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RURAL WORKERS EXPOSURE TO ORGANOPHOSPHATES AND CARBAMATES

EXPOSIÇÃO DE TRABALHADORES RURAIS A ORGANOFOSFORADOS E CARBAMATOS

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ABSTRACT

Pesticides are compounds widely used in agriculture, due the productive efficiency increase. However, these toxic compounds can exert negative effects to environment and human health. This work aim was analyzing the occupational exposure of rural workers to pesticides, through a descriptive-analytical study with cross-sectional and quantitative approach. The sample consisted of 63 farm workers. Socioeconomic profile characterization, pesticide management, and health conditions was carried out through interviews. After biological samples collection, erythrocyte acetylcholinesterase enzyme activity was assessed in two moments: pre- and post-exposure to pesticides in one of planting and harvesting cycle. Rural workers age mean was 48.1 ± 7.6 years. They reported using personal protective equipment, although incompletely or inadequately, and 46% reported pesticide poisoning. Mood disorders such as anxiety (50.3%) and depressive state (27.0%) were also reported by workers. There was a significant decrease in the activity of the erythrocyte acetylcholinesterase enzyme from 0.83 ± 0.06 delta pH/hour to 0.71 ± 0.11 delta pH/hour ($p < 0.05$). Individual comparison of enzyme activity values showed that 19.6% of the workers were intoxicated with carbamate and organophosphate. Contamination is attributed to the inadequate management of pesticides. Adopting measures to minimize intoxications and other harmful effects on the health of rural workers is considered urgent.

Keywords: agrochemicals; occupational exposure; biomarkers; acetylcholinesterase.

RESUMO

Os pesticidas são compostos amplamente utilizados na agricultura, por causa do aumento da eficiência produtiva, no entanto esses compostos tóxicos podem exercer efeitos negativos ao meio ambiente e à saúde humana. O objetivo deste trabalho foi analisar a exposição ocupacional de trabalhadores rurais a agrotóxicos, através de um estudo descritivo-analítico com abordagem transversal e quantitativa. A amostra foi composta de 63 trabalhadores agrícolas. A caracterização do perfil socioeconômico, o manejo de pesticidas e as condições de saúde foram realizados por meio de entrevistas. Após a coleta das amostras biológicas, a atividade da enzima acetilcolinesterase eritrocitária foi avaliada em dois momentos: pré e pós-exposição a pesticidas em um ciclo de plantio e colheita. A idade média dos trabalhadores rurais foi de 48,1 ± 7,6 anos. Eles relataram usar equipamentos de proteção individual, embora de forma incompleta ou inadequadamente, e 46% relataram intoxicação por agrotóxicos. Transtornos do humor como ansiedade (50,3%) e estado depressivo (27,0%) também foram relatados pelos trabalhadores. Houve uma diminuição significativa na atividade da enzima acetilcolinesterase eritrocitária de 0,83 ± 0,06 delta pH/hora para 0,71 ± 0,11 delta pH/hora ($p < 0,05$). A comparação individual dos valores da atividade enzimática mostrou que 19,6% dos trabalhadores estavam intoxicados com carbamatos e organofosforados. A contaminação é atribuída ao manejo inadequado de pesticidas. Considera-se urgente a adoção de medidas para minimizar intoxicações e outros efeitos nocivos à saúde dos trabalhadores rurais.

Palavras-chave: agrotóxicos; exposição ocupacional; biomarcadores; acetilcolinesterase.

INTRODUCTION

With the changes in the agricultural production process that have occurred in recent decades, especially with regard to the intensive use of pesticides, the damage caused to the environment has become increasingly evident (LOPES; ALBUQUERQUE, 2018; MAJOLO; REMPEL, 2018). As pesticides can contaminate water, air, and soil, the natural habitat of numerous species becomes altered, causing significant negative impacts on ecosystems. Fish, insects, amphibians, among other animals, suffer from poisoning by pesticides present in the environment (CHELINHO *et al*., 2012; GONÇALVES *et al*., 2015).

