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Green coffee been exposure and symptoms in dock workers in Trieste (Italy)

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Summary

Background: *Green coffee workers can develop allergic symptoms due to green coffee beans (GCB) or to castor bean (CB) that can contaminate sacks used for the transportation. Data are limited in literature and a previous study performed in Trieste demonstrated allergic symptoms in 14.3% of dockworkers handling GCB.* **Objectives:** *To evaluate symptoms and exposure to GCB ultrafine particles in Trieste dockworkers.* **Methods:** *Workers involved in GCB sacks transportation, storage and opening were asked to fill out a questionnaire on allergic respiratory symptoms. They performed a spirometry test and an evaluation of NO exhaled breath condensate. Inhalable and respirable dust exposures were evaluated by means of personal and environmental pumps. Ultrafine particles exposure was evaluated by means of portable particles counter DISCMini.* **Results:** *Between the 40 dockworkers exposed to GCB, 28 participated in the study (70%). Five (17.9%) reported personal allergy symptoms and two workers (7.1%) reported allergic oculorhinitis during work. One subject had symptoms only with Tanzania sacks and he resulted sensitized to CB. Workplace dust evaluation demonstrated values below Threshold Limit Values, but some work tasks were associated with exposure to more than 40,000 ultrafine particles with a geometric mean size of 37.2±1.35 nm.* **Conclusions:** *Prevalence of allergic symptoms in GCB workers was low but the presence of peaks of ultrafine particles exposure suggests the need to protect workers from exposure, limiting powder dispersion, avoiding the unloading of sacks inside the container and suggesting personal protective equipment regular use (FFP3).*

Riassunto

«Esposizione a caffè verde e sintomi nei lavoratori del porto di Trieste (Italia)». **Introduzione:** *I lavoratori del caffè possono sviluppare sintomi allergici a causa degli allergeni presenti nei chicchi di caffè verde (GCB) oppure sensibilizzazioni al ricino (CB) che può contaminare i sacchi per il trasporto. I dati presenti in letteratura sono pochi ed uno studio precedentemente condotto a Trieste ha riportato sintomi allergici nel 14,3% dei lavoratori portuali che movimentavano caffè crudo.* **Obiettivi:** *Valutare i sintomi e l'esposizione a particelle ultrafini di caffè verde nei lavoratori del porto di Trieste.* **Metodi:** *Ai lavoratori che operano nel trasporto e stoccaggio del caffè è stato chiesto di compilare un questionario riguardante i sintomi allergici e di sottoporsi ad una spirometria e al dosaggio dell'ossido nitrico esalato (FeNO). Le polveri inalabili e respirabili sono state misurate tramite campionamento ambientale e personale su filtro. L'esposizione a particelle ultrafini invece è stata valutata con campionatore portatile (DiSCMini).*

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Risultati: *Tra i 40 lavoratori esposti al caffè verde, 28 hanno partecipato allo studio (70%). Cinque soggetti (17,9%) hanno riportato sintomi allergici personali e due (7,1%) hanno riferito oculoriniti allergiche durante il lavoro. Uno dei due soggetti accusava sintomi solamente lavorando con sacchi provenienti dalla Tanzania, ed è risultato positivo al ricino. I campionamenti di polveri hanno dimostrato che le concentrazioni rientrano entro i TLV previsti dall'ACGIH. Tuttavia in alcune fasi di lavoro sono state riscontrate concentrazioni di polveri ultrafini superiori alle 40.000 particelle/cm^3, con una un diametro medio di 37,2±1,35 nm.* **Conclusioni:** *La prevalenza di sintomi allergici nei lavoratori del caffè verde è risultata bassa, ma la presenza di picchi di esposizione alle particelle ultrafini suggerisce il bisogno di proteggere i lavoratori da questa esposizione, limitando la dispersione di polveri, evitando lo scarico dei sacchi dall'interno dei container e prevendendo l'uso regolare dei dispositivi di protezione individuale FFP3.*

Introduction

Respiratory symptoms in coffee workers have been linked to allergies for the first time between the 1950s and 1960s. Respiratory symptoms were believed to be caused by a sensitization to green coffee bean (GCB) or to castor bean (CB) which contaminated the jute bags, reused for GCB (4, 6, 17). From 1970 onwards bags were mainly used for the transport of coffee (9) although they may still be used ubiquitously.

