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DYNAMICS OF SOME CELLULAR AND HUMORAL NON-SPECIFIC IMMUNE MECHANISMS IN BESTER (*Huso huso* L. x *Acipenser ruthenus* L.).

Halina Kolman, Ryszard Kolman**, Andrzej K. Siwicki***

*Department of General Biology, Institute of Biology and Environment Protection, WSP in Olsztyn
**The Stanisław Sakowicz Inland Fisheries Institute in Olsztyn

A B S T R A C T. Some cellular and humoral non-specific immune response mechanisms were studied in third generation bester (F_3). During three years of tank-rearing in water recirculation system, activity of leucocytes and number of eosinophils in bester correlated with fish body mass. Tank-reared bester had lower eosinophil counts, lower phagocytic activity of microphages, and lower lysozyme activity and index compared to cage-reared fish. On the contrary, NBT reduction ability, Cp activity, and γ-globulin fraction level were higher. Total leucocyte and lymphocyte counts in circulating blood, % of NBT-positive cells, and NBT index did not differ between fish groups.

Key words: *Acipenseridae*, BESTER (*Huso huso* L. x *Acipenser ruthenus* L.), IMMUNOLOGY, CELLULAR AND HUMORAL NON-SPECIFIC IMMUNE RESPONSES

INTRODUCTION

Interspecific hybrid of beluga (*H. huso* L.) and sterlet (*A. ruthenus* L.) was obtained for the first time in 1952 (Nikolyukin, Timofeeva 1953). It was followed by production of other hybrid sturgeons, and by undertaking studies on these fish (Milshtejn, Popova 1969, Kozlov 1969, Krylova 1980, 1987, Burtsev et al. 1985, Shevchenko 1991, Kuzina, Zhelabovskaya 1991, Krylova, Gershanovich 1991, Kolman, Szczepkowski 1995). Bester showed high growth rate (after beluga), and early reproductive maturity typical for sterlet (Burtsev 1969). The hybrid was improved obtaining subsequent hybrid generations F_2 and F_3, and using reciprocal cross-breeding to produce SBS (sterlet x bester), and BBS (beluga x bester) (Burtsev et al. 1987, Arefyev 1991). Due to considerable variability revealed in course of biotechnological and genetic studies, F_2 generation was unsuitable for rearing (Arefyev 1989, Krylova, Gershanovich 1992). In F_3 generation, on the other hand, basic features stabilised at a level observed in parental species (Arefyev 1989). Thus, bester F3 may be considered a new race: a domestic sturgeon well adapted to intensive rearing

conditions (Kolman, Szczepkowski 1995). In the present paper, preliminary results on some cellular and humoral non-specific immune response mechanisms in this hybrid are discussed.

MATERIAL AND METHODS

Bester juveniles reared in a water recirculation system were divided into 4 groups: three groups aged 0+, and one aged 2+, of average body mass 15, 37, 324, and 3840 g, respectively. One 1+ group of average body mass 278 g was reared in cages located in a channel carrying discharge waters from a power plant. The fish were in good condition and healthy.

Water quality in the recirculation system was maitained at optimum level for sturgeons: ammonia concentration below 0.02 mg/l, nitrite – 0.15 mg/l, and dissolved oxygen level in the outflowing water did not drop below 60% saturation. Water temperature in the tanks was 20±3°C.

Water quality in the discharge was of the II class, well oxygenated, with temperatures changing according to seasonal and daily patterns, ranging in the experimental season from 23 to 27°C.

Fry was given trout pellets „Kristall" made by Aller Mølle, and the fish over 100 g of body mass were given FM-48/14 by Kraft. The feed was supplied using automatic feeders. Feeding rate changed with the average individual body mass, according to the feeding curves for sturgeons (Kolman R. 1996, 1997).

Before blood sampling, the fish were anesthetized using *Propiscin*. Blood was collected from alive fish using a heparinized needle. Blood plasma was obtained by centrifugation and stored at –20°C. The following parameters were eveluated: total leucocyte counts, leucogram, metabolic and phagocytic activity of blood leucocytes, lysozyme (LZM) and ceruloplasmin (Cp) activity, total plasma protein and γ-globulin fraction level. Metabolic activity of polimorphonuclear cells (PMN) was evaluated using nitrotetrazolium blue (NBT) reduction test with the spectrophotometric method (Studnicka et al. 1985). 0.2% NBT solution (Sigma) was used. Percentage of NBT-positive PMN cells was measured according to the cytochemical method (Szczylik et al. 1979). Samples were fixed with alcohol, and the cells were stained with safranin (Van Oss et al. 1973). Phagocytic activity of leucocytes was determined using the method described by Avtalion, Shahrabani (1975) and O'Neill (1985), and expressed as phagocytic index (IF). *Staphylococcus aureus* 209 P suspension was used.