Similar to what happens with different species of animals in nature, the use of pesticides has affected human health, increasing the risk of diseases and work accidents related to intoxication, especially among rural workers (PIGNATI *et al*., 2017). Rural workers represent the population group most exposed to pesticides and, consequently, most vulnerable to health problems resulting from poisoning with these compounds (MURUSSI *et al*., 2014; STRELITZ; ENGEL; KEIFER, 2014). Among the health problems, the adverse effects on the central nervous system (CNS) and peripheral system, increased incidence of cancer, malformations, and endocrine and immune disorders can be mentioned (JONAS, 2015; KIM; KABIR; JAHAN, 2017; MOSTAFALOU; ABDOLLAHI, 2017). The greater susceptibility of this population group is related to factors such as neglect in the use of personal protective equipment (PPE), since rural workers do not use it, or use equipment that is not appropriate, making them even more vulnerable to exposure to pesticides (SIQUEIRA *et al*., 2013).

Organophosphates and carbamates are among the most used pesticides and the most frequently associated with occupational poisoning (LOZANO-PANIAGUA *et al*., 2016). These substances act as inhibitors of the enzyme acetylcholinesterase (AChE), causing an accumulation of acetylcholine at cholinergic receptors. Thus, postsynaptic cholinergic transmission does not cease in adequate time, leading to hyperstimulation, which may trigger symptoms such as headache, tremors, dizziness, loss of consciousness and fainting (EDDLESTON *et al*., 2012; ANDRADE FILHO; SOUZA, 2013; SIQUEIRA *et al*., 2013).

The level of acetylcholinesterase enzyme activity in the blood becomes an important biomarker to demonstrate the exposure to pesticides of the organophosphate and carbamate classes, still used despite their harmful effects on health (MURUSSI *et al*., 2014; MAGNARELLI, 2015). In this sense, the objective of this study was to analyze occupational exposure to pesticides and the relationship between exposure and levels of the enzyme acetylcholinesterase in rural workers in western Santa Catarina.

MATERIALS AND METHODS

This is a descriptive-analytical study with a cross-sectional and quantitative approach involving rural workers occupationally exposed to pesticides.

Population, sample, and selection

The study population consisted of 658 male rural workers from a rural municipality in western Santa Catarina, aged between 19 and 60 years (SISAB, 2017). The G* Power 3.1 software was used to calculate the sample size. A significance level of 5%, test power of 80.0%, equal standard deviations in pre- and post-exposure scores, and a correlation coefficient of 0.30 (minimum value to be detected in the consistency assessment) were considered. Based on this calculation, although the minimum sample size required was 35 participants, 63 rural workers were included. For the constitution of the sample, the subjects were drawn from random numbers generated on a website generating random numbers. Each participant drawn to compose the sample was visited at home by a researcher properly trained to perform data collection.

Ethical aspects

This study followed resolution 466 / CNS / 2012 (BRASIL, 2012), of the National Health Council of Brazil, which establishes guidelines to preserve the dignity, rights, security, and well-being of research participants. This study was approved by the Research Ethics Committee Involving Human Beings of Unochapecó University (protocol number 2100319).

All subjects in the sample were informed about the objectives and procedures of the study and signed an Informed Consent Form, in two copies, authorizing their participation in the research. A copy of the term was given to the participant and another was under the responsibility of the researchers, together with all the data collected in the study.

Interview and data collection instrument

Initially, rural workers answered a questionnaire applied in the form of interviews, with questions related to socioeconomic and demographic characteristics, knowledge about the use of pesticides, and health conditions. The application of the questionnaire occurred in an individualized way at the worker's home.