GCB contains allergens responsible for Ig-E mediate allergic reactions that can cause symptoms in 7-40% of exposed workers (6, 17, 22). Several studies report a significant correlation between sensitization to GCB and chronic and allergic respiratory symptoms (3, 4, 9, 16, 19, 20, 23-25), in particular asthma, oculorhinitis, rash and cough, which may manifest themselves more or less seriously, depending on exposure and individual characteristics. GCB and CB prevalence of sensitization are wide in different studies, ranging between 4.6% and 15% for GCB, and between 2.7 and 16.7% for CB. Table 1 reports available data on GCB workers from 1979 onwards.

Recent studies (10, 18) have identified the proteins responsible for allergic reactions called *Cof a 1, Cof a 2* and *Cof a 3*. However, the study by Peters et al. (18) showed that the current diagnostic tests are not sensitive enough to detect all sensitizations in exposed workers.

Exposure to GCB can occur in dock workers that handle sacks containing GCB (4), during the opening of the sacks or in workers employed in coffee manufacturing factories (9). In 1988, we studied GCB sensitization and symptoms in Trieste dockworkers finding 4.6% and 9.6% of sensitization to GCB and CB, respectively, and 14.3% of workers with work-related allergic symptoms (4). During the last 20 years, working conditions have improved due to a partial automation of the sacks storage and opening.

With the aim to verify the effectiveness of prevention measures adopted, we studied occupational related allergic symptoms and exposure to GCB in a group of dockworkers. The characterization of exposure included respirable and inhalable powders count and the measurement of ultrafine particles count and size, produced during different work tasks. *Ultrafine particles* are the fraction of particulates between 1 and 100 nm involuntarily produced by other processes (6). The presence of ultrafine particles, could lead to a possible increase of coffee dust penetration in the lung with possible onset of diseases (7).

Methods

We developed a questionnaire, derived from the ECRHS II [European Community Respiratory Health Survey] *Lung Function Test Questionnaire* and the *Recommended Respiratory Disease Questionnaires for Use with Adults and Children in Epidemiological Research* of the American Thoracic Society. (1, 5) Our questionnaire collected data on physical features of the worker (age, height, weight), his work history (years of working with green coffee, hours of working per week, and previous jobs); allergic symp-

Table 1 - Sensitization to Green Coffee Bean (GCB) and Castor bean (CB) and occupational related allergic symptoms in workers exposed to GCB reported in literature

Year of publication	Author	Workplaces	Number of workes	Positive to GCB		Positive to CB		Symptomatic workers
1979	Zuskin E et al. (25)	Packaging and roasting	103			-		Asthma, rhinitis, dyspnea: 3.9-33%
1981	Zuskin E et al. (24)	Roasting process	45	11	24.0%	-	-	Rhinitis, asthma, dyspnea: 9-40%
1988	De Zotti R et al. (4)	Docks	218	10	4.6%	21	9.6%	Asthma, oculorhinitis: 14.3%
1991	Thomas KE et. al (20)	Coffee manufacturing plant	197	28	14.2%	29	14.7%	Rhinitis, cough, dyspnea: 12.7%
1995	Romano C et al. (19)	Coffee manufacturing plant	211	32	15.0%	47	22.0%	Oculorhinitis, asthma: 25.6%
1998	Larese F et al. (9)	Coffee manufacturing plant	112	7	6.3%	3	2.7%	Asthma, oculorhinitis: 20%
2009	Oldenburg M et al. (16)	Haulage company, silo, decaffeinating company	60	3	5.0%	10	16.7%	Oculorhinitis, rash: 25-53%

toms, characteristics and onset (during the whole year, in spring, at work), lifestyle (smoking, chronic bronchitis symptoms, pre-existing pathologic conditions and/or drug use) and history of allergies in family. The questionnaire was administered to the workers directly at the workplace. A group of workers, on a voluntary basis, underwent a spirometry using a portable spirometer Minispir Italy (MIR Medical International Research S.r.l. - Roma Italy) following guidelines suggested by the American Thoracic Society (12). Nitric oxide exhaled breath condensate (FeNO) was assessed using an electrochemistry-based NIOX MINO device (Aerocrine AB, Solna, Sweden), fitted with a NIOX MINO 300 sensor pre-calibrated from the manufacturer in 2016. The measurements were performed in accordance with the ATS/ERS guidelines (2).

