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WATER QUALITY PARAMETERS WHICH INFLUENCE RAINBOW TROUT (*Oncorhynchus mykiss*) WELFARE IN CLASSIC SYSTEMS

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Abstract

Water quality parameters determines the success or the failure of a fish culture operation, so any proper-prepared plan for aquaculture must describe the quality and quantity of water available for this purpose. The aim of this study was to evaluate the physical and chemical water parameters in Rainbow trout culture, in the summer season from three salmonid farms, due to the environmental changes that are nowadays happening and affect the fish culture operation. The water samples were collected from Bistrița-Năsăud County, from three trout farms: Strâmba, Șoimul de Jos and Fiad, in the summer of 2018, between May and August. For the determination of water parameters (dissolved oxygen, total dissolved solids, electrical conductivity and resistivity, pH, temperature, salinity) was used the Hanna HI 9828/4-01 Multi-Parameter and for the chemical parameters (total ammonia, nitrates, nitrites) samples were transferred to the USAMV laboratories. The samples collection was made in each farm from three different places: catchment, basins and evacuation water areas. The results of the study showed that the parameters observed from the three farms were different, with major differences in month of July and August. The environment of fish aquaculture is a complex system with critical parameters as are the temperature, suspended solids, dissolved oxygen, nitrite and ammonia. However, the temperature and the dissolved oxygen are the most important parameter, requiring continuous monitoring in aquaculture production systems, due to the fish aerobic metabolism which requires an elevated level of dissolved oxygen at optimum temperatures.

Key words*: pH, nitrates, welfare, water parameters*

INTRODUCTION

Water quality can be defined as a set of physical, chemical, biological and bacteriological characteristics, expressed in values, which allow a sample to be classified in a category. To determine the quality of water, out of all the physical, chemical, biological and bacteriological characteristics, a smaller number is used, using only those that are more significant (Diersing, 2009).

The welfare of salmonids depends to a large extent on the quality of the aquatic environment in which the fish live, thus needing to know the physico-chemical parameters of the water is essential (Ashley, 2007; Lawrence et al., 2014).

Any variation of these parameters above or below the biological limits of salmonids leads to a state of stress, a condition that, if extended over a longer period, leads to the installation of pathological conditions and mass mortality (Delfosse et al., 2016).

Salmonids are poikilotherm organisms, so they do not need a large amount of energy for thermal regulation of the body, compared to homeotherms (Stanković et al., 2015; Page & Burr, 2011).

The growth, development and reproduction of salmonids, implies the knowledge of the minimum and maximum limits of the values of the medial parameters, specific to the species of interest, as well as the application of an effective management regarding the fish production (Cocan et al., 2018). The fish welfare level in an aquatic environment is considered satisfactory if the values of the water quality parameters do not deviate from the optimum values necessary for the fish development. In this interval, the optimum conditions are highlighted when the intensity of the physiological processes registers the

highest level, and the physiological functions are performed in a normal way (Relic et al., 2010).

The environmental factors that have major implications in the physiological processes of salmonids are represented by: water temperature, dissolved oxygen, water pH, nitrates and nitrates, ammonia, carbon dioxide, dissolved solids, hydrogen sulphide, phosphates, etc. (Brune, 2005).

The biggest problem of welfare in salmon farming is given by the poor quality of the water or its deterioration. This deterioration of water quality can lead to both acute violations and a chronic reduction in the welfare state of salmonids (Relic et al., 2010). Rainbow trout go through several distinct stages throughout their lives (eggs, fry, young, juvenile, adult, brood fish), each with its own requirements regarding optimal environmental conditions. Degradation or absence of optimal habitat for any of the early stages will certainly affect the next stages of the fish life cycle (Hay et al., 2006).

Fish are conscious animals, which can feel pain, suffering and stress, so they require increased attention from farmers, especially in the case of salmonids, as it is known that in captivity, the life span of animals is reduced (Volpato et al., 2009; Uiuiu et al., 2019) and that environmental conditions influence their welfare.

