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Evaluation of occupational exposure to flour dust and additives in a milling industry

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Abstract

This study aimed to assess an environmental risk in a workstation: the occupational exposure of workers to flour dust, and mixtures of flour dust with additives in the cereal milling industry. The purpose was to understand how exposure to flour dust, and mixtures of flour dust with additives affects the health of workers. In the facilities of the milling company where this study was carried out, there is an area where workers are particularly exposed to flour dust and mixtures of flour dust with additives involved. Therefore, one of the main objectives of this study was to evaluate if these workers were subjected to occupational health hazards during their working hours, due to the contact with suspended flour dust in their workstations, focusing special attention to this area, whenever possible. A sampling of particles suspended in the air was carried out, in order to perform a quantitative analysis. Suction pumps were used, placed on workers, who work in three different workstations, to make a quantitative comparison. An average concentration (a.c.) of 17.27 mg/m^3 was obtained in the workstation of the preparation of mixtures, an a. c. of 1.35 mg/m^3 and one of 2.25 mg/m^3 in the bagging workstation – for plain flour and for added flour, respectively. It was found that all values obtained exceed the Exposure Limit Value proposed by the Standard NP 1796:2014, which presents a value calculated as a weighted average of 0.5 mg/m^3. Mitigation with the use of personal protective equipment (PPE), FFP3 type masks, is enough to protect workers.

1. INTRODUCTION

"The worker has the right to work in conditions that respect his safety and health, ensured by the employer or, in situations identified by the law, by the individual or collective person who manages the facilities in which the activity is carried out" (Portuguese Law No. 3/2014, 2014). It is based on this assumption that this study was developed, focusing on the health and safety conditions of workers in their workstation.

The milling industry is characterized by exposing its workers to various occupational hazards. In this industry it can be found workers exposed to flour dust and mixtures of flour dust with additives, that are suspended in the air of their workstations (Stobnicka & L. Górny, 2015). The adverse effects associated with exposure to flour dust have been known since the1700s (Martinelli, A. & al, 2020). Since then, various research and exposure studies have been conducted to try to better understand the impact of flour dust on the human respiratory system, and its effect on the overall health of workers in the milling and baking industry (Powis, R. K., Bianchi A., 2024). Occupational exposure to particles is an environmental risk that must be measured, controlled, and mitigated whenever possible, especially in an industry where the presence of particles suspended in the air is predominant and exists at all production stages (Stobnicka & L. Górny, 2015).

The bibliography on this topic, which describes the hazards associated with the contact with dangerous agents in the workstation, reveals that in the food sector there are several problems associated with allergies whose source can be molds, bacteria, dust mites, organic grain powders, milk powder or flour contaminated by biological agents. The solution to this situation involves isolating production processes, preventing the formation of aerosols, separating work areas where contamination may occur, adopting appropriate hygiene measures and, finally, correctly using personal protective equipment (Rim & Lim, 2014).

Numerous studies suggest that ill-health responses are indeed more complex than simply reactions to flour dust itself; in addition to flour, enzymes - often used within improvers - and allergens - such as Aspergillus fungi - contribute to respiratory sensitization and symptoms. The risk can be particularly high during the milling process due to the high volume of flour handled and additional risk factors from co-associated biological agents within the raw materials undergoing processing (Powis, R. K., Bianchi A., 2024).

The cereal milling process generates particles that remain suspended in the air and that can come from different processes. The flour that is suspended in the air during bagging, mixing, maintenance and cleaning processes, for example, comes into direct or indirect contact with the worker and can, in certain cases, cause various health problems, from conjunctivitis to serious cases of asthma and problems in the upper respiratory tract. The occupational diseases caused by exposure to dust depend on constitution and concentration of dust, duration of exposure, and variation in personal immunity (Dewangan, K. & Patil M., 2015). The level of exposure is conditioned by the size of the company and its production capacity and varies depending on the exposure time of workers.