Symptomatic subjects underwent a skin prick test with common allergens and GCB extracts (Lofarma-Milano). Test was read after 20 minutes according to guidelines and positive reactions were defined with a wheal reaction ≥3 mm. An informed consent was signed.

Dust sampling for total and respirable dusts, during the discharge of coffee beans in the silos, were performed using environmental and personal samples (Zambelli, Milano), connected to 35 mm Millipore closed-faced filter cassettes with cellulose filters of 0.8 μm pore size, conditioned at 20°C and humidity 50% in the chamber Activa "Climatic" Aquaria Srl, following the European Standard EN12341 (11/1998), UNICHIM 285 (2003) and NIOSH suggestions (15).

In the same day ultrafine dusts measurements were conducted using a Diffusion Size Classifier miniature DiSCmini (Matter Aerosol AG, Wohlen, CH), a handheld sensor for the measurement of nanoparticles number and average diameter with a time resolution of up to 1 second (1 Hz) and a size range from 10 to 300 nm. This instrument permits a quick and reliable evaluation of nanoparticles in the area (11, 21). The measurements were performed near the workers, in the breathing zone, to simulate personal exposure. The measurements included four stages of 15 minutes each (figure 1): background; at the beginning, in the middle and at the bottom

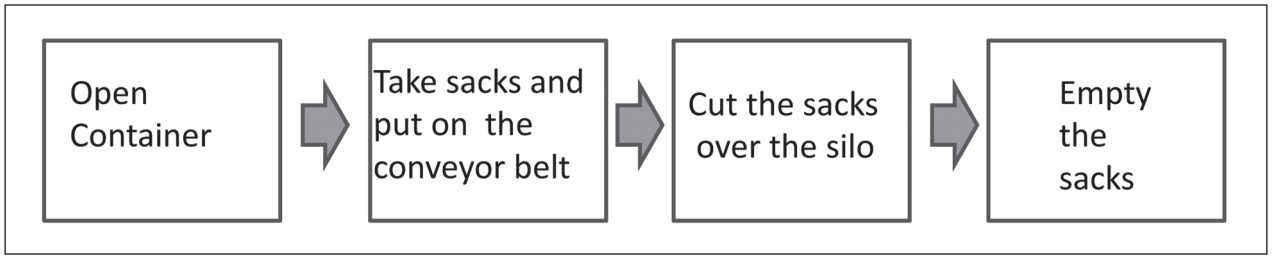

Figure 1 - Work process lay out

of the container and at the emptying of coffee bags in the silo (during which 140 coffee sacks were opened). The dock area is dedicated to coffee sacks transportation using a conveyor belt and is far from traffic, nevertheless background measures identified the presence of nano particulates as result of environmental exposure.

Data were analyzed using the statistical software STATA (Rel. 17, Texas - USA). Continuous data were summarized as means and standard deviation (SD) or as geometric mean and geometric SD according to data distribution. The difference between means was tested by Student's t test or by non-parametric tests. Categorical data were analyzed by the likelihood χ^2 techniques. For all statistical analyses, a 0.05 level of significance was used, and all p values were two sided.

Results

Symptoms

The port of Trieste hosts different types of employment and 40 dockworkers handle green coffee. Between them, 28 questionnaires (70%) were filled in and returned to us. The characteristic of our population is reported in table 2. Thirty-five per cent of workers are smokers (same as the city percentage). The mean age is under 50 years, with a mean work seniority of 22 years. Five workers (17.9%) reported personal allergy symptoms, not related to GCB exposure and generally associated with atopy. Two workers (7.1%) reported allergic symptoms during work. One subject reported oculorhinitis and shortness of breath handling only Tanzania GCBs; he resulted sensitized to CB but not to GCB by skin prick test. We prescribed to him the avoidance of exposure to Tanzania sacks. The other worker, who reported only mild rhinitis, refused to underdo skin prick test.

Of those 28 workers, only 11 accepted to perform a spirometry and an exhaled Nitric Oxide (FeNO) measurement for the evaluation of airways inflammation. None of them reported symptoms during work, all have normal lung function with values above the 100% of predicted, FeNO values were normal except for 2 cases with values above the 25 ppb, that is considered the limit value for normal lung. This group reported a higher percentage of common allergic symptoms and of familiar atopy compared to the questionnaire group ($p<0.05$).