Thus, the values for the physico-chemical factors that ensure the welfare of the Rainbow trout, must be within the following limits: temperature (T°C) 16-20°C, transparency (Tr) 1.5-1.8 m, pH 6.0-8.5 units, totally dissolved solids (TDS) max. 10 mg/l, dissolved oxygen (DO) ≥ 9.0 mg/l, carbon dioxide (CO_2) < 10 mg/l, hydrogen sulphide (H_2S) absent - mg/l, ammonia (NH_3) < 0.07 mg/l, chemical consumption of oxygen (COD) < 15.0 mg/l, biochemical oxygen consumption (BOD) < 30.0 mg/l, Nitrates (NO_2^-) < 0.05 mg/l, nitrates (NO_3^-) < 15.0 mg/l, Phosphates PO_4^{3-}) < 0.3 mg/l, Iron (Fe) < 0.5 mg/l (Hay et al., 2006).

MATERIALS AND METHODS

In order to determine the qualitative parameters (physico-chemical parameters) of the water which influence the welfare of salmonids, water samples were taken from three salmonid farms from Bistrița-Năsăud County (Fiad, Strâmba, and Șoimul de Jos trout farms), in the summer season, between May and August.

The following physico-chemical parameters were monitored: pH (pH), temperature (°C), resistivity (Ω/cm), conductivity (μS/cm), total dissolved solids (TDS), salinity, dissolved oxygen (mg/L), ammonia (NH_3), nitrites (NO_2^-) and nitrates (NO_3^-) during the summer season.

The pH, temperature, resistivity, conductivity, total dissolved solids, salinity and dissolved oxygen of the water were monitored at daybreak, at 8 A.M. from different points of the basins (catchment, centre and evacuation of water from the basins).

To determine the parameters listed above, the Hanna HI 9828/4-01 multiparameter was used, which according to the manufacturer, for the temperature parameter has a measurement range from -5.00 to 55.00°C, resolution 0.01°C and an accuracy of ± 0.15°C. For pH, the measurement range is between 0.00 and 14.00 units, ± 600.0 mV (pH) and ± 2000.0 mV.

For dissolved oxygen, the measurement range is 0.00-50.00 mg/l, for conductivity (0.000-200,000 μS/cm), for total dissolved solids (0-400000 mg/l), for resistivity (0-1.0000 MΩ/cm) and salinity (0.00-70.00 PSU).

Ammonia, nitrites and nitrates were monitored monthly, water samples being collected, transported and analysed in the Fisheries Hygiene laboratory within the USAMV Cluj-Napoca, within a maximum of four hours from their collection.

The methods used to determine the nitrogen-based elements were the reference ones corresponding to the current requirements. For the determination of ammonia (NH^3) - STAS 9800-2/71, nitrites (NO_2^-) - SR ISO 6777/1996 and nitrates (NO_3^-)-SR ISO 7890: 1-1998 was used the spectrometric method.

For the statistical analysis, the Kolmogorov-Smirnov and Shapiro-Wilk tests were used, to test the normality of the distributions.

To perform the correlation analysis, we used Pearson's coefficient to see how strong the relationship is between measured indicators, between calendar months (May, June, July, August) and between farms (Fiad, Strâmba, Șoimul de Jos). The final results were presented both in text and table form.

RESULTS AND DISCUSSIONS

In our study, we analysed the following parameters: pH, temperature, resistivity, conductivity, total dissolved solids, salinity, dissolved oxygen, nitrites, nitrates and ammonia.

In Table 1 are presented the mean values of the physico-chemical parameters of the water in the Fiad farm, in Table 2 for Șoimul de Jos farm and in Table 3 for Strâmba trout farm, during the summer season. The values recorded for all the parameters are within the limits necessary to ensure the welfare of the rainbow trout.

