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**Environment**

# Levels of exhaled carbon monoxide in steakhouse workers in a town in the Brazilian Legal Amazon region

## Níveis de monóxido de carbono exalado em trabalhadores de churrascarias em uma cidade da Amazônia Legal Brasileira

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## ABSTRACT

Occupational exposure to smoke from commercial kitchens such as steakhouses may be associated with an increase in the prevalence of respiratory symptoms and an acute reversible decrease in pulmonary functional capacity, and exposure to coal smoke is a risk factor for the development of respiratory diseases. The objetive of study was evaluate the levels of exhaled carbon monoxide (COex) and carboxyhemoglobin (COHb) in steakhouse workers. This is an observational, longitudinal and prospective study in the city of Cuiabá, Mato Grosso, Brazil. The total of 29 professionals working in steakhouses participated in the study. Data on socio-demographic characteristics, work environment characteristics, life habits and respiratory symptoms were extracted from questionnaires. COex and COHb levels were measured before exposure and every hour up to a 4 hour exposure period. Twenty-nine workers participated, with a predominance of females (55.2%), with a mean age of 36.40±11.49 years. It was observed that 18 (62%) of the workers had respiratory symptoms. COex and COHb levels were elevated after 4 hour exposure ($p<0.05$), but within acceptable parameters. COex and COHb levels are elevated in a short period of time to occupational exposure to steakhouse activities.

**Keywords**: Carbon monoxide; Occupational groups; Occupational exposure; Occupational health; Air pollution

## RESUMO

A exposição ocupacional à fumaça de cozinhas comerciais, como churrascarias, pode estar associada a um aumento na prevalência de sintomas respiratórios e uma diminuição reversível aguda capacidade funcional, sendo a exposição à fumaça do carvão um fator de risco para o desenvolvimento de doenças respiratórias. O objetivo do estudo foi avaliar os níveis de monóxido de carbono exalado (COex) e carboxihemoglobina (COHb) em trabalhadores de churrascaria. Trata-se de um estudo observacional, longitudinal e prospectivo realizado na cidade de Cuiabá, Mato Grosso, Brasil. Um total de 29 profissionais que trabalham em churrascarias participaram do estudo. Foram aplicados questionários com questões referentes a características sócio demográficas, características do ambiente de trabalho, hábitos de vida e sintomas respiratórios. Os níveis de COex e COHb foram medidos antes da exposição e a cada hora até um período de exposição de 4 horas. Dos vinte e nove trabalhadores que participaram, a predominância foi do sexo feminino (55,2%), com média de idade de 36,40±11,49 anos. Foi observado que 18 (62%) dos trabalhadores apresentavam sintomas respiratórios. Os níveis de COex e COHb estavam elevados após 4 horas de exposição ($p<0,05$), mas dentro dos parâmetros aceitáveis. Os níveis de COex e COHb são elevados em curto período de tempo de exposição ocupacional em atividades laborais de churrascaria.

**Palavras-chave**: Monóxido de carbono; Trabalhadores; Exposição ocupacional; Saúde do trabalhador; Poluição do ar

# 1 INTRODUCTION

Restaurants is one of the most common companies in the world, employing millions of workers. However, these workers are at risk of exposure to various toxic compounds, and their health and safety is often neglected (BELANGER; TRICHE, 2009).

A very popular practice throughout the world is the use of charcoal for barbecuing indoors and outdoors (KABIR; KIM; YOO, 2011). Work activities in barbecue restaurant, contribute significantly to indoor air pollution, being a source of emissions of various toxic compounds combustion of charcoal, including varying sizes of particulate matter (PM), carbon monoxide (CO) and other air pollutants (HUANG; LEE; WU, 2016; NAEHER *et al.*, 2007).

CO is a colorless, odorless and non-irritating gas, produced by the incomplete combustion of organic carbonaceous materials, also present in restaurant environments, being considered an extremely dangerous pollutant that gains attention due to its ability to harm human health. When inhaled in high concentrations it can render a person unconscious or even kill within minutes (BRUCE; PEREZ-PADILLA; ALBALAK, 2000; LACERDA; LEROUX; MORATA, 2005). Such toxicity can be explained when the gas competes with oxygen for hemoglobin, resulting in anoxia caused by the conversion of oxyhemoglobin to carboxyhemoglobin (COHb) (REHFUESS; BRUCE; SMITH, 2011).

