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Original Article

Lung Function of Grain Millers Exposed to Grain Dust and Diesel Exhaust in Two Food Markets in Ibadan Metropolis, Nigeria

Kemi Iyogun, Suraju A. Lateef*, Godson R.E.E. Ana

Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria

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A B S T R A C T

Background: Despite growing concern over occupational exposure to particulate matter (PM) such as grain dust and diesel exhaust, information about the exposure level and health implications among workers in small-scale milling enterprises in developing countries like Nigeria has not been adequately documented. The purpose of this study was to assess the level of exposure to grain dust and diesel exhaust and effect on lung function among grain millers in food markets in Ibadan metropolis, Nigeria.
Methods: The study adopted descriptive cross-sectional design with a comparative approach. Sixteen grain milling shops each were randomly selected from two major food markets in Ibadan metropolis for indoor PM_{10} and $PM_{2.5}$ monitoring. Seventy-two respondents each were proportionately selected from grain millers and shop owners for forced expiratory volume in one second and peak expiratory flow rate tests.
Results: The $PM_{2.5}$ concentrations for both market locations ranged between 1,269.3 and 651.7 $\mu g/m^3$, while PM_{10} concentrations were between 1,048.2 and 818.1 $\mu g/m^3$. The recorded concentrations exceeded the World Health Organization guideline limit of 50 $\mu g/m^3$ and 25 $\mu g/m^3$ for $PM_{2.5}$ and PM_{10}, respectively. As compared with control group (2.1 L), significantly lower forced expiratory volume in one second value (1.61 L) was observed among the exposed group ($p < 0.05$). Likewise, significantly lower peak expiratory flow rate value (186.7 L/min) was recorded among the exposed group than the control group (269.51 L/min) ($p < 0.05$).
Conclusion: Exposure to grain dust and diesel exhaust accentuated respiratory disorders with declines in lung functions amongst grain millers. Improved milling practices and engaging cleaner milling facilities should be adopted to minimize exposure and related hazards.

1. Introduction

Exposure to airborne particulates is a major occupational hazard especially in small-scale milling enterprises where levels of exposure may be unacceptably high. The risk of exposure is higher in small-scale milling enterprises when compared with large-scale industrial milling enterprises because of the use of older technology, poor working environment, lack of awareness of potential health hazards associated with exposure to airborne particulates, and lack of use of personal protective measures. An estimated 12% of mortality from chronic obstructive pulmonary diseases had been attributed to occupational exposures to air-borne particulates [1]. One of the air-borne particulates of interest in milling sector is flour dust. Flour dust is a fine powder produced by milling of cereals or other edible starchy plant seeds [2] and may contain a large number of contaminants including silica, bacterial endotoxins, pollens, insect fragments, mites, animal dander, bird and rodent feces and various chemical additive such as pesticides and herbicides [2,3].

Flour dust varies in size with aerodynamic sizes ranging from ≤4 to 30 μm [4]. In dusty areas, up to 20% of the flour dust particles have smaller aerodynamic sizes [5], hence they can easily enter the respiratory tract of an exposed person and can cause or aggravate pulmonary and respiratory diseases among exposed workers. Wagh et al. [6] reported a reduced lung efficiency of flour mill workers in India because of excessive exposure to fine organic dust prevalent in the workplace environment. Moghaddasi et al. [7] reported that dust pollution adversely affected the forced vital capacity and forced expiratory volume in one second (FEV_1) of

* Corresponding author. Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria.
E-mail address: surpaul2000@yahoo.com (S.A. Lateef).

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exposed workers with mean flour dust concentration of 28 mg/m^3. Mohammadien et al. [3] also reported significant increases in respiratory symptoms and decrements in pulmonary function of exposed flour mill workers. Other clinical manifestations observed among exposed mill and bakery workers include conjunctivitis, allergic asthma, wheezing, febrile reactions, grain fever, lung fibrosis, rhinitis, allergic alveolitis, impairment of lung function, and chronic obstructive pulmonary disease [1,8].