1.1 Occupational exposure in the milling industry

Studies reveal that in the cereal milling industry, the observed concentration of total flour reaches more than 400 mg/m^3 in the case of peak exposure analysis (Stobnicka & L. Górny, 2015). In addition to all these problems, there is also a history of occupational diseases associated with contact with flour dust in industries of this type, specifically pneumoconiosis and the existence of workers who acquire chronic asthma. Three groups of workers have an increased risk of adverse health effect appearance when exposed to flour dust: (a) workers with a flour sensitization after repeated exposure to low levels of flour dust, (b) workers with an atopic status or an allergic constitution, (c) workers with pre-existing asthma or those with more general respiratory symptoms. Epidemiological reports have showed that asthma, conjunctivitis, rhinitis and dermal reactions are the major health effects of flour dust exposure. From among these outcomes, baker’s asthma is the most severe and frequent manifestation of occupational allergy (Page, EH. & al, 2010; Skjold T. & al, 2008). The respiratory symptoms are major problems among flour mills workers as the fine flour dust particles are of tiny sizes which can easily enter the respiratory tract of exposed workers, causing irritation in the respiratory tract which is the primary symptom of respiratory disorder. In addition to this, longtime exposure, bad ventilation in the workstation and failure to use personal protective equipment (PPE) increases the possibility of occurrence of respiratory symptoms among mills workers (Elghazally et al., 2023).

The consultation of scientific literature on the subject in question, shows that of the different phases of flour production through cereals, the bagging and the cleaning of the grain were the phases in which the highest concentrations of particles are reached.

Some bagging areas involve the distribution and previous mixing of different substances such as flour with additives. It is in these conditions where the highest concentrations of substances dispersed in the air are reached (Talini, et al., 2002).

This study focused its attention on the workstation were mixing the four with additives and bagging are carried out. Specifically, the purpose was to analyze what the exposure levels would be for a worker who was in daily and permanent contact with these types of substances. The Portuguese Standard 1796 of 2014 describes that the analysis of the risk of exposure to chemical agents associated with the development of professional activities includes the determination of the concentration of those agents in the air, in the workstation. This concentration, when representative of the occupational exposure under study, is compared with reference values that represent exposure thresholds corresponding to acceptable risk levels (NP 1796:2014, 2014).

For these and other reasons that will be discussed throughout this work, it is important to characterize some jobs in the company in question, considering that Moagem Ceres A. de Figueiredo & Irmão S.A. is one of the largest cereal mills in Portugal (Bio-Based Industries Consortium, 2021).

1.2 Different type of particles

The World Health Organization and several organizations such as the American Conference of Governmental Industrial Hygienists (ACGIH), establish the fractions of particles presented below, according to the places of deposition and action in the respiratory system. In this way, the particles are defined as (Pinto, 2012; NP EN 481:2004):

- Inhalable Fraction – fraction of a dust cloud that can be blown and/or inhaled into the nose or mouth.
- Thoracic Fraction – total fraction of inhalable particles that enter into the respiratory system beyond the larynx, reaching the thorax.
- Breathable Fraction – corresponds to the fraction of particles capable of penetrating to the alveolar region

The bibliography consultation shows that the aerodynamic diameter of the flour particles varies between 4 and 30 μm (Stobnicka & L. Górny, 2015), which means that most of the particles discussed in this study are classified as inhalable particles.

1.3 Additives

Some of the additives that are used in the factory are dangerous to health and this knowledge exists because all the additives used are catalogued, thus fulfilling the obligations inherent to the existence of a food management system.

The issue of additives is more chemical than physical. The visualization of safety data sheets and technical data sheets of the additives showed that the particle size is not significantly different from the inhalable fraction. On the other hand, the chemical components that are present in these mixtures are more dangerous.

1.4 Personal protective equipment

The Society for Food Hygiene and Technology assumes that a worker's ears, eyes, and nose require protection. They also describe in their report that handling dusty ingredients such as flour, wearing a face mask will protect the lungs from inhaled dust (The Society of Hygiene and Technology, 2009).

