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Biology-Ecology

Redox signaling and inflammatory statuses of farmers exposed to agrochemicals

Perfil redox e inflamatório de agricultores expostos a agrotóxicos

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ABSTRACT

Physiological changes take place in the human body upon exposure to pesticides. These changes may be followed by oxidative stress, which is caused by imbalance between the antioxidant defense system and reactive oxygen species (ROS) generation. Pesticides can cause inflammatory changes, which alter the structure of some cytokines essential for the functioning of the human body. Therefore, the aim of the present study is to assess the oxidative and inflammatory status of farmers exposed to pesticides. Blood samples from 50 exposed farmers and 50 non-exposed individuals (Control Group - CG) were collected. Oxidative stress and inflammatory marker levels were assessed. Na increase in TBARS ($p<0.0001$), IL-6 ($p=0.03700$), IL-8 ($p=0.0011$) and IL-10 ($p=0.0011$) levels was found, a decrease in enzymatic activity: SOD ($p<0.001$), CAT ($p=0.0251$), GPx ($p<0.001$), GST ($p<0.001$), GR ($p<0.0001$) in the evaluted farmers in relation to the CG data. Farmers demonstrated high oxidative damage. Low levels of antioxidants and inflammatory changes.

Keywords: Farmers; Intoxication; Oxidative stress

RESUMO

Durante a exposição a agrotóxicos ocorrem alterações fisiológicas no organismo humano, como o estresse oxidativo, caracterizado por um desequilíbrio entre o sistema de defesa antioxidante e a geração de espécies reativas de oxigênio (EROs). Os pesticidas podem ocasionar alterações inflamatórias, em algumas citocinas, que são essenciais para o funcionamento do nosso organismo. Neste contexto, o objetivo desse estudo foi avaliar o perfil oxidativo e inflamatório de agricultores expostos a agrotóxicos. Foram utilizadas amostras de sangue de 50 agricultores e 50 indivíduos não expostos a agrotóxicos

(Grupo Controle – GC). Foram mensurados no plasma dos participantes marcadores de dano oxidativo e marcadores inflamatórios. Foi encontrada uma elevação nos níveis de TBARS ($p<0,0001$), IL-6 ($p=0,03700$), IL-8 ($p=0,0011$) e IL-10 ($p=0,0011$), diminuição da atividade das enzimas: SOD ($p<0,001$), CAT ($p=0,0251$), GPx ($p<0,001$), GST ($p<0,001$), GR ($p<0,0001$), GSH ($p<0,0001$) e BChE ($p<0,0001$) nos agricultores avaliados em relação aos dados do GC. Os agricultores demonstraram um elevado dano oxidativo, baixos níveis de antioxidantes e alterações inflamatórias.

Palavras-chave: Produtores agrícolas; Intoxicação; Estresse oxidativo

1 INTRODUCTION

Pesticide use has been growing globally, as it has become essential for crop management and pest control. Rio Grande do Sul is among the four states where pesticide use is most widespread in Brazil (DE MORAES, 2019). Rural workers are directly exposed to pesticides, as these substances have several chemical properties with different biological functions and actions; therefore, they can be highly toxic to human health (JACOBSEN-PEREIRA *et al*., 2018). Thus, appropriate use of Personal Protective Equipment (PPE) by rural workers is essential to protect their health (RISTOW *et al*., 2020).

The human body undergoes significant physiological changes upon exposure to pesticides. Oxidative stress may result from it, given the imbalance between the antioxidant defense system and Reactive Oxygen Species (ROS) production (YARIBEYGI *et al*., 2018). Absorption of toxic substances by the biological system triggers ROS production. When these substances are not eliminated by the antioxidant defense system, the following issues may arise: Enzyme inactivation, excessive consumption of endogenous antioxidants (ANTONIJEVIC *et al*., 2018; CLASEN *et al*., 2018), cell damage such as oxidation of cellular molecules through Lipid Peroxidation (LPO) (AKBEL *et al*., 2018) protein carbonylation and excessive activation of pro-inflammatory genes. As a result, rural workers exposed to pesticides develop serious diseases (SILVERIO; PINHEIRO, 2020).

Cell damage suffered by farmers can be assessed through the study of oxidative stress and inflammatory markers, which helps understanding biological changes caused by exposure to agrochemicals (FARKHONDEH *et al*., 2020).