Other major source of particulates in milling sector in Nigeria is the diesel engine which is largely used as an alternative power source by macro and micro industries [9]. Fine particles emitted from unfiltered diesel engines are rated as one of the most toxic forms of air pollution [10]. Diesel engine exhaust contains harmful pollutants in a complex mixture of gases and particulates including carcinogens, mutagens, respiratory irritants, and other toxins that result in a range of diverse health effects [11]. Light-duty and heavy-duty diesel engines can emit 50–80 and 100–200 times particulates mass, respectively, than catalytically equipped gasoline engines [12]. Exposure to diesel exhaust is an environmental and occupational health concern. Diesel exhaust particulates are small enough to penetrate deep into the lungs (particle size of <2.5 μm) resulting in diverse health effect [10,11]. Acute effects of diesel exhaust exposure include nose and eye irritation, swollen airway, headache, fatigue, nausea, and respiratory changes [10,13] while chronic effects result in cardiovascular diseases, respiratory disease, and lung cancers [14–17].

Nigeria, being dominated by small-scale industries, has predominantly small-scale milling enterprises involved in the processing of agricultural produce such as grains, legumes, and other dried agro products. The enterprises are mostly run by self-employed individuals, who are more concerned about their business survival than improving health and safety conditions and tend to use relatively old equipment and low level of technology. Consequent on these, the workers are directly exposed to high levels of flour dust and exhaust fumes from poorly maintained diesel engines. Poor ventilation, absence or improper use of personal protective equipment, and inadequate awareness of health hazards in the workplace increase the workers' exposure level, which might predispose them to respiratory health disorders in their work environment.

Health surveillance is regarded as an effective measure to control negative health implications of continuous exposure of workers in flour mills to particulate matter (PM), as information on exposure level and pulmonary function may be helpful in improving workers' health and work environment [3]. However, achieving health surveillance in an informal setting might be difficult because the sector is not well organized and the labor force is mostly uneducated. Hence, the need for conducting research on work-place exposure in informal setting by public health professional.

Lung function tests are beneficial in early detection of pulmonary disorders [3]. Spirometry is one of the most important, widely used, effort-dependent pulmonary function test and shows the degree of effects of restriction or obstruction on lung function in occupational respiratory disease [2,8]. In Nigeria, studies have reported increased risk of developing respiratory symptoms and a reduced lung function among workers in large scale flour milling industry [1,18,19]. However, the lung status of grain millers exposed to flour dust and diesel exhaust fumes in the small-scale informal sector where exposure conditions may be high because of direct exposure to the emission source has not been adequately documented. The objectives of this study were to determine the level of PM_{10} and $PM_{2.5}$ in the indoor grain milling environment of small-scale enterprise and also to determine the FEV_1 and peak expiratory flow rate (PEFR) of the grain millers in relation to the pulmonary function of an unexposed group. In addition, the effect of duration of exposure to grain dust on lung function was assessed.

2. Materials and methods

2.1. Study site and study subjects

Purposive sampling technique was used to select the two markets within Ibadan metropolis: Bodija and Oja-Oba markets. Bodija is one of the busiest markets and a leading foodstuff market in Ibadan with large number of grain traders; hence milling activity is intense in the market. Likewise Oja-Oba market is a food market with a large number of grain millers. A descriptive cross-sectional design which had a comparative approach was also employed. Seventy-two grain mill workers with a mean age of 34.6 ± 10.8 years were proportionately allocated from both markets, and 72 shop owners (SOs) with a mean age of 32.7 ± 9.2 years (unexposed group) were selected as controls for the lung function test. Simple random sampling was used to select the number of grain millers needed from each market based on the eligibility status. Inclusion criteria for the study subjects were as follows: must be engaged in milling within the two selected markets; must be in full operation of grinding (at least 6–8 hours/daily for 5 days in a week); must have been in operation for at least 1 year before the commencement of data collection; and must have voluntarily agreed to participate in the study. Smokers were excluded from the study. The research protocol was approved by the University of Ibadan (UI), Ibadan, Nigeria/University College Hospital (UCH), Ibadan, Nigeria joint Ethical Review Board.