There are several types of protective masks that provide different levels of protection. At European level, the European Standard for Respirators (EN 149:2001+A1:2009, 2009) distinguishes three classes:

- FFP1- minimum filtration efficiency of 80%
- FFP2- minimum filtration efficiency of 94%
- FFP3- minimum filtration efficiency of 99%

1.5 Action Level

According to the Occupational Safety and Health Administration (OSHA) the action level corresponds to half of the weighted average exposure limit value and is the value from which measures to control hazardous atmospheres must be taken (Miguel, 2014). This information is exemplified in Table 1. The action level is a reference that is used to study the severity of occupational exposure in each workstation and, consequently, the hazard associated with a worker's occupational health. It was one of the parameters evaluated after analysing the samplings from the workstations in the industry in question.

Table 1. Action level exposure limit values (TLVs) and weighted average (WA) (Miguel, 2014)

Action Level	Action Level for Flour Dust (2001)	Measures
$\frac{\text{Concentration}}{\text{TLV} - \text{WA}} < 0,5$	$\text{Concentration} < 0,25\ \text{mg/m}^3$	The existing situation does not cause significant risks for workers.
$0,5 < \frac{\text{Concentration}}{\text{TLV} - \text{WA}} < 1$	$0,25\ \text{mg/m}^3 < \text{Concentration} < 0,5\ \text{mg/m}^3$	The existing situation may cause occupational exposure risks to workers in the work area. Periodic medical control of these workers is recommended.
$\frac{\text{Concentration}}{\text{TLV} - \text{WA}} > 1$	$\text{Concentration} > 0,5\ \text{mg/m}^3$	The existing situation is risky. Regular medical control of exposed workers should be carried out, as well as the adoption of organizational measures to obtain: Concentration<0.5

1.6 Regulatory Framework

The most important normative document in Portugal, with regard to exposure to dust in the workstation, is the Portuguese Standard NP 1796 of 2014. This standard establishes exposure limit values and biological exposure indices for harmful substances in the air of workstations, expressed either in mg/m^3 or in ppm. It is a practical standard that allows the comparison of concentration values measured through sampling in workstations with a legal basis. It will be referred throughout this study, as it will be used as a term of comparison against the results that will be obtained in the sampling that was carried out. Those reference values, designated in this Standard as "exposure limit values", are established for each identified chemical agent and constitute risk criteria, within the scope of risk assessment of exposure to chemical agents (NP 1796:2014, 2014). This Standard adopts as Exposure Limit Values, like other EU Member States, the exposure limit values (TLVs) proposed by the American Conference of Governmental Industrial Hygienists (ACGIH). ACGIH publishes these values annually. The maximum exposure limit value for flours/dusts is 0.5 mg/m^3. It is calculated on a weighted average basis, i.e., for an 8 h working day and a 40 h/week.

2. METHODOLOGY

Monitoring is an excellent tool for ongoing exposure performance assessment. Properly applied should drive ongoing commitment towards continuous improvement (Powis, R. K., Bianchi A., 2024). To perform this quantitative analysis, it was necessary to carry out a sampling of particulate material, consisting of a mixture of flour with additives, in specific workstations. It was also analysed the relationship between the concentration of particles from a workstation where only flour was suspended in the air to another workstation where there was a mixture of flour with additives. An occupational hygiene consultancy in Canada carried out a shift sampling with the purpose of collecting total or inhalable dust in bakeries where flour dust is predominant. Only the inhalable fraction of dust was collected using a sampling pump with a flow rate of 2 L/min and a polyvinyl chloride (PVC) filter. The analysis was performed by an American industry and a laboratory accredited by the "Hygiene Association" (Aidoo, et al., 2018).