Plasma lysozyme activity (LZM) was evaluated with the turbidimetric method (Studnicka et al. 1986). *Micrococcus lysodeikticus* (Sigma) suspension in phosphate buffer was used. Extinction was measured with a spectrophotometer Eskalal – Smith Kline Instruments, USA. Lysozyme of chicken egg (Sigma) was used as the standard. LZM index was calculated according to Siwicki and Studnicka (1987). Ceruloplasmin activity (Cp), total plasma protein, and g-globulin fraction level were measured with the micromethods described by Siwicki and Anderson (1993b). Significance of the differences was tested using t-Student's test.

RESULTS

Bester reared in water recirculation system showed very high growth rate: fish body mass increased 262 fold during the experiment (Tab. I). Cage-reared fish grew much slower, and at the age 1+ reached only 278 g – less than one year younger (0+) tank-reared bester (Tab. I). The oldest fish of average body mass 3840 g (age 2+) were 12 months older than cage-reared ones.

In most groups of fish, total leucocyte count was of the same magnitude (about 50 thousand/mm^3), with lymphocytes predominating (Tab. I). However, significant differences were observed in neutrophil and eosinophil counts and percentage. Neutrophils were more numerus in fish reared in a recirculation system, in 0+, and 2+ groups (Tab. I). On the other hand, number of eosinophils was higher in cage-reared fish (Tab. I, Fig. 1). Moreover, eosinophil counts decreased significantly with fish body mass, according to the regression equation: $Y=-0.8\ \ln X+8.4$ (Fig. 2). Besters reared under different environmental conditions did not differ in respect to monocyte numbers.

Differences in the percentage of NBT-positive PMN cells observed between the groups of 15 and 37 g were not significant: in both cases 15% of the cells were NBT-positive. In 324 g fish, however, this parameter increased significantly to 27.2±6.2%. With futher body mass increase, changes were not significant. No statistically significant differences in % of NBT-positive PMN cells were observed between these fish and cage-reared sturgeon (0+ and 2+ groups, Tab. I).

NBT reduction ability decreased with the increase of body mass, according to the equation $Y=-0.1\ln X+1.5$ (Fig. 3). In cage-reared fish, this parameter was lower compared with tank-reared ones of similar body mass (Tab. I).

TABLE I

Values of immnophysiological indices of circulating blood in bester reared in tanks with water recirculation system and in cages

Mean body weight	Age	Total number of leucocytes	Number of neutrophils	Number of eosinophils	Number of monocytes	Number of lymphocytes	% MN NBT+	NBT reduction ability	NBT index	IF	LZM activity in serum	LZM index	Cp activity in serum	γ-globulin in serum	Total protein in serum
g	years	th./mm³	th./mm³	th./mm³	th./mm³	th./mm³	%	mg/ml			µg/ml		mg%	g/l	g/l
15.1	0+	52±6.5	11.96±3	6.7±3.1	1.04±0.5	31.7±2.1	18.4±6.0	1.3±0.17	0.11±0.014	-	10.3±3.9	0.9±0.23	8.7±4.3	-	-
37.3	0+	55.0±7	10.4±2.7	5.5±2.7	1.1±0.5	37.9±3.3	12.5±5.0	1.0±0.14	1.0±0.014	-	4.4±0.6	0.43±0.06	-	5.3±0.9	16.5±1.6
364.0	0+	2.5±5.4	11.5±3.7	2.6±1.57	0.5±0	38.3±4.7	27.2±6.2	0.88±0.13	0.09±0.038	1.8±1	57.1±12.7	4.96±0.9	30±5.9	4.9±1.6	15±3.1
278.0*	1+*	50.8±3	7.6±3.0*	7.6±2.5*	0.5±0*	35.6±4.1*	30.0±5*	0.64±0.06*	0.085±0.01*	7.4±1.2*	107±21.6*	14±2.85*	12±3.7*	4.7±2.2	25±3.8*
3840.0	2+	48.0±1.5	8.6±3.4	2.4±0.96	1.0±0.48	36.5±4.3	28.0±8.0	0.91±0.15	0.13±0.059	2.03±1.	48.3±5.5	5.6±0.64	21.2±5.5	11.3±5.5	26±5.5

