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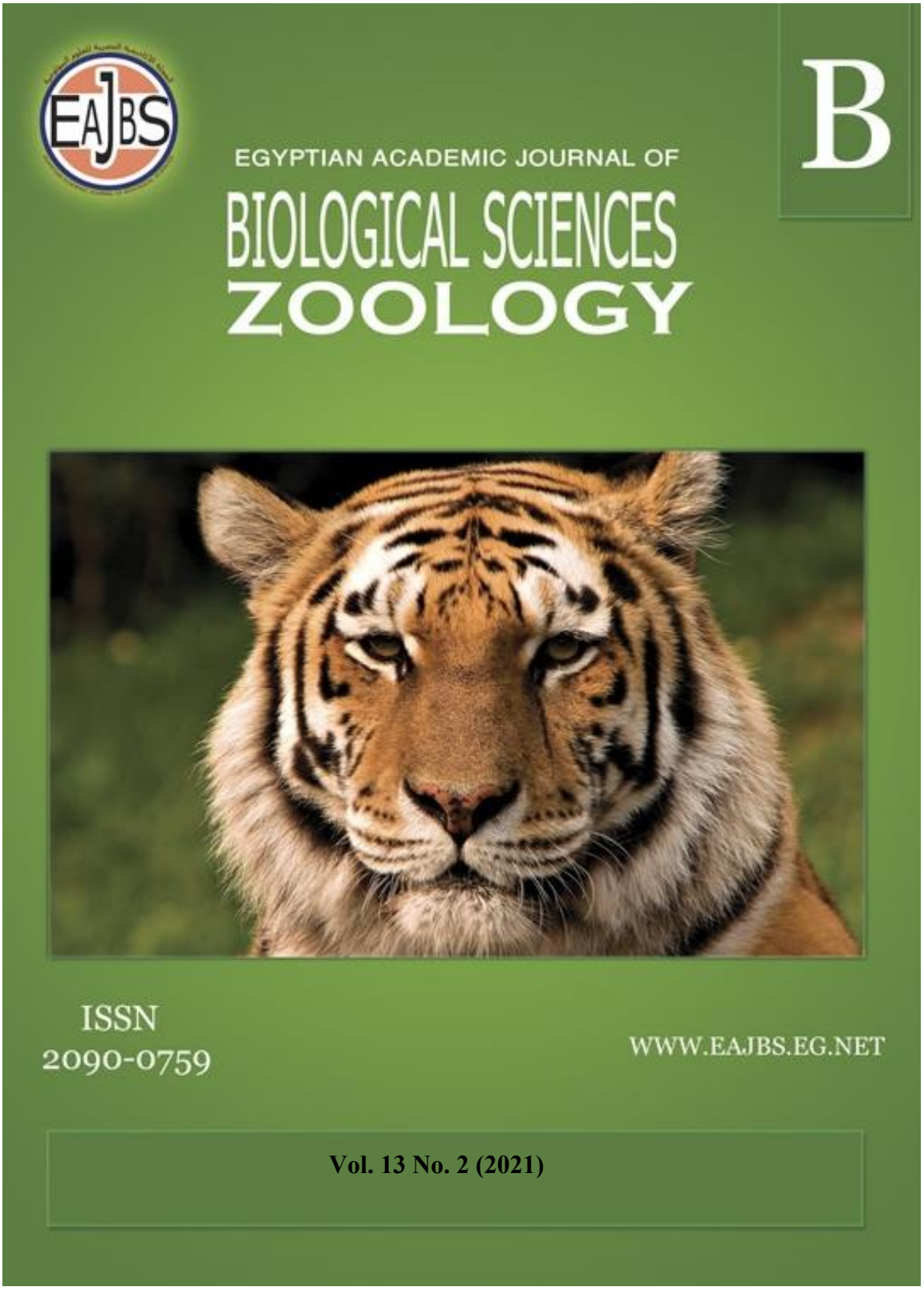

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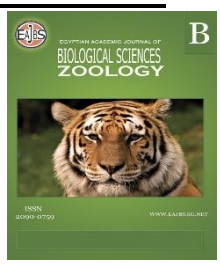

Comparative Acute Exposure Study of Abamectin Different Formulations Inducing Physiological and Oxidative Stress Biomarkers in Nile Tilapia, (*Oreochromis niloticus*).

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ABSTRACT

The goal of this study is to assess the acute and sublethal potential hazards on tilapia fish (*Oreochromis niloticus*) exposed to two different commercial formulations of abamectin (ABM, 5%): emulsifiable concentration (EC) and microemulsions (ME). The median lethal concentration (LC_{50} - 96 h) to each formulation was determined, as well as the adverse effects of sublethal concentrations (½ LC_{50}) on physiological and oxidative stress biomarkers after 96hs of exposure. The LC_{50} (96 h) values for EC and ME were 10 and 16.6 µg/L, respectively. Furthermore, in both EC and ME, the findings of physiological and oxidative stress aspects revealed significant markedly increases in serum total protein, albumin, globulin, and urea, as well as a significant decline in aminotransferases activity (ALT and AST), and creatinine levels (Cre). Moreover, superoxide dismutase (SOD), malondialdehyde (MDA), catalase (CAT), and glutathione peroxidase (GPx) were greatly increased, whereas glutathione-S-transferase (GST) and glutathione (GSH) were significantly reduced in the liver and brain.