It is known that almost half of the population depends on solid fuels for use in cooking, just like restaurant workers (BONJOUR *et al.*, 2013) These fuels are typically burned in devices that are often inefficient and poorly ventilated, such as traditional open stoves and barbecue grills (NAEHER *et al.*, 2007).

In addition, occupational and environmental pollution in the form of dust, fumes, vapors and toxic gases are risk factors for the development of respiratory disorders, lung cancer, increased prevalence of respiratory symptoms and acute reversible decrease in pulmonary functional capacity (FERNANDES; STELMACH; ALGRANTI, 2006; KURMI; LAM; AYRES, 2012; NEGHAB *et al.*, 2017).

Due to the large number of polluting agents in the kitchens and in the barbecue environment, these workers are at high risk and consequently constitute one of the working classes that are occupationally exposed to develop these alterations (TANER; PELEY; PEKEY, 2013; BADYDA *et al.*, 2018; WONG *et al.*, 2011). This issue becomes more important when it comes to takes into account that these workers spend an average of six hours a day in this environment (MAHEMBE; MKOMA; KINAMBO, 2010).

Studies on air pollution and the health effects of the population have shown that, even when pollutants are below the levels determined by legislation, they are capable of causing effects on people's health (MARTINS *et al.*, 2002; MORAES *et al.*, 2010; AMÂNCIO; NASCIMENTO, 2012; GAVINIER; NASCIMENTO, 2014). Currently, the literature lacks knowledge about the effects of short-term exposure of the population using biomass fuel such as charcoal (DIETTE *et al.*, 2012).

The aim of the present study was to evaluate the levels of exhaled carbon monoxide (COex) and carboxyhemoglobin (COHb) in steakhouses workers in a municipality in the Brazilian Legal Amazon region.

## 2 MATERIAL AND METHODS

An observational, longitudinal and prospective study was conducted involving steakhouses workers in the city of Cuiabá, Mato Grosso (MT), Brazil, from April 2018 to June 2018. The city's climate is classified as semi-humid tropical with maximum daily temperatures that oscillate between 30ºC and 36ºC with two well-defined seasons, one being dry (autumn-winter) and one rainy (spring-summer) (MARQUES *et al.*, 2010; SANTOS *et al.*, 2013)

Convenience sampling was performed among in steakhouses workers with air conditioning and refrigeration. This sampling was carried out according to convenience, because it was difficult to obtain authorization from the restaurants owners.

The study included worker aged 18 and 59 years who were working in steakhouses in the city of Cuiabá for at least 6 months. Pregnant women, workers with the presence of hemolytic and pulmonary diseases, using corticosteroids, practitioners of intense physical exercises and smokers were excluded from the study.

Data were collected in the employees' own work environment during their working hours. A data collection form was used with questions related to sociodemographic characteristics, the work environment and workers' life habits. British Medical Research Council based questionnaire was used to obtain information on respiratory symptoms. Thus, the following outcomes were assessed: presence of cough (yes/no), sputum (yes/no) and wheezing (yes/no). Subsequently, participants who responded positively to at least one of the items were classified as symptomatic. Workers who responded negatively to all assessed symptoms were classified as asymptomatic.

To ensure that workers did not have respiratory disease, lung function was assessed using spirometry, using a portable digital spirometer (model Datospir Micro C of brand Sibelmed®, year 2016), with graphic record in accordance with criteria of European Respiratory Society (ERS) e American Thoracic Society (ATS) (MILLER *et al.*, 2005). Each participant performed three forced expiration maneuvers to obtain the ideal curve. The parameters analyzed were forced vital capacity (FVC), forced expiratory volume in the first second ($FEV_1$), forced expiratory flow at 25-75% ($FEF_{25-75}$) and the Tiffeneau index ($FEV_1$/FVC). The evaluation and classification of lung function were determined according to the criteria of studies of the Brazilian population (PEREIRA *et al.*, 2007).