**culture in cages in the discharge channel*

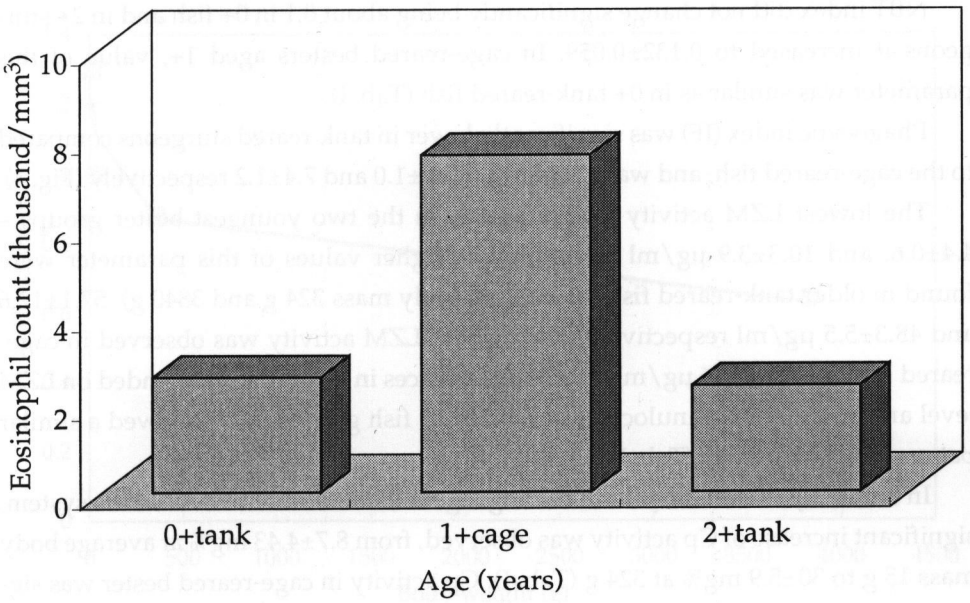

Fig. 1. Eosinophil count in bester reared under various environmental conditions

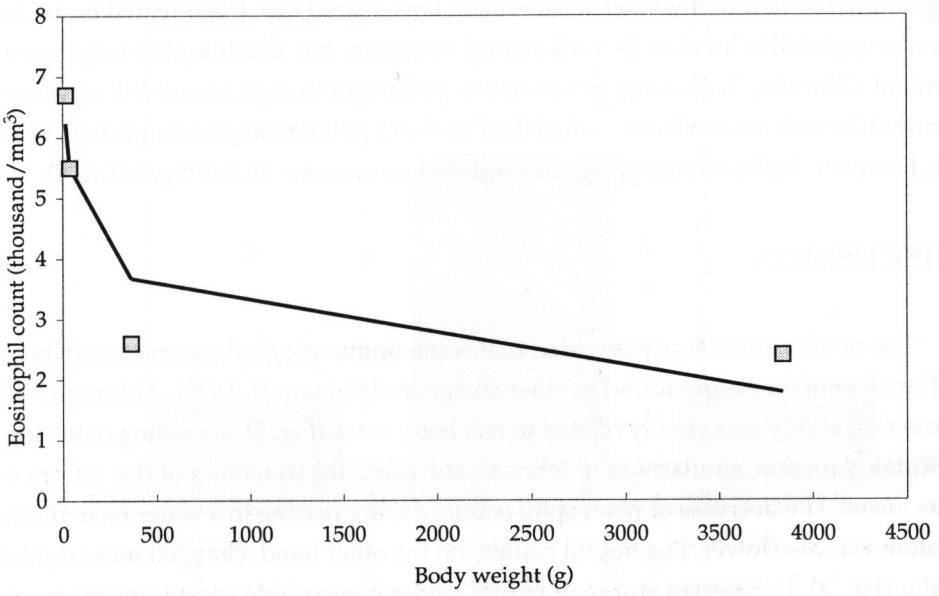

Fig. 2. Relation between eosinophil count and average body mass of bester

NBT index did not change significantly being about 0.1 in 0+ fish and in 2+ sturgeons it increased to 0.132±0.059. In cage-reared besters aged 1+, value of this parameter was similar as in 0+ tank-reared fish (Tab. I).

Phagocytic index (IF) was significantly lower in tank-reared sturgeons compared to the cage-reared fish, and was equal to 1.8-2.0±1.0 and 7.4±1.2 respectively (Fig. 4).

The lowest LZM activity was observed in the two youngest bester groups – 4.4±0.6, and 10.3±3.9 μg/ml respectively. Higher values of this parameter were found in older tank-reared fish (of average body mass 324 g and 3840 g): 57.1±12.6 and 48.3±5.5 μg/ml respectively. The highest LZM activity was observed in cage-reared bester - 107±21.6 μg/ml (Fig. 5). Differences in LZM index depended on LZM level and number of granulocytes in particular fish groups, and followed a similar pattern as LZM activity (Tab. I, Fig. 6).

In bester fry in the first year of rearing (age 0+) in the water recirculation system, significant increase of Cp activity was observed, from 8.7±4.43 mg% at average body mass 15 g to 30±5.9 mg% at 324 g (Tab. I). Cp activity in cage-reared bester was significantly lower (Fig. 7).

In the first year of life (0+), no significant differences in total plasma protein and γ-globulin fraction content were observed in tank-reared fish. Cage-reared bester had similar γ-globulin level as 0+ tank-reared sturgeon, but much higher total protein content - 25±3.8 g/l. Average values of this parameter in cage-reared fish were similar as in 2+ tank-reared bester, which had 26.0±5.5 g/l of total plasma protein. Bester 2+, however, had significantly higher γ-globulin content – 11.3±5.5 g/l (Tab. I).