Analysing the values registered all together, in the three salmonid farms, in the case of the temperature parameter we observe that Fiad farm records the highest water temperatures (May - 13.47°C; June - 17.12°C; August - 16.66°C), followed by Strâmba farm (July - 15.29°C) and the lowest temperatures are observed in Șoimul de Jos farm (May - 10.47°C; June - 13.35°C; July - 13.75°C; August - 14.47°C (Tables 2 and 3). The fluctuating values of the temperature are directly influenced by the values of the atmospheric air, values that exert a direct action on the temperature of the water in the basins, so that the heating or cooling of the atmospheric air prints the same course for the water temperature because the depth of the basins is small (1-1.5 m).

For the dissolved oxygen (DO) parameter, due to the negative correlation between temperature and oxygen, the lowest levels of dissolved oxygen are recorded in Fiad farm (May - 9.50 mg/l; June - 9.06 mg/l; July - 9.36 mg/l; August - 9.1 mg/l) and the highest levels of dissolved oxygen are observed in Strâmba farm (May - 10.08 mg/l) and Șoimul de Jos farm (May - 10.79 mg/l; June - 9.29 mg/l; July - 9.95 mg/l) (Table 1). Dissolved oxygen had variations and oscillations during each month, oscillations that are directly influenced by the temperature, so it is observed that if the value of the temperature increases the dissolved oxygen level decreases and vice versa.

Table 1. Physico-chemical parameters of water recorded in Fiad trout farm

Parameters		Summer Month			
		May	June	July	August
pH	X±SD	7.84±0.15	7.71±0.43	6.65±0.22	7.07±0.35
	V%	2%	6%	3%	5%
Temperature (°C)	X±SD	13.47±0.13	17.12±0.39	14.6±0.02	16.66±0.25
	V%	1%	2%	0%	2%
Resistivity (Ω/cm)	X±SD	4746.33±303.62	5153.67±79.41	5910.33±46.2	4244.67±43.43
	V%	6%	2%	1%	1%
Conductivity (µS/cm)	X±SD	214.33±13.01	189±12.12	176.67±7.64	242.67±11.72
	V%	6%	6%	4%	5%
TSD (mg/l)	X±SD	0.12±0.02	0.11±0.01	0.09±0.01	0.12±0.001
	V%	14%	13%	6%	1%
Salinity (PSU)	X±SD	0.1±0.01	0.09±0	0.08±0.01	0.11±0
	V%	6%	0%	7%	0%
Dissolved oxygen (mg/L)	X±SD	9.5±0.1	9.06±0.1	9.36±0.09	9.1±0.22
	V%	1%	1%	1%	2%
Nitrites - NO_2 (mg/dm^3)	X±SD	0.17±0.02	0.003±0	0.02±0.01	0.06±0
	V%	10%	0%	35%	1%
Nitrates - NO_3 (mg/dm^3)	X±SD	3.29±0	4.08±0.13	3.94±0	3.02±0.01
	V%	0%	1%	0%	1%
Ammonia - NH_3 (mg/l)	X±SD	0.01±0.0003	0.002±0.0002	0.005±0.0043	0.03±0.02
	V%	6%	11%	88%	53%

* X±SD – Mean ± Standard Deviation; V% - Coefficient of variation; TSD – Total dissolved solids

Table 2. Physico-chemical parameters of water recorded in Șoimul de Jos trout farm

