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Health Risks Due to Coffee Dust

Marcus Oldenburg, MD; Cordula Bittner, MD; and Xaver Baur, MD

Objective: This study assessed current health risks due to occupational exposure to coffee dust. **Methods:** We performed a cross-sectional study in a coffee haulage company (n = 24), a coffee silo (n = 19), and a decaffeinating company (n = 17). Cross-shift and cross-week case histories of these employees as well as lung function values were recorded. During the handling of green coffee, measurements of airborne dust were conducted.

Results: The employees in these workplaces were mainly affected by erythematous and rhinoconjunctival symptoms. They occurred especially in subjects exposed to a high dust load (> 10 mg of inhalable dust per cubic meter of air; n = 28) [Pearson χ^2 test, p = 0.020 and p = 0.023]. IgE antibodies to green coffee and castor beans were detected in 3 workers and 10 workers, respectively. The majority of them (two employees and six employees, respectively) had shown respiratory symptoms during the past 12 months. The preshift lung function values were below average but were not dependent on the level of the inhalable coffee dust exposure. Employees with a coffee dust load > 10 mg/m³ of air showed higher unspecific bronchial responsiveness more frequently than those with lower exposures.

Conclusion: During the transshipment (especially during unloading) of green coffee, a high and clinically relevant exposure to irritative and sensitizing dust occurs. Therefore, efforts to reduce these dust exposures are generally recommended. (CHEST 2009; 136:536–544)

Abbreviations: CI = confidence interval; FEV₁/FVC% = FEV₁/FVC percentage; kUA = kilounits; OR = odds ratio; PD₂₀ = applied dose of methacholine inducing a 20% drop in FEV₁; PM = particulate matter

Coffee is a favorite beverage of millions of people. Only the two coffee species Arabica and Robusta are of economic importance. Coffee cherries are harvested up to twice a year and collected in jute bags. After emptying the bags, the cores, the so-called green coffee beans, are removed from the pulp of the coffee cherries. These beans are shipped worldwide, mainly in big bags inside 20-ton contain-

ers. During the transport and refinement of the green coffee in ports, exposures to irritative and sensitizing dust occur.¹

A high frequency of asthmatic diseases among workers of a green coffee processing factory was already observed in the 1950s.¹ It was also described that roasted coffee may be implicated in occupational asthma due to heat-resistant allergens.² In addition to coffee, castor beans were also regarded as a cause of asthma.³ Castor beans have a wide variety of uses. Among others, they are used in lamps, in laxatives, and as a fertilizer. In the countries of origin, the plantations of castor and coffee beans frequently border each other, and the harvested beans are transported by the same ship. Castor beans are thought to be an accidental contaminant of green coffee beans because some coffee bags may have been used previously for the transportation of castor beans or stored in contaminated ship containers.^{3–6}

Nowadays, green coffee stored in big containers is imported by ships and transported by trucks of

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specialized haulage companies to coffee-processing factories (eg, coffee silos or decaffeinating companies). The drivers of the haulage companies unload the coffee at tilting stations. In coffee silos, the coffee is roughly purged and placed in the silos for interim storage on call. In decaffeinating companies, the green coffee is impacted by steam after a rough cleaning and decaffeinated by chemical treatment. Afterward, the coffee is dried and polished. The aim of our study was to determine whether the exposure to coffee dust during loading and processing under the presently improved hygienic conditions (eg, use of effective exhaust systems during discharge) still represents a health hazard to employees.

MATERIALS AND METHODS

We performed an occupational medical cross-sectional study in a haulage company mainly dealing with the transport of coffee, in a coffee silo, and in a decaffeinating company. Willing participants were 24, 19, and 17 exclusively male subjects (82.8%, 100%, and 100%, respectively). All employees of the three investigated companies were personally informed about the study by the management and the company physician. Furthermore, a separate meeting was held to explain the objective of our investigation. The participation in this study was absolutely voluntary. All participants gave their informed consent, and the authors received institutional review board approval for the study.

We performed three investigations in each of the three companies: at the beginning of the shift on Monday morning, at the end of that shift, and on the following Friday noon. Each time the focus was on exposure-related symptoms, and a spirometry, including measurements of bronchial responsiveness by means of methacholine testing, was conducted. Preceding the investigation on Monday morning was a period of at least 1.5 days without exposure to coffee dust (median, 65.6 h [range, 38 to 744 h]).