The levels of COex and COHb were assessed by the Micro CO Monoximeter (Micro Medical AS). To perform the maneuver, the worker remained seated, performing a maximum inspiration until the total lung capacity (TLC), followed by a 20-second apnea to balance blood CO levels with alveolar CO, slowly exhaling until residual volume (RV). Reference parameters of 6 ppm for COex (SANTOS *et al.*, 2001), and 2.5% for COHb were used (SIQUEIRA *et al.*,1997). Values were obtained before the start of the workday, followed by four more evaluations, respectively, after 60, 120, 180 and 240 minutes of exposure smoke from barbecue grill.

The population characteristic was represented in tables with data distributed in frequency, proportion, mean and standard deviation. Analysis of variance was used for comparisons between levels of COex and COHb over the time of exposure followed by the Tukey test. The unpaired T test and Mann-Whitney test were used to verify the association between respiratory symptoms and the workers' personal and occupational characteristics. The level of significance established for the statistical tests was 5%.

This study was approved by the Research Ethics Committee of the University of Cuiabá under CAAE opinion: 66061316.5.0000.5165. All individuals received a free consent form that was previously signed to participate in the research.

## 3 RESULTS

A total of 36 individuals were evaluated, and of that amount, 9 were excluded according to the following criteria: smokers, changes in lung function, previous lung disease and withdrawal.

Participated in the study 27 non-smoking steakhouses workers, with a mean age of 36.60±11.62 years, predominantly female (59.2%) and non-white color (70.3%). It was observed that most were married (55.5%) and had completed high school (25.9%) (Table 1).

Table 1 – Distribution of demographic characteristics of steakhouse workers in the municipality of Cuiabá (MT), 2018

| **Characteristics** | **n=27** |
|---|---|
| Age | 36.60±11.62 |
| Sex | |
| Female | 16 (59.2%) |
| Male | 11 (40.7%) |
| Weight | 71.8±11.14 |
| BMI | 25.9±3.43 |
| Color | |
| White | 9 (33.3%) |
| Others | 18 (66.6%) |
| Marital status | |
| Married | 15 (55.5%) |
| Not married | 12 (44.4%) |
| Education | |
| Without instruction | 1 (3.7%) |
| Incomplete elementary school | 4 (14.8%) |
| Complete elementary school | 5 (18.5%) |
| Incomplete secondary education | 5 (18.5%) |
| Complete secondary education | 7 (25.9%) |
| Superior education incomplete | 2 (7.4%) |
| Superior education complete | 3 (11.1%) |
| Physical activity | |
| Yes | 8 (29.6%) |
| No | 19 (70.3%) |

Age: years; weight: kg; height: meters. BMI (body mass index): $m/cm^2$
Fonte: Authors (2018)

The presence of respiratory symptoms was reported by 17 workers (62.9%). Regarding the characteristics of the work environment, 18 individuals (66.6%) belonged to functions with access to the kitchen/barbecue environment, 17 workers (62.9%) had knowledge about personal protective equipment (PPE) and only 9 (33.3%) reported using it. With regard to the daily workday, 19 workers (70.3%) worked within 8 hours (Table 2).

Table 2 – Occupational characteristics and respiratory symptoms of steakhouse workers. Cuiabá (MT), 2018

| **Characteristics** | **n=27** |
|---|---|
| Respiratory symptoms | |
| Symptomatic | 17 (62.9%) |
| Asymptomatic | 10 (37%) |
| Occupation from workers | |
| Exposed environment (kitchen/barbecue grill) | 18 (66.6%) |
| Unexposed environment (hall/buffet) | 9 (33.3%) |
| Work time | |
| Up until 8 hours | 19 (70.3%) |
| More of 8 hours | 8 (29.6%) |
| Knowledge about PPE | |
| Yes | 17 (62.9%) |
| No | 10 (37%) |
| Use of PPE | |
| Yes | 9 (33.3%) |
| No | 18 (66.6%) |

PPE= personal protective equipment.
Fonte: Authors (2018)

The average COex before exposure was 1.66±0,96ppm and COHb was 0.27±0.14% with exhaled levels showing statistical difference after 1 hour of exposure ($p<0.05$), reaching final values of 6.07±2.49ppm for COex and COHb 0.97±0.39% (Table 3).