DISCUSSION

The results of the study revealed that some immunological parameters in bester differed from the values found in other sturgeons (Kolman H. 1996). Although NBT-reduction ability was closely related to fish body mass (Fig. 3), according to the logarithmic function, similarly as in Siberian sturgeon, the dynamics of this parameter was lower. The decrease of neutrophil counts during rearing in a water recirculation system was also lower. Eosinophil counts, on the other hand, changed more dynamically (Fig. 2). In Siberian sturgeon reared under comparable conditions these relations were not observed (Kolman H. 1996). High number of eosinophils were also noted in an another hybrid (Russian sturgeon x bester) (Kolman H. 1996).

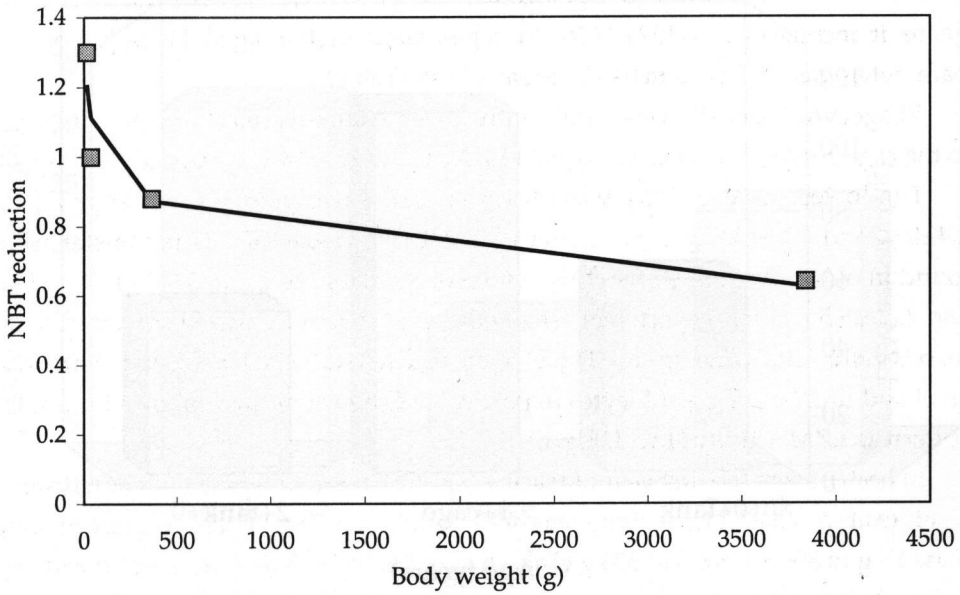

Fig. 3. Relation between NBT-reduction ability and average body mass of bester

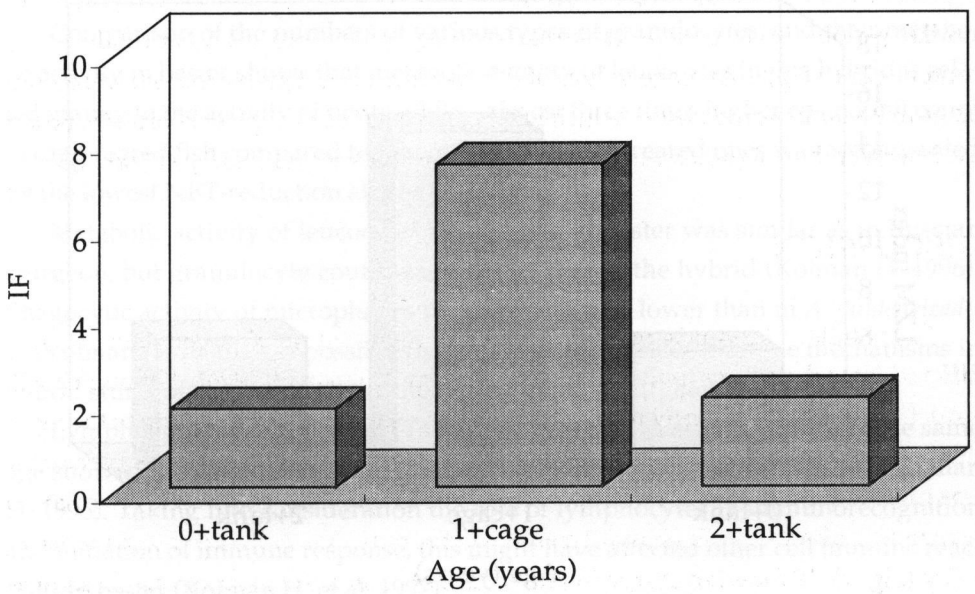

Fig. 4. Values of phagocytic index of blood in bester reared under various environmental conditions