2.2. Data collection

2.2.1. Air quality monitoring

Air quality monitoring was carried out in 16 grain milling shops which were randomly selected from each market. Permission was sought and obtained from respondents to monitor the level of $PM_{2.5}$ and PM_{10} in the shops chosen. The levels of PM_{10} and $PM_{2.5}$ were monitored using a calibrated Thermo Scientific MIE pDR-1500 particulate matter monitor. Six readings were taken for PM_{10} and $PM_{2.5}$ in each milling shop for duration of 1 hour. Each study location was monitored in the morning (between 9 AM–12 PM) and afternoon (between 1 PM–4 PM) every day to capture the peak activity periods including weekends. The monitoring was carried out for 1 month.

2.2.2. Survey and onsite observations

A semistructured, interviewer-administered questionnaire was used to obtain occupational histories and practices of the grain mill workers among other information. An observational checklist was used to document the environmental conditions and to validate the grain mill workers' practices. The items in the checklist included location, air pollution sources, ventilation, air pollution control facility, evidence of use of personal protective equipment, and status of the work environment.

2.2.3. Pulmonary function test

Pulmonary function test was conducted for the grain millers and control group while at work. Among the pulmonary function parameters, FEV_1 and PEFR were measured using a PIKO-1 Electronic peak flow/FEV_1 meter. The maneuver was explained to each respondent and demonstrated before measurement. The subjects were encouraged to practice this maneuver before performing the lung function tests. A disposable mouth piece was inserted to the inlet of spirometer for each participant, where air was blown to avoid contamination. The subjects were instructed to inspire deeply and rapidly and then exhale forcefully (i.e., with a "blast") and fully into the electronic peak flow/FEV_1 meter for the duration of one second and readings were taken. This procedure was repeated three times and the highest reading was chosen. The height and age of the subjects were also documented.

2.3. *Statistical analysis*

Descriptive and inferential statistics were used in this study. Descriptive statistics were used to summarize the data. Mean $\pm$ standard deviation and range were calculated for $PM_{2.5}$ and PM_{10} levels of the grinding environment. The mean $\pm$ standard deviation and range of FEV_1 and PEFR values were determined for the two groups (grain millers and control group). Analysis of variance was used to compare PM_{10} and $PM_{2.5}$ concentrations across the mill shops while the student *t* test was used to compare FEV_1 and PEFR levels of the two groups both at 5% level of significance.

3. Results

3.1. *Air quality monitoring*

3.1.1. *Particulate matter (PM_{10}) concentration*

The workplace air monitoring of the grain milling shops in both market locations showed high concentrations of PM_{10} and $PM_{2.5}$ in the grain milling environment. The PM_{10} concentrations monitored in the morning and afternoon across grain milling shops in both markets are graphically represented in Figs. 1 and 2, respectively. Generally, the mean PM_{10} concentrations across milling shops were higher in the afternoon than in the morning for the two market locations. In addition, the concentrations were above the World Health Organization (WHO) recommended guideline limit of a 24-hour of 50 μg/m^3 for indoor environment. In Oja-Oba market, PM_{10} concentrations in the monitored locations ranged from 214.5 to 1,711.2 μg/m^3 in the morning and 418.6 to 2,065.2 μg/m^3 in the afternoon, whereas in Bodija market, they ranged from 212.7 to 1,432.6 μg/m^3 in the morning and 822.3 to 2,299.6 μg/m^3 in the afternoon.

3.1.2. *Particulate matter ($PM_{2.5}$) concentration*

The levels of $PM_{2.5}$ in the indoor grain milling environments of the two market locations were also very high compared with the WHO recommended guideline limit of a 24-hour of 25 μg/m^3 (Figs. 3 and 4). In Oja-Oba market, $PM_{2.5}$ concentrations ranged from 103.4 to 1,729.9 μg/m^3 in the morning and 368.6 to 1,768.3 μg/m^3 in the afternoon, whereas in Bodija market, they ranged from 124.9 to 2,226.5 μg/m^3 in the morning and 406.8 to 3,755.2 μg/m^3 in the afternoon.