The socioeconomic profile was evaluated through the application of the questionnaire based on the Brazilian Economic Classification Criteria of the Brazilian Association of Research Companies (*Associação Brasileira de Empresas de Pesquisa* — ABEP). These criteria are based on an economic classification tool that uses a survey of the characteristics of the household (presence and quantity of some domestic comfort items and level of education of the head of the family) to differentiate the population (ABEP, 2015). Each item of the instrument is scored and, at the end, the results are added up and the individual's socioeconomic classification is performed, observing the following cutoff points: class A: 45-100 points; class B1: 38-44 points; class B2: 29-37 points; class C1: 23-28 points; class C2: 17-22 points; and classes D-E: 0-16 points (ABEP, 2015).

During data collection, collections of blood samples were scheduled for further analysis of acetylcholinesterase activity.

Enzyme dosage

To determine exposure to carbamate and organophosphate classes pesticides by measuring the enzymatic activity of erythrocyte acetylcholinesterase, two 4-mL blood samples were collected in EDTA tubes at the outpatient clinic of the municipality's Health Unit, in two moments. The first collection of blood samples occurred before the agricultural planting period (pre-exposure) and the second collection occurred after five months, at the end of the harvest (post-exposure). AChE enzyme activity was analyzed by the potentiometric method, which allows quantifying from electrodes, the pH variation of a medium containing the sample (erythrocyte solution) and the acetylcholine substrate. The enzyme acetylcholinesterase present in erythrocytes should hydrolyze acetylcholine and, as a consequence, release acetic acid. The acidification of the medium promotes quantifiable pH variation, which can be measured by an acid-sensitive electrode, and the enzymatic activity can be expressed as pH variation per hour (delta pH/h). The normal reference values range from 0.58 to 0.95 delta pH/h for men (MICHEL, 1949; HOLAS *et al*., 2012).

According to Ribeiro and Mella (2007), it is necessary to perform the pre-exposure baseline test in workers who will have contact with organophosphates and carbamates, considering that the cholinesterase basal levels vary from one person to another.

Statistical analysis

Data were presented as means and respective standard deviations or absolute and relative frequencies (%). The normality of the continuous data was analyzed by the Shapiro-Wilk test. The Wilcoxon test for related samples was used to compare pre- and post-exposure data. The Statistical Package for the Social Sciences (SPSS®), version 20.0 was used for all analyses. The significance level was set at 5% ($p < 0.05$).

RESULTS AND DISCUSSION

Characterization of the study population and contact with pesticides

The study sample consisted of 63 rural male workers, with a mean age of 48.1 ± 7.6 years, of whom 92.1% were married. Regarding education, 39.7% had elementary education and 28.6% had primary education. In general, 68.3% of the subjects in the sample studied for up to eight years. Most workers were classified in the middle and low economic classes, with 57.1% in class B (B1 and B2) and 38.0% in class C (C1 and C2).

The average pesticide exposure time for rural workers in the present study was 24.8 ± 8.3 years. Although 95.2% of individuals reported using PPE, these were not always adequate or sufficient to protect them from pesticides (Table 1). Only 39.7% used the mask with a filter that provides effective protection, 79.0% stated they used gloves, 20.6% used goggles, and 88.9% mentioned the use of coveralls (Table 1). These data demonstrate a high degree of vulnerability of these workers due to the conditions under which they are exposed to pesticides, a condition also observed in other studies (SIQUEIRA *et al.*, 2013; WAHLBRINCK; BICA; REMPEL, 2017; CORCINO *et al.*, 2019).

The workers reported that the non-use of PPE is related to the fact that some equipment causes thermal discomfort, making it difficult to perform the tasks. For this reason, especially in small rural communities, it is common to find rural workers without PPE during the handling and application of pesticides, despite the mandatory use of such equipment.

It is important to consider that washing the PPE is also an important source of contamination because the PPE is washed and stored by other people in the family, usually the wife. Another worrying aspect is the washing of clothes used during the application of pesticides, since 41.3% of workers stated that their clothes were washed together with those of the family (GONÇALVES; MELO, 2014).