INTRODUCTION

Insect control boosts production efficiency, hence, pesticides are important in modern agriculture. However, since pesticides have become more widely used in agriculture in recent decades, environmental hazards and negative impacts on aquatic organisms have become a serious issue (Kayhan, *et al.*, 2013; Huang, *et al.*, 2019). Pesticides have a deleterious influence on environmental biodiversity and may cause physiological and stress impacts on non-target species (Elsharkawy, 2020), aquatic biotas, and human and animal health (Ali, *et al.*, 2020). Aquatic creatures, such as fish, are in direct contact with pesticides dissolved in the water, making them more vulnerable to pesticides (Covantes-Rosales, *et al.*, 2019). Fish are one of the most polluted species because of their economic value and high sensitivity to pollutants. The toxicology tests

are carried out on various fishes which were used extensively in the bioassay (Nazifi *et al.*, 2000). Pesticides as environmental stressors can cause oxidative stress by inducing the generation of reactive oxygen species (ROS). ROS may cause damage to DNA and biological macromolecules to induce cell injury. Moreover, ROS could alter protein structure or function. Consequently, the antioxidant defenses are potentially sensitive biomarkers to assess the pesticides exposure (Lushchak, 2011). Oxidative damage produces from an imbalance between oxidants and antioxidant levels, which increases ROS generation. ROS react with biomolecules, such as lipids and proteins, affecting cell viability (Menezes *et al.*, 2012; Yonar, 2018).

Avermectins are naturally fermented products (macrocyclic lactone) of fungus microorganism *Streptomyces avermitilis* (Campbell, 1989) with nematicidal, acaricidal and insecticidal activity (Ali *et al.*, 1997; Casali-Pereira *et al.*, 2015). They include abamectin, ivermectin and doramectin, which are highly effective against a wide range of agricultural pests, making them one of the most extensively used parasiticide groups, internal and external parasites, (Chapman *et al.*, 1994; Wislocki *et al.*, 1989; Novelli, *et al.*, 2012). Avermectins have also been reported to be effective mosquito control agents and veterinary drugs (Tišler and Erzˇen, 2006; Pridgeon *et al.*, 2009). Abamectin (ABM) is a combination of two molecules, avermectin B1a and B1b, with the purity of avermectin B1a being around 80%. (Campbell, 1989; EFSA, 2020) and is used to control pests in livestock, agriculture, and forestry on controlling lepidoptera, diptera, homoptera pests and mites with the characteristics of high efficiency, low toxicity, no pollution, lasting drug efficacy (Zhang, 2014; Kushwaha *et al.*, 2020). Spray applications as insecticides and acaricides against dipteran leaf miners and mites in permanent greenhouses and walk-in tunnels were evaluated as representative uses (EFSA, 2020).

Many pesticide product formulations (PPFs) might be based on a single active ingredient (a. i.), which can vary in composition depending on brands produced in different countries. PPFs are often made up of a cocktail of one or more active chemicals, as well as "inerts," "adjuvants," and "co-formulants." These compounds are added to the active component to improve its effectiveness, as well as its solubility, stability, absorption, and other desirable pesticide features (Nagy, *et al.*, 2020; Stevanovic *et al.*, 2021). Abamectin comes in a variety of commercial formulations, including Emulsifiable Concentrate (EC), Micro-emulsion (ME), Emulsion, Oil in Water (EW), Suspension Concentrate (SC = Flowable Concentrate), and Capsule Suspension (CS), and is used by a wide range of farmers and ranchers. This can pose a threat to food safety and animal health (Vajargah *et al.*, 2018; APC, 2021). Abamectin is prevalent in ecosystems, and its hazard effects are dependent on degradation processes and the amount of ABM released into ecosystems. In addition to these factors, commercial pesticide formulations may be more hazardous than their technical component (a.i). However, depending on components of these formulations, the additives to the active ingredient (a.i) can dramatically increase the toxicity of the end-use products to non-target species, (Erzen, *et al.*, 2005; Ying, 2006; Vajargah and Hedayati, 2014) mammals and the environment (Stevanovic *et al.*, 2021).

To address the issue of toxicity of two different commercial formulations of abamectin (ABM): Profery® EC (Emulsifiable Concentrate) as an older type of formulation (conventional formulation), and Spider gold® ME (Microemulsion) as a newer type of formulation (new generation) were selected in the present study. Both formulations contain abamectin as an active ingredient (5%) and are currently in use. The objective of this study is to compare the median lethal concentration after 96 hours (LC_{50} – 96 h) of the two abamectin (ABM) formulations. Moreover, to investigate the negative effects of sublethal concentrations (½ LC_{50}) of the two formulations on

oxidative stress biomarkers after 96 hours of exposure. The hepatic and renal toxicity was also detected in this study to clarify the relevance between oxidative stress and tissue injury.