3.2. *Onsite observation of the grain milling environment*

Checklist was used to carry out onsite observation of grain milling environment. The result of the location of the milling facility showed that 64% of the shops fulfilled the spacing requirement of 400 m from residential area. However, there was no adequate spacing between one milling facility and another, with 52% of the facilities separated by a distance of only 0–5 m.

Around half (53%) of the locations had particulate emissions to be highly present while 47% had particulate emissions to be moderately present. None of the grain milling shops had air pollution control devices. A majority (71%) of the shops were congested without adequate work space. Furthermore, 63% of the

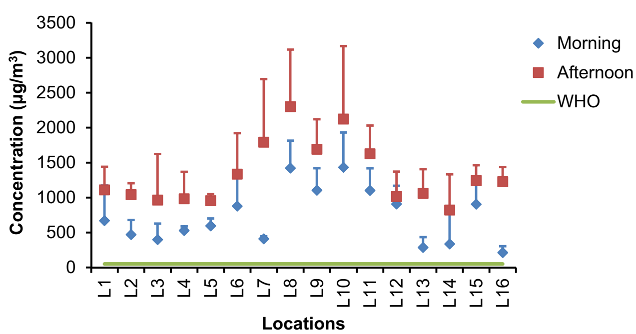

Fig. 1. Variation of morning and afternoon mean PM_{10} concentrations among 16 selected grain milling shops in Bodija market.
PM, particulate matter; WHO, World Health Organization.

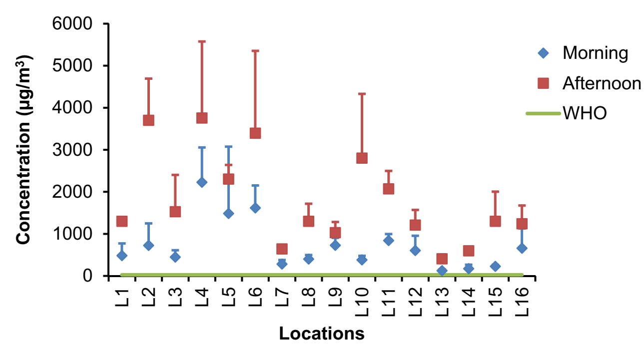

Fig. 3. Variation of morning and afternoon mean $PM_{2.5}$ concentrations among 16 selected grain milling shops in Bodija market.
PM, particulate matter; WHO, World Health Organization.

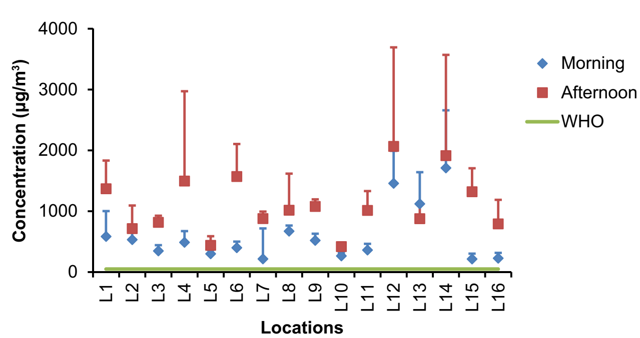

Fig. 2. Variation of morning and afternoon mean PM_{10} concentrations among 16 selected grain milling shops in Oja-Oba market.
PM, particulate matter; WHO, World Health Organization.

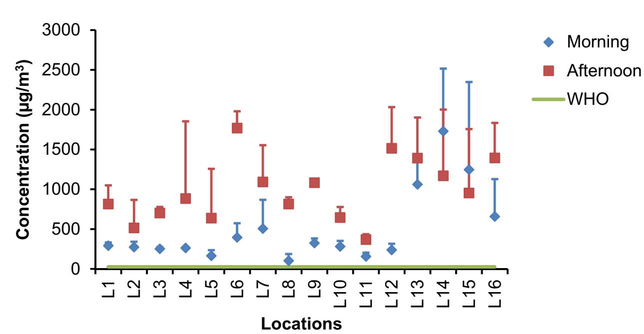

Fig. 4. Variation of morning and afternoon mean $PM_{2.5}$ concentrations among 16 selected grain milling shops in Oja-Oba market.
PM, particulate matter; WHO, World Health Organization.

shops had no windows, with 100% of the shops partially enclosed. As regards adequate ventilation, 87% of the shops had no adequate indoor ventilation, 84% of the grain milling shops had poor housekeeping practices, and 84% of those shops had poor floor hygiene. Use of personal protective equipment (PPE) was very minimal with only 5% always wearing a nose mask.