Farmworkers were also asked about direct skin contact with pesticides, and 66.7% admitted that such contact occurred at the time of preparation or application of the pesticide, and such contact occurred in many parts of the body (64.3% on the hands, 33.3% on the face, 21.1% on the back, 7.1% on the legs and arms, and 2.4% on the neck). These data also indicate the incorrect use of PPE by the participants.

The inappropriate use of PPE leaves workers exposed to the absorption of pesticides that can occur through the dermal, respiratory and oral routes, and can lead to acute and/or chronic poisoning (CARGNIN; ECHER; SILVA, 2017). In this sense, the relevance of hygiene measures after the manipulation of pesticides is an important action to reduce the possibility of contamination and absorption of products by the usual routes of entry into the human body.

Workers were also asked about training to work with pesticides, as well as handling empty containers (Table 2). Regarding training on the use of pesticides

Table 1 – Personal protective equipment used by rural workers living in a municipality in western Santa Catarina (2018).

Personal protective equipment	N	%
Simple mask	33	52.4
Mask with filter	25	39.7
Gloves	50	79.0
Boots	57	90.5
Glasses	13	20.6
Coveralls	56	88.9
Impervious apron	25	39.7

and the necessary care in handling them, only 54.0% of workers reported having received information, of which 47.0% stated that the training was carried out by the company that sold the products and 52.9% by other institutions, such as the Municipal Secretariat of Agriculture and the Agricultural Research and Rural Extension Company of Santa Catarina (*Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina* — EPAGRI). The guidelines provided by the selling company basically consisted of the number of products that should be applied to the crops.

Adequate technical assessment of the existence of problems related to the attack of insects and diseases harmful to plantations and the real need for the use of pesticides, as well as technical guidance on the use of pesticides as a means of control, are important measures to prevent accidents and pesticide-related poisonings (JACOBSON *et al*., 2009; SIQUEIRA *et al*., 2013).

Handling empty containers also requires special attention. According to NBR 13968 (ABNT, 1997), the containers must be washed three times and returned to the manufacturer. In this sense, 98.4% of the rural workers interviewed stated that they perform the triple washing of empty containers and 68.3% reported discarding the washing water using the product's own application equipment (Table 2).

Although workers were aware of the importance of triple washing and subsequent return of containers to the place where they were purchased, a considerable number of workers (30.2%) declared to discard water in inappropriate places such as close to homes and streams (Table 2). This fact is quite worrying, as these actions imply an increased risk of contamination by other family members, besides domestic animals and water, as observed in previous studies (SIQUEIRA *et al*., 2013; MIRANDA, 2016).

Table 2 – Characterization of training and management of empty containers by rural workers in a municipality in western Santa Catarina, 2018.

Variables	N	%
Training to work with pesticides		
Yes	34	54.0
No	29	46.0
Provider of the training*		
Selling company	16	47.0
Others	18	52.9
Disposal of empty containers		
Return to the provider	60	95.2
Storage	3	4.8
Triple wash		
Yes	62	98.4
Place of elimination of triple washing water		
Spray	43	68.3
Ground/place where it is washed	19	30.2
Others	1	1.3

*Only workers who said to have received training responded this item.

The results of the present study also made it possible to know the type of destination given to empty containers. In 95.2% of cases, respondents reported returning the packaging to the place of purchase, according to the law. Moreover, rural workers reported being aware of the existence of the law that determines the correct disposal of pesticide packaging.

Adequate disposal is considered to go beyond a conscious attitude toward compliance with the law, which establishes the rules for the return of empty packaging according to the instructions on the package inserts (Law No. 7,082, of July 11th, 1989, and Decree No. 9,974, of June 6th, 2000). The deadline for disposal is up to one year from the date of purchase. A longer term is only possible if authorized by the regulatory agency (BRASIL, 2000). Failure to comply with this law can result in fines for the farmer, dealer and even the pesticide manufacturer.