Inhalative Dust Exposure During the Handling of Green Coffee

To assess the airborne level of alveolar or inhalable dust (particles with an aerodynamic diameter [particulate matter (PM)] $<2.5\ \mu\text{m}$ [$\text{PM}_{2.5}$] and $10\ \mu\text{m}$ [PM_{10}]) during the handling of coffee, air measurements were performed using the sampling system of the Institute for Occupational Health and Safety, St. Augustin, Germany (Project-No. BIA 1061).⁷ Dust measurements were conducted with a glass fiber filter, type MN 85/90, by maintaining an airflow rate of $0.6\ \text{m}^3/\text{h}$ or $0.21\ \text{m}^3/\text{h}$ for the inhalable or alveolar dust fraction (according to EN 481), respectively.⁸ During five different working shifts, 12 personal and stationary gravimetric air measurements of the alveolar or inhalable coffee dust were conducted over several hours.

The measurements were task related and therefore not completely identical with the prescribed procedure in order to obtain the shift-related mean value. In Germany, the general threshold limit value of dust is $3\ \text{mg}/\text{m}^3$ for the alveolar fraction and $10\ \text{mg}/\text{m}^3$ for the inhalable fraction. If these limits are maintained, no increased health risk is expected in the case of nonsensitizing agents (Technical Regulation for Hazardous Goods 900).

The employees at the tilting stations were presumably highly exposed to coffee dust. To evaluate the health effects of green

coffee, these workers (all employees of the haulage company and four employees of the coffee silo; $n = 28$) were allotted to the "higher dust-exposed group" ($> 10\ \text{mg}$ of inhalable dust per cubic meter of air) and the remaining ones to the "lower dust-exposed group" ($\leq 10\ \text{mg}/\text{m}^3$; $n = 32$).

Measurements of the Airborne Exposure to Germs

Air measurements of germs were performed in the decaffeinating company to roughly assess the level of germs during the handling of organic raw coffee. Sedimentation plates were installed in several company areas for 30 min and agar specifically incubated. To determine the total number of germs and the mold concentration, Caso and DG-18 agars were used.

Furthermore, the impaction method RCS Plus using the serial devices of the Biotest Company (St. Georgen, Germany) were applied for the quantitative determination of airborne germ concentrations. To measure the total germ count and the mold concentration, the TC-18 and DG-18 bands were applied with airflows of 100 L and 200 L, respectively. The colonies of bacteria and molds were counted, and the number of colony forming units were determined.

Questionnaire

The standardized interview included questions of demographic data as well as airway and skin symptoms. The questions regarding symptoms were mostly identical to those of the German National Health Interview and Examination Survey 1997/98 (BGS 98).⁹ Moreover, specific occupational parameters were recorded. In addition to the preshift questionnaire, we used a postshift and a postweek questionnaire focusing the subjects' complaints in the course of time (see Online Data Supplement).

Asthma was defined in patients with current asthma medication use and asthma attacks during the past 12 months. Furthermore, work-exacerbated asthma was defined in cases of chest tightness, wheezing, cough, and shortness of breath during the exposure to coffee dust. Chronic bronchitis was diagnosed if coughing and phlegm occurred for a minimum of 3 months per year and for not less than 2 successive years.¹⁰

Serologic Parameters

The blood of 59 coffee workers was sampled for IgE determination. Total IgE and specific IgE to green coffee beans (comprising *Coffea arabica*, *Coffea canephora/robusta*, and *Coffea liberica*) and to castor beans were measured by fluorescent enzyme immunoassay (UniCAP; Phadia; Freiburg, Germany). To investigate immunologic cross-reactivity between coffee and castor beans, $100\ \mu\text{L}$ of the castor bean IgE-positive serum were incubated with $50\ \mu\text{L}$ of green coffee solution (4 mg Robusta coffee protein per milliliter) overnight at 4°C . UniCAP subsequently measured the IgE binding to castor bean allergens. Specific IgE levels above the threshold of 0.35 kilounits (kUA) per liter of serum (CAP class 1)¹¹ were interpreted as sensitization according to the recommendation of the manufacturer.

Lung Function Analysis

During the three investigations just described, lung function measurements were conducted in a sitting position by using a nose clip. Lung function measurements with a portable spirometer (MasterScope 4.5; Jaeger; Wuerzburg, Germany) were performed by a trained technician in the company offices. Forced expiratory spirometry were performed for the whole study

population (n = 60) according to the recommendations of the American Thoracic Society.^{12,13} For assessment, the reference values by Brändli et al^{14,15} were used. They assumed¹⁴ an obstructive ventilation pattern when FEV₁/FVC percentage (FEV₁/FVC%) was lower than the limit for normal.