Dust and nanoparticles exposure

Total and respiratory dust exposure during different work tasks are reported in table 3. Dust concentration was very low in silos and higher in containers, but below suggested limits.

Ultrafine particles monitoring is reported in figure 1 and in table 4 compared to background

The number of particles increased as a function of different work tasks with a corresponding reduction in their size. Ultrafine particles are significantly higher inside the container and during the emptying of the sacks, lower in the middle of the container and similar to background at the door of the container, as a result of natural ventilation.

The peaks during the *opening and emptying of the sacks* (figure 2) correspond to the unloading of seven pallets of sacks in the plant; the different heights of the peaks are probably due to the different countries of origin of the product and the bags them-

Table 2 - General characteristics of the population of workers exposed to green coffee/Caratteristiche della popolazione di lavoratori esposta a caffè verde

	Questionnaire	Lung function
Number of workers	28	11
Mean age (SD); median years	48 (±8); 44	46 (±4); 42
Mean work seniority (SD); median years	22 (±11); 18	25 (±6); 23
Mean hours of work per week (SD), median	39 (±7); 39	40 (±2); 39
Allergy in family N. (%)	3 (10.7)	2 (18.2)*
Personal allergy N. (%)	5 (17.9)	3 (27.3)*
- asthma or wheezing N. (%)	2 (7.1)	2 (18.2)
- oculorhinitis N. (%)	4 (14.3)	3 (27.3)
- rash N. (%)	1 (3.6)	0
Cough N. (%)	4 (14.3)	2 (18.2)
Phlegm N. (%)	4 (14.3)	4 (36.4)
Work-related symptoms N. (%)	2 (7.1)	0
- asthma or wheezing N. (%)	1 (3.6)	-
- oculorhinitis N. (%)	2 (7.1)	-
- rash (N. %)	1 (3.6)	-
- cough N. (%)	1 (3.6)	-
- phlegm N. (%)	1 (3.6)	-
Chronic bronchitis N. (%)	4 (14.3)	1 (9.1)
Current smokers N. (%)	10 (35.7)	3 (27.3)
Mean FeNO (SD) ppb	-	16 (±9)
FeNO >25ppb N. (%)	-	2 (18.2)
Mean Vital capacity % (SD)	-	107 (±11)
Mean FEV1%* (SD)	-	107 (±11)
Mean FEV25-75**% (SD.)	-	107 (±17)

*FEV1 = Forced expiratory volume in 1 second
** FEV 25-75% = Forced expiratory volume 25-75% percentiles

Table 3 - Total and respirable dust exposure during different work tasks (TLV/TWA 2012 10 mg/m^3 for total powders; 3 mg/m^3 for respirable powders)

Filter	Silo (env)	Silo (env)	Silo (env)	Silo (env)	Container (pers)	Container (pers)
Size	Total	Total	Resp	Resp	Total	Resp
Flow rate (l/min)	2	2	2.5	2.5	2	2.5
Time (min)	147	101	147	107	127	105
Volume (l)	294	202	367.5	267.5	254	262.5
Dust concentration (mg/m^3)	0.533	0.262	0	0	2.337	1.347

RESP=respirable, Env=environment, Pers=personal

selves, which influenced (also visibly) the quantity and quality of dust. The same phenomenon occurred during the handling of sacks in the container and the peaks correspond to the dropping of bags from the highest file to the conveyor belt, while the displacement of the bag from the lowest file did not produce dust, and therefore did not generate a significant increase in the number of measured particles.

Discussion

Exposure to green coffee can lead to the onset of allergic symptoms (asthma, rhino conjunctivitis, rash) in 3.9 to 40% of workers (3, 4, 9, 16, 19, 20). In our study, we found that 2 workers (7%) exposed to GCB reported symptoms caused by allergic sensitization. Out of the two workers with work related