Types of pesticides used by workers

Rural workers were asked about the types of pesticides used. Farmers use an average of 6.4 ± 4.1 types of pesticides, with those using less using only one type and those using more using 24 different types. Different formulations were mentioned, including all classes of pesticides, such as insecticides, fungicides, herbicides, poison for ants, termiticides and growth regulators. It is worth mentioning that the participants cited the commercial names of the pesticides and, subsequently, a search was made in the monographs provided by the National Health Surveillance Agency (*Agência Nacional de Vigilância Sanitária* — ANVISA) on the active ingredients (AI), chemical groups, toxicological classification, among other information. Fifty-eight active ingredients were mentioned, and the 10 most cited are described in Table 3.

The herbicide glyphosate was the substance most cited by rural workers, and all the interviewees mentioned the use on their farms. Although glyphosate is classified as little toxic (Class IV), it has been in the process of toxicological re-evaluation by ANVISA since 2008 due to indications of its carcinogenic potential and other human health hazards. For this reason, its use will be banned in France from 2022 (BOMBARDI, 2017). It is also worth noting that three of the ten active principles most cited belong to the toxicological classifications I and II (extremely and highly toxic, respectively).

Other active ingredients cited by rural workers in the present study, such as 2,4-D and abamectin, paraquat and acephate, which are on the list of the ten best-selling agrochemicals in Brazil, were reassessed by ANVISA, and their use was kept restricted after the evaluation.

Table 3 – Active ingredients used by rural workers living in a municipality in western Santa Catarina, 2018.

Active ingredients	Chemical group	Toxicological classification
Glyphosate	Substituted glycine	Class IV
Trifloxystrobin	Strobilurin	Class II
Prothioconazole	Triazolinethione	Class IV
Lambda-cyhalothrin	Pyrethroid	Class III
Methomyl	Oxime methyl carbamate	Class I
Thiamethoxam	Neonicotinoid	Class III
Chlorantraniliprole	Anthranilamide	Class III
2.4-D	Aryloxyalkanoic acid	Class I
Paraquat	Bipyridylium	Class III
Diurom	Urea	Class III

In the European Union (EU), they were banned in 2009 and 2003, respectively. The thiamethoxam insecticide, the sixth most used by the population studied, was also banned in the EU (CARNEIRO, 2015; BOMBARDI, 2017).

The active ingredients used by the rural workers participating in the study belonged to the following toxicological classifications: 46.5% class III, 27.6% class II, 13.8% class I; and 12.1% class IV. The use of a high number of active ingredients belonging to toxicological classes I and II (41.4%) indicates that the population is exposed to highly harmful substances. However, in most cases, these substances can be replaced by less toxic compounds.

According to Hess (2018), many products registered with ANVISA belong to toxicological classes III and IV, which meet most of the demands of farmers and with less toxicity. Therefore, the authorized use of highly toxic active substances (classes I and II) is not justified because they can be replaced by products with lower toxicity.

In addition, the main chemical groups used were pyrethroids and triazole, with six ingredients each, followed by organophosphates, carbamates, and strobilurin, with four active ingredients each group, and the neonicotinoids with three active ingredients. It should also be noted that of the 58 active ingredients mentioned, only eight belonged to the chemical groups of organophosphates and carbamates, which cause changes in the activity of the enzyme acetylcholinesterase, with the possibility of acute intoxications. For the other chemical groups used by rural workers, there are no specific biomarkers for the identification of acute or chronic poisoning.

Characterization of the effects of pesticides on population health

Table 4 shows that the population with occupational exposure to pesticides presented intoxication conditions, with 26 signs/symptoms reported after handling or applying pesticides. Data analysis showed a significant prevalence of intoxication reported by rural workers (46%). Other Brazilian studies found lower prevalence rates of poisoning, ranging from 11 to 22% (FARIA, 2012; CABRAL, 2012; BURALLI, 2016).