MATERIALS AND METHODS

Pesticide Used:

Abamectin (ABM) as two formulations: 5% EC (Profery) and 5% ME (Spider gold) were supplied by the central agricultural pesticide laboratory (CAPL), Agricultural Research Center, Dokki, Giza, Egypt.

Experimental Fish and Treatments:

Seventy-eight fish of Nile tilapia (*Oreochromis niloticus*) were obtained from a private fish farm in Kafr El-Sheikh Governorate, Egypt. The initial body weight of the fish was 80 ± 10 g on average. Before the test, all the fish were acclimated for two weeks in an aquarium. Fish were fed commercial feed at a rate of 3% of body weight twice a day. Each aquarium had an aeration system, and the water physicochemical conditions were consistent across the board. According to APHA, (2015) the water utilized in these tests had the following physicochemical properties: (24 ± 2) °C, 7 to 9 mg/l dissolved oxygen, 7.5 to 8 pH, and 210 mg/l total hardness. The fish were divided into two groups after acclimation. The 1st group for determination of LC_{50} values, and the 2nd group for acute toxicity after exposure short term (96h).

LC_{50} Study:

Determination of LC_{50} – 96 h was performed according to OECD (2019), and we employed 48 fish in four concentrations in both abamectin formulations (5% EC and ME). At times 0, 24, 48, 72, and 96 hours, dead fish were removed from the water and mortality rates were recorded. The LC_{50} – 96 h and its confidence level (95%) were estimated and achieved within 96 hours by Weil (1952).

Acute Toxicity Study (Short Term):

According to toxicity test guidelines (OECD, 2019), thirty fish were used to investigate acute toxicity (short term). After 96 hours of aqueous exposure, fish were taken out for blood separation and dissection with abamectin 1/2 LC_{50} (5 µg/L of EC and 8.3 µg/L of ME). Blood samples were obtained from the caudal vein at the end of the exposure period and placed in non-heparinized clean dry centrifuge tubes, which were allowed to clot at room temperature for around 20 minutes before centrifuging at 3600 rpm for 15 minutes at 4 ºC. For biochemical analysis, the serum was carefully separated, collected, and refrigerated at -80 °C. The liver and brain of the fish were removed, washed in normal saline, dried, and stored at -40 °C for analyses of antioxidant enzyme activity and oxidative damage biomarkers.

Serum Biochemical Analysis:

Clinico-biomarkers of liver and kidney function were extracted from blood serum. Commercial diagnostic kits were used to determine these biomarkers. The activity of transaminases [alanine aminotransferase (ALT) and aspartate aminotransferase (AST)], and alkaline phosphatase (ALP) were measured according to Reitman and Frankel (1957), Roy (1970). Total protein (TP) and albumin (Alb) concentrations were assayed according to Bradford (1976) and Doumas *et al.* (1971). In addition, the ALT / AST ratio was calculated using Nyblom *et al.* (2006) and the Kaneko *et al.* (2008) formula was used to estimate globulin concentration (Glb) and the Alb/Glb ratio (A/G ratio). The urea level was determined by Fawcett and Scott (1960) method, whereas the creatinine (Cre) level was estimated using Siest *et al.*, kinetics' approach (1985).

Oxidative Stress and Antioxidants Analysis in the Liver and Brain:

Individually perfused in ice-cold saline, the liver and brain tissues were homogenized in ice-cold 50mM sodium phosphate buffer (pH: 7) containing 0.1 mM ethylenediaminetetraacetic acid (EDTA) yielding 10% (W/V) homogenate. The homogenates were centrifuged at 12.000 g for 30 min at 4 ºC., and the supernatants were aliquoted and kept at -40 ºC for oxidative stress and antioxidant enzyme assays.

Using the method of Bradford (1976**)** was quantified the total protein level (TP) of tissues homogenate. The concentration of thiobarbituric acid reactive products (malondialdehyde, MDA) was used to estimate lipid peroxidation (Ohkawa *et al.*, 1979). Superoxide dismutase (SOD), Catalase (CAT) and glutathione - s - transferees (GST) activity was measured by the methods of Marklund and Marklund (1994); Aebi *et al.* (1984) and Habig, *et al.* (1973) respectively. Total glutathione (GSH) content and glutathione peroxidase activity were examined by Beutler *et al.* (1963).

Ethical Statement: All the experimental procedures were carried out according to the principles and guidelines of the Ethics Committee of Zagazig University, Zagazig, Sharkia, Egypt. This study was approved by the Institutional Animal Care and Use Committee of Zagazig University under No. (ZU-IACUC/2/F/47/2021).

Statistical Analysis:

The mean ± standard error (M ± SE, n = 5) is used to represent the data received from the biochemical study of various groups. The significance of the difference from the control and between the groups was calculated using one-way analysis of variance (ANOVA) and the Least Significant Differences (LSD) test in IBM's Statistical Package for Social Science (SPSS) for Windows (version 25, Chicago, USA). P values of 0.05, 0.01, and 0.001 were considered significant (*), high significant (**), and very high significant (***), respectively, when compared to the control.

