	7.75	8.47
	x	8.20	8.13	8.01	8.40	8.24	8.08	8.35	8.07	7.57	8.35
O_2, $mg.l^{-1}$	min	4.4	5.3	9.9	9.33	5.6	3.4	6.4	9.0	8.3	8.2
	max	11.4	8.8	10.6	13.00	10.3	10.8	10.0	13.7	11.3	12.6
	x	8.2	6.7	10.1	9.98	7.9	6.9	7.68	10.2	9.5	10.4
Oxidability by KMnO4, $mg.l^{-1}$	min	2.22	5.33	1.28	11.31	5.82	6.40	5.72	0.35	0.35	2.00
	max	11.47	7.20	4.29	20.18	13.2	11.25	9.90	6.97	1.91	3.17
	x	5.46	6.17	2.50	11.80	8.88	8.50	7.16	3.26	1.27	2.57
N-NH4, $mg.l^{-1}$	min	0.07	0.01	0.01	0.16	0.03	0.01	0.01	0.03	0.01	0.01
	max	0.94	0.06	0.07	0.66	0.32	0.10	0.07	0.17	0.04	0.05
	x	0.47	0.04	0.04	0.33	0.08	0.05	0.05	0.09	0.03	0.02
N-NO3, $mg.l^{-1}$	min	0.02	0.06	1.32	0.02	0.20	0.20	0.36	1.44	1.02	0.34
	max	1.20	1.20	5.10	2.21	1.44	1.06	0.88	4.50	2.71	0.98
	x	0.76	0.71	3.13	1.20	0.75	0.53	0.65	3.00	1.74	0.67
Total nitrogen (Nt), $mg.l^{-1}$	min	0.09	0.09	1.33	0.18	0.23	0.21	0.37	1.02	1.03	0.35
	max	2.14	1.26	5.17	2.87	1.76	1.16	0.95	2.71	2.75	1.03
	x	1.23	0.75	3.17	1.53	0.82	0.58	0.70	1.47	1.77	0.69
$P\text{-}PO_{4,}$ $mg.l^{-1}$	min	0.14	0.17	0.40	0.44	0.23	0.13	0.16	0.16	0.14	0.14
	max	0.93	0.94	0.55	0.61	0.59	0.59	0.62	0.78	0.81	0.75
	x	0.41	0.36	0.48	0.44	0.37	0.37	0.35	0.50	0.42	0.33

Chemical oxygen demand (permanganate). The average seasonal values of the permanganate oxidation ranged between 1.27 $mg.l^{-1}$ and 11.80 $mg.l^{-1}$. The minimum detected values were from 0.35 $mg.l^{-1}$ to 11.31$mg.l^{-1}$, and the maximum ones – from 1.91 $mg.l^{-1}$ to 20.18 $mg.l^{-1}$ (SemiIS-4, July). The data suggest that oxidation was compliant to technological norms for warmwater fish species. Permanganate oxidation levels of 15.0 to 30.0 $mg.l^{-1}$ for summer months are typical for carp farming ponds (Grozev et al., 1999, Hadjinikolova, 2013). This allowed concluding that studied water ponds were not loaded with organic waste.

Ammonia and nitrate nitrogen. Average seasonal values of ammonia nitrogen varied within a very large range – from 0.02 to 0.47 $mg.l^{-1}$, with higher levels in SemiIS-1 and SemiIS-4.

The average amount of nitrate nitrogen were between 0.53 $mg.l^{-1}$ – 1.34 $mg.l^{-1}$ (station 2 and station 1) and peak values – from 1.69 $mg.l^{-1}$ to 3.13 $mg.l^{-1}$. A higher level of nitrate nitrogen was registered for production systems in the Bistritsa dam lake aquatory resulting from higher background values in karst waters supplying the water basin (10.5 $mg.l^{-1}$).

Total nitrogen. The average seasonal values of total water nitrogen in the major part of studied systems were under the optimum value of the parameter (2.0 $mg.l^{-1}$) varying between 0.58 $mg.l^{-1}$ and 1.77 $mg.l^{-1}$. The only exception was SemiIS-3 whose total nitrogen water level of 3.17 $mg.l^{-1}$ was associated with higher nitrate nitrogen concentration of karst water supplying the dam lake. In general, the dynamics of total nitrogen content of water follows that of nitrate nitrogen content, as their relative proportion in total nitrogen (TN) is limiting. This tendency was established for all studied aquatic ecosystems.

Phosphorus (phosphate P). The average seasonal values of soluble inorganic phosphorus (phosphate P) for the different studied production systems were between 0.33 $mg.l^{-1}$ and 0.50 $mg.l^{-1}$. The registered maximum values (0.55 $mg.l^{-1}$ – 0.94 $mg.l^{-1}$) were optimum for carp farming ponds.

To sum up, the results from physico-chemical analysis of water indicate that factors with limiting significance for carp farming (temperature, dissolved oxygen content, water pH, chemical oxygen demand (permanganate), phosphates) were maintained within the technological reference ranges (Privezentsev, 2000; Hadjinikolova, 2013). A temperature lower than 19-20^{0}C, which is assumed to be the low optimum limit of this parameters for carps (Backiel, 1964; Mazurkiewcz, 2009; Szumiec and Szumiec, 1985) was observed in the Bistritsa dam lake production system due to the fact that the dam lake is supplied with water from several karst springs with flow rate of 70 $l.sec^{-1}$, and average seasonal temperature of 13^{0}C, located in close vicinity to the tail of the reservoir. For the other studied systems, a similar temperature was measured by the end of the vegetation period, in October. According to several authors (Adelman, 1975; Wolny, 1974; Karpinski, 1994; Wojda, 2006) the effective temperature for carp farming, accounts for maximum weight increase, is from 23-28^{0}C to 32^{0}C. Data indicate that during the active vegetation period (June-September), water temperature of studied production systems remained within the optimum limits for carps (22.0 – 28.0^{0}C).

The electric conductivity of water in Budak dere dam was over the allowances for freshwater in lake-type basins, pointing out at external pollution of the pond.

CONCLUSIONS

The quality of water in nine systems producing carp for consumption with different level of intensification, type of used ponds and supply water sources was determined.

It was found out that with regard to the analysed 9 primary physico-chemical parameters, the water was compliant with technological norms for carp farming.

It was found out that the quality of water in studied production systems was influenced at a greater extent by the temperature and background mineral, solids and biogenic substances content of supply water.

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