3.3. Occupational history of respondents

The exposed group was grain millers involved in the milling of agricultural produce such as maize, dried raw cassava, dried raw yam, wheat, and soybeans into flour. Milling of these produces generates substantial amount of dust. While grinding, the workers usually stand very close to the grinding engines and as a result they are continuously exposed to high concentration of flour dust. The other group (unexposed group) composed of traders selected from other distant locations from grinding section within the market and from street with busy traffic.

The survey of the type of engine used by the grain miller showed that majority (91.7%) used diesel engine and the rest used premium motor spirit fueled engine. Half of the millers (50%) serviced their engines 4–5 times in a year, 19.4% serviced their engines 2–3 times, and 30.6% serviced their engines twice in a year. There were no specific durations for running the engines. The engines were run as long as the services of the grain millers were needed. However, it was observed that the peak period of grinding activities was in the afternoon. The duration of work exposure (in years) and daily working duration of the respondents from the two groups were assessed, and the results are presented in Fig. 5. A majority of the grain millers (about 75%) and of the SOs (about 80%) had worked for more than 5 years. In addition, a majority of the grain millers (73.6%) reported daily work duration of more than 8 hours (Fig. 5B).

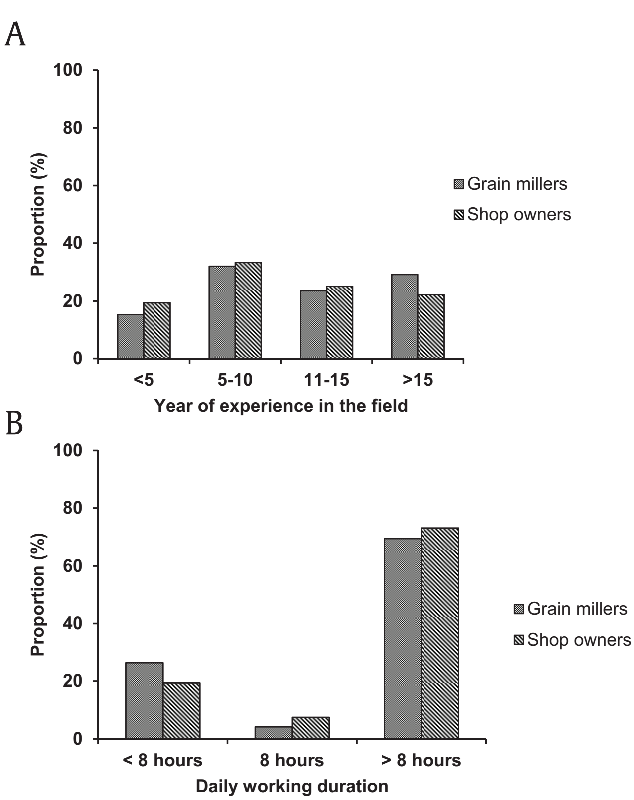

Fig. 5. Description of the working population depending on the years of experience. (A) In the field. (B) Daily work duration.

A similar trend was observed in the results of daily working duration for SOs.

3.4. Lung function status (FEV_1 and PEFR) of respondents

A total of 144 workers were included in the study for lung function test, comprising 72 grain millers and 72 SOs (control group). The anthropometric variables such as age, height and weight, and lung function parameters of respondents are presented in Table 1. There were no significant differences between the means of anthropometric parameters ($p > 0.05$). There were significant declines in FEV_1 and PEFR values among the grain millers when compared with that of control group. The FEV_1 and PEFR values of the respondents were compared with duration of work exposures, and the results are presented in Figs. 6 and 7. Generally, the FEV_1 and PEFR values of respondents decreased with duration of work exposures for both the exposed and control groups, respectively. Moreover, there was a significant ($p < 0.05$) decline in FEV_1 and PEFR values among the grain millers in comparison with SOs as duration of exposures at workplace increased.