RESULTS

The effects of two different abamectin formulation types on Nile Tilapia fish (*Oreochromis niloticus*) are investigated in this study. A protocol for selecting appropriate biomarkers to assess fish health is presented.

LC_{50} Evaluation:

Table (1) shows the results of determining the median lethal concentration after (LC_{50} - 96 h) of abamectin on fish (*Oreochromis niloticus*) and its confidence level (95%). The mortality of fish was checked during the exposure times at 24, 48, 72 and 96 h. The current results showed that the LC_{50} - 96 h of pesticide abamectin (5% EC and ME) was 10 µg/L and 16.6 µg/L, respectively, based on the LC_{50} values of the investigated formulation types. The confidence limits (95%) were 13.759 – 7.275 µg/L for EC and 20.38 – 13.52 µg/L for ME formulation.

Acute Toxicity Evaluations:

Serum liver and kidney function, as well as oxidative stress and antioxidants in liver and brain tissues, were used to determine acute toxicity.

Liver and Kidney Functions:

The activity of several enzymes (ALT, AST, and ALP), as well as the levels of serum total protein (TP), albumin (Alb), and globulin (Glb) as hepatotoxic indicators, are represented in Table (2). Our results reported that serum total protein and globulin (Glb) levels were enhanced with ABM (5% EC) as well as the Alb/Glb ratio with ABM (5% ME). Furthermore, when compared to the control group, substantial increases in serum albumin (Alb) and ALT/AST ratio were identified, as well as a significant decrease in

aspartate aminotransferase (AST) in each ABM formulation (5% EC and ME). Also exposing tilapia fish (*Oreochromis niloticus*) to ABM (5% EC) resulted in considerable suppression of ALT activity but no significant alterations in alkaline phosphatase (ALP) activity was noticed at both exposures.

The results for the renal function parameters (Table 2) revealed a highly significant change in urea levels ($p \leq 0.001$), but a reduction in creatinine (Cre) in ABM (5% EC) when compared to the unexposed group.

Table 1: Values of Acute LC_{50} -96 h of Abamectin (5% EC and ME) and its confidence limits (95%) on Nile tilapia, *(Oreochromis niloticus).*

Pesticide		Conc. (µg/l)	No. Dead	LC_{50} value (µg/l)	Confidence Limits (95 %)	
					Upper	Lower
Abamectin (5%)	EC	6.670	1 / 6	*10.005*	*13.759*	*7.275*
		10.006	4 / 6			
		15.007	4 / 6			
		22.511	6 / 6			
	ME	10.00	2 / 6	*16.6*	*20.38*	*13.52*
		15.00	2 / 6			
		22.50	4 / 6			
		33.75	6 / 6			

EC = emulsifiable concentration, ME = microemulsion.

Table 2: Effect two formulation (5% EC and ME) of abamectin (AMB) on serum liver and kidney functions of Nile Tilapia (*Oreochromis niloticus*) after acute exposure (96 h).

Treatments / Parameters	Control	ABM (5%)	
		EC	ME
Liver Functions			
ALT (U / l)	5.296 ± 0.1124	5.561 ± 0.0612	4.443 ± 0.0798***
AST (U / l)	45.80 ± 1.832	24.40 ± 0.7860***	34.08 ± 1.014***
ALT / AST	0.1164 ± 0.00572	0.4849 ± 0.01067***	0.2288 ± 0.00732***
ALP (U / l)	16.53 ± 0.3981	17.43 ± 0.6022	17.28 ± 0.3709
TP (g / dl)	4.082 ± 0.0380	4.9255 ± 0.0432***	4.253 ± 0.1352
Alb (g / dl)	0.9584 ± 0.0267	1.185 ± 0.0383**	1.360 ± 0.0505***
Glb (g / dl)	3.124 ± 0.0602	3.740 ± 0.0544***	2.893 ± 0.1037
A / G	0.3079 ± 0.0149	0.3175 ± 0.0137	0.4713 ± 0.0182***
Kidney Functions			
Urea (mg / dl)	5.694 ± 0.1473	9.996 ± 0.2726***	5.940 ± 0.1069
Creatinine (mg / dl)	1.655 ± 0.0392	1.379 ± 0.0121***	1.739 ± 0.0555

n = 5, Data are presented as (M ± SE), EC = emulsifiable concentration, ME = microemulsion, ** and * significant at P ≤ 0.01 and 0.001 respectively.**

Oxidative Stress and Antioxidants of the Liver and Brain:

As demonstrated in Figure (1), all exposed fish to ABM (5% EC and ME) had significantly higher lipid peroxidation (MDA) levels in their liver and brain tissues after the short term of exposure ($p \leq 0.001$) as compared to the unexposed group.

