Journal of Aquatic Science and Marine Biology
Volume 2, Issue 2, 2019, PP 33-39
ISSN 2638-5481

Factors Affecting Fish Blood Profile: C Effect of Other Environmental and Genetic Factors

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ABSTRACT

Many studies in the fields of fish nutrition, reproduction, and biology including blood tests revealing factors influence blood composition. In the present part of the serial studies, more lights are given on effects of fish species, sex and size as well as different water bodies' locations (lake, farm, Nile) and water salinity and temperature on fish blood changes.

Keywords: *Haematology, blood biochemistry, fish species, size, sex, fresh water, salt water, brackish water, water temperature.*

INTRODUCTION

Penzlin (1977) cited that blood constituents of fish are variable than those of the terrestrial animals. **Abdelhamid (1991)** argumenta for the variation between fish and terrestrial animals to the huge number of fish species (ca. 25.000) and strains (40.000) in comparison with the mammalian species (ca. 4.500). Additionally, **Abdelhamid (2009)** cited that fish are variable in their morphology, biology, anatomy, physiology, reproduction, respiration, body composition, and blood profile. Blood parameters of fish are useful tools that aid in the immnuopotentiators studies (**Ellis, 1981**). **Press and Evensen (1999)** expected species variation in the morphology of the immune system within the teleost fishes. However, data available about the on to genic development of the innate immunological system in fish is limited (**Magnadóttir, 2006)**. Recently, some factors were studied as affecting fish blood profile (**Abdelhamid*et al*., 2019a & b**).

The present study was designed to evaluate the effect of some other factors affecting some blood parameters. These factors included fish species and size, water salinity, and rearing conditions; since, it was given in Verse 12 of SuraFaatir of Holly Quran concerning the variations in water and fish composition: "**And not alike are the two bodies of water. One is fresh and sweet, palatable for drinking, and one is salty and bitter. And from each you eat tender meat and extract ornaments which you wear, and you see the ships plowing through [them] that you might seek of His bounty; and perhaps you will be grateful**". So, this was also included in the objectives of the present study.

MATERIALS AND METHODS

Random fish samples were taken for blood collected from the caudal peduncle by special syringe. Five-ml-syringes were used for blood withdrawal into two types of test tubes, the 1st with ethylene diamine tetra acetic acid (EDTA) for the haematological parameters and the 2nd without EDTA for the biochemical parameters. Blood plasma was obtained by centrifugation at 3500 rpm for 15 min. Dragoon pipets were used for withdrawing the samples from the test tubes as shown from the following pictures. Blood plasma samples were used for determination of creatinine **(Tietz, 1986)**, triglycerides **(Mc Gowan *et al*., 1983)**, total proteins (**Tietz, 1990**) and albumin (**Wotton and Free man, 1982)** concentrations as well as the activity of aspartate amino transferase (AST) and alanine amino transferase (ALT) using commercial test kits (Humalyzer 3000 manufactured by Human, Germany) in a private lab. In Kafr El-Sheikh governorate, Egypt. Globulin level was Calculated by subtracting albumin from total protein. The other samples of blood were used to determine the blood hematology as concentration of hemoglobin (Hb), total count of erythrocytes (RBCs), and total leukocytes (WBC_S) (**Natt and Herrick, 1952)** and hematocrit (Hct) using Auto Counter (920 EO+ manufactured by Swe lab Switzerland) **(Decie and Lewis, 2006)** in the same lab. The other hematological parameters were mathematically calculated. Blood analysis data was statistically analyzed according to **SAS (2006)**. When F- test was significant at P≤0.05, **Duncan's** test (**1955**) was carried out.

RESULTS AND DISCUSSION

Five fish (250±3 g for each sex, species, and location) from each fish species (Nile tilapia, *Oreochromisniloticus* and African catfish, *Clariasgariepinus*), fish sex (male and female), and location (Lake Borulus, a fish farm, and the River Nile, Rosetta branch) were chosen for blood collection and analysis during September 2018.