A methacholine challenge using the Pari Provocation Test (Pari Company; Starnberg, Germany) with spirometric measurements was conducted during each investigation.¹⁶ The applied dose of methacholine inducing a 20% drop in FEV₁ (PD₂₀) was calculated by linear interpolation or extrapolation up to 2,000 µg of methacholine.¹⁶ Bronchial hyperresponsiveness was diagnosed when PD₂₀ was < 300 µg of methacholine (inhaled cumulative dose).¹⁷ Acute cross-shift changes in pulmonary function (Δ lung function parameter) were expressed for each subject as a percentage of the value before exposure.¹⁶

Statistical Analysis

Data were analyzed using statistical software (SPSS for Windows, version 13.0; SPSS GmbH Software; Munich, Germany). Continuous data were expressed as mean ± SD and in case of nonnormal distribution as median (minimum to maximum). For the nonparametric group of metric/ordinal values, the Mann-Whitney test and the Kruskal-Wallis test were performed. The Pearson χ² test determined the frequency differences between the two groups. The provided p values were two sided, and an α value of < 0.05 was regarded as statistically significant.

To analyze exposure-response relationships between exposure and obstructive ventilation patterns, the logistic regression with or without adjusting for the potential confounding variable smoking status (nonsmoker, former smoker, and smoker) was conducted. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were estimated.

RESULTS

Dust Exposure During the Handling of Coffee

Haulage Company: We performed dust measurements in the ambient air of three representative tilting stations and found a high inhalable coffee dust

concentration during unloading (> 10 mg inhalable dust per cubic millimeter of air) [Table 1].

Coffee Silo: The inhalative dust load during discharge was equal to the exposure of truck drivers at tilting stations. High dust concentrations occurred during the operation of silo systems. The cleaning staff performed activities in different locations. The duration was similar to that in the two other working areas studied. Therefore, the average dust load during coffee unloading and system operation in the silo was calculated to estimate the exposure of these employees (Table 1).

Decaffeinating Company: The inhalative exposure during coffee discharge mostly performed by chain trough conveyors was distinctly lower than that of truck drivers and silo workers at the tilting stations. In the working area of system operators, foremen, and cleaning personnel, only low dust concentrations were measurable on account of the shielded conveyor systems (Table 1).

The measured concentrations of germs and molds ranged from 114 to 1,279 cfu/m³ and from 108 to 325 cfu/m³, respectively. Measurements of the total number of bacteria in the atmosphere exclusively showed Gram-positive normal germs occurring in the environment (especially *Bacillus* spp). Measurements of molds revealed *Cladosporium* spp, *Aspergillus niger*, and *Penicillium* spp. The total mold concentrations in reference areas were distinctly higher than on system tracks exposed to coffee dust.

Demographic Data and Clinical Symptoms

The demographic data on employees of the haulage company, silo, and decaffeinating company were

Table 1—Measuring Results of Personal Coffee Dust Concentrations in the Air During Different Activities in Investigated Companies

Variables	Dust Concentration, mg/m ³		Employees		
	Alveolar	Inhalable	Haulage Company (n = 24)	Coffee Silo (n = 19)	Decaffeinating Company (n = 17)
Coffee discharge					
At tilting station	1.38	11.65 (10.1–15.7)	24	4	3*
By chain trough conveyors		3.80 (2.6–4.0)			
System operation					
Coffee silo	0.85 (0.3–1.35)	7.05 (3.7–10.3)		7	
Decaffeinating company		1.60 (1.3–1.9)			7
Activities in several areas (cleaning staff, foremen)					
Coffee silo	1.12†	9.35†		8	
Decaffeinating company		0.70 (< 0.2–1.1)			7

Data are presented as the median (minimum-maximum) or No.

*Twenty percent of the coffee discharge at tilting stations and 80% by chain trough conveyors.

†Mean value of dust concentrations during coffee discharge and system operation in silo.

Table 2—Demographic Data and Level of Anamnestically Recorded Coffee Dust Exposure in the Investigated Companies

Variables	Haulage Company (n = 24)	Coffee Silo (n = 19)	Decaffeinating Company (n = 17)	p Value*
Participation rate, %	82.8	100	100	
Age, yr	40.4 (7.7)	39.6 (10.5)	44.5 (10.3)	0.202
Smoking status, No. (% of company)				
Nonsmokers	2 (8.3)	7 (36.8)	2 (11.8)	
Former smokers	6 (25.0)	4 (21.1)	6 (35.3)	
Smokers	16 (66.7)	8 (42.1)	9 (52.9)	
Pack-years, No.	28.4 (17.0)	17.6 (9.1)	21.9 (11.3)	0.116
Period without coffee exposure before Monday morning examination, h	77 (58–727)	63 (38–233)	66 (63–744)	< 0.001†
Coffee dust exposure (according to anamnestical data)				
Current, h/d	3 (1–8)	6 (0.5–8)	5 (0–8)	0.086
Cumulative, yr	10.7 (0.5–32)	11.8 (0.5–35)	17.3 (4–34)	0.074

Data are presented as mean (SD) or median (minimum–maximum) unless otherwise indicated.