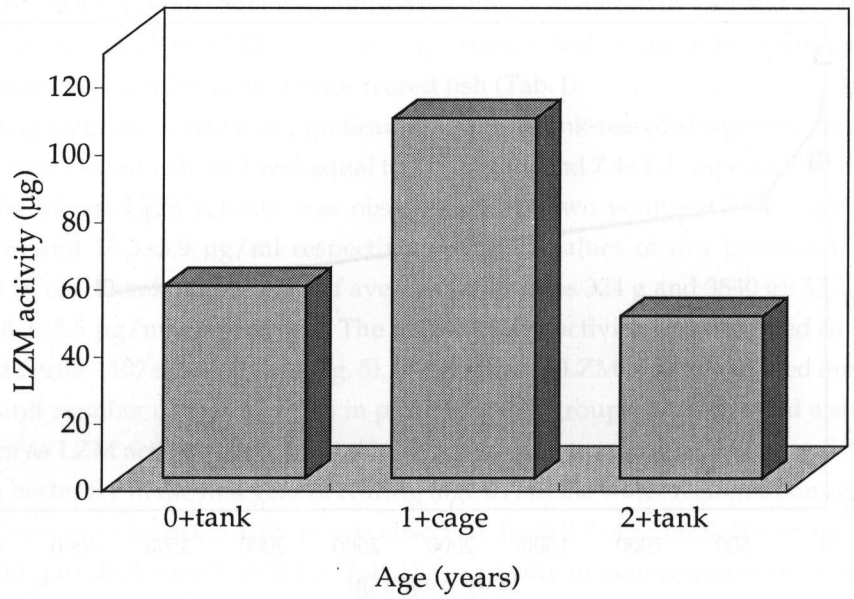

Fig. 5. Values of plasma lysozyme activity in bester reared under various environmental conditions

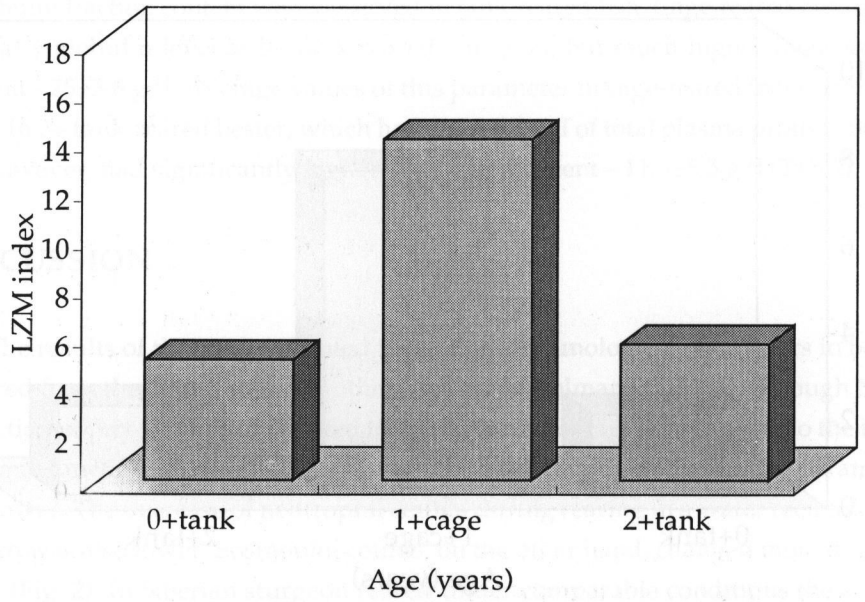

Fig. 6. Values of plasma lysozyme index in bester reared under various environmental conditions

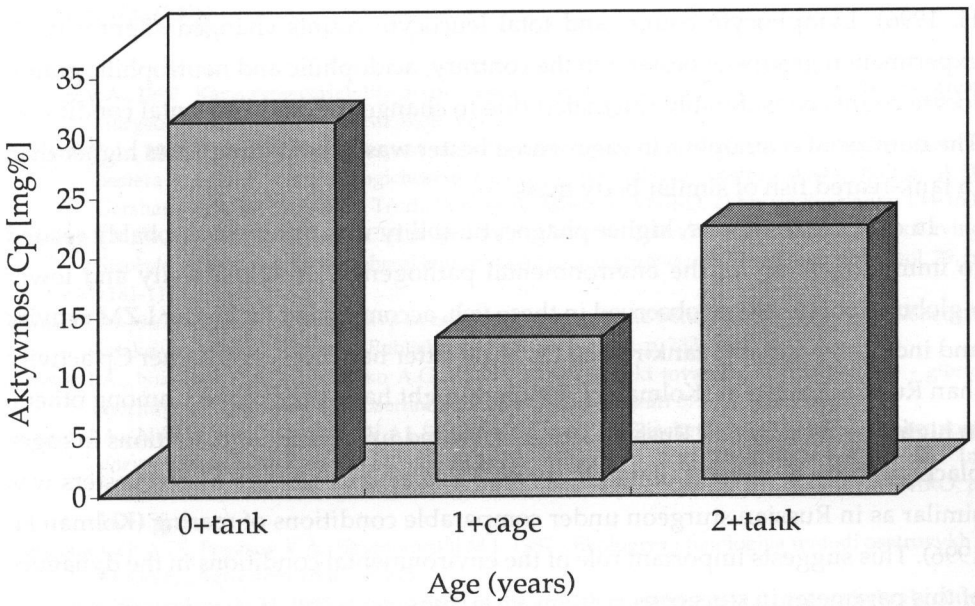

Fig. 7. Values of plasma ceruloplasmin activity in bester reared under various environmental conditions