Since rural workers exposed to pesticides are more likely to suffer from physiological changes, high levels of oxidative biomarkers and changes in inflammatory markers, the aim of present study was to assess redox signaling and inflammatory status of farmers exposed to pesticides due to labor activities.

2 METHODS

2.1 Ethical considerations

The present study is subproject of research projects known as “Occupational monitoring of rural workers exposed to agrochemicals based on biomarker using” approved by the Research Ethics Committee of *Cruz Alta* University (UNICRUZ) under Substantiated Opinion n. 0071.0.417.000-11. This is an analytical cross-sectional study on the biological material of rural workers exposed to pesticides due to labor activities. All participants signed the informed consent form.

2.2 Population and Sample

Farmers who participated in the study were chosen at random, but they met the inclusion criterion: having been exposed to pesticides at any degree. Collections were carried out in Alto Jacuí region, Rio Grande do Sul State, which is known for the presence of large rural properties. Fifty farmers exposed to pesticides expressed their wish to participate in the study. Samples were randomly collected from 50 individuals non-exposed to pesticides due to labor activities (control group); this number was equivalent to that of exposed farmers. The study included participants in the age group 18 to 60 years. Individuals with the following chronic diseases were excluded from the research: Asthma, high blood pressure, diabetes mellitus, among others. Therefore, the study encompassed 100 participants, in total.

All study participants (farmers and controls) answered a questionnaire composed of a structured set of questions regarding age, sex, farming duration, time since last exposure to pesticides, PPE using and most used pesticides.

2.3 Blood collection and sample preparation

Blood collection was carried out at participants' homes. First, blood was collected into vacuum tubes pre-filled with ethylenediaminetetraacetic acid (EDTA) for plasma analysis. Next, blood samples were centrifuged at 3000 rpm for 10 minutes. The samples were stored in freezer at -20ºC for further laboratory analyses.

2.4 Laboratory analyses

All the collected plasma was analyzed in triplicate. Glutathione S-transferase (GST) enzyme activity was determined through the method described by Habig, Pabst and Jakoby (1974). Results were expressed in μmol GS-DNB/min/mg protein. CAT enzyme activity was determined based on the method described by Nelson (1972) and results were expressed in nmol/mg ptn/min. The activity of enzymes Glutathione Reductase (GR), Glutathione Peroxidase (GPx) and Superoxide Dismutase (SOD) was determined with the aid of VIDA biotecnologia® (commercial kit brand) in colorimetric microplate readers - results were expressed in pg/mL. Reduced Glutathione (GSH) levels were determined through the method described by Ellman (1959) - results were expressed in μmol GSH/mL.

Thiobarbituric Acid Reactive Substance (TBARS) levels were determined according to the protocol by Jentzsch *et al*., (1996). Results were expressed in ηmol/mL (MDA). Total protein (ptn) was measured with the aid of Labtest® (commercial kit) and Protein Carbonylation (PC) levels were measured according to the method described by Levine (1990). Results were expressed in ηmol/mg ptn .

Butyrylcholinesterase (BChE) enzyme activity was measured with the aid of Labtest® (commercial kit) and results were expressed in UI/mL. Interleukin (IL-6, IL-8, IL-10) levels and the Tumor Necrosis Factor (TNF-α) were determined through microplate-based screening with the aid of VIDA biotecnologia® (commercial kit brand) - results were expressed in pg/mL.

2.5 Statistical analyses

Results were expressed in mean ± standard deviation. Data normality was assessed through Kolmogorov-Smirnov and Shapiro-Wilk tests. The assessed groups were compared through nonparametric student's t-test. Differences between groups were considered statistically significant when $p<0.05$.