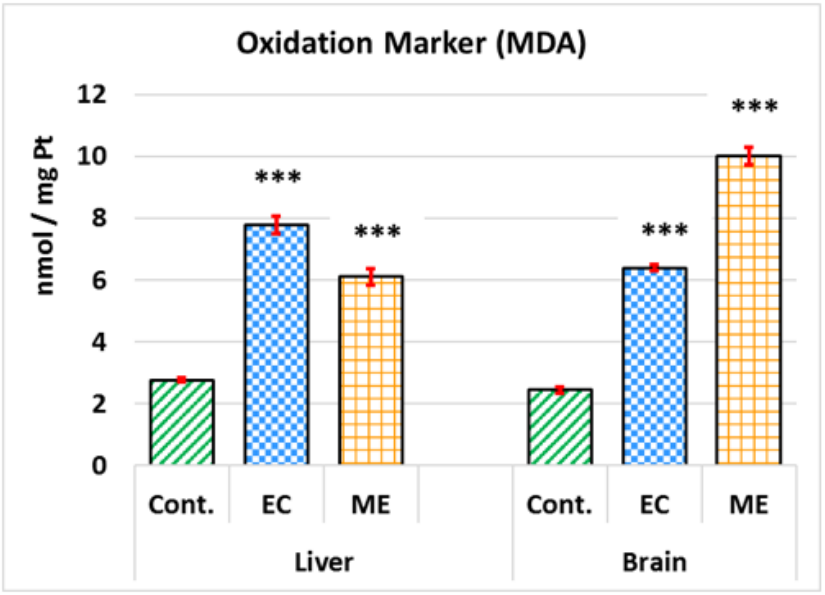

Fig. 1: Effect two formulation (5% EC and ME) of abamectin on an oxidation marker, MDA (nmol/mg Pt), in brain and liver of Nile Tilapia (*Oreochromis niloticus*) after acute exposure (96 h).

n = 5, Data are presented as (M ± SE), EC = emulsifiable concentration, ME = microemulsion, Pt = protein in the tissue, * significant at P ≤ 0.001.**

After the experimental period (96 h), both ABM (5% EC and ME) treatments considerably increased (***) superoxide dismutase (SOD) and GPx in liver and brain homogenate (Fig. 2), and similar elevation was also detected in liver catalase (CAT) by ABM (5% EC) when compared to the untreated group. On the other hand, the activity of liver and brain Glutathione-s-transferases (GST) was reduced with the two formulations (EC and ME). GSH levels were also measured in the liver and brain and when compared to the control group, two treatment groups had lower GSH levels in the liver, and the ME group had lower GSH levels in the brain (Fig. 2). Fourth, protein levels in the liver and brain of fish (*Oreochromis niloticus*) subjected to each ABM formulation were significantly reduced ($p \leq 0.001$).