*Kruskal-Wallis test.

†Indicates significant findings.

not significantly different (Table 2). On the basis of these anamnestic data, we placed the employees according to the exposure median in categories with current and cumulative exposure to low and high dust levels (Table 2). Compared to employees with lower dust exposure, an increase of symptoms, lung functional impairments, or allergologic findings was not observed in employees with anamnestically higher current or cumulative dust exposure.

The total group reported that Arabica coffee triggers symptoms twice as often as Robusta coffee (18 times vs 9 times). In particular, the coffee of Brazil-

ian origin was reported to elicit complaints. The participants exhibited mainly erythematous and rhinoconjunctival symptoms during the past 12 months (Fig 1). Employees with currently higher dust exposure ($> 10 \text{ mg/m}^3$) complained more frequently than those with currently lower dust exposure about erythematous (42.9% vs 15.6%, respectively; Pearson χ^2 test, $p = 0.020$), conjunctival (53.6% vs 25.0%, respectively; $p = 0.023$), and sneezing (35.7% vs 25.0%, respectively; $p = 0.366$) symptoms during the past 12 months.

According to the questionnaire, symptoms of the lower airways in the sense of asthmatic complaints

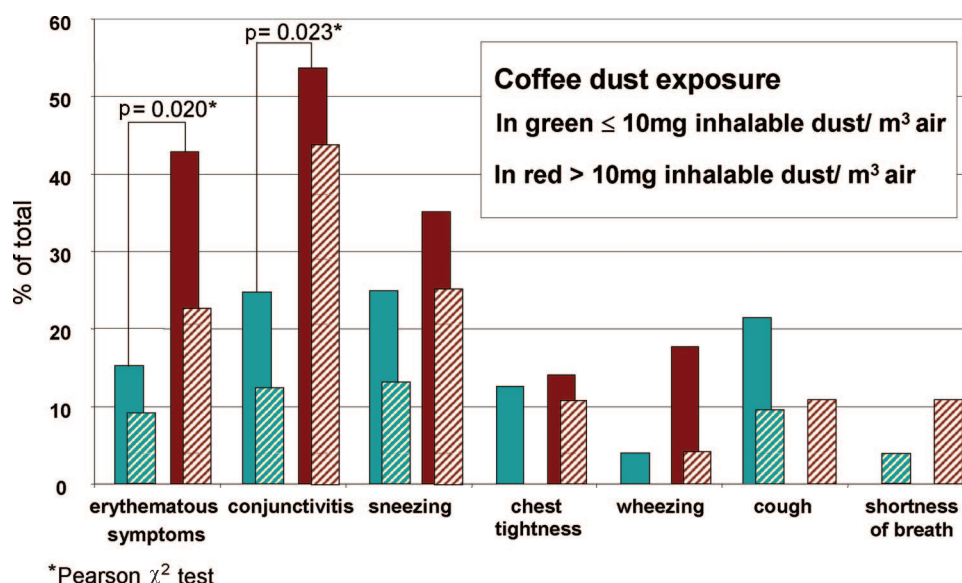


FIGURE 1. Prevalence (%) of symptoms during the past 12 mo among employees with coffee dust exposure $\leq 10 \text{ mg/m}^3$ and $> 10 \text{ mg/m}^3$ inhalable dust ($n = 32$ and $n = 28$, respectively); work-related symptoms are shown as hatched columns.

occurred more rarely, however. Because none of the investigated employees took any antiasthmatic medication or had suffered from an asthma attack during the past 12 months, no participant was regarded as having asthma. Thus, based on our questionnaire, there was no evidence for preemployment asthma in the study sample. During the period of exposure to coffee dust, work-exacerbated asthma (increase in chest tightness, wheezing, cough, and shortness of breath) developed in two subjects. Both subjects had a currently higher exposure to inhalable coffee dust. Furthermore, these two subjects showed IgE antibodies to green coffee and castor beans but no obstructive ventilation pattern; one employee exhibited bronchial hyperresponsiveness.

The diagnostic criteria of chronic bronchitis were fulfilled in three employees. All of them were non-smokers and had a currently lower coffee dust exposure. These three subjects had no obstructive ventilation pattern (risk group 0 according to the Global Initiative for Chronic Obstructive Lung Disease criteria of COPD).¹⁸ Work-related erythema and conjunctivitis during the past 12 months were more often observed in employees exposed to $> 10 \text{ mg/m}^3$ than to $\leq 10 \text{ mg/m}^3$ (erythematous symptoms, 22.2% vs 9.4%, respectively [$p = 0.172$]; conjunctivitis, 42.9% vs 12.5%, respectively [$p = 0.008$]).