Table 3 – Exhaled carbon monoxide and carboxyhemoglobin levels of steakhouse workers in the municipality of Cuiabá (MT), 2018. Means with the same superscript letters do not differ significantly according to Tukey's HSD post-hoc procedure

| **Exhaled carbon monoxide (ppm)** | | **Carboxyhemoglobin (%)** | |
|---|---|---|---|
| **Exposure time** | **Mean** | **Exposure time** | **Mean** |
| Initial | $1.66 \pm 0.96^{a}$ | Initial | $0.27 \pm 0.14^{a}$ |
| 1h | $2.77 \pm 1.08^{b}$ | 1h | $0.44 \pm 0.17^{b}$ |
| 2h | $3.85 \pm 1.63^{bc}$ | 2h | $0.61 \pm 0.26^{bc}$ |
| 3h | $5.07 \pm 1.93^{cd}$ | 3h | $0.81 \pm 0.31^{cd}$ |
| 4h | $6.07 \pm 2.49^{d}$ | 4h | $0.97 \pm 0.39^{d}$ |

Different Lowercase letters in columns indicate statistical difference by Tukey's test ($p < 0.05$).
Fonte: Authors (2018)

Regarding the association between respiratory symptoms and the personal and occupational characteristics of the research participants, no statistically significant differences were observed (Table 4).

Table 4 – Association between respiratory symptoms with the personal and occupational characteristics of steakhouse workers in the city of Cuiabá (MT), 2018

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| | **General** | | **Respiratory symptoms** | | | | **P-value*** |
|---|---|---|---|---|---|---|---|
| | | | **Symptomatic (n=17)** | | **Asymptomatic (n=10)** | | |
| | **N** | **(%)** | **n** | **(%)** | **n** | **(%)** | |
| Sex | | | | | | | 0.544 |
| Male | 16 | (59.3) | 11 | (68.8) | 5 | (31.3) | |
| Female | 11 | (40.7) | 6 | (54.5) | 5 | (45.5) | |
| Age | | | | | | | 0.458 |
| Up until 30 anos | 13 | (48.1) | 7 | (53.8) | 6 | (46.2) | |
| More of 30 anos | 14 | (51.9) | 10 | (71.4) | 4 | (28.6) | |

Table 4 – Association between respiratory symptoms with the personal and occupational characteristics of steakhouse workers in the city of Cuiabá (MT), 2018

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| | **General** | | **Respiratory symptoms** | | | | **P-value*** |
|---|---|---|---|---|---|---|---|
| | | | **Symptomatic (n=17)** | | **Asymptomatic (n=10)** | | |
| | **N** | **(%)** | **n** | **(%)** | **n** | **(%)** | |
| Color | | | | | | | 0.668 |
| White | 9 | (33.3) | 5 | (55.6) | 4 | (44.4) | |
| Others | 18 | (66.7) | 12 | (66.7) | 6 | (33.3) | |
| Marital status | | | | | | | 0.347 |
| Not married | 12 | (44.4) | 9 | (75.0) | 3 | (25.0) | |
| Married | 15 | (55.6) | 8 | (53.3) | 7 | (46.7) | |
| Use of PPE | | | | | | | 0.820 |
| Yes | 9 | (33.3) | 6 | (66.7) | 3 | (33.3) | |
| No | 18 | (66.7) | 11 | (61.1) | 7 | (38.9) | |
| Physical activity | | | | | | | 0.979 |
| Yes | 8 | (29.6) | 5 | (62.5) | 3 | (37.5) | |
| No | 19 | (70.4) | 12 | (63.2) | 7 | (36.8) | |
| Occupation | | | | | | | 0.668 |
| Exposed environment | 18 | (66.7) | 12 | (66.5) | 6 | (33.3) | |
| Unexposed environment | 9 | (33.3) | 5 | (55.6) | 4 | (44.4) | |
| Work time | | | | | | | 0.147 |
| Up until 8 horas | 19 | (70.4) | 14 | (73.7) | 5 | (26.3) | |

Mann-Whitney U test of independent samples
Fonte: Authors (2018)

## 4 DISCUSSION

The use of firewood and charcoal for culinary purposes is used by about 3 billion people in developing countries (LANGBEIN; PETERS; VANCE, 2017). It is known that the combustion of charcoal, firewood, biomass fuel in stoves and open fires emit a substantial amount of carbon monoxide (CHEN; XING; HAN, 2009; VENKATARAMAN; RAO, 2001).