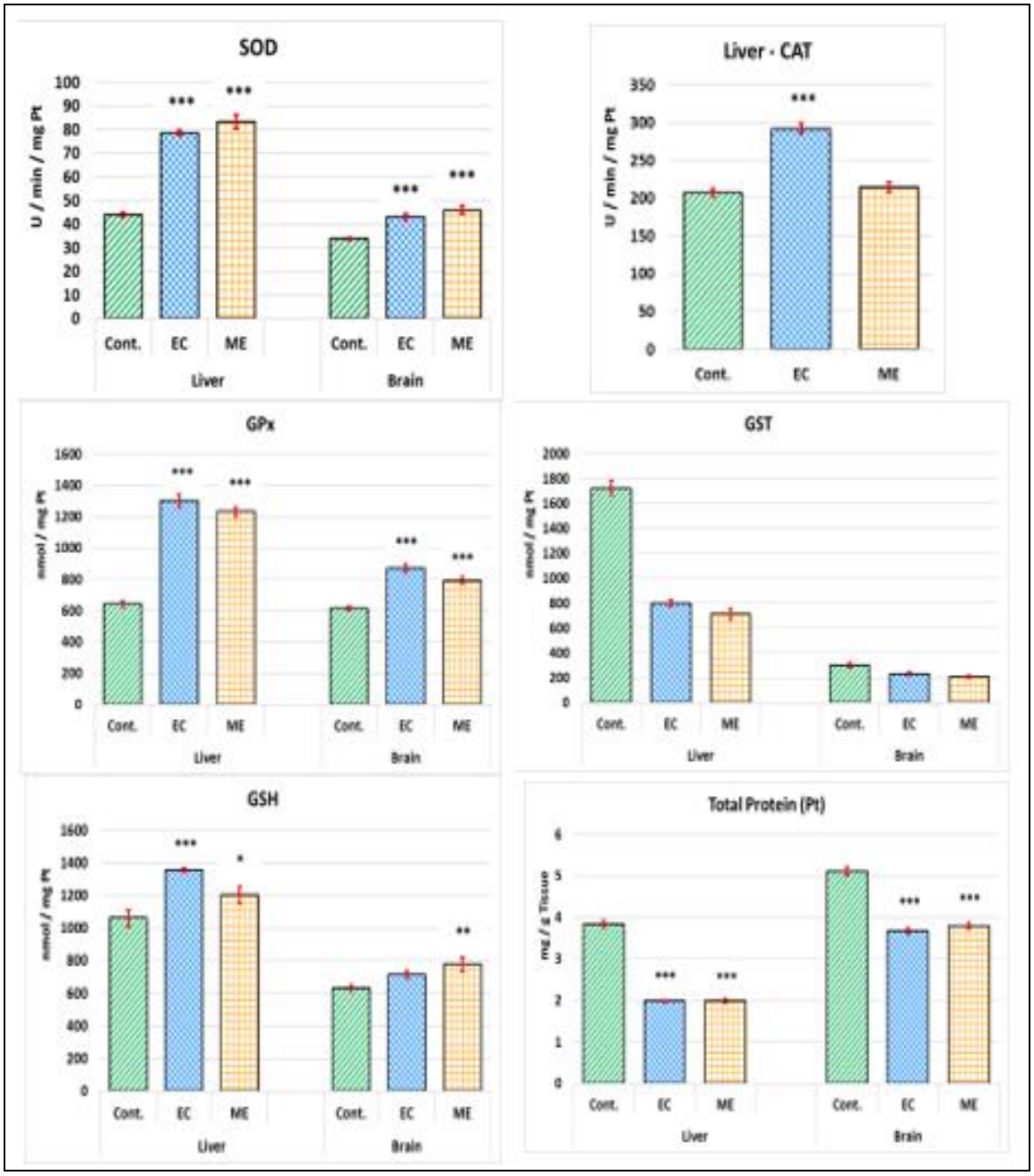

Fig. 2: Effect two formulation (5% EC and ME) of abamectin (ABM) on antioxidants and total protein in liver and brain of Nile Tilapia (*Oreochromis niloticus*) after acute exposure (96 h).

n = 5, Data are presented as (M ± SE), EC = emulsifiable concentration, ME = microemulsion, Pt = protein in the tissue, *, ** and * significant at P ≤ 0.05, 0.001 and 0.001 respectively.**

DISCUSSION

The findings of the LC_{50} – 96 h values showed that abamectin (5% EC) was more hazardous than abamectin (5% ME). According to these results, abamectin was classified as very high toxicity by the EPA's Office of Pesticide Programs (OPP) for fish (*Oreochromis niloticus*) and very toxic (Category 1) by the GHS (The Globally Harmonized System of Classification and Labelling of Chemicals).

Numerous studies on the toxicity of abamectin in aquatic organisms have been conducted; for example, Hedayati *et al.* (2014) reported that the LC_{50} (96 h) of abamectin for common carp, *Cyprinus carpio*, was 1.243 mg/L; and Novelli *et al.* (2012) discovered that abamectin was highly toxic on aquatic organisms, with an EC_{50} (48 h) for *Daphnia similis* (a zooplankton) of 5.1 ng/L, LC_{50} (96) h for *Chironomus xanthus* (an insect) of 2.67 µg/L and LC_{50} (48 h) for *Danio rerio* (fish) of 33 µg/L.

Abamectin is extremely poisonous to aquatic invertebrates and highly toxic to fish. (EPA, 1990). The increase in chloride ions after abamectin exposure hyperpolarizes neurons and muscle cells, eventually interfering with neuromuscular transmission and resulting in death (Novelli *et al.,* 2016). Emulsifiable concentration (EC) formulations typically contain active ingredients dissolved in an organic solvent with surfactants added to promote good emulsification after water dilution. Surfactants allow the active ingredient in microemulsions (ME) formulations to stay suspended in water, ensuring product stability and simple suspension formation after dilution with water. Microemulsions with a high surfactant content and solubilization of the active component may have increased biological activity. Both formulations have a similar level of efficiency on target species, but one key distinction is that the active ingredient in the ME formulation is released gradually, whereas the active ingredient in the EC formulation is immediately available (Knowles, 2008).

The current findings revealed that when fish were given ABM, their AST and ALT activities were significantly reduced as compared to control fish. Because of enzymatic inhibition, a reduction in the permeability of the hepatic cell membrane caused by the toxicant, causing the enzymes to accumulate in the cells, or liver injury without regeneration, a decrease in the activity of these enzymes in serum is a sensitive signal (Stoyanova, *et al.,* 2020). Because the liver produces most serum proteins, a change in total protein level indicates a problem with liver function. In ABM (EC) fish group, there was a considerable increase in serum total protein, albumin, and globulin levels. Total serum protein is made up of albumin and globulins, and it is utilized as a biomarker of liver impairment and may indicate systemic and progressive liver damage (Firat *et al.* 2011). The increased blood total protein and globulin concentrations in the exposed groups could also be related to liver dysfunction and protein biosynthesis disruption (Abdel-Tawab *et al.*, 2011).

As seen in this investigation, an increase in urea in ABM-based pesticide-treated fish showed impairment of kidney function. The concentration of urea in the blood is primarily determined by glomerular function; the observed increase in serum urea could be due to glomerular malfunction (Amin and Hashem, 2012). As shown in fish subjected to ABM (5% EC), low creatinine levels indicate that the nephrons' structural integrity has been substantially impaired (Hany *et al.*, 2019).