Signs and symptoms of poisoning related to exposure to similar pesticides were also found in other studies (CABRAL, 2012; OLIVEIRA, 2017). The signs and symptoms cited by the workers are linked to acute poisoning (nausea, vomiting, headache, salivation, tremors, mental confusion, convulsion, among others) and chronic poisoning (agitation, weakness, respiratory diseases).

Some of these symptoms may be related to poisoning by cholinesterase inhibitors. Early symptoms related to the CNS include headache, dizziness, agitation, tremors, muscle weakness, fatigue, cramps and excessive salivation, which is a common muscarinic signal (ALONZO; CORRÊA, 2014).

It is important to emphasize that 29 workers (46%) reported intoxication, however, when analyzing the symptoms mentioned (Table 4), 37 workers reported feeling discomfort (58.8%), 34 reported headache (54%), and 31 reported nausea (49.2%), these were typical of mild acute poisoning. Buralli (2016) demonstrated in his study that, although a minority of workers reported poisoning by exposure to pesticides, a considerable number of workers reported having experienced various signs and symptoms characteristic of the poisoning.

The fact that farmworkers do not understand these signs as a possible poisoning reveals that the damages are not always perceived, or their occurrence is not given due importance. There is great misinformation among workers about the use and dangers of pesticides. They also show to be afraid of recognizing the symptoms of poisoning, and do not seek medical care or do not admit that the symptoms they have may be related to the use of these substances (LONDRES, 2011).

As to the occurrence of health problems, there was a high number (50.8%) of workers with anxiety. It is of fundamental importance to highlight the occurrence of behavioral disorders as an effect of exposure to pesticides. Such disorders include anxiety, irritability, attention disorders, and sleep disorders. In an epidemiological study, Faria *et al*. (2000) quantitatively demonstrated a strong association between pesticide poisoning and minor psychiatric disorders such as nervousness, anxiety, and discouragement.

Regarding depression, this study demonstrated that 27.0% of rural workers mentioned this disease and reported the use of antidepressants. When compared to the urban male population, the situation is even more worrying. A study conducted in an urban population estimated that the prevalence of depression was 12.7% among men (PRADO *et al.*, 2012). In this study, the value found for the male population was more than double (27%), suggesting that rural workers are more susceptible to the occurrence of depression than urban workers.

The high prevalence of signs and symptoms evidenced in the present study indicates that the health of rural

Table 4 – List of signs and symptoms reported by rural workers residing in a municipality in western Santa Catarina after handling/applying pesticides, 2018.

Variables	N	%
Reported intoxication	29	46.0
Malaise	37	58.8
Headache	34	54.0
Nausea	31	49.2
Weakness	27	43.0
Salivation	26	41.3
Eye irritation	25	39.7
Shaking	24	38.0
Dizziness	24	38.0
Vomiting	19	30.1
Tremors	19	30.1
Sweating	17	27.0
Colic	15	23.8
Tingling	14	22.2
Blurry vision	14	22.2
Palpitation	13	20.6
Diarrhea	12	19.0
Numbness	11	17.5
Cough	11	17.5
Skin irritation	10	15.9
Shortness of breath	10	15.9
Chest pain	7	11.1
Cramps	5	8.0
Mental confusion	5	8.0
Others	3	4.7
Convulsion	2	3.1
Uncoordinated movements	1	1.6

workers is compromised and conditioned to the intensive use of pesticides. According to Gomes Filho Neto, Andrade and Felden (2018), understanding the relationship between poisoning and diseases (mental or not) associated with the use of pesticides, is essential for health and occupational safety professionals to act preventively and minimize damage to workers. Exposure to pesticides should be seen as a risk determinant for the health of rural workers, and as such, requires public health programs aimed at promoting the health of this population (SILVA, 2013).

Evaluation of the erythrocyte acetylcholinesterase enzyme activity

According to Ribeiro and Mella (2007), a baseline test is necessary before exposure of workers who will have contact with organophosphate and carbamate pesticides, considering that baseline levels of cholinesterase vary from one person to another.

The analysis of the activity of the erythrocyte AChE and the comparison of its values before and after exposure are shown in Figure 1.