Comparison of the numbers of various types of granulocytes, and their metabolic activity in bester shows that metabolic activity of leucocytes in this hybrid is related mainly to the activity of neutrophils – almost three times higher eosinophil count in cage-reared fish compared to that observed in tank-reared ones was accompanied by the lowest NBT-reduction ability (Tab. I).

Metabolic activity of leucocytes in cage-reared bester was similar as in Russian sturgeon, but granulocyte count was twice higher in the hybrid (Kolman H. 1996). Phagocytic activity of microphages in bester was also lower than in *A. guldensteadti* L. (Kolman H. 1996). It is possible that non-specific cellular immune mechanisms in hybrid sturgeon are less active compared with pure sturgeon species.

Lymphocyte counts in bester (Tab. I) compared to Russian sturgeon of the same age showed lower fluctuations, being the least labile among the sturgeons (Kolman H. 1996). Taking into consideration the role of lymphocytes in immunorecognition and initiation of immune response, this might have affected other cell immune reactions in bester (Kolman H. et al. 1997).

The results of the present study indicate that lymphocytes predominated among white blood cells in bester and other sturgeons, pure species, and hybrids (Kolman

H. 1996). Lymphocyte counts and total leucocyte counts changed slightly in all experimental groups of bester. On the contrary, acidophilic and neutrophilic granulocyte counts considerably fluctuated due to changes of environmental conditions. The number of eosinophils in cage-reared bester was almost three times higher than in tank-reared fish of similar body mass.

In cage-reared bester, higher phagocytic ability was observed, probably related to immunogenicity of the environmental pathogens. Also Cp activity and lower γ-globulin content were observed in these fish, accompanied by higher LZM activity and index compared to tank-reared fish. The latter had, however, higher Cp activity than Russian sturgeon (Kolman H. 1996). It might have been related, among others, to higher growth rate of Russian sturgeon reared under similar conditions in cages placed in heated water (Kolman H. 1996). LZM activity in cage-reared besters was similar as in Russian sturgeon under comparable conditions of rearing (Kolman H. 1996). This suggests important role of the environmental conditions in the dynamics of this parameter in sturgeons.

In tank-reared bester, % of NBT-positive cells was less variable than in *A. baeri* (13.1-47.8) reared under similar conditions (Kolman H. 1996). Also dynamics of other parameters: total leucocyte counts, lymphocyte counts, NBT-reduction ability, and NBT index were lower. It seems that the differences might have also resulted from more careful selection of bester newly hatched larvae, and biological autonomy of the hybrid. This hypothesis, however, should be confirmed for other sturgeon species and their hybrids. The results show that values of some parameters in bester were different than in Siberian sturgeon (Kolman H. 1996), but overall dynamics of the immunological indices in F3 bester during ontogenesis was similar as in *A. baeri* reared also in a water recirculation system (Kolman et al. 1997).

In tank-rearing, under stable environmental conditions, growth rates of bester and Siberian sturgeon were similar (Kolman H. 1996). On the contrary, bester reared in cages in the power plant discharge channel grew much slower (Tab. I). Different growth rate caused by variations of environmental conditions might have considerably affected the analysed immunological parameters (Gershanovich et al. 1983, Kolman H. 1996, Kolman et al. 1997).

Many immunophysiological parameters in bester were less variable during the ontogenesis and due to changes of environmental conditions compared with pure sturgeon species, and the values of non-specific cellular immune indices were lower.

REFERENCES

Arefyev V.A., 1989 - Karyotype variability in successive generations after hybridization between the great sturgeon, *Huso huso* (L.) - J. Fish. Biol., Vol. 34, s. 819-828.

Arefyev V.A., 1991 - Tsitologicheskij aspekt raznokachestvennosti proizvoditelej vozvratnogo gibrida bestera i belugi - In: Biologicheskie osnovy industrialnogo osetrovodstva. Editor: A.D. Gershanovich. Sborn. Nauch. Trud., Publishing Moskva - VNIRO, 212 p. (in Russian) p.134-150.

Avtalion R.R., Shahrabani R. 1975 - Studies on phagocytosis in fish. I. In vitro uptake and killing of living *Staphylococcus aureus* by peripheral leukocytes of carp (*Cyprinus carpio*) - Immunology, vol. 29, p. 1181-1187.