Postshift and postweek increases of work-related symptoms were mainly found in workers with a coffee dust exposure $> 10 \text{ mg/m}^3$ (erythematous symptoms, 21.4% vs 0%, respectively [$p = 0.006$]; conjunctivitis, 25.0% vs 6.3%, respectively [$p = 0.090$]; sneezing, 17.9% vs 15.6%, respectively [$p = 0.631$]; chest tightness, 14.8% vs 3.1%, respectively [$p = 0.140$]; wheezing, 7.1% vs 0%, respectively [$p = 0.165$]; cough, 17.9% vs 9.4%, respectively [$p = 0.335$]). The same exposure-dependent increase of work-related symptoms was observed in the postweek examination.

Lung Function Parameters

Due to the respiratory complaints of five employees, their methacholine challenge testing was not possible at the end of the week. The lung function comparison of the smoker group ($n = 33$) with that of the total group ($n = 60$) did not reveal noticeable differences. Therefore, we evaluated the lung function findings independent of the employees' smoking status.

With regard to lung function parameters of the total group, the average percentage deviations from reference mean values by Brändli et al¹⁴ of FVC, FEV₁, and FEV₁/FVC% were 94.5%, 93.6%, and 96.0%, respectively, indicating slight lung function impairments. Seven employees showed an obstructive ventilation pattern (FEV₁/FVC $<$ FEV₁/FVC% lower limit of normal) before the Monday shift (two

workers and five workers with a dust exposure $\leq 10 \text{ mg/m}^3$ and $> 10 \text{ mg/m}^3$); three were smokers, and four were former smokers. The pack-year history of these seven people did not differ from those of the other smokers/former smokers (showing normal lung function) of the total group (mean, 25.6 pack-years vs 23.5 pack-years; Mann-Whitney test, $p = 0.841$). No significant association between obstructive lung function impairment and dust exposure level ($\leq 10 \text{ mg/m}^3$ vs $> 10 \text{ mg/m}^3$ air) was found. Among the seven employees with obstructive ventilation patterns, five were assigned to risk group 1 and two to risk group 2 according to the Global Initiative for Chronic Obstructive Lung Disease criteria of COPD.¹⁸

On Monday before the shift, lung function was independent of the exposure level of inhalable coffee dust (Table 3). Results of the preshift methacholine challenge on Monday showed that workers with coffee dust exposure $> 10 \text{ mg/m}^3$ had bronchial hyperresponsiveness significantly more often (25.0% vs 6.3%). Postshift and postweek measurements also revealed bronchial hyperresponsiveness more frequently in workers with higher work-related dust concentrations. Therefore, in the three investigations we calculated a significantly lower effective PD₂₀ for employees with a dust concentration $> 10 \text{ mg/m}^3$. Based on the anamnestic data about the period of coffee dust exposure (in years), no association between cumulative dust exposure and lung function impairment was found (Fig 2).

The prevalence of postweek bronchial hyperresponsiveness ($n = 10$) was associated with dust exposure level (OR, 5.47; 95% CI, 1.04 to 28.74). After adjusting for smoking status (nonsmoker, former smoker, and smoker), this relationship remained significant (OR, 5.31; 95% CI, 1.01 to 28.01), and the smoking status did not reach statistical significance (OR, 1.33; 95% CI, 0.42 to 4.26). Thus, no major effect of smoking on bronchial hyperresponsiveness in employees was observed in this study.

In the total group ($n = 60$), the cross-shift course of lung function values revealed an average change in FEV₁, FEV₁/FVC%, and FVC of -0.8% , -2.2% , and $+0.7\%$, respectively. The lung function comparison before the shift with that at the end of the week showed a slightly stronger lung function impairment in the postweek measurement (-2.5% , -2.1% , and -0.4% , respectively).

In the course of the week, the subjects with preshift bronchial hyperresponsiveness demonstrated work-related symptoms significantly more often than the rest of the group (chest tightness, 22.2% vs 6.0%, respectively [$p = 0.014$]; wheezing, 12.5% vs 4.2%, respectively [$p > 0.05$]; cough, 44.4% vs 7.8%, respectively [$p = 0.003$]; erythematous symptoms, 37.5% vs 4.2%, respectively [$p = 0.002$]; conjunctivitis,

Table 3—Lung Function Findings of Examined Employees (n = 60) Depending on Inhalable Coffee Dust Exposure