The total lung capacity of a human being with a normal breathing cycle can vary from 4 to 6 L/min, an amount well above what is proposed by the norm (Kreider, 2010). Individuals in exertion have a greater need for air well above the mentioned value, which in extreme cases can reach 110 L/min. For this reason, it can be said that on average an individual in 8 hours of work collects 2,800 liters of air and can achieve gas exchanges of air in the lungs of up to 50,000 liters (Tecnitel, 2019).

It is important that, with the main objective of simulating the normal breathing conditions of industrial workers, the maximum suction flow of the pump is imposed, in relation to that established by the method. The NIOSH 0500:1994 was the method that was performed, as in the study of A. Zamani et al. (2021). According to the NIOSH 0500 method, a 37-mm polystyrene closed face cassette (SKC, USA) with a pre-weight 5-μm pore size PVC filter (SKC, USA) was used with a flow rate of 2 L/min (Zamani a. et al., 2021). t is a non-specific method and determines the total dust concentration to which a worker is exposed using gravimetry as the main technique (NIOSH (NMAM), Fourth Edition, 1994). The sampling strategy adopted was based on NIOSH 0500:1994, with area/static samples being collected, a suitable methodology when workers are mostly static, working in the same location. As the method imposes a sampling flow of 2 L/min and a maximum volume of 133 L of sample, the sampling time is 67 minutes maximum. The sampling moments were decided depending on the activities of each worker in the three different sectors. The number of samples to be collected was extremely important, as it was related to the confidence placed in the estimated value of the concentration of a contaminant (Miguel, 2014). Consequently, three samples were carried out in each location, on different days.

2.1. Sampling location

The decision on sampling workstations is consistent with the articles referred in the introduction to this study, which assumes that the workstations where flour is bagged, mixed, and transported are the ones where there is a greater probability of having a higher concentration of particles in the air (Talini, et al., 2002). The chosen sampling workstations are presented in Figure 1.

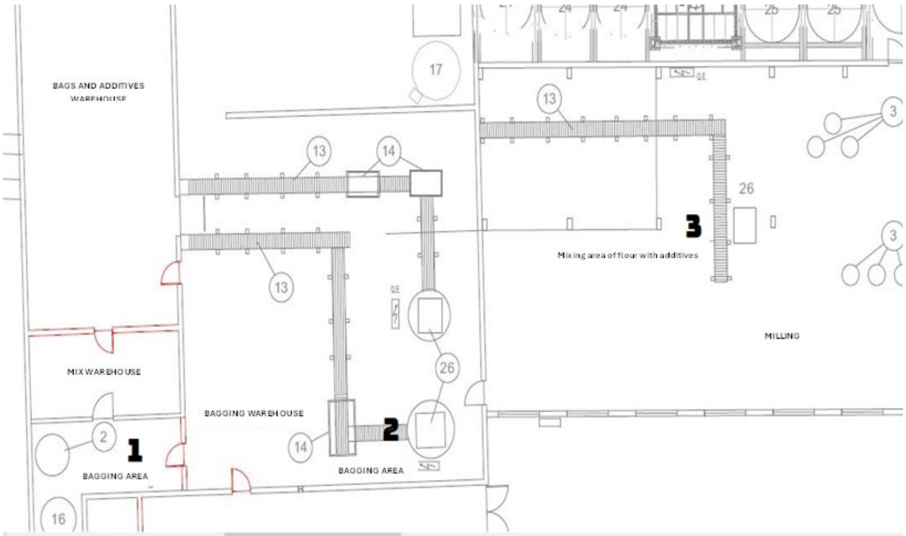

Figure 1. Sampling workstations

The sampled workstations correspond to two flour bagging areas (1 and 2) and a mixing area of flour with additives (3). They are all located on the ground floor of the factory, separated by solid walls, and mixing of suspended particles from the three sampled workstations is not expected to occur. Dust sampling was all taken simultaneously for each worker. Finally, the 8-h time-weighted average of exposure to flour dust was calculated as milligrams/cubic meter (Eller P., Cassinelli, M., 1994).