4. Discussion

Exposure to workplace pollution is one of the major sources of health risk. Associations between workplace exposure and health outcomes are often poorly characterized because of lack of detailed environmental monitoring. In view of this reason, monitoring of indoor environment of the milling shops was carried out. Data of PM_{10} among the milling shops monitored showed a wide spread in particulate concentrations, reflecting the different indoor work environment. Similarly, Jeffrey et al. [20] also reported wide variation in levels of occupational exposures among bakery workers with total inhalable dust concentration ranging from 0.1 to 23.7 mg/m^3 and respirable dust concentration ranging from 0.01 to 3.6 mg/m^3 with an average of 2.8 mg/m^3. Several factors must have influenced the variation in PM_{10} concentrations in the different shops monitored such as the degree of activity and the type of product being milled at the point of monitoring. The ventilation rate of the shop is one factor among others influencing the PM_{10} concentration as similarly observed by Braniš et al. [21], who reported significant inverse correlation between wind speed and indoor PM_{10} concentration. Lack of ventilation causes the accumulation of PM in the indoor environment and decreases mixing and dilution of the PM [22].

Generally, mean PM_{10} concentration was significantly higher than the WHO guideline of 50 $\mu g/m^3$ for a 24-hour exposure period. The result of the present study showed that the overall mean PM_{10} concentration was 1,048.2 $\mu g/m^3$ for Bodija milling site and

Table 1
Comparison of anthropometric characteristics and lung function parameters between grain millers and shop owners.

Anthropometric variable/ Lung function parameter	Group	Mean	SD	t test	p
Age (y)	Shop owners Grain millers	32.70 34.6	9.2 10.8	1.1	0.260
Weight (kg)	Shop owners Grain millers	64.6 67.3	12.1 11.3	−1.4	0.178
Height (cm)	Shop owners Grain millers	165.9 164.7	8.1 7.7	0.9	0.321
PEFR (L/min)	Shop owners Grain millers	269.5 186.7	93.6 91.7	3.5	<0.001
FEV_1 (L)	Shop owners Grain millers	2.1 1.6	0.4 0.6	6.0	<0.001

FEV_1, forced expiratory volume in one second; PEFR, peak expiratory flow rate; SD, standard deviation.

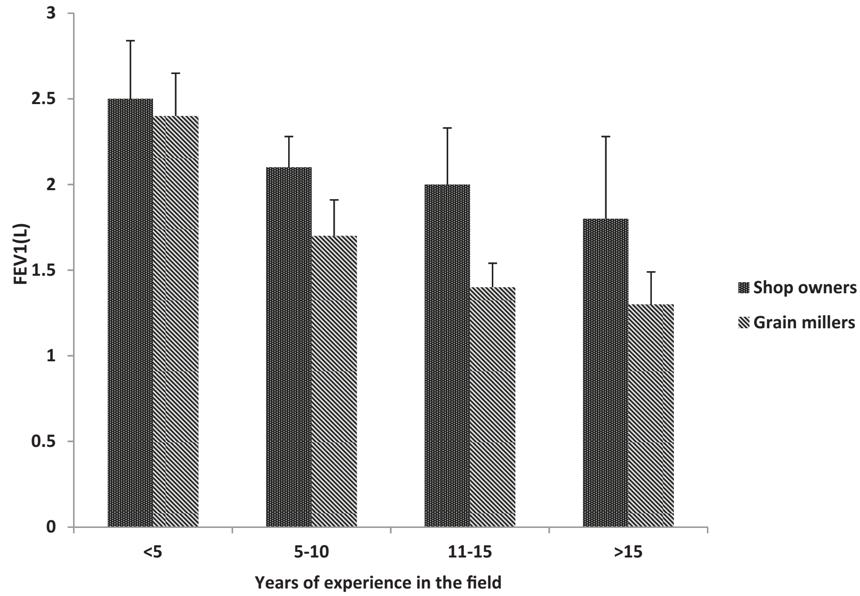

Fig. 6. FEV_1 values among grain millers and shop owners depending on the time spend at the present working place. Bars represent observed standard variation. FEV_1, forced expiratory volume in one second.