Parameters		Month			
		May	June	July	August
pH	X±SD	7.42±0.21	7.46±0.18	7.59±0.18	7.66±0.07
	V%	3%	2%	2%	1%
Temperature (°C)	X±SD	10.47±0.24	13.35±0.1	13.75±0.2	14.47±0.23
	V%	2%	1%	1%	2%
Resistivity (Ω/cm)	X±SD	5981±1289.12	6058±2083.67	5653±297.65	4485±262.5
	V%	22%	34%	5%	6%
Conductivity (µS/cm)	X±SD	172.67±38.21	180±81.63	187.67±6.51	207.7±11.93
	V%	22%	45%	3%	6%
TSD (mg/l)	X±SD	0.09±0.02	0.1±0.04	0.1±0.004	0.12±0.005
	V%	22%	38%	4%	4%
Salinity (PSU)	X±SD	0.08±0.02	0.08±0.01	0.08±0.01	0.09±0
	V%	18%	8%	7%	0%
Dissolved oxygen (mg/L)	X±SD	10.79±0.2	9.29±0.16	9.95±0.2	9.95±0.08
	V%	2%	2%	2%	1%
Nitrites - NO_2 (mg/dm^3)	X±SD	0.005±0.002	0.004±0.001	0.001±0.0003	0.09±0.09
	V%	35%	36%	25%	1%
Nitrates - NO_3 (mg/dm^3)	X±SD	9.29±0	11±1.42	2.2±0.87	9.82±0.003
	V%	0%	13%	40%	3%
Ammonia - NH_3 (mg/l)	X±SD	0.004±0.002	0.002±0.001	0.003±0.002	0.001±0.001
	V%	48%	50%	68%	87%

* X±SD – Mean ± Standard Deviation; V% - Coefficient of variation; TSD – Total dissolved solids

Following the pH analysis, we can see that in May, the highest pH value is found in Fiad farm and the lowest in Strâmba farm (Tables 1 and 3). In June, the Șoimul de Jos farm registers the lowest pH value and the highest value in the Fiad farm (Table 2). In July and August, the highest pH value is found in the farm Șoimul de Jos and the lowest in the farm Fiad. The monthly variation of the pH parameter is very small, which indicates that there is a very good capacity for water buffering and that the values fluctuations are within the normal limits of the rainbow trout life cycle.

We have noticed that in the case of the resistivity and the conductivity parameters, in all summer months we registered high values of the variability coefficient. As we mentioned in the Material and methods section the samples were taken from different points of the basins (entrance, centre and evacuation of water from the basins). The resistivity or the conductivity helps us to monitor the purity level of the water. Resistivity is the reciprocal of conductivity and either may be used to inexpensively monitor the ionic purity of water. Resistivity or conductivity of water is a measure of the ability of the water to resist or conduct an electric current. (Light et al., 2005). The ability of water to resist or conduct an electric current is directly related to the amount of ionic material (salts) dissolved in the water. Dissolved ionic material is commonly referred to as total dissolved solids or TDS.

Water with a relatively high TDS will have a low resistivity and a high conductivity. The opposite is true for water with low TDS. The relationship of electrical conductivity and TDS is non-linear being both ionic concentration and temperature dependent.

Therefore, in our experiment, this it is confirmed by the registered values during the summer season. The highest values were recorded at the catchment of water in the basins, followed by the centre and the evacuation of basins.

As for the nitrogen cycle in water ecosystems, we registered that there is no exceedance of the maximum allowed values in the case of any recorded parameter.

Nitrite is an important pollutant in aquatic systems (Nicolae et al., 2017). Major sources of NO_2^- contamination are microbial processes, nitrite being an intermediary in bacterial nitrification and denitrification pathways. It is very toxic to many freshwater vertebrates and invertebrates (Doblander, 1996).

Nitrite is a natural component of the nitrogen cycle in ecosystems, and its presence in the environment is a potential problem due to its well-documented toxicity to animals (Lewis & Morris, 1986; Jensen, 2003). Increased nitrite concentrations cause major problems in intensive cultivation of commercial fish species and ornamental fish (Svobodova et al., 2005).