The water quality in these locations was as follow:

Water temperature, °C	pH	Dissolved oxigen, mg/l	Ammonia, mg/l	Salinity, g/l
River Nile (Rosetta branch)				
32	7.8	5.3	1.20	2.4
Lake Borulus				
30.9	7.1	7.8	0.64	5.3
Fish farm				
32.1	6.3	4.3	0.71	1.1

Tables 1 and 2 show that sampling location significantly (P≤0.05) affected all haemato logical and most biochemical parameters measured. That may be attributed to the wide variations in their water conditions, particularly to their salinity (1.1-5.3 g/l), ammonia (0.64-1.2 mg/l), and dissolved oxygen (4.3-7.8 mg/l). The same trend was recorded for fish species; it significantly (P≤0.05) affected also all haemato logical and most biochemical parameters under study. Fish sex was less affecting the blood profile, particularly the biochemical ones. Therefore, the interactions were more significant among the haematological than among the biochemical parameters. **Abdel-Moneim*et al.* (2013)** found that increasing ammonia in the rearing water of tilapia was responsible for decreased serum total iron, total binding iron capacity, amylase and lipase while insulin significantly increased. Also, **Hassanen and AbdElnabi (2017)** found that increased ammonia level in red tilapia rearing water led to higher urea, uric acid and creatinine values in the fish blood. Also, Moreover, **Abd El-Ghaffar and Abu El- Nasr (2017)** confirmed that rearing water pH affects significantly all blood physiological parameters of Nile tilapia. **Helal *et al.* (2018)** studied also the harmful effects of water pollution on some physiological responses of the Nile tilapia (*Oreochromis niloticus*) in both Qarun and Burullus Lakes These findings are in accordance with those found by **Abdelhamid*et al.* (2019b)** concerning the effect of farm location and condition, fish species, and water salinity.

Table1. *Effect of sampling locations and fish species and sex on some haematological parameters (means* ± standard errors)*

	Hb (g/dl)	Hct (%)	RBCs (X 10^6/µl)	MCV (fl)	MCH (pg)	MCHC (%)	Platelets (X 10^3/µl)	WBCs (X 10^3/µl)
Sampling location								
Lake	11.27^{c}±0.33	27.97^{c}±2.00	2398^{a}±36.88	151.60^{a}±1.39	60.52^{b} ±1.94	40.88^{b} ±1.70	170150^{b} ±14052	88185^{a} ±2223
Farms	13.45^{a}±0.34	30.16^{a}±0.52	2253^{b} ±51.91	137.50^{b} ±2.16	61.53^{b} ±1.44	44.49^{a} ±1.48	218450^{a} ±7972	75300^{b} ±5237
Nile	12.29^{b}±0.49	28.79^{b} ±2.36	2267^{b} ±52.20	150.00^{a} ±1.27	65.79^{a} ±1.76	44.56^{a} ±1.15	162050^{b} ±4315	77510^{b} ±3558
Fish species								
Nile tilapia	11.09^{b}±0.29	23.49^{b}±1.24	2257^{b} ±38.87	146.03 ±0.53	66.96^{a} ±1.33	45.87^{a} ±0.94	210667^{a} ±8534	82543 ±3477
African cat fish	13.58^{a}±0.27	34.46^{a}±0.87	2354^{a} ±39.75	146.70 ±2.46	58.26^{b} ±1.09	40.74^{b} ±1.29	156433^{b} ±6431	78120 ±3070

Fish sex								
Male	12.36 ±0.39	28.05^{b} ±1.61	2291 ±40.86	147.43^{a} ±2.01	63.21 ±1.49	44.79^{a} ±1.45	176583^{b} ±7426	73953^{b} ±3591
Female	12.31 ±0.33	29.90^{a} ±1.31	2320 ±39.63	145.30^{b} ±1.49	62.02 ±1.42	41.83^{b} ±0.87	190517^{a} ±10315	86710^{a} ±2479
Interactions								
Location*Species	0.0001	0.0001	0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
Location*sex	0.2570	0.0001	0.1235	0.0570	0.0201	0.6942	0.0215	0.0028
Species*sex	0.0018	0.0001	0.0380	0.2134	0.0057	0.0025	0.0011	0.9906
Location*Species*sex	0.0001	0.0001	0.4632	0.2505	0.0001	0.0001	0.0072	0.8950