3. RESULTS AND DISCUSSION

Table 2, Table 3 and Table 4 show the results of the measurements of the particles suspended in the air. From its analysis it is possible to conclude that the results of the calculations indicate situations of risk of exposure of workers to agents with a potential to produce sensitization through the respiratory tract, since the limit of 0.5 mg/m^3 described in the NP 1796:2014 is exceeded in all sampled workstations. However, a deeper analysis can be carried out based on the definition of TLV-MC (exposure limit value - maximum concentration), that is, the concentration that should never be exceeded during any period of exposure. Consequently, according to NP 1796:2024 (NP 1796:2014, 2014), for substances whose limit value is expressed by a weighted daily average, concentration fluctuations above the average must not exceed 3 times the TLV-WA in more than 30 minutes in total per working day and must never exceed 5 times the TLV-WA.

In these circumstances, the values obtained in the evaluations carried out should be between 1.5mg/m^3 (3xTLV-WA) and 2.5mg/m^3 (5xTLV-WA), a situation that occurs with the average concentrations presented in Table 3 and Table 4, whose values are within these limits.

Regarding the workstation where the flour and additives are mixed, the value obtained was 17.27 mg/m^3, with an exposure time of 2 hours. This fact makes the analysis of this location more complex and requires special attention.

Table 2. Data and results of the measured concentration in the mixing of flour with additives workstation

Filter	Exposure Time (h)	Concentration (mg/m^3)	Average Concentration (mg/m^3)	TLV NP1796:2014 (mg/m^3)	FFP1 Masks (mg/m^3)	FFP2 Masks (mg/m^3)	FFP3 Masks (mg/m^3)
15/22	2	14.39	**17.27**	0.5	2	6	25
16/22	2	2.33					
17/22	2	5.15					
18/22	2	47.20					

Table 3. Data and results of the concentration measured in the bagging workstation for industrial uses - Simple Flour

Filter	Exposure Time (h)	Concentration (mg/m^3)	Average Concentration (mg/m^3)	TLV NP1796:2014 (mg/m^3)	FFP1 Masks (mg/m^3)	FFP2 Masks (mg/m^3)	FFP3 Masks (mg/m^3)
09/22	7	0.59	**1.35**	0.5	2	6	25
10/22	7	1.16					
11/22	7	2.30					

Table 4. Data and results of the concentration measured in the bagging workstation for industrial uses - Additive Flour

Filter	Exposure Time (h)	Concentration (mg/m^3)	Average Concentration (mg/m^3)	TLV NP1796:2014 (mg/m^3)	FFP1 Masks (mg/m^3)	FFP2 Masks (mg/m^3)	FFP3 Masks (mg/m^3)
12/22	7	1.30	**2.25**	0.5	2	6	25
13/22	7	4.19					
14/22	7	1.24					

Legal compliance with sampling workstations is not met, since the analysis should have been carried out without taking into account the attenuation percentage related to the use of personal protective equipment. However, workers use them for their own protection, and, for this reason, it was possible to understand whether the PPE used are sufficient to prevent greater consequences on the workers' occupational health.

Given the special needs of some workstations, the selection of PPE must be viewed with special attention. To choose the appropriate respiratory protective equipment, it is necessary to consider several factors, such as the type of contaminant present in the work environment, its concentration, exposure time and the individual characteristics of the worker, such as the shape of the face and the presence of a beard. In this sense, the respiratory protection factor becomes a fundamental concept when it comes to ensuring the safety and health of workers exposed to respiratory risks in the workstation. This is an indicator that measures the efficiency of respiratory protective equipment (PPE) in filtering harmful particles present in the air in the workstation. The analysis carried out in Tables 2-4 considered the nominal protection factor (NPF), a value attributed to PPE according to its filtering capacity. The NPF is determined through laboratory tests that simulate real-use conditions, considering factors such as the size of the filtered particles and the efficiency of the respirator. Given the circumstances of the workstation – four with additive mixing area, the protection factor to be applied should be the Work Protection Factor (WPF), since it is more restrictive and applied to more specific and higher risk situations. This is a protection factor obtained through sealing tests carried out with the PPE in use. These tests evaluate the efficiency of the equipment in sealing the user's face and ensuring that there are no leaks of contaminated air into the mask (Almeida Teresa et al., 2016; NP EN 529:2008,2008).