When analyzing the biological consequences in damaged environments, it is well understood that the use of a diverse set of biomarkers is critical, as a single biomarker may not accurately reflect an organism's health status. Some investigators believe that using a battery of biomarkers to avoid false-negative results produced with a single biomarker is a good idea (Beliaeff and Burgeot, 2002; Linde-Arias *et al.*, 2008). In general, there are two types of biomarkers for oxidative stress: free radical biomarkers in biological systems and antioxidant protection factors (Di Giulio, and Meyer, 2008). Biological systems have measures in place to protect the organism against free radical damage. Antioxidant enzyme defence, which neutralises free radicals, is one of the key strategies. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GRx) are some of the most significant antioxidant enzymes in biological systems (Sies, 1997). Enzymatic antioxidants are necessary for fish cells to maintain their redox

balance and act as a protective barrier against oxidative damage. Damage to biological systems or failure of the antioxidant defence system is a sign of oxidative stress in fish (Monteiro, *et al.*, 2006). Tissue antioxidant response to oxidative stress shows species differences due to differences in tissue antioxidant potential (Puerto, 2010).

MDA activity was increased in the liver and brain of fish (*Oreochromis niloticus*) exposed to both ABM formulations, according to our findings. These results agree with those obtained by Kushwaha *et al.* (2020) who discovered that ABM poisoning with 40, 45, and 55 ppb for 48 hours increased the activity of lipid peroxidation in fish (Oreochromis mossambicus). The formation of hydroxyl radicals, which cause oxidative damage to hepatocytes, is aided by increased activity of lipid peroxidase (LPO). The LPO peroxides the lipid in the plasma membrane, causing it to leak, allowing the necrotic process to proceed (Zambo *et al.*, 2013). As well as Ogueji *et al.* (2020) and Kushwaha *et al.* (2020) found a negative correlation between catalase activity and GSH levels in *Clarias gariepinus* and *Oreochromis mossambicus* after acute ABM exposure

In this respect, we found a considerable increase in SOD activity in the liver and brain of all ABM - exposed Nile tilapia (*Oreochromis niloticus*) when compared to the control group. These results are in accordance with those of Jin, *et al.* (2010) who demonstrated that atrazine exposure was linked to enhanced SOD activity, particularly in the zebrafish (*Danio rerio*) liver.

During the bioactivation of xenobiotics in the tissues, the SOD–CAT system offers the first line of defense against oxygen toxicity, and the induction of SOD and CAT systems provides the first line of protection against reactive oxygen species (ROS). The dismutation of the superoxide radical O_2 to oxygen and hydrogen peroxide is catalyzed by superoxide dismutase (H_2O_2). Because CAT is responsible for the detoxification of H_2O_2 to water, catalase activity in organ tissues could be in response to H_2O_2 created by SOD activity (Hossain and Bhattacharya, 2006). Increased SOD activity implies an increase in O_2 generation (Hossain and Bhattacharya, 2006), or it could be related to an increase in ROS production (Puerto, 2010).

The data of this investigation demonstrated that ABM-EC treatment greatly increased CAT activity in the liver of Nile tilapia (*Oreochromis niloticus*). Some studies have found a considerable increase in CAT activity after pesticide exposure in fish (Kavitha and Rao, 2007 and Stara, *et al.*, 2012). This compensatory reaction, together with the stimulation of other antioxidants (SOD and CAT), may assist stressed organisms to avoid the accumulation of free radicals and their products (Kavitha and Rao, 2007 and Stara, *et al.*,2012).

On ABM-EC- exposed fish, the activity of catalase in liver homogenate was shown to be greater. During the experiment, low levels of GSH were found in all the treated ABM groups in both exposed fish's examined organs (*Oreochromis niloticus*). GSH is involved in the removal of H_2O_2. As a result, lowering GSH levels causes an increase in H_2O_2 generation, which boosts LPO activity, confirming our findings. Our findings are consistent with those of Al Ghais *et al.* (2019), who found a drop in GSH levels in the liver tissue of *O. mossambicus* after 96 hours of ABM exposure.

As a result, a significant level of GPx was found in all fish tissues as compared to controls, although GST levels in Nile tilapia (*Oreochromis niloticus*) subjected to ABM decreased. GSH is a protective agent capable of quenching oxyradicals in addition to being a required cofactor for GPx and GST function (Ross, 1988). The increase in GPx activity could be an adaptation to protect fish from ABM-induced free radical toxicity (Ogueji *et al.*,2020).

By facilitating the conversion of hydrogen peroxide to water and oxygen, GPx protects against oxidative stress. The concentration of reduced glutathione (GSH) is also

strongly related to GPx activity. This is because it uses reduced glutathione to remove hydrogen peroxide, resulting in oxidised glutathione (GSSG) production (Ogueji, *et al.*, 2020).