Burtsev I.A. 1969 - Poluchenie potomstva ot mezhrodovogo gibrida belugi so sterladyu - In: Genetika, selekciya i gibridizaciya ryb. Publishing Moscow - Nauka, p. 232-242.

Burtsev I.A., Nikolaev A.L., Slizchenko A.G., 1985 - Novyj obyekt tovarnogo osetrovodstva - gibrid mezhdu russkim i sibirskim osetrami (*Acipenser gueldenstaedti* Br. x *A. baeri* Br.).

Burtsev I.A., Nikolaev A.I., Arefyev V.A., Serebrannikova E.V. Slizchenko A.G., 1987 - Osobennosti vozvratnykh form bestera i napravlenija selekcii s ikh ispolzovaniemp.134-150. In: Geneticheskie issledovanija morskikh gidrobiontov. Sborn. Nautch. Trud., Moskva VNIRO, p. 143-156.

Gershanovich A.D., Pegasov V.A., Shatunovskij M.I. 1987 - Ekologiya i fiziologiya molodi osetrovykh - Moskva, „Agropromizdat", p. 215.

Kolman R., Szczepkowski M. 1995 - Comparison of the growth rate and survival of three hybrids of the sturgeon *Huso huso* L. and *Acipenser rutenus* L. - Mat. International Conf., Szczecin, p.19-25.

Kolman R., 1996 - Chów jesiotra w stawach pstrągowych - Mat. XXI Krajowej Konf. Hodowców ryb łososiowatych, Ustka 10.X-12.X., Wyd. IRS - Olsztyn, p. 89-95.

Kolman R., 1997 - Intensywny chów ryb jesiotrowatych - Kom. Ryb. Wyd. IRS - Olsztyn, s. 20-23.

Kozlov V.I., 1969 - O geterozise u gibrida shipa s sevrugoj - In: Genetika, selekciya i gibridizaciya ryb. Publishing Moscow Nauka, p. 227-231.

Krylova V.D. 1980 - Izmenchivost' i nasledovanie priznakov gibridami belugi so sterladyu - *Huso huso* (L.) x *Acipenser rutenus* (L.) pervogo i vtorogo pokolenij v svyazi s selekcionnoj rabotoj - Vopr. Ikhtiol., t.20, no 2 (121), p. 232-247.

Krylova V.D., 1987 - Ispolzovanie morfologicheskikh priznakov - testov v diagnostike selekcioniruemykh form bestera - In: Geneticheskie issledovaniya morskikh gidrobiontov. Mat. III Vsesoyuzn. soveshch. po genetike, selekcii i gibridizacii ryb, IX, 1986, Tartu; Publishing Moscow - VNIRO, p. 119-138.

Krylova V.D., Gershanovich A.D., 1991 - Vlijanie nachalnoj massy molodi bestera vtorogo pokolenija na rezultaty vyrashchivanija segoletkov v sadkakh - S.26-32. In: Biologicheskie osnovy industrialnogo osetrovodstva. Ed.: A.D. Gershanovich, Sborn. Nautch. Trud., Publishing Moskva - VNIRO, 212 p.

Kuzina V.F., Zhelabovskaya S.M. 1991 - Kharakteristika mezhrodovykh gibridov russkogo osetra s belugoj s izmenyonnoj ploidnostyu - In: Biologicheskie osnovy industrialnogo osetrovodstva. Sborn. Nauch. Trudov, Publishing Moscow - VNIRO, p. 159-172.

Milshtejn V.V., Popova A.A. 1969 - O geterozise v postembrionalnyj period pri skreshchivanii raznykh biologicheskikh grup osetra - In: Genetika, selekciya i gibridizaciya ryb. Publishing Moscow Nauka, p. 224-226.

Nikolukin N.L., Timofeeva N.A., 1953 - Gibridizacija belugi so sterlayu - Dokl. Akad. Nauk, t.93, nr 5, s. 899.

O'Neill J.G. 1985 - An in vitro study of Polymorphonuclear phagocytosis and the effect of temperature - In: Fish Immunology, Ed-s: Manning M., Tatner M., Academic Press London, p. 47-55.

Pavlov D.S., Savvaitova K.A., Sokolov L.I., Alekseev S.S. 1994 - Redkie i ischezayushchie zhivotnye. Ryby - Ed-r: Sokolov V.E. Publishing Moscow - Wyzhshaya shkola, 234 p.

Rezanova G.N., Sokolskij A.F. 1991 - Vyrashchivanie tovarnoj belugi v raznotipnykh vodojomakh - In: Biologicheskie osnovy industrialnogo osetrovodstva. In: Sborn. Nauch. Trudov, Publishing Moscow - VNIRO, p. 15-26.

Shevchenko V.N. 1991 - Biotekhnologiya vyrashchivaniya novogo obyekta osetrovodstva gibrida russkuj osiotr x lenskij osiotr do tovarnoj massy - In: Biologicheskie osnovy industrialnogo osetrovodstva. Sborn. Nauch. Trudov, Publishing Moscow - VNIRO, p.5-15.