**: n= 5, a-c: means superscripted with different letters significantly (P≤0.05) differ, Hb: haemoglobin, Hct: haematocrit, RBCs: red blood cells, MCV: mean corpuscular volume, MCH: mean corpuscular haemoglobin, MCHC: mean corpuscular haemoglobin concentration, WBCs: white blood cells.*

Table2. *Effect of sampling locations and fish species and sex on some blood biochemical parameters (means* ± standard errors)*

	AST (u/l)	ALT (u/l)	AL (g/dl)	GL (g/dl)	TP (g/dl)	Creatinine (mg/dl)	Urea (mg/dl)	TCH (mg/dl)	TG (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
Location											
Lake	168.9^{a} ±6.02	43.35 ±1.60	1.04^{a} ±0.03	2.27^{b} ±0.08	3.90^{a} ±0.10	1.21 ±0.13	4.43^{b} ±0.19	265.9^{a} ±8.51	181.1^{b} ±11.50	96.15 ±2.13	133.1^{a} ±6.39
Farms	108.5^{b} ±14.24	41.80 ±2.96	1.03^{a} ±0.03	2.63^{a} ±0.12	4.11^{a} ±0.11	1.22 ±0.14	8.35^{a} ±0.98	261.9^{a} ±8.57	216.8^{a} ±10.28	93.40 ±1.98	129.6^{a} ±9.00
Nile	168.2^{a} ±2.23	41.55 ±0.88	0.94^{b} ±0.03	1.74^{c} ±0.10	3.32^{b} ±0.07	1.31 ±0.05	8.03^{a} ±0.67	233.6^{b} ±7.01	151.0^{c} ±5.11	96.20 ±1.44	106.4^{b} ±7.29
Fish species											
Nile tilapia	160.9^{a} ±6.64	45.53^{a} ±1.83	0.97^{b} ±0.02	1.94^{b} ±0.09	3.66^{b} ±0.10	1.27 ±0.10	4.87^{b} ±0.19	231.1^{b} ±7.18	177.9 ±10.67	93.27^{b} ±1.33	104.8^{a} ±7.20
African catfish	136.2^{b} ±10.36	38.93^{b} ±1.12	1.03^{a} ±0.02	2.48^{a} ±0.10	3.88^{a} ±0.09	1.22 ±0.09	9.00^{a} ±0.72	276.4^{a} ±3.54	188.0 ±7.05	97.23^{a} ±1.63	141.2^{a} ±3.36
Fish sex											
Male	143.8 ±7.90	41.30 ±1.41	1.00 ±0.02	2.22 ±0.11	3.87 ±0.10	1.29 ±0.10	7.06 ±0.66	251.8 ±6.97	194.6^{a} ±11.01	96.97 ±1.39	115.3^{b} ±6.46
Female	153.3 ±9.90	43.17 ±1.81	1.00 ±0.02	2.20 ±0.11	3.68 ±0.09	1.20 ±0.09	6.82 ±0.64	255.7 ±7.12	171.3^{b} ±5.90	93.53 ±1.60	130.8^{a} ±6.34
Location	0.0001	0.7358	0.0241	0.0001	0.0001	0.2262	0.0001	0.0003	0.0001	0.3560	0.0030
Species	0.0027	0.0021	0.0513	0.0001	0.0481	0.2862	0.0001	0.0001	0.0706	0.0325	0.0001
sex	0.2268	0.3616	0.8486	0.7834	0.0917	0.1193	0.4089	0.5490	0.0001	0.0626	0.0216
Location* Species	0.0001	0.0019	0.0241	0.0001	0.8371	0.0001	0.0001	0.0011	0.0001	0.0001	0.0189
Location*sex	0.3498	0.8301	0.2012	0.6001	0.8154	0.5890	0.5229	0.3177	0.0402	0.9997	0.1388
Species*sex	0.3731	0.4727	0.6295	0.3018	0.2487	0.8499	0.7128	0.3147	0.1576	0.6722	0.2602
Location* Species*sex	0.6190	0.9757	0.0666	0.7277	0.6817	0.3416	0.5626	0.4119	0.0001	0.1931	0.0839