3 RESULTS AND DISCUSSION

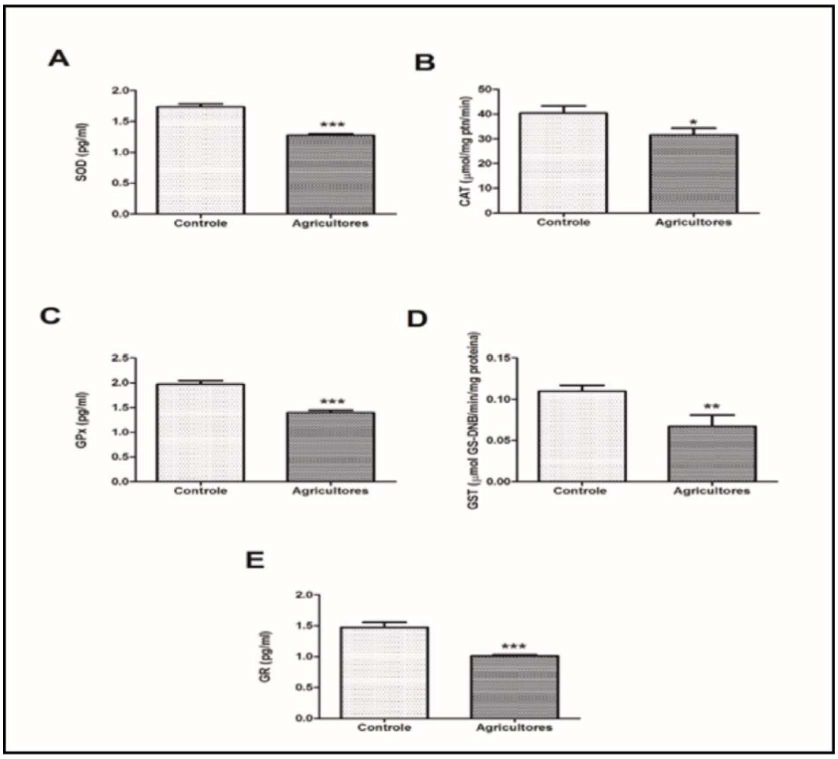
Fifty farmers exposed to agrochemicals for more than 8 years (exposed group) and 50 healthy individuals - not exposed to pesticides - (control group) participated in the study. Farmers' mean age was 52 years and 92.62% of them were men, whereas control participants were mean age of 32 years and 62.15% of them were men. The questionnaire assigned to the participants has shown that the mean time of agrochemical exposure was 29 years and the last exposure happened at least 90 days before the assessment.

Results recorded for the PPE using assessment evidenced that 46.06% of farmers have used it, 11.09% have used it occasionally and 42.85% did not use any type of PPE. The most widespread pesticides belonged to the following categories: organophosphates, carbamates, pyrethroids, organochlorides, fungicides and herbicides. Exposed farmers had lower enzyme activities than the control group (Fig. 1): SOD (A) ($p<0.001$), CAT (B) ($p=0.0251$), GPx (C) ($p<0.001$), GST (D) ($p<0.001$) and GR (E) ($p<0.0001$). Moreover, farmers' GSH levels were lower than those of individuals non-exposed to agrochemicals ($p<0.0001$) (Fig. 2).

Farmers reported increased TBARS biomarker levels (p<0.001) (Fig. 3). However, PC levels (p=0.3505) were not significantly different between the assessed groups (data not shown). The exposed group reported BChE enzyme activity (p<0.0001) lower than that of the control group (Fig. 4).

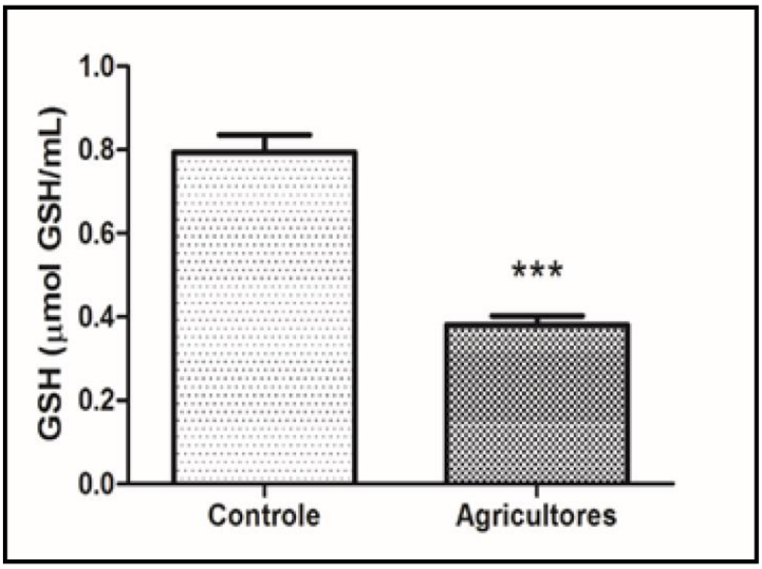
Furthermore, according to figure 5, the exposed group reported increased IL-6 (A) (p=0.03700), IL-8 (B) (p=0.0011) and IL-10 (C) (p=0.0011) levels. There was no significant difference in TNF-α levels among farmers (p=0.4620) (data not shown).