Table 3. Physico-chemical parameters of water recorded in Strâmba trout farm

Parameters		Month			
		May	June	July	August
pH	X±SD	7.28±0.08	7.51±0.03	6.68±0.09	6.88±0.38
	V%	1%	0%	1%	6%
Temperature (°C)	X±SD	11.57±0.04	15.34±0.68	15.29±0.37	16.48±0.53
	V%	0%	4%	2%	3%
Resistivity (Ω/cm)	X±SD	5597.67±115.78	4775.67±21.5	5576.67±82.92	5977.67±469.68
	V%	2%	0%	1%	8%
Conductivity (µS/cm)	X±SD	178.67±4.04	209.33±1.53	179.67±2.52	167.67±12.7
	V%	2%	1%	1%	8%
TSD (mg/l)	X±SD	0.09±0.002	0.11±0.003	0.09±0.003	0.08±0.01
	V%	2%	2%	3%	8%
Salinity (PSU)	X±SD	0.08±0.01	0.1±0	0.09±0.01	0.08±0.01
	V%	7%	0%	7%	8%
Dissolved oxygen (mg/L)	X±SD	10.08±0.2	9.21±0.21	9.95±0.11	9.22±0.25
	V%	2%	2%	1%	3%
Nitrites - NO_2 (mg/dm^3)	X±SD	0.05±0.09	0.008±0.003	0.01±0.006	0.12±0.01
	V%	159%	35%	43%	7%
Nitrates - NO_3 (mg/dm^3)	X±SD	6.24±0.06	12.97±0.32	3.26±0.36	3.01±0.003
	V%	16%	2%	11%	22%
Ammonia - NH_3 (mg/l)	X±SD	0.003±0.001	0.003±0.001	0.005±0.002	0.03±0.02
	V%	21%	27%	35%	71%

* X±SD – Mean ± Standard Deviation; V% - Coefficient of variation; TSD – Total dissolved solids

A major problem associated with the recirculation of water in a salmonid farm is the potential accumulation of ammonia and nitrite, which urges us to study the possible interactive effects of these pollutants. In a study of the Rainbow trout species (Vedel et al., 1998), when the desired concentrations of nitrites and ammonia were obtained by the addition of dissolved $NaNO_2$ and NH_4NO_3, the combined exposure to nitrites and ammonia resulted in high mortality to high exposure concentrations (600 µM NO_2^- și 18 µM NH_3). Higher oxygen levels in water at lower temperatures and lower fish metabolic rate at lower temperatures could make nitrite a less potent toxin at lower water temperatures (Jensen, 2003).

The bivariate Pearson correlation produces a sample correlation coefficient that measures the strength and direction of the linear relationships between pairs of variables.

I was analysed the correlations between the water parameters in all four consecutive

months and between the three fish farms. All relationships are positive, but not all are statistically significant. The strongest correlation between the farms is encountered in the case of Strâmba and Șoimul de Jos trout farms resulting in a significance threshold of 1%. This can also be seen from the collected data, where it can see that the parameters values are very close to each other. These strong correlations are the result of the close proximity of the two farms and due to their geomorphological conditions because there are located in areas volcanic mountains. Geographical location and landscape are the main elements that directly influence the climatic and meteorological properties of the area. In Strâmba and Șoimul de Jos trout farms, the distance between the springs and the water emplacement of the farm is relatively short, 5 km (Strâmba) and 4 km (Șoimul de Jos). Fiad farm is supplied by the Sălăuţa River, which has a length of 20 km from the spring to the emplacement of the farm.

CONCLUSIONS

Although salmonids, in general, are capable of tolerating wide variations of physical and environmental variables, tolerance intervals may be disregarded under certain circumstances in salmonid units. In particular, the maximum summer temperatures may exceed the critical thermal tolerance of the species (temperatures above 22-26°C, dissolved oxygen under 8-8.5 mg/l, lower or higher pH values than normal), which can cause high mortalities among the fishes (especially in the earlier stages of development).

Thus, as a recommendation, in the case of setting up a salmonid farm, at least the annual minimum and maximum values of temperature, pH, and dissolved oxygen of water should be evaluated before the actual construction is carried out, in order to be sure that the water quality ensure the salmonid welfare.

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