**: n= 5, a-c: means superscripted with different letters significantly (P≤0.05) differ, AST: aspartate aminotransferase, ALT: alanine aminotransferase, GL: globulin, TP: total protein, TCH: total cholesterol, TG: triglycerides, HDL: high density lipoprotein, LDL: low density lipoprotein.*

Water salinity is an important factor; since, it was given in Verse 12 of SuraFaatir (No.35 of Holly Quran) concerning the variations in water com Location**:** "**And not alike are the two bodies of water. One is fresh and sweet, pala table for drinking, and one is salty and bitter. And from each you eat tender meat and extract ornaments which you wear, and you see the ships plowing through [them] that you might seek of His bounty; and perhaps you will be grateful**". Also, in Surah Ar-Rahman (The Most Graciouse, No. 55 of Holly Quran) in Verses 19-21**: " He released the two seas, meeting [side by side] (19); Between them is a barrier [so] neither of them trans gresses (20); So which of the favors of your Lord would you deny? (21).** For this reason, Nile fish [(5 of each Nile tilapia *Oreochrom is* *niluticus* (150g) and *Tilapia aurea*, Trewavas, 1965 (160g)] and sea fish [(5 of each sea bass, 125g and Tobara mullet (*Liza ramada*), 140g)] were collected to examine their blood. The water conditions of Nile [inshore, in front of the Barzakh (Isthmus/Barrierthat found between fresh and salt water)] and sea [off-shore, behind the Barzakh (Isthmus/Barrier) that found between fresh and salt water] in Rosetta Strait region (where the Barzakh (Isthmus/Barrier) is given in Holly Quran) were:

Temperature, °C	pH	Dissolved oxygen, mg/l	Ammonia, mg/l	Salinity, g/l
Nile water				
26.9	5.9	7.6	2.1	8.7
Sea water				
26.5	7.8	6.2	2.8	15.3

Tables 3 and 4 revealed significant (P≤0.05) variation between Nile (fresh water, 2 species, each 5 fishes) and sea (salt water, 2 species, each 5 fishes) in all haematological parameters, except platelets and white blood cells (WBCs) counts; yet most biochemical parameters did not influence, except globulin (GL), total protein (TP), total cholesterol (TCH), and high density lipoprotein (HDL). Sea fish (sea bass and Tobara) had often higher values than for Nile fish [*Oreochromisniluticus* and *Tilapia aurea*], except for MCHC. This may be due to the effect of water salinity (8.7 vs. 15.3 g/l) which affects not only fish blood characteristics but mainly fish species, which is suitable according to each water salinity; hence, fish species are classified into fresh water fishes and salt water fishes (**Abdelhamid, 2019a & b**). As said before, the God in Holly Quran, since 1440 years ago (Hegira of profit Mohamed), stated about the variation between fresh and salt water.

Table3. *Effect of sampling locations from Rosetta Strait on some haematological parameters (means* ± standard errors)*

Location	Hb (g/dl)	Hct (%)	RBCs (X 10^6/µl)	MCV (fl)	MCH (pg)	MCHC (%)	Platelets (X 10^3/µl)	WBCs (X 10^3/µl)
Nile	11.20^b ±0.21	22.25^b ±0.32	1858^b ±30.62	117.6^b ±2.77	59.76^b ±0.73	51.01^a ±1.67	513800 ±53190	86740 ±8142
Sea	17.57^a ±0.38	52.77^a ±0.76	4114^a ±52.16	128.3^a ±3.39	42.15^a ±0.40	33.94b ±1.22	546700 ±28133	71050 ±3452