Figure 1 – Antioxidant enzyme levels in the plasma of farmers occupationally exposed to pesticides



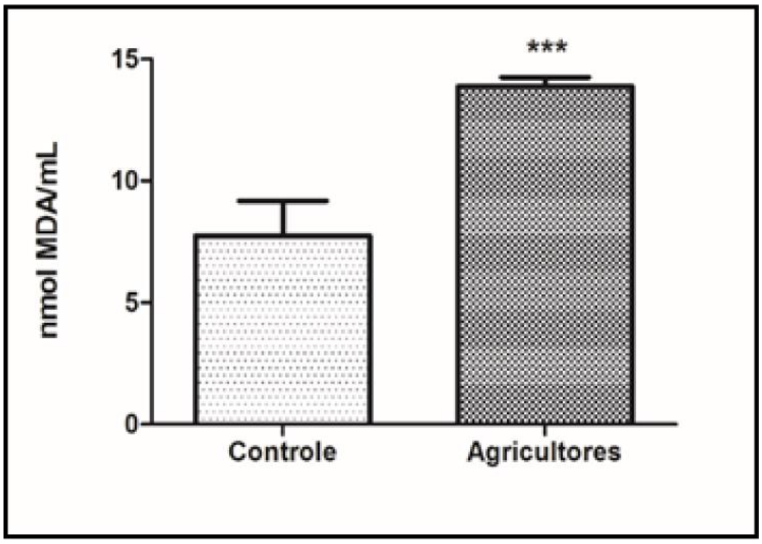
(A) Superoxide Dismutase (SOD); (B) Catalase (CAT); (C) Glutathione Peroxidase (GPx); (D) Glutathione-S-Transferase (GST); (E) Glutathione Reductase (GR)
*Statistically significant results ($p < 0.05$) according to student's *t*-test. Data is expressed as mean ± standard deviation

Figure 2 – Reduced Glutathione (GSH) Levels in the plasma of farmers exposed to pesticides due to labor activities



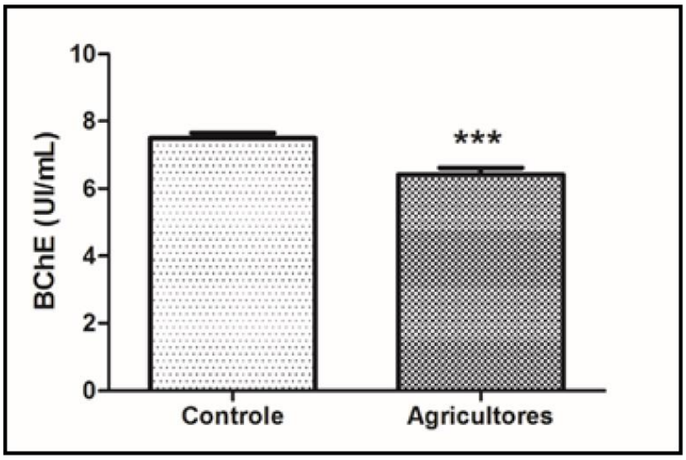
*Statistically significant results (p < 0.05) according to student's t-test. Data is expressed as mean ± standard deviation

Figure 3 – Thiobarbituric acid reactive substance (TBARS) levels in the plasma of farmers exposed to pesticides due to labor activities



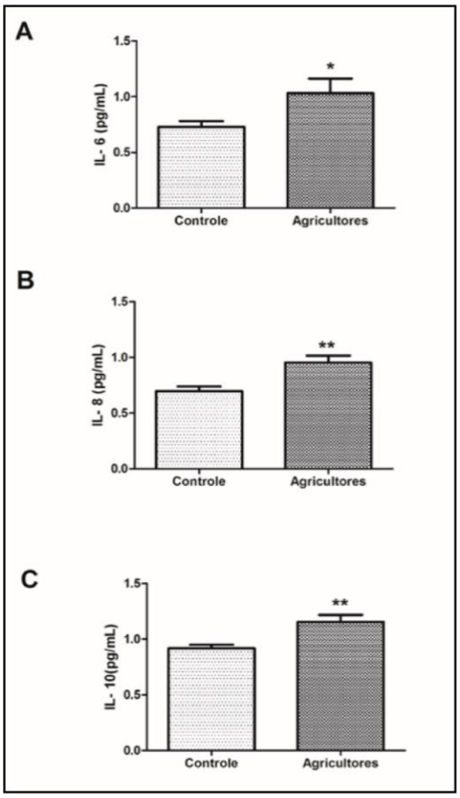
*Statistically significant results (p < 0.05) according to student's t-test. Data is expressed as mean ± standard deviation