4.1 Comparison with the Portuguese standard NP 1796:2014

Although NP 1796:2014 presents TLV, to compare with personal sampling, in this study the sampling carried out was static, to characterize a given workstation.

This situation is taken into consideration when comparing the values obtained with the respective TLV.

Focusing on Table 2, it is possible to verify that an average concentration value of this workstation was 17.27 mg/m^3. Food additives that are dispersed in the air do not have the same settling rate as flour particles and are therefore subject to being easily inhaled by workers. The importance of characterizing this workstation is related to the fact that there is a large dispersion of dust, whether particles of flour, or particles from additives. The discussion of these results must be carried out carefully, since anyone who does not know the task performed could make the mistake of eliminating one of the concentration values found, because they are quite different from each other. The reality is that while the additives are being handled and mixed with the flour to make different food references, the dispersion of particles in the air is large and workers find themselves in situations where the concentrations of particles present in the air can be considered concentration peaks. Food additives that are dispersed in the air do not have the same sedimentation speed as flour particles and are therefore subject to being easily inhaled by workers. The importance of characterizing this workstation is because there is a large dispersion of dust, whether flour or additive particles.

The reality is that these substances come into direct contact with workers who mix them, a fact that is proven by the high concentration measured for total dust.

In Table 3, it is possible to verify that an average concentration value of this workstation was 1.35 mg/m^3. As this sampling area is a bagging workstation with the same particles suspended in the air during the sampling time, it is expected that the calculated concentration will be identical between the sampling days. The task may change depending on the number of packages damaged during the bagging task.

In Table 4, it is possible to verify that an average concentration value of this workstation was 2.25 mg/m^3. This sampling area, in addition to being a flour bagging workstation, is the place where the flour mixed with additives is bagged. Therefore, different levels of dispersion are present in the air. In addition to that, the bagging mouth is not suitable for the quantities of packages that are bagged, which causes a higher concentration of flour dust in the air.

Comparing the two bagging workstations, it appears that the assumptions were correct, i.e., the place where the flour mixed with additives is bagged has higher concentration values, than the workstations where the plain flour is bagged.

4.2 Mitigation of the use of personal protective equipment

The use of personal protective equipment, such as dust masks respirators, is crucial for minimizing flour dust exposure (Enitan, S., & al, 2023).

Through Table 2, it is possible to conclude that the use of FFP3 masks, if properly applied, can protect the workers in working environments with concentrations of flour and dust up to 25 mg/m^3. This means that, considering the average concentration calculated, the worker is protected from contact with the referenced contaminant.

Through Table 3, it is possible to conclude that the use of any of the three types of masks presented, FFP1, FFP2 and FFP3, if properly applied, can protect the workers in working environments with concentrations of flour and dust up to 2 mg/m^3, 6 mg/m^3 and 25 mg/m^3, respectively, which means that, taking into account the calculated average concentration, the workers are protected from contact with the referenced contaminant.

Finally, through Table 4, it is possible to conclude that the use of the two types of masks presented, FFP2 and FFP3, if properly applied, can protect the workers in working environments with concentrations of flour and dust up to 6 mg/m^3 and 25 mg/m^3, respectively, which means that, considering the calculated average concentration, the workers are protected against contact with the referenced contaminant.

4.3 Action Level

The greater the difference between the calculated mean concentration and the TLV, the greater the urgency to carry out measures to reduce this concentration in the different sampling workstations. Occupational health and safety rules dictate that the implementation of a respiratory protection program consistent with the existing risks is recommended (CCOHS, 2018). For this reason, if the company were to adopt a working plan whose main purpose was to reduce the concentration of particles suspended in the air, according to the calculated action level, it should start at the flour with additive mixing workstation, followed by the workstation where this mixture is bagged, and ending at the simple flour bagging workstation.