**: n= 10 (collective of 2 species, 5 each), a-b: means superscripted with different letters significantly (P≤0.05) differ, Hb: haemoglobin, Hct: haematocrit, RBCs: red blood cells, MCV: mean corpuscular volume, MCH: mean corpuscular haemoglobin, MCHC: mean corpuscular haemoglobin concentration, WBCs: white blood cells.*

Table4. *Effect of sampling locations from Rosetta Strait on some blood biochemical parameters (means* ± standard errors)*

Location	AST (u/l)	ALT (u/l)	AL (g/dl)	GL (g/dl)	TP (g/dl)	Creatinine (mg/dl)	Urea (mg/dl)	TCH (mg/dl)	TG (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
Nile	179.3 ±36.18	136.6 ±6.66	1.89 ±0.03	3.03^b ±0.02	5.17^b ±0.03	0.48 ±0.02	8.50 ±0.17	341.40^b ±2.34	275.40 ±5.05	96.70^b ±0.87	189.6 ±2.40
Sea	231.9 ±5.77	113.9 ±22.04	1.89 ±0.09	3.27^a ±0.04	5.38^a ±0.08	0.45 ±0.02	9.10 ±0.23	350.20^a ±3.34	282.70 ±2.67	101.70^a ±1.97	192.3 ±1.62

**: n= 10 (collective of 2 species, 5 each), a-b: means superscripted with different letters significantly (P≤0.05) differ, AST: aspartate aminotransferase, ALT: alanine aminotransferase, GL: globulin, TP: total protein, TCH: total cholesterol, TG: triglycerides, HDL: high density lipoprotein, LDL: low density lipoprotein.*

Fish size (regardless to sampling location, sex, rearing condition etc. as a cumulative sample) of Nile tilapia significantly (P≤0.05) Hb, MCH, MCHC, platelets, and most biochemical parameters, except urea and HDL (Tables 5 and Effect of fish size on its blood profile was studied too by **Abdelhamid *et al.* (2019a).**

Table5. *Effect of Nile tilapia size on some haematological parameters (means* ± standard errors)*

Fish size (g)	Hb (g/dl)	Hct (%)	RBCs (X 10^6/µl)	MCV (fl)	MCH (pg)	MCHC (%)	Platelets (X 10^3/µl)	WBCs (X 10^3/µl)
50	10.63^b ±0.32	23.86 ±1.43	1752 ±110.4	139.9 ±1.93	64.88^{ab} ±2.18	46.35^a ±1.77	121733^b ±14447	89247 ±5398

150	10.34b ±0.16	24.21 ±1.52	1737 ±94.90	140.2 ±1.40	62.91^{ab} ±2.30	45.13^{ab} ±1.42	125927^{b} ±15132	80640 ±4040
250	10.45^{b} ±0.18	23.68 ±1.36	1694 ±92.23	139.9 ±5.76	70.83^{a} ±4.47	46.43^{a} ±1.57	186650^{a} ±13217	80310 ±4690
400	11.38^{a} ±0.14	27.37 ±0.47	1904 ±41.54	147.6 ±1.43	60.97^{b} ±1.21	41.88^{b} ±0.50	198740^{a} ±4601	77617 ±2279

**: n= 30 (cumulative sample), a-c: means superscripted with different letters significantly (P≤0.05) differ, Hb: haemoglobin, Hct: haematocrit, RBCs: red blood cells, MCV: mean corpuscular volume, MCH: mean corpuscular haemoglobin, MCHC: mean corpuscular haemoglobin concentration, WBCs: white blood cells.*

Table6. *Effect of Nile tilapia size on some blood biochemical parameters (means* ± standard errors)*