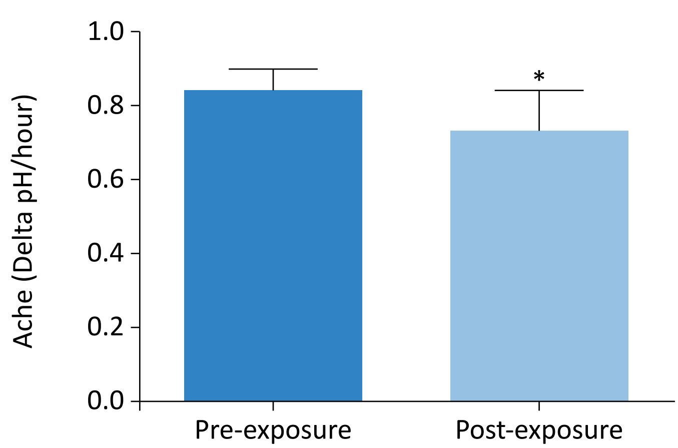
The activity of the AChE enzyme reduced from 0.83 ± 0.06 delta pH/hour in pre-exposure to 0.71 ± 0.11 delta pH/hour in post-exposure (Figure 1). Wilcoxon's nonparametric test indicated a statistically significant ($p < 0.05$) decrease in post-exposure AChE values as compared to the pre-exposure values. The decrease in enzyme activity ($p < 0.05$), suggests that rural workers were contaminated by pesticides of the organophosphate and carbamate classes.

This statistically significant decrease indicates that rural workers exposed to pesticides are vulnerable to the harmful action of these substances. It should be noted that the determination of acetylcholinesterase activity constituted an appropriate indicator to monitor the exposures to these pesticides, but it is not suitable for pesticides from other chemical groups.

When the results of the enzymatic dosages of each individual worker were compared, 12 workers (19.6%) were poisoned as indicated by the enzymatic activity with a reduction greater than or equal to 30%, in accordance with the NR-7 (BRASIL, 2013).

These data indicate that the inadequate management of pesticides by rural workers allowed a significant absorption of organophosphates and carbamates after exposure. Other studies found between 3.6 and 4.6% of the sample presenting a reduction greater than 30% in acetylcholinesterase levels (OLIVEIRA-SILVA *et al*., 2001; NASCIMENTO, 2013; NASCIMENTO *et al*., 2013; NERILO *et al*., 2014).

It is important to note that thousands of farmers are intoxicated as a result of exposure to pesticides worldwide (OPAS; OMS, 2018), which has generated great concern for several countries and also for the World Health Organization (KOS *et al*., 2013). The potential



*Statistically significant difference ($p < 0.05$).

Figure 1 – Dosage of erythrocyte acetylcholinesterase enzyme activity in rural workers of a municipality in western Santa Catarina pre- and post-exposure to pesticides, 2018.

toxicity of organophosphates and carbamates has been demonstrated in several studies that have shown significant reductions in acetylcholinesterase activity in exposed rural workers, making the problem of poisoning by these compounds even more evident (OLIVEIRA-SILVA *et al*., 2001; DHANANJAYAN *et al*., 2012; MURUSSI *et al*., 2014; NERILO *et al*., 2014; KLEIN *et al*., 2018).

In this study, the analysis of erythrocyte acetylcholinesterase activity indicates that farmworkers are vulnerable to pesticide contamination and may suffer health damage over time. A significant reduction in enzyme activity after exposure indicates inadequate handling of pesticides and unsatisfactory use of protective equipment that allowed an important absorption of these compounds.

CONCLUSIONS

The results show that exposure to pesticides can have serious health consequences. Acknowledging the complexity of the problem and the adoption of more sustainable and responsible agricultural alternatives are urgently needed in order to reduce the use of these substances and the damage to human health and the environment.

CONFLICT OF INTERESTS

All authors declare no conflicting interests.

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