Variables	Coffee Dust Exposure (Inhalable Fraction)		p Value
	≤ 10 mg/m ³ (n = 32)	> 10 mg/m ³ (n = 28)	
Preshift measurement (Monday)			
FEV ₁ , L	3.9 (0.7)	4.0 (0.6)	0.876*
FEV ₁ /FVC%	75.5 (6.7)	75.8 (6.0)	0.801*
FVC, L	4.9 (0.7)	5.3 (0.8)	0.073*
FEV ₁ , % predicted	95.4 (13.4)	91.4 (10.8)	0.110*
FEV ₁ /FVC%, % predicted	96.2 (7.3)	95.9 (7.8)	0.988*
FVC, % predicted	93.9 (8.8)	95.2 (12.8)	0.778*
Positive BHR, No. (% of exposure group)	2 (6.3)	7 (25.0)	0.042†‡
PD ₂₀ , mg	2 (0–2)	1.5 (0–2)	0.013*†
Postshift measurement (Monday)			
Positive BHR, No. (% of exposure group)	4 (12.5)	7 (25.0)	0.212‡
PD ₂₀ , mg	2 (0.1–2)	1.2 (0–2)	0.029*†
Postweek measurement (Friday)§			
Positive BHR, No. (% of exposure group)	2 (7.1)	8 (29.6)	0.031†‡
PD ₂₀ , mg	2 (0–2)	2 (0–2)	0.020*†
Postshift vs preshift findings, %			
ΔFEV ₁	−1.4 (−15.7–18.1)	1.1 (−11.9–37.6)	0.133*
ΔFEV ₁ /FVC%	−2.1 (−17.4–9.1)	−2.8 (−21.3–18.7)	0.859*
ΔFVC	1.9 (−10.3–27.5)	0.3 (−25.1–59.1)	0.830*
Postweek§ vs preshift findings, %			
ΔFEV ₁	−3.9 (−100.0–18.9)	1.4 (−11.9–41.0)	0.033*†
ΔFEV ₁ /FVC%	−3.5 (−100.0–18.4)	0 (−14.0–19.2)	0.039*†
ΔFVC	−2.1 (−100.0–10.0)	2.2 (−22.1–38.5)	0.218*

Data are presented as mean (SD) or median (minimum-maximum). BHR = bronchial hyperresponsiveness.

*Mann-Whitney test.

†Indicates significant findings.

‡Pearson χ^2 test.

§Five employees did not undergo bronchial hyperresponsiveness test due to respiratory complaints.

25.0% vs 20.8%, respectively [$p > 0.05$]; sneezing, 50.0% vs 16.7%, respectively [$p < 0.033$]). The seven subjects with obstructive ventilation patterns did not notice work-related airway symptoms. This may be due to a good adaptation to their lung function limitation.

Allergologic Findings

IgE antibodies to green coffee and castor beans were detectable in three workers and six workers

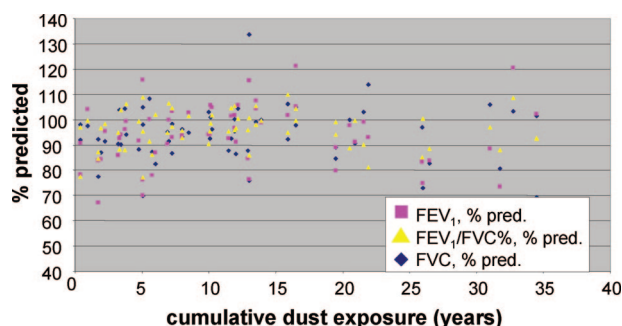


FIGURE 2. Baseline lung function of all employees independent of the number of years of cumulative coffee dust exposure.

with an inhalable coffee dust exposure $> 10 \text{ mg/m}^3$ (Table 4). The three employees with IgE antibodies to coffee beans also demonstrated IgE antibodies to castor beans. Also, four subjects with a coffee dust load $\leq 10 \text{ mg/m}^3$ revealed IgE antibodies to castor beans. Elevated total IgE ($> 100 \text{ kUA/L}$) occurred 20 times in the total group independent of the level of the subjects' average coffee dust load.

Two workers and six workers with IgE antibodies to green coffee and castor beans, respectively, had respiratory symptoms during the past 12 months. In total, no association between specific/total IgE and work-related symptoms during the past 12 months was found. UniCAP inhibition assays with coffee extracts did not suppress the IgE binding to castor beans.

DISCUSSION

This study shows that high exposures to inhalable dust ($> 10 \text{ mg/m}^3$) occur during the handling of green coffee. We observed great differences between the haulage company, coffee silo, and decaffeinating company. Concentrations of the alveolar

Table 4—Allergologic Findings of Examined Employees (n = 59) Depending on Fraction of Inhalable Coffee Dust Exposure*

Variables	Coffee Dust $\leq 10 \text{ mg/m}^3$ (n = 32)		Coffee Dust $> 10 \text{ mg/m}^3$ (n = 27)	
	Exposure Group, No. (%)	Respiratory Symptoms, No.†	Exposure Group No. (%)	Respiratory Symptoms, No.†
Total IgE				
< 100 kUA/L	21 (65.6)	9	18 (66.7)	8
$\geq 100 \text{ kUA/L}$	11 (34.4)	5	9 (33.3)	5
Specific IgE				
Green coffee beans				
CAP class < 1	32 (100)	14	24 (88.9)	11
CAP class ≥ 1	0	0	3 (11.1)	2
Castor beans				
CAP class < 1	28 (87.5)	11	21 (77.8)	10
CAP class ≥ 1	4 (12.5)	3	6 (22.2)	3

*One subject rejected blood sampling.