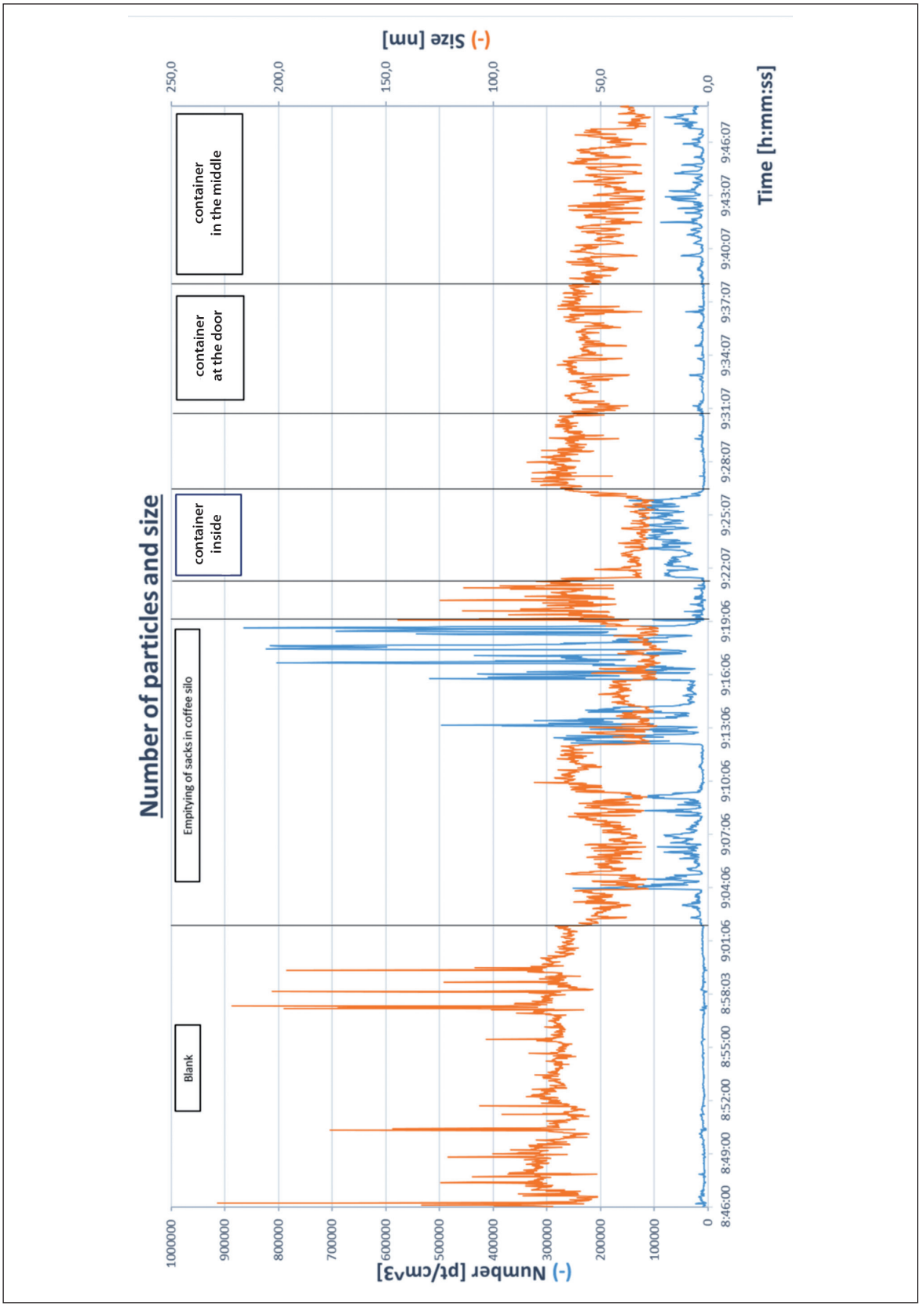

Figure 2 - Number of particles and size during different work tasks compared to background

Table 4 - Ultrafine particles monitoring during different work tasks. Values are compared to background/ Monitoraggio delle polveri ultrafini durante varie mansioni. I valori sono comparati con quelli di fondo

	Geometric average	Geometric St.dev.	Median	Min	Max
Background					
particles/cm^3	8653.30	1.26	8716	2285	22662
size (nm)	73.71	1.18	71.60	51.50	228.50
Container (at the door)					
particles/cm^3	10309.11	2.45	9644	7023	41339
size (nm)	57.19	1.36	68.60	31	70.10
Container (in the middle)					
particles/cm^3	18512.54*	1.71	16620	7763	88788
size (nm)	45.79	1.23	47.80	26.90	66
Container (inside)					
particles/cm^3	45022.24*	2.44	63801	6001	146541
size (nm)	37.27	1.35	33.10	25.10	82.30
Silo (emptying sacks)					
particles/cm^3	39268.37*	3.13	29975	7072	864326
size (nm)	42.48	1.35	42.50	22.10	144.50

*$p<0.05$ compared to background values

symptoms, one was sensitized to CB, which can contaminate the jute bags (17), but resulted negative to GCB. The second worker did not want to undergo the suggested tests.