Siwicki A.K., Anderson D.P., Antychowicz J. 1993a - Nonspecific defence mechanisms assay in fish. I. Phagocytic index, adherence and phagocytic ability of neutrophils (NBT test) and myeloperoxidase activity test - In: Fish diseases diagnosis and preventions methods. Ed-s: Siwicki A.K., Anderson D.P., Waluga J. Publishing Olsztyn - IRS, p. 95-104.

Siwicki A.K., Anderson D.P. 1993b - Nonspecific defence mechanisms assay in fish. II. Potential killing activity of neutrophils and monocytes, lysozyme activity in serum and organs and total immunoglobulin (Ig) level in serum - In: Fish diseases diagnosis and preventions methods. Ed-s: Siwicki A.K., Anderson D.P., Waluga J. Publishing Olsztyn - IRS, p. 105-112.

Studnicka M, Siwicki A.K., Ryka B. 1985 - Phagocytic ability of neutrophils in carp (*Cyprinus carpio* L.) - Bamidgeh, vol. 37, p. 123-128.

Studnicka M., Siwicki A.K., Ryka B. 1986 - Lyzozyme levels in carp (*Cyprinus carpio* L.) - Bamidgeh, vol. 38, p. 22-25.

Studnicka M., Siwicki A.K., Kazuń K., Głąbski E. 1993a - The nonspecific cellular and humoral immune response in commoc carp to the Eimeria subepithelialis antigen - In:Fish diseases diagnosis and preventions methods. Ed-s: Siwicki A.K., Anderson D.P., Waluga J. Publishing Olsztyn - IRS, p. 165-170.

Studnicka M., Siwicki A.K., Ryka B. 1993b - Study of the effect of methylmercury compound on the nonspecific immune responce in experimentally infected carp - In: Fish diseases diagnosis and preventions methods. Ed-s: Siwicki A.K., Anderson D.P., Waluga J. Publishing Olsztyn - IRS, p. 171-176.

Szczylik C., Gornas P., Carewicz R. 1979 - Test redukcji NBT - metodyka i praktyczne zastosowanie - Diag. Lab., no 1, p. 35-40.

Van Oss C.J., Fuji H., Wicher K., Rabin B., Kite J. 1973 - Phagocytosis - In: Methods in Immunodiagnosis, Ed-s: Rose N.R., Bigazi P.E., John Wiley, New York, p. 157-159.

STRESZCZENIE

KSZTAŁTOWANIE SIĘ WYBRANYCH NIESWOISTYCH KOMÓRKOWYCH I HUMORALNYCH MECHANIZMÓW ODPORNOŚCIOWYCH U BESTERA (*Huso huso* L. x *Acipenser rutenus* L.)

Bester, krzyżówka międzyrodzajowa bieługi (*Huso huso* L) ze sterletem (*A. rutenus* L.) jest płodnym. W trzecim pokoleniu (F_3) charakteryzuje się stabilizacja cech hodowlanych na poziomie charakterystycznym dla gatunków wyjsciowych. W pracy przedstawiono pierwsze wyniki badań nad kształtowaniem się wybranych nieswoistych komórkowych i humoralnych mechanizmów odpornościowych u tego hybryda.

Ryby chowane w basenach zamkniętego obiegu wody charakteryzowały się znacznie wyższym tempem wzrostu niż w sadzach umieszczonych w kanale zrzutowym elektrociepłowni.

W okresie trzech lat chowu w basenach obiegu zamkniętego stwierdzono ścisłą zależność aktywności metabolicznej leukocytów oraz liczby eozynofili od masy ciała ryb. Bestery z obiegu charakteryzowały się niższym poziomem liczby eozynofili, indeksu fagocytarnego, aktywności oraz indeksu lizozymu niz bestery z sadzów na kanale zrzutowym elektrociepłowni; ale wyższą aktywnoścla metaboliczną leukocytów, wyższą aktywnością Cp, i wyższym poziomem frakcji γ-globulinowej. Grupy tych ryb nie różniły się istotnie pod względem ogólnej liczby leukocytów, liczby limfocytów, procentu komórek PMN NBT-pozytywnych, indeksu NBT. W kształtowaniu się oznaczonych parametrów dyskutowano rolę tempa wzrostu ryb, warunków środowiskowych oraz autonomii biologicznej krzyżówki.

ADRESY AUTORÓW:

Dr Halina Kolman
Instytut Biologii i Ochrony Środowiska
10-561 Olsztyn, ul. Żołnierska 14

Doc. dr hab. Ryszard Kolman
Instytut Rybactwa Śródlądowego
10-917 Olsztyn, ul. Oczapowskiego 10

Prof. dr. hab. Andrzej K. Siwicki
Instytut Rybactwa Śródlądowego
Zakład Patologii i Immunologii Ryb
Żabieniec, 05-500 Piaseczno