Figure 4 – Butyrylcholinesterase (BChE) levels in the plasma of farmers exposed to pesticides due to labor activities



*Statistically significant results ($p < 0.05$) according to student's t-test. Data is expressed as mean ± standard deviation

Figure 5 – Inflammatory changes in the plasma of farmers exposed to pesticides due to labor activities



(A) Human Interleukin 6 (IL-6); (B) Human Interleukin 8 (IL-8) and (C) Human Interleukin 10 (IL-10)
*Statistically significant results ($p < 0.05$) according to student's t-test. Data is expressed as mean ± standard deviation

Results indicated low PPE using among farmers, which further exposes them to pesticide poisoning; however, farmers claim that the tropical climate makes PPE using very uncomfortable (NETO; ANDRADE; FELDEN, 2018; SHIMOKOMAKI; COSTA, 2018).

Pesticide exposure triggers inflammatory processes that lead to cell proliferation, ROS production and inflammatory cytokine release (SILVERIO; PINHEIRO, 2019). Imbalance between increased ROS levels and antioxidant defenses features oxidative stress (JACOBSEN-PEREIRA et al., 2018; KIM; KABIR; JAHAN, 2017).

Antioxidants work together through different mechanisms, such as elimination or recovery of damaged biological structures through ROS inactivation (AKBEL et al., 2018). Decreased antioxidant enzyme (SOD, CAT, GPx, GST, GR) activity and GSH levels indicated that enzymatic inhibition was most likely caused by chronic exposure to pesticides due to inappropriate PPE using (KLENIEWSKA; PAWLICZAK , 2017; RISTOW et al., 2020).

Weakening of the antioxidant system is confirmed when farmers present increased LPO levels, which indicate increased ROS production. These species can attack polyunsaturated fatty acids (PUFA) by altering the permeability, fluidity and integrity of membranes and forming lipid peroxidation products such as MDA, which is highly harmful to the body because it hinders recovery and induces programmed cell death (apoptosis) (HU; WANG; HAN, 2017; LATUNDE-DADA, 2017).

Cholinesterases are specific molecular targets of pesticides; therefore, their activation is a human biomarker for poisoning by these chemicals. Organophosphates and carbamates are specific cholinesterase inhibitors (ANTONIJEVIC et al., 2018; SUAREZ-LOPEZ, 2018). Results have shown decreased butyrylcholinesterase enzyme activity in rural workers, which indicates pesticide poisoning assumingly caused by farmers lack of understanding about the importance of using PPEs (DE MELO; DA CUNHA, 2017; KLEMZ; DE ASSIS, 2017).

The close association between oxidative stress and inflammatory response may explain the results recorded for the herein described inflammatory status. Evidence shows that inflammation can be activated by substance release in tissues or by environmental agents such as ultraviolet radiation and xenobiotics, i.e., pesticides (GUZIK; TOUYZ, 2017; NAGAMI; SUENAGA; NAKAZAKI, 2017).

Inflammatory processes begin when Pattern Recognition Receptors (PRR) detect the external pathogen. Some PRRs activate antimicrobial transcriptional responses, while other PRRs protect the organism by aggregating complex redox signaling molecules, known as inflammasomes. Some studies indicate that pesticides are potential agents that can trigger inflammasome formation during inflammation processes (CHEN; NUÑEZ, 2010; JANG et al., 2015; LIU et al., 2017; TAKEUCHI; AKIRA, 2010; TASSI et al., 2010).

This inflammasome is part of the inflammatory activation response; it is followed by the activation of the proinflammatory cytokine cascade (CHEN; BOLDT; RAN, 2015; KLEMZ; DE ASSIS, 2017). Accordingly, oxidative stress is defined as a crucial inflammasome activator (KIM et al., 2016). Pesticides can induce the overexpression of inflammasomes (KEPP; GALLUZZI; KROEMER, 2011; ZHOU et al., 2011), since it increased the herein assessed oxidation and interleukin (IL 6, IL 8 and IL 10) levels.