CO is a product of incomplete combustion of organic matter that, when combined with hemoglobin, forms COHb, altering the blood's ability to carry oxygen, resulting in several adverse health effects due to acute intoxication or chronic exposure (BAUER; PANNEN, 2009; CLAYTON *et al.*, 2001).

In the present study, the average levels of COex and COHb by steakhouse workers showed a significant increase ($p<0.05$) after one hour of exposure, reaching a peak of 6.07ppm and 0.97% respectively for COex and COHb in 4 hours of exposure. Although the values increased over the measured exposure time, according to the literature, they were within the normal range (SANTOS *et al.*, 2001; SIQUEIRA *et al.*, 1997).

No other studies were found in which COex was measured before and after exposure directly at the workplace in steakhouse establishments, as well as the time of exposure during workers' hours. In addition, most research evaluates environmental measures for carbon monoxide, nicotine and lung function. Therefore, this study represents the first evidence what compare the levels of CO and COHb on a period of occupational exposure in steakhouses.

A study showed that COex had a stronger association with environmental exposure of CO in 2 hours compared to exposure in the last 4 and 6 hours. This weaker association of COex in the last 4 and 6 hours being due to the half-life of inhaled CO (LAWIN *et al.*, 2017). The half-life of CO is 2 to 6 hours and, therefore, it is understandable that COex may better reflect the most recent exposure in 2 hours, making it a potential marker of acute exposure (UNDERNER; PEIFFER, 2010).

Considering this information and the lack of research that evaluates the exposure to COex over time and not only before and after the exposure, such as the difficulties in measuring it during the work, it was decided to measure this variable in 4 hours at 1-hour intervals.

In the investigation by Al *et al.*, (2009) high levels of COHb (6.5±1.5%) were found in 40 employees of Kebab restaurants in Turkey. Another study was also found that assessed the levels of COHb conducted with 47 Turkish furnace operators, with a mean age of 35.3±3.9 years, with COHb levels of 4.5±1.5% (AL *et al.*, 2012), being higher than the findings of the present study. Both surveys measured COHb levels before and after exposure to the oven, similar results that can be highlighted in a case study conducted with prolonged exposure to CO, which found 4.5% COHb in a 22 year old after 8 hours in contact with the outdoor grill (DIKME; DIKME; TOPACOGLU, 2018).

Although this study investigates individuals exposed to indoor pollutants, the COex and COHb values found are higher than some studies conducted in the same region. Salício *et al.*, (2016) found an average of 2.69ppm of COex and 0.43% of COHb in elderly people who practice physical activity outdoors (external environment), findings that corroborate the study by Santos *et al.*, (2001) who found mean of 2.5±2.1 ppm and 0.43±0.14% in non-smokers and ex-smokers, respectively.

CO levels in the body can be increased by direct inhalation of environmental gases, or by oxidative stress due to exposure to various pollutants (JOHNSON; KOZMA; COLOMBARI, 1999; DAWSON; SNYDER, 1994; WU; WANG, 2005). An important aspect to be taken into account to control other sources of exposure to carbon monoxide that could potentially influence COex and COHb measures was the participation of air-conditioned, ventilated and closed restaurants / steakhouses, that is, the people inside the establishment did not have contact with the external environment (sidewalks/streets). Thus, the high levels of COex and COHb found among the workers in this research can be justified due to the inhalation of the smoke from the barbecue.