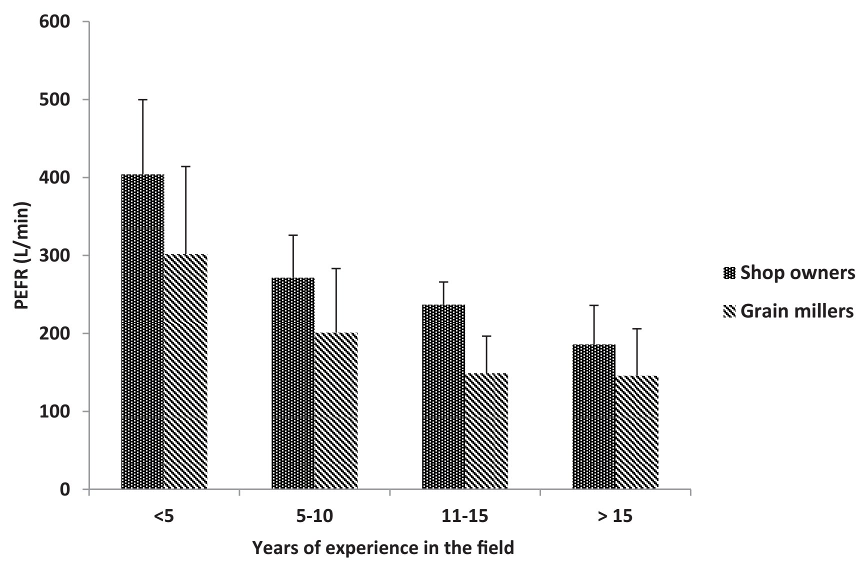

Fig. 7. PEFR values among grain millers and shop owners depending on the time spend at the present working place. Bars represent observed standard variation. PEFR, peak expiratory flow rate.

818.1 $\mu g/m^3$ for Oja-Oba milling site. A study conducted by Mounier-Geyssant et al. [23] also reported a similarly high level of PM_{10} concentration (flour dust) which was 0.63 mg/m^3 (630 $\mu g/m^3$) in summer. In addition, Wagh et al. [6] reported dust concentration (PM_{10}) ranged between 430 and 814 $\mu g/m^3$ with an average of 624 ± 190 $\mu g/m^3$. However, in a study among flour mill workers by Tosho et al. [1], a lower mean concentration of 0.28 ± 0.05 mg/m^3 (280 $\mu g/m^3$) was reported. The variances in PM concentrations in the studies cited might be because of differences in the work environment and facilities put in place for PM control. The results of the studies mentioned and this study indicate excessive exposure to flour dust among the mill workers. Poor technological standard as regards particulate control in the work places and poorly ventilated work places must have resulted in high level of pollution in all the work places monitored.

In this study, there was a statistically significant difference ($p < 0.05$) in PM_{10} concentration for morning (9–12 AM) and afternoon (1–4 PM) PM levels observed. The high particulate concentration in the afternoon might be explained by increased activity rate compared to morning. Similarly, in a study conducted in Gwagwalada market environment, Abuja, Nigeria, it was also reported that PM concentrations were higher in the afternoon as compared to that observed in the morning [24]. Aside from human activity levels, temperature and humidity might have affected the concentrations of PM in the morning because the temperature is normally low in the morning. This makes the environment moist and may further trap dust particles in the air thereby reducing the particulate concentrations in air circulation in the morning. However, as noon approaches there is a steady increase in temperature which may dry up the moist particles, thus increasing their kinetic properties thereby making them highly dispersed and more available in the atmosphere with a corresponding increase in particulate burden at noon [25].