Fish size (g)	AST (u/l)	ALT (u/l)	AL (g/dl)	GL (g/dl)	TP (g/dl)	Creatinine (mg/dl)	Urea (mg/dl)	TCH (mg/dl)	TG (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
50	197.7^{a} ±10.97	57.73^{b} ±3.62	1.34^{a} ±0.08	2.55^{b} ±0.17	4.04^{b} ±0.21	0.88^{a} ±0.10	6.82 ±0.92	140.10^{c} ±10.27	139.50^{c} ±8.01	84.50 ±4.80	50.27^{b} ±8.19
150	179.7^{a} ±11.67	52.97^{b} ±3.04	1.36^{a} ±0.09	2.34^{b} ±0.14	3.98^{b} ±0.18	0.94^{a} ±0.10	7.13 ±0.76	156.17^{b} ±12.13	165.83^{b} ±8.73	86.23 ±4.83	53.40^{b} ±8.27
250	115.6^{b} ±8.85	42.53^{b} ±2.13	1.03^{b} ±0.03	3.16^{a} ±0.15	4.32^{ab} ±0.13	0.91^{a} ±0.08	7.71 ±0.80	183.63^{ab} ±11.94	145.70^{bc} ±8.98	86.53 ±3.53	67.27^{ab} ±10.64
400	184.7^{a} ±12.61	80.03^{a} ±10.19	1.02^{b} ±0.02	3.47^{a} ±0.08	4.49^{a} ±0.08	0.58^{b} ±0.02	5.50 ±0.26	206.70^{a} ±3.94	226.67^{a} ±7.53	86.93 ±1.76	74.87^{a} ±3.33

**: n= 30 (cumulative sample), a-c: means superscripted with different letters significantly (P≤0.05) differ, AST: aspartate aminotransferase, ALT: alanine aminotransferase, GL: globulin, TP: total protein, TCH: total cholesterol, TG: triglycerides, HDL: high density lipoprotein, LDL: low density lipoprotein.*

Regardless to other variables, fish species and water temperature significantly (P≤0.05) affected all tested blood parameters, whether haematological or biochemical (Tables 7-10) without concerning trends for all species within all parameters at 30 as well as at 10°C. There was no specific effect of water temperature on different blood parameters tested.

Table7. *Haematological parameters (means* ± standard errors) of different fish species at 30°C.*

Items/Species	Tilapia	Catfish	Mullet	Sea bream	Sea bass
Hb (g/dl)	11.167^{d}±0.216	13.373^{b}±0.243	18.100^{a}±0.200	12.433^{c}±0.128	11.167^{d}±0.152
Hct (%)	38.04^{a}±0.864	29.65^{c}±1.089	37.46^{a}±1.139	36.53^{ab}±0.723	34.02^{b}±0.612
RBCs(X 10^6/µl)	2723^{b}±44.95	2265^{c}±77.85	3809^{a}±80.70	2596^{b}±92.48	2650^{b}±59.85
MCV(fl)	142.6^{a}±2.09	124.9^{c}±3.74	84.1^{d}±1.36	145.3^{a}±2.44	135.1^{b}±0.58
MCH(pg)	43.95^{b}±0.567	61.64^{a}±1.979	41.81b^{c}±0.313	44.33^{b}±0.886	38.23^{c}±2.015
MCHC (%)	32.43^{c}±0.520	52.65^{a}±3.210	46.09^{b}±0.601	31.50^{c}±0.172	30.49^{c}±0.098
Platelets(X 10^3/µl)	274567^{a}±10592	100267^{c}±14881	193600^{b}±3947	272800^{a}±8118	254000^{a}±7274
WBCs(X 10^3/µl)	36067^{c}±961	187133^{a}±20477	78107^{b}±2369	43533^{c}±3050	37667^{c}±1454

**: n= 15 (collective sample), collective sample, a-d: means in the same row superscripted with different letters significantly (P≤0.05) differed, Hb: haemoglobin, Hct: haematocrit, RBCs: red blood cells, MCV: mean corpuscular volume, MCH: mean corpuscular haemoglobin, MCHC: mean corpuscular haemoglobin concentration, WBCs: white blood cells.*

Table8. *Haematological parameters (means* ± standard errors) of different at 10°C. Fish species*