In accordance with OSHA and the general principles of prevention provided by the Portuguese legislation (Law no. 102/2009), the legal Regime for the Promotion of Safety and Health at Work and respective updates, the employer must ensure that the risks to the safety and health of workers resulting from the presence of dangerous chemical agents on site are eliminated or reduced to a minimum.

Some measures that should be adopted according to this specific sequence are presented below:

- Apply collective protection measures at the source of release, namely adequate extraction (reinforcement).
- Adopt appropriate organizational measures (limit exposure time, reduce the number of exposed workers), such as studying and determining the maximum exposure time allowed for each task, to ensure that TLV-WA is not exceeded.
- If it is not possible to avoid exposure through the measures indicated above, adopt individual protection measures for workers (mandatory and adequate use of the FFP3 mask in use).
- Ensure periodic health surveillance for exposed workers.
- Inform, train, and coach workers regarding risk assessment, appropriate preventive measures and measures for workers to protect themselves at the workstations.

4. CONCLUSIONS

It is concluded that the total dust present in the cereal milling industry is a serious occupational problem within the scope of industrial hygiene and must be treated with the urgency it deserves by the employers. This problem is not national, it is transversal to the whole world and is present in all workstations where there are organic particles of flour suspended in the air, as it can be concluded from some of the reports mentioned above (Talini, et al., 2002) (Said, AbdelFattah, & Almawardi, 2017). In fact, the bibliography consulted corroborates the conclusions drawn from this study. Flour mill workers in Sohag Governorate, like grain workers elsewhere, were at an increased risk of developing pulmonary symptoms, a strong association exists between exposure to flour dust and the prevalence of respiratory symptoms and functional impairments of the lungs (Mohammadien H., & al, 2013). On this study, the sampling shows that at the workstation of mixing flour with additives the concentration of total dust can reach up to 47.20 mg/m^3, a value well above the legal limit.

Inhalable particles are the predominant type of particles in the cereal processing industry. The Portuguese standard NP 1796:2014 recommends sampling the inhalable fraction in flour and dust and such information is described in several scientific articles. However, the consultation of the additive safety data sheets, the sampling process and the bibliography showed that food additives, in mixing areas, can be characterized as thoracic and even breathable dust fractions, assuming themselves as dangerous particles for workers both, physically as well as chemically (Stobnicka & L. Górny, 2015).

It can be concluded that the main purpose of this study was accomplished. It was possible to understand how exposure to dust flour, and mixtures of dust flour with additives affects the health of workers and whether, currently, these workers are at risk in occupational health related to their working activity.

The results of the evaluation carried out indicate situations of risk workers' exposure to agents with the potential to produce sensitization through the respiratory route, so the employer must adopt, as soon as possible, adequate prevention and protection measures. The employer adopted some protection measures for its workers. Nevertheless, since they were not adopted in accordance with the proposed prevention sequence, they could not effectively protect workers from the environmental risk to which they are exposed. The use of FFP3 masks is sufficient to filter the described chemical agents. However, safeguard through coaching, information, and periodic surveillance of the health of exposed workers, that the use of a mask, is essential so that the consequences of occupational diseases do not become evident later.

Through this study, the company became aware that it must take preventive measures immediately to eliminate, or significantly reduce the environmental risk that workers are exposed to in their workstations.

The characterization of suspended dust in the cereal milling industry in Portugal has not been widely studied, and the consequences of exposure to dust by workers are not well known or studied.

In the bibliographical research carried out for this study, several case studies were found, where the main theme was occupational exposure to flour dust. The sampling and discussion of the results, on the other hand, showed that the working conditions, in the milling industry in Portugal, are not that different from those in other countries. In some workstations sampled, the concentration of particles suspended in the air is considered serious and could become an occupational health problem. Therefore, it must be mitigated.

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