Our report is comparable to those of (Ogueji *et al.* (2017), who found a tissue-specific response to diazepam in *C. gariepinus* in terms of GPx activity. GPx levels in the liver tissue increased on day 7. According to Modesto, and Martinez (2010) the considerable increase in GPx activity in the Roundup Transorb (5 mg glyphosate/l) group of fish after 24 and 96 hours of exposure indicates that the antioxidant pathway was stimulated, most likely due to enhanced peroxide generation. Although this enzyme is well known for removing organic peroxides, it also plays a role in the metabolism of hydrogen peroxide.

GST is a multifunctional dimeric enzyme that aids in the detoxification of both endogenous (intracellular metabolites) and exogenous (extracellular metabolites) pollutants. GST is part of a multigene family found in all living organisms, and the structural diversity of the GST family of isoenzymes allows it to conjugate a wide range of chemicals. Induced GST activity may indicate the enzyme's participation in xenobiotic-induced lipid peroxidation toxicity prevention (Ural *et al.*, 2013). On the other hand, the GST is a cytosolic or microsomal enzyme that catalysis the conjugation of electrophilic xenobiotics to GSH, transforming a reactive lipophilic molecule into a non-reactive water-soluble compound. As a result, the GST plays a key function in tissue protection against oxidative stress (Monteiro *et al.*, 2006; Yonar, 2012). In the current work, a decrease in GST activity could be linked to a decrease in the availability of GSH which is required to attenuate the ROS impact. Bagnyukova *et al.* (2006) discovered a reduction in hepatic GST activity in fish exposed to the herbicide for 6 and 24 hours, which supports the hypothesis of the presence of oxidants that would cause the enzymatic activity to be inactivated. (Hermes-Lima and Storey, 1993) since GST is sensitive to Haber–Weiss reaction products. In addition, Lushchak *et al.* (2009) found that after 96 hours of exposure to Roundup original, GST inhibition was demonstrated in the liver of goldfish (glyphosate-based herbicides)

According to the LC_{50} values in this study, abamectin is severely toxic to Tilapia fish (*O. niloticus*). Also, after short-term exposure, ABM (5% EC) had a great influence on fish than ABM (5% ME). These differences in toxicity of the formed products were evident in both mortality and sublethal negative effects, and they occurred at environmentally relevant levels. The EC formulation's higher toxicity may be attributable to the active component's increased mobility in the aquatic environment because of the solvent and surfactant, whereas the ME formulation's toxicity was reduced due to the controlled release of the active ingredient from it. These toxicity effects are caused by abamectin's harmful nature on oxygen consumption and biochemical elements of Tilapia fish (*O. niloticus*).

CONCLUSION

Our findings suggest that the ABM's toxicity to non-target species at low concentrations may be significantly higher in the case of commercial compound use in aquaculture. The changing of biomarker aspects, which represent changes in the normal activities of numerous functional systems, resulted from the pesticide abamectin and its metabolites that will naturally influence the nutritional value of Tilapia fish (*O. niloticus*). Therefore, changes in the biochemical makeup of aquatic species exposed to pollutants must be monitored. So, the current study highlights the need of evaluating the dangers that ABM-formulated items pose to the environment and non-target animals, as well as the importance of optimal formulation selection for environmental preservation.

Finally, we recommend that more research be done on various aquatic animal

species following long-term exposure. As well as one approach for reducing the environmental impact of ABM (EC and ME) is to make the EC solvent greener, while another is to generate water-based emulsions such as Micro-Emulsion (ME).

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ARABIC SUMMARY

دراسة التعرض الحاد المقارن لمستحضرات مختلفة من الأبامكتين التى تحفز المؤشرات الحيوية للإجهاد الفسيولوجي والتأكسدي فى البلطي النيلي (*Oreochromis niloticus*)

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الهدف من هذه الدراسة هو تقييم المخاطر المحتملة الحادة وشبه المميتة على أسماك البلطي (*Oreochromis niloticus*) المعرضة لصورتين تجاريتين مختلفتين من مبيد الأبامكتين (ABM) : 5٪ مركز قابل للاستحلاب (EC) ومستحلب دقيق (ME) تم تحديد التركيز المميت ل 50% من الأسماك بعد 96 (LC_{50}-96) ساعة لكل صورة، بالإضافة إلى دراسة الآثار الضارة للتركيزات شبه المميتة على المؤشرات الفسيولوجية وعلى الإجهاد والتأكسد بعد 96 ساعة من التعرض. كانت قيم LC_{50} (96 ساعة) لكل من EC و ME 10 و 16.6 ميكروجرام/لتر على التوالي. علاوة على ذلك، في كل من الصورتين EC و ME ، كشفت نتائج جوانب الإجهاد الفسيولوجي والتأكسدي عن زيادات ملحوظة في البروتين الكلي في الدم، والألبومين، والجلوبيولين، واليوريا، بالإضافة إلى إنخفاض كبير في نشاط إنزيمى (ALT; AST) ومستويات الكرياتينين. علاوة على ذلك، تمت زيادة بشكل واضح فى نشاط انزيمات (SOD)، (MDA)، (CAT)،(GPx) ، في حين إنخفض نشاط انزيم (GST) ومستوى الجلوتاثيون (GSH) بشكل كبير في كلا من الكبد والدماغ .