Items/Species	Tilapia	Catfish	Mullet	Sea bream	Sea bass
Hb(g/dl)	10.013^{d}±0.329	14.780^{b}±0.588	17.693^{a}±0.510	12.233^{c}±0.228	11.000^{d}±0.201
Hct(%)	17.95^{d}±0.777	26.33^{c}±1.274	38.70^{a}±1.343	37.84^{a}±0.919	34.24^{b}±0.634
RBCs(X 10^6/µl)	1333^{c}±51.40	2339^{b}±121.5	4029^{a}±136.1	2460^{b}±94.52	2510^{b}±64.95
MCV(fl)	141.7^{a}±2.62	117.9^{c}±2.43	98.3^{d}±2.88	146.1^{a}±2.46	133.9^{b}±0.94
MCH(pg)	74.95^{a}±0.596	66.61^{b}±0.798	44.15^{c}±0.659	43.24^{c}±1.080	37.93^{d}±1.220
MCHC (%)	53.01^{b}±0.995	57.35^{a}±1.233	46.17^{c}±0.863	31.75^{d}±0.232	30.46^{d}±0.259
Platelets (X 10^3/µl)	75400^{d}±6544	58867^{d}±4987	163600^{c}±7054	294667^{a}±8054	210267^{b}±17037
WBCs(X 10^3/µl)	95947^{b}±2715	167180^{a}±7958	80753^{c}±4348	38267^{d}±1925	28600^{d}±1446

**: n= 15 (collective sample), collective sample, collective sample, a-d: means in the same row superscripted with different letters significantly (P≤0.05) differed, Hb: haemoglobin, Hct: haematocrit, RBCs: red blood cells, MCV: mean corpuscular volume, MCH: mean corpuscular haemoglobin, MCHC: mean corpuscular haemoglobin concentration, WBCs: white blood cells.*

Table9. *Blood biochemical parameters (means* ± standard errors) of different fish species at 30°C.*

Items/Species	Tilapia	Cat fish	Mullet	Sea bream	Sea bass
AST(u/l)	173.5^{a}±3.64	112.8^{b}±20.03	58.0^{c}±1.95	127.9^{b}±0.81	130.1^{b}±2.38
ALT(u/l)	63.40^{a}±2.34	32.13^{d}±1.04	52.40^{b}±3.64	35.87^{cd}±1.07	41.33^{c}±0.64
AL(g/dl)	1.19^{ab}±0.02	1.00^{c}±0.05	1.26^{a}±0.06	1.09^{b}±0.03	1.10^{b}±0.02
GL(g/dl)	3.34^{a}±0.08	2.61^{b}±0.14	2.65^{b}±0.12	3.41^{a}±0.09	3.44^{a}±0.09
TP(g/dl)	4.77^{a}±0.08	3.88^{c}±0.10	4.31^{b}±0.08	4.88^{a}±0.08	4.93^{a}±0.06
Creatinine(mg/dl)	0.36^{c}±0.01	1.32^{a}±0.12	0.61^{b}±0.01	0.27^{c}±0.01	0.25^{c}±0.01
Urea(mg/dl)	16.27^{a}±0.40	9.13^{c}±1.01	3.87^{d}±0.19	13.47^{b}±0.38	13.67^{b}±0.41
TCH(mg/dl)	281.7^{c}±5.64	210.3^{d}±17.88	183.7^{d}±2.36	382.2^{a}±8.86	320.4^{b}±3.66
TG(mg/dl)	211.1^{b}±11.94	188.9^{bc}±9.49	167.0^{c}±2.92	242.7^{a}±9.00	188.9^{bc}±3.65
HDL(mg/dl)	106.1^{c}±4.38	69.1^{d}±6.04	75.5^{d}±3.55	196.2^{a}±5.26	153.1^{b}±1.46
LDL(mg/dl)	133.1^{a}±3.85	103.5^{b}±12.85	74.8^{c}±3.98	137.4^{a}±6.98	129.4^{a}±4.28

**: n = 15 (collective sample), a-d: means in the same row superscripted with different letters significantly (P≤0.05) differed, AST: aspartate aminotransferase, ALT: alanine aminotransferase, GL: globulin, TP: total protein, TCH: total cholesterol, TG: triglycerides, HDL: high density lipoprotein, LDL: low density lipoprotein.*