4 CONCLUSIONS

Farmers presented severe lipid peroxidation, decreased antioxidant enzymes, decreased main non-enzymatic endogenous antioxidants and inflammatory changes. These conditions, in addition to BChE enzyme inhibition, are mostly associated with occupational exposure to pesticides.

These changes trigger oxidative stress, which causes inflammatory diseases in farmers. Therefore, the present results have proven that pesticides altered both the oxidative stress and inflammatory statuses of rural workers. Briefly, these results highlighted the importance of proper and conscious use of PPEs, and of giving special attention to the health of rural workers, as they are exposed to toxic chemicals on a daily basis.

Furthermore, data in the current research entails a contemporary discussion on pesticide using and on its relationship with the environment. Intoxication is caused not only by PPE negligence, but also by PPE using in disagreement with usage guidelines and technical specifications.

Nevertheless, such data indicate that damage caused to the health of rural workers can also affect people who do not live in the countryside, since they have access to pesticide waste that reaches urban areas through waste found in food, water resources and wind drift. It also indicates the presence of pesticide in the environment, which is harmful to flora, fauna and microorganisms.

REFERENCES

AGÊNCIA NACIONAL DE VIGILÂNCIA SANITÁRIA (ANVISA). Disponível em: http://portal.anvisa.gov.br/agrotóxicos. Acesso em: 11 set. 2017.

AKBEL, E. et al. The subchronic exposure to malathion, an organophosphate pesticide, causes lipid peroxidation, oxidative stress, and tissue damage in rats: the protective role of resveratrol. *Toxicol Research*, 2018.

ANTONIJEVIC, E. et al. Effect of six oximes on acutely anticholinesterase inhibitor-induced oxidative stress in rat plasma and brain. *Arch Toxicol*, v.92, n.2, p.745-757, 2018.

CHEN, G. Y.; NUÑEZ, G. Sterile inflammation: sensing and reacting to damage. *Nat Rev Immunol*, v.10, n.12, p.826-837, 2010.

CHEN, L.; BOLDT, E.; RAN, Q. NLRP3 inflammasome activation by mitochondrial reactive oxygen species plays a key role in long-term cognitive impairment induced by paraquat exposure. *Neurobiol Aging*, v.36, n.9, p.2533-2543, 2015.

CLASEN, B. et al. Bioaccumulation and oxidative stress caused by pesticides in Cyprinus carpio reared in a rice-fish system. *Sci Total Environ*, v.626, p.737-743, 2018.

DA SILVA, J. M. et al. Agrotóxico e trabalho: uma combinação perigosa para a saúde do trabalhador rural. *Ciência & Saúde Coletiva*, v.10, n. 4, p.891-903, 2015.

DE MELO, J. B.; DA CUNHA, G. S. J. Fatores que predispõem a intoxicação por agrotóxicos no município de Paty do Alferes. *Revista Pró-UniverSUS*, v.3, n.2, p. 07, 2017.

ELLMAN, G. L. Tissue sulfhydryl groups. *Archives Biochemistry and Biophysics*, v.82, n.1, p.70-77, 1959.

GANGEMI, S. et al. Occupational and environmental exposure to pesticides and cytokine pathways in chronic diseases. *International journal of molecular medicine*, v. 38, n.4, p.1012-1020, 2016.

GUZIK, T. J.; TOUYZ, R. M. Oxidative Stress, Inflammation, and Vascular Aging in Hypertension. *Hypertension*, v. 70, n.4, p.660-667, 2017.

HABIG, W. H.; PABST, M. J.; JACOBY, W. B. Glutathione S-transferase, the first enzymatic step in mercapturic acid formation. *J Biol Chem*, v.249, n.22, p.7130–7139, 1974.

HU, C.; WANG, M.; HAN, X. Shotgun lipidomics in substantiating lipid peroxidation in redox biology: Methods and applications. *Redox biology*, v. 12, p. 946-955, 2017.

JACOBSEN-PEREIRA, C. H. et al. Markers of genotoxicity and oxidative stress in farmers exposed to pesticides. *Ecotoxicol environ saf*, v.148, p.177-183, 2018.