†Sneezing, chest tightness, wheezing, and/or shortness of breath during the past 12 mo.

dust fraction $> 3 \text{ mg/m}^3$ were not detectable, however. High exposures to inhalable dust were especially found during the discharge of green coffee at tilting stations. The containers with green coffee were unloaded without protective equipment in a relatively short period of time (30 to 45 min). The alternative coffee discharge via chain trough conveyor required more time (45 to 60 min) but resulted in a distinctly lower dust load due to the uniform and optimal velocity. The described transshipment of green coffee represents the current standard. An optimization of the coffee unloading process, such as the use of chain trough conveyors, is generally recommended. Engineering controls and personal respiratory equipment might be effective preventive measures. So far, they have not been realized, however.

The microbial ambient air measurements during the handling of coffee did not reveal an extraordinary concentration of bacteria or molds. Therefore, a noticeable influence on lung function caused by microorganism is unlikely.

Green coffee elicits sensitizing as well as irritative effects. According to the literature, coffee dust exposures primarily result in asthmatic symptoms and rhinoconjunctival complaints.^{19–25} The subjects of our study with an exposure $> 10 \text{ mg/m}^3$ air showed significantly more frequent erythematous and rhinoconjunctival symptoms in the first examination as well as in the cross-shift and cross-week course. Considering our measurements of higher concentrations of the inhalable dust fraction in some investigated areas, these coffee workers are generally at a higher risk for irritant-induced symptoms of different organs such as erythema and conjunctivitis.

The predominance of upper airway symptoms in this study could be due to the high exposure to inhalable but not to the alveolar dust fraction. Our

questionnaire revealed manifest symptoms of the lower airways during coffee dust exposure in only two subjects. Both had a currently higher exposure to inhalable coffee dust and IgE antibodies to green coffee and castor beans. One employee showed bronchial hyperresponsiveness consistent with the beginning of work-exacerbated allergic asthma. In addition, one-third of the examined employees of both subgroups ($\leq 10 \text{ mg/m}^3$ and $> 10 \text{ mg/m}^3$) had increased total IgE levels, indicating an immunologic stimulation.

Our study group reported work-related symptoms to occur twice as often by Arabica than by Robusta coffee. This indicates that the Arabica species, regarded as a high-grade and pure coffee, constitutes a higher health hazard than the qualitatively lower Robusta coffee. To our knowledge, this study describes work-related symptoms due to different coffee species for the first time.

Lung function parameters of examined workers were, on the average, below reference mean values. Jones et al²⁶ had already described lower mean FEV₁ values in men exposed to green coffee dust. This is surprising because the working population is expected to have supranormal values. In this study, however, no long-term effect of coffee dust exposure on lung function was observed. All three investigations showed bronchial hyperresponsiveness to be significantly related to the dust exposure level; this relationship remained significant after adjusting for smoking status. Thus a major effect of smoking on the employees' bronchial hyperresponsiveness is unlikely.

The reason why the spirometry improved slightly in the high exposure group at the end of the week cannot be explained definitively. This may indicate a work-organizational effect because in contrast to the employees with coffee dust exposure $\leq 10 \text{ mg/m}^3$,

those workers with high exposure (especially the truck drivers unloading the coffee at the tilting stations) had shorter assignments in these coffee dust areas on Friday and thereby the opportunity to compensate for their overtime worked.

Due to respiratory complaints, the methacholine challenge test with five subjects could not be performed on Friday. This indicates that the dust load had impaired their lung function so that the risk of bronchial hyperresponsiveness on Friday might have been underestimated. Zuskin et al²⁷ showed that the inhalation of green coffee extracts can lead to an obstructive ventilation pattern in healthy subjects.

According to several, mostly older studies, the frequency of sensitization to green coffee beans is between 20% and 25% in coffee workers.^{4,5,27,28} Osterman et al⁶ found a level > 50%. In our study, however, specific IgE antibodies to green coffee beans were only detectable in three workers (5%). All of them were exposed to > 10 mg/m³. In recent years, coffee producers have started using new burlap or plastic bags and/or specific containers that considerably reduce the risk of castor bean contamination of green coffee beans.²⁰ Furthermore, the use of dust exhaust systems during the coffee unloading process in some of the investigated tilting stations improved the hygiene. This may explain the relatively low prevalence of sensitization to coffee dust in our study in comparison with former investigations.