Table10. *Blood biochemical parameters (means* ± standard errors) of different fish species at 10°C.*

Items/Species	Tilapia	Cat fish	Mullet	Sea bream	Sea bass
AST	144.7^{a}±8.35	60.6^{c}±0.47	60.4^{c}±2.20	122.0^{b}±3.61	128.9^{b}±6.06
ALT	39.93^{c}±1.62	33.07^{c}±1.48	51.60^{b}±4.21	34.80^{c}±1.50	69.20^{a}±4.02
AL	1.01^{bc}±0.04	0.89^{c}±0.04	1.51^{a}±0.11	1.05^{bc}±0.03	1.09^{b}±0.03
GL	1.94^{c}±0.14	2.95^{b}±0.08	3.08^{ab}±0.12	3.38^{a}±0.10	3.39^{a}±0.11
TP	3.20^{c}±0.13	4.09^{b}±0.09	4.79^{a}±0.14	4.76^{a}±0.10	4.70^{a}±0.11
Creatinine	1.39^{b}±0.07	1.69^{a}±0.05	0.56^{c}±0.03	0.23^{d}±0.01	0.22^{d}±0.01
Urea	4.18^{b}±0.19	12.00^{a}±0.45	4.00^{b}±0.28	12.93^{a}±0.63	12.80^{a}±0.56
TCH	118.4^{e}±5.12	162.7^{d}±2.68	180.6^{c}±7.42	351.2^{a}±7.35	331.1^{b}±6.04
TG	163.9^{b}±8.57	220.0^{a}±15.36	177.0^{b}±3.80	221.6^{a}±8.19	228.3^{a}±7.34
HDL	99.3^{c}±3.04	175.3^{b}±5.15	81.1^{c}±5.28	234.3^{a}±4.08	219.9^{a}±7.78
LDL	16.6^{c}±1.62	45.07^{b}±2.93	64.53^{a}±7.50	72.67^{a}±6.48	65.53^{a}±5.68

**: n= 15(collective sample), a-d: means in the same row superscripted with different letters significantly (P≤0.05) differed, AST: aspartate aminotransferase, ALT: alanine aminotransferase, GL: globulin, TP: total protein, TCH: total cholesterol, TG: triglycerides, HDL: high density lipoprotein, LDL: low density lipoprotein.*

Press and Evensen (1999) mentioned that species variation in the morphology of the immune system is to be expected, given the large number and diversity of species within the teleost fishes. **Dominguez *et al.* (2004)** confirmed that elevating rearing water temperature (18.4, 23, and 28 ºC) for 2 weeks increased the circulating IgM concentration in Nile tilapia, but rearing the fish at 33 ºC resulted in a decrease in IgM concentration.

These results suggest that the specific immune system of tilapia changes by certain factors in aquatic environment. **Abdelhamid*et al.* (2015)** revealed that catfish gave significantly higher values for most of the hematological parameters referring to best tolerance among the studied fish species. Except MCV, all other hematological parameters reflected significant interaction effects (diet X species), where the highest Hb and MCV values were of catfish fed the control diet, but sewage sludge fed catfish gave the highest MCHC and WBC_s, catfish fed the sewage sludge had also the highest RBC_s and PCV, and control fed tilapia only had the highest MCH value.

Conclusively

These results confirm that fish blood parameters are strong variable influenced by fish species, size, and sex as well as by the location, and rearing water temperature and salinity. Therefore, the interpretation of blood data of fish must be done on light of the specific individual experiment condition because of absence of referenced ranges for fish haematological and biochemical measurements.

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Citation: *Abdelhamid M. Abdelhamid, Mohamed M. A. H. Refaey, Mahmoud F. Salem et al, "Factors Affecting Fish Blood Profile: C Effect of Other Environmental and Genetic Factors", Journal of Aquatic Science and Marine Biology, 2019, 2(2), pp.33-39.*