The adverse effects of air pollution on human health have been recognized for decades and have shown that, even when pollutants are below the levels determined by legislation, they are capable of causing effects on people's health (MARTINS *et al.*, 2002; MORAES *et al.*, 2010; AMÂNCIO; NASCIMENTO, 2012; GAVINIER; NASCIMENTO, 2014). Recently, kitchen vapors have received greater public attention as an internal and external source of air pollution (WHO, 2019), and according to the World Health Organization (WHO), smoke from fuel during cooking kills about 4,3 million of people around the world each year, more deaths than caused by malaria, tuberculosis and human immunodeficiency viruses (HIV) combined making it one of the most lethal risks to environmental health (WHO, 2016; MARTIN *et al.,* 2011).

Several studies have also linked the influence of exposure to carbon monoxide in various diseases. Quinn *et al*., (2016) found an association between exposure to CO from wood stoves and increased blood pressure in pregnant women. In another study by Blaskievicz *et al*., (2020), it was found that exposure to CO and pollutants originating from the burning of biomass increases the activity of the disease in patients with systemic lupus erythematosus (SLE).

In addition, it is known that the large number of pollutants in kitchens are risk factors for the development of respiratory disorders and lung cancer, and employees of commercial kitchens are a risk group to develop these changes (FERNANDES; STELMACH; ALGRANTI, 2006; KURMI; LAM; AYRES, 2012; TANER; PELEY; PEKEY, 2013; BADYDA *et al*., 2018; WONG *et al*., 2011). Such an issue becomes more important when it is taken into account that they spend an average of six hours a day in this environment ((MAHEMBE; MKOMA; KINAMBO, 2010). Therefore, it is extremely important to develop preventive strategies and measures to promote workers' health in the context of commercial kitchens, seeking an improvement in production processes that make the worker's activity less unhealthy.

Regarding respiratory symptoms, a study conducted in Tanzania, in the East African region, which used a similar respiratory symptoms questionnaire, found that 68.9% of kitchen workers had respiratory symptoms resulting from exposure in this environment. For the authors, different types of fuels used in restaurants increase the risk of respiratory symptoms among workers ((MAHEMBE; MKOMA; KINAMBO, 2010). These results are similar to the present study, which noted that the majority of workers (62%) were also symptomatic. In an attempt to find out the reasons that may also justify the presence of respiratory symptoms in these workers, they were asked about the use of personal protective equipment (PPE). It was noted that 69% of workers reported that they do not use it. The high frequency of respiratory symptoms and the low institutional adherence to preventive measures such as this may influence the symptoms presented and in the future contribute to the appearance of respiratory disorders.

Despite the similarities mentioned above, in this study there were no significant associations between respiratory symptoms and the individual and occupational characteristics of barbecue restaurants workers. Since there were no associations, the high prevalence of symptomatic patients and the changes found in the levels of COex and COHb in workers may be associated with a higher emission of CO from the combustion of charcoal (CHEN; XING; HAN, 2009; VENKATARAMAN; RAO, 2001). The fact that reinforces the possibility of the influence of pollutants on exhaled levels is that the group of workers in this study was composed of active individuals, non-smokers, without changes in lung function previously assessed by spirometry and excluding those who used medicines, with previous illnesses and practitioners of intense physical exercises that could increase endogenous production and favor changes in COex ((SANTOS *et al.*, 2001; JOHNSON; KOZMA; COLOMBARI, 1999).

This study had some limitations, such as the type of sample being of convenience due to the difficulty in obtaining authorization from the owners of the establishments, which limits the possibility of extrapolation to the totality of steakhouse workers. Other limitations were the sample size and the difficulty in carrying out the exams, due to the fact that the individuals are working hours and, therefore, have to stop their activities to participate. Despite the limitations, this study presented itself as an important guide for the health conditions of workers, considering that there are few studies that evaluated professionals in commercial kitchens exposed to smoke from charcoal. In this way, it contributes to the planning of more effective environmental health surveillance actions, minimizing the anthropic impacts and possible risks to the health of these workers.

## 5 CONCLUSIONS

The levels of exhaled carbon monoxide and carboxyhemoblogline in steakhouse workers are elevated in four hours of exposure and there was a high prevalence of reports of respiratory symptoms. Such findings can contribute to planning and surveillance strategies in environmental health, both for minimizing the possible health risks of these workers and for the anthropic impacts resulting from indoor air pollution.

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