Our examination showed 10 subjects (17%) had IgE antibodies to castor beans. Four of them had a low coffee dust exposure (≤ 10 mg/m³). Inhibition test results of antibody-allergen reactions indicate that the identified castor bean sensitization cannot be explained by a cross-reactivity with coffee. The causative source of the castor bean allergens in imported green coffee has not yet been finally explained (castor beans were never transported or handled by the examined employees).⁶

A limitation of this study is its relatively small sample size, so it cannot be excluded that some findings might be accidental. The participation rate of the coffee dust exposed workers, however, was extraordinarily high and constituted a representative sample of each coffee company. Furthermore, in spite of the low number of examined employees, we observed statistically significant differences between workers with currently higher and lower coffee dust exposure. These differences not only covered bronchial hyperresponsiveness but were consistently also true of work-exacerbated clinical symptoms among bronchial hyperresponsive subjects. Thus, the exposure-related bronchial hyperresponsiveness was associated with a higher frequency of work-related respiratory symptoms.

In summary, our results demonstrate a significantly higher prevalence of erythematous and conjunctival symptoms as well as bronchial hyperresponsiveness among employees with a higher coffee dust exposure than in those with a lower one (> 10 mg/m³ vs ≤ 10 mg/m³).

In addition to the known sensitizing potential, irritative effects of green coffee dust appear to be important pathogenetically. Thus, coffee bean dust still represents a health hazard to employees, so the improvement of hygienic conditions (*ie*, further optimization of exhaust systems) is recommended.

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Health Risks Due to Coffee Dust

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Questionnaire on the *pre-shift exposure level* to coffee dust

DUST EXPOSURE: *The following questions concern your current and previous occupational activities*

1 What is the area you are currently assigned to in the company? _____

2 Since when have you had contact with coffee dust? since /
month year

3 When was your last contact with coffee dust? hours ago

4 Are there any special coffee species eliciting health problems? ☐ Yes ☐ No

If yes, 4,1 ☐ which coffee species (Arabica/ Robusta)? _____

4,2 ☐ which country of origin? _____

SYMPTOMS: *In the following, we ask about health problems during the past 12 months*

5 Have you had any erythematous symptoms during the past 12 months? ☐ Yes ☐ No

If yes, 5,1 which part of the body has been affected? _____

5,2 have they been more pronounced in the workplace? ☐ Yes ☐ No

6 Have you had continuous eye burning, eye itching, tear-filled eyes or eye reddening during the past 12 months? ☐ Yes ☐ No

If yes, 6,1 have these been more pronounced in the workplace? ☐ Yes ☐ No

7 Have you had continuous rhinitis, sneezing or a clogged nose during the past 12 months? ☐ Yes ☐ No

If yes, 7,1 have these been more pronounced in the workplace? ☐ Yes ☐ No

8 Have you had chest tightness during the past 12 months? ☐ Yes ☐ No

If yes, 8,1 has it been more pronounced in the workplace? ☐ Yes ☐ No

9 Have you had wheezing at any time during the past 12 months? ☐ Yes ☐ No

If yes, 9,1 has it been more pronounced in the workplace? ☐ Yes ☐ No

9,2 have you have wheezing while not having a cold? ☐ Yes ☐ No

9,3 have you ever had shortness of breath during wheezing? ☐ Yes ☐ No

10 Have you had repeated coughing during the past 12 months? ☐ Yes ☐ No

If yes, 10,1 has it been more pronounced in the workplace? ☐ Yes ☐ No

10,2 has the cough been accompanied by phlegm for a minimum of 3 months

per year and for not less than two successive years? ☐ Yes ☐ No

11 Have you had shortness of breath during the past 12 months? ☐ Yes ☐ No

If yes. 11,1 has it been more pronounced in the workplace? ☐ Yes ☐ No

12 Do you currently take any drugs against asthma and shortness of breath
(e. g. inhalations, dosage aerosols, spray or tablets)? ☐ Yes ☐ No

If yes. 13,1 which drugs: _____

13 Have you had an asthma attack at any time during the past 12 months? ☐ Yes ☐ No

OTHER SPECIFICATIONS:

14 Smoking status

☐ I have never smoked (apart from rare occasions)

☐ Yes, I have smoked (since (year)), approximately cigarettes per day

If yes. I smoked my last cigarette hours/ days/ months/ years ago

☐ Yes, I smoked in the past (from to), but I do not smoke at present;

in the past I smoked an average of cigarettes per day.

15 Year of birth: 19

16 Sex: ☐ male ☐ female

Comments: _____

Thank you very much for your cooperation!