Our group is characterized by high seniority of work and low prevalence of personal allergy (17.9%), so we can speculate a "healthy worker effect". Seniority of work and allergic symptoms are higher in the group that underwent lung function examinations: 27.3% of subjects reported some allergic diseases, but no one reported work-related symptoms. In this group lung function tests were normal and FeNO values were over the limit only in 2 atopic workers. Moen et al. (13) found higher values of FeNO in workers exposed to GCBs with a correlation with number of years worked in contact with green coffee. In our study, we did not find any correlation with FeNO and work seniority. However, additional factors can affect the concentration of exhaled nitric oxide and smoking habit decreases FeNo values.

In our study, occupational related symptoms prevalence is lower compared to previous reports (table 1), probably due to the general improvement of working conditions and the consequent reduction of airborne dust. Indeed, older studies reported higher concentrations of total and respirable dusts: Thomas et. al (20) measured, while unloading a container, 3.2 mg/m^3 of inhalable dust and 0.25 mg/m^3 of respirable dust; Oldenburg et al. (16) detected levels above 10 mg/m^3 at different stages of the production cycle.

The results of our environmental and personal dust sampling showed that the limits established by the ACGIH for common dusts are fully respected and that the concentration of dusts in the workplace are low, but with a significant increase inside the container. Moreover, occupational exposure limits for aerosol allergens need to be settled considering the intrinsic properties of specific allergens (14), because the respect of TLV-TWA for dusts is not enough to protect workers from sensitization. For wheat flour dust, a similar high weight allergen, ACGIH TLV-TWA is 0.5 mg/m^3 for inhalable dust: considering this limit, the exposure into the container is more than 2 times higher, thou this exposure could increase the risk to develop sensitizations and symptoms in exposed workers.

We found that the fraction of ultrafine particles represents a significant component of airborne dusts. Nanoparticles can enter more easily into airways, probably causing respiratory diseases (7), but we have no data on similar exposure in other green coffee workers.

Considering occupational exposure limits suggested for exposure to "generic" nanoparticles, IFA (8) suggested that dusts from biopersistent materials with a density higher than 6000 kg/m^3 should not exceed a concentration of 20,000 particles/cm^3 and dusts from biopersistent materials with a density of less than 6000 kg/m^3 should not exceed a concentration of 40,000 particles/cm^3.

Although these limits are not directly applicable to our case, we can make a few comments on the fact that in the entrance of the coffee silo we found average values very close to the limit and, inside the container, average values exceeded the limit. Despite the full respect of TLV (Threshold Limit Value) for respirable and inhalable dust, the large presence of ultrafine particles poses a possible risk for the onset of allergies to GCB. Anyway their role in this specific context must be scaled back in light of the very few symptoms reported by workers.

Moreover, it is interesting to observe the changes in the concentrations of airborne dusts depending on the type of bag and coffee species: this aspect can be relevant to explain the sensitization to CB reported by a worker, probably caused by the mixed use of jute bags for GCB and CB in certain countries of origin (i.e.: Tanzania).

Despite the evidence reported by scientific literature, there were just two workers who reported work-related symptoms. This result can be linked to several factors: 1. dust concentrations were quite low and workers did not develop sensitization to coffee allergens; 2. the questionnaire was not administered to every exposed but to the 70%; 3. The *healthy worker effect*, for which sensitized workers left the job to avoid exposure and the onset of symptoms at work.

In conclusion, companies, whose workers handle green coffee beans, have to provide information and training on allergic risk, reminding them to undergo medical examinations in case of work related symptoms. Moreover, a set-up of an automatic system to move sacks outside the container or at least better ventilation during the unloading inside the container is needed. Finally, the use of FFP3 respirators must be compulsory during the work with exposure to GCB powders.

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