JANG Y. et al. Chlorpyrifos induces NLRP3 inflammasome and pyroptosis/apoptosis via mitochondrial oxidative stress in human keratinocyte HaCaT cells. *Toxicology*, v.338, n.1, p.37-46, 2015.

JENTZSCH, A. M. et al. Improved analysis of malondialdehyde in human body fluids. *Free Radical Biology & Medicine*, v.20, n.2, p.251-256, 1996.

KEPP, O.; GALLUZZI, L.; KROEMER, G. Mitochondrial control of the NLRP3 inflammasome. *Nat Immunol*, v.12, n.3, p.199-200, 2011.

KIM, H. K. et al. Nod-like receptor pyrin containing (NLRP3) in the post-mortem frontal cortex from patients with bipolar disorder: a potential mediator between mitochondria and immune-activation. *J Psychiatr Res*, v.72, n.1, p.43-50, 2016.

KIM, K. H.; KABIR, E.; JAHAN, S. A. Exposure to pesticides and the associated human health effects. *Sci Total Environ*, v.575, p.525-535, 2017.

KLEMZ, C.; DE ASSIS, H. C. S. Efeitos do endosulfano na atividade da acetilcolinesterase de cascudo (Ancistrus multispinnis, Fish, Teleostei). *Revista Acadêmica: Ciência Animal*, v.3, n.4, 2017.

KLENIEWSKA, P.; PAWLICZAK, R. The participation of oxidative stress in the pathogenesis of bronchial asthma. *Biomedicine & Pharmacotherapy*, v.94, p. 100-108, 2017.

LATUNDE-DADA, G. O. Ferroptosis: Role of lipid peroxidation, iron and ferritinophagy. *Biochimica et biophysica acta*, v.1861, n.8, p.1893-1900, 2017.

LEVINE, R.L. et al. Determination of carbonyl contente in oxidatively modified proteins. *Methods in Enzymology*, v.186, p.464-478, 1990.

LIU, Z. et al. Oxidative Stress in Neurodegenerative Diseases: From Molecular Mechanisms to Clinical Applications. *Oxidative Medicine and Cellular Longevity*, v.2017, 2017.

NAGAMI, H.; SUENAGA, T.; NAKAZAKI, M. Pesticide exposure and subjective symptoms of cut-flower farmers. *J rural med*, v.12, n.1, p.7-11, 2017.

NELSON, D. P.; KIESOW, L. A. Enthalpy of the composition of hidrogen peroxide by catalase at 25ºC. *Analytical Biochemistry*, v.49, p.474-479, 1972.

NETO, M. G. F.; ANDRADE, R. D.; FELDEN, É. P. G. Trabalho na agricultura: possível associação entre intoxicação por agrotóxicos e depressão. *Rev Perspect Cien Saúde*, v.3, n.1, 2018.

PEREIRA D. M. Avaliação da capacidade antioxidante e anti-inflamatória do isolado proteico de soja, do okara e de seus hidrolisados [tese]. Campinas: Universidade de Campinas; 2017.

SHIMOKOMAKI, F. K.; COSTA, C. Verificação de armazenamento de defensivos agrícolas em fazendas certificadas de café em Monte Carmelo-MG. *Revista GeTeC*, v.7, n.1, 2018.

SUAREZ-LOPEZ, J. R, et al. Acetylcholinesterase activity and time after a peak pesticide-use period among Ecuadorian children. *Int J Occup Environ Health*, v.91, n.2, p.175-184, 2018.

TAKEUCHI, O.; AKIRA, S. Pattern recognition receptors and inflammation. *Cell*, v.14, n.6, p.805-820, 2010.

TASSI, S. et al. Altered redox state of monocytes from cryopyrin-associated periodic syndromes causes accelerated Il-1β secretion. *Proc Natl Acad Sci USA*, v.107, n.21, p.9789-9794, 2010.

YARIBEYGI, H.; MOHAMMADI, M. T.; SAHEBKAR, A. Crocin potentiates antioxidant defense system and improves oxidative damage in liver tissue in diabetic rats. *Biomed Pharmacother*, v.98, p.333-337, 2018.

ZHOU, L. et al. Redox proteomics screening cellular factors associated with oxidative stress in hepatocarcinogenesis. *Proteomics-Clinical Applications*, v. 11, n.3(4), 2017.

ZHOU, R. et al. A role for mitochondria in NLRP3 inflammasome activation. *Nature*, v.469, n.7329, p.221-225, 2011.

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