The mean concentrations of $PM_{2.5}$ in all sampling locations were above the WHO guideline limit of 24-hour of 25 μg/m^3. Fine particles ($PM_{2.5}$) are emitted from combustion processes, especially diesel-powered engines, power generation, and wood burning [26]. Diesel engines have been reported to be the most important primary particle exhaust emitters, producing about 100 times more PM than a normal petrol engine [13,25]. Use of diesel engines that are unregulated for particulate emissions in all the shops monitored must have resulted in the high level of $PM_{2.5}$ observed in this study. Old model of diesel engines emit significantly higher level of PM than the new technology diesel engines which are fitted with wall-flow particulate filters [11]. Organic particles generated during milling of agricultural produce could also be a source of the observed $PM_{2.5}$. Mounier-Geyssant et al. [23] in their study among bakery and pastry apprentice showed that air-borne flour dust was responsible for the high average values of $PM_{2.5}$ observed, which exceeded the American Conference of Governmental Industrial Hygienists recommendations. Hence, the observed high level of $PM_{2.5}$ in this study might be as a result of the complex combination of organic particles from flour dust and chemical particles from diesel exhaust.

The indoor work environment must have also influenced the level of $PM_{2.5}$ concentrations. Particulate concentration in indoor work environment had been shown to be higher compared to its corresponding concentration in outdoor air. Its concentration may be attributed to both indoor and outdoor sources, depending on the penetration of outdoor particles into the indoor environment and the intensity of indoor aerosol sources [27,28]. In this study, peak concentrations of $PM_{2.5}$ was noted for diesel engines that were poorly maintained and malfunctioning releasing high concentrations of fine PM ($PM_{2.5}$).

Similar high exposure levels for diesel exhaust emissions had been reported for different work environments. A report by US Environmental Protection Agency [11] stated that the exposure levels ranged from approximately 10 μg/m^3 to 1,280 μg/m^3 for workers in coal mines and noncoal mines using diesel-powered equipment. Groves and Cain [29] reported that respirable dust concentration was in the range of 180–1,356 μg/m^3 for workers exposed to diesel engine exhaust emission in their work places.

In Nigeria, a report by Nnaji and Chiedozie [9] stated that the levels of suspended PM ranged from 11.73 to 11.93 mg/m^3 in a commercial area of Lagos State. In addition, Orogade et al. [30] also reported annual average concentration of $PM_{2.5}$ of 135.7 μg/m^3 in an agricultural processing industry using diesel generators. Mounier-Geyssant et al. [23] reported average personal exposure among bakery workers for $PM_{2.5}$ in the range of 350–710 μg/m^3. PM concentration from diesel engines varies depending on the sulfur content of the fuel, engine maintenance, and the technology put in place for PM emission control.

In the grain milling industry, exposure to flour dust may cause diverse lung diseases with different severity of symptoms ranging from irritation to allergic rhinitis or occupational asthma. Chronic exposure to flour dust can result in lung problems. Furthermore, exposure to diesel exhaust may result in diverse acute and chronic respiratory health disorders, such as nose and eye irritation, swollen airway, headache, fatigue and nausea, poor lung function, increase in allergic reactions, asthma and pneumoconiosis, among exposed workers [13]. Small size of diesel exhaust particulates makes them highly respirable and able to reach the alveoli [11].

The result obtained from this study showed significant ($p < 0.05$) lowering of FEV_1 values among the grain millers (1.61 L) as compared to that of control group (2.10 L). This is similar to findings from Wagh et al. [6] who reported a significant difference between mean FEV_1 of flour mill workers (1.9 L) and controls (2.5 L). Ige and Awoyemi [18] also reported a significant difference between mean FEV_1 of bakery workers (3.5 L) and controls (3.1 L). Nayak et al. [31] using computerized parameter in flour mill workers also reported an observed mean value of 1.65 L. A lower mean value (1.49 L) was reported by Moghaddasi et al. [7]. In contrast to the results stated above, Hosseinabadi et al. [8] reported mean FEV_1 to be not significant among the exposed group and controls. They, however, stated that the small sample size (35 and 20 for exposed and control, respectively) was a limitation to their study, which probably explains the nonsignificant difference in FEV_1 values among the exposed groups and controls.

It was observed that the mean PEFR value was significantly ($p < 0.05$) reduced in grain mill workers compared with controls. This is similar to the findings of a study conducted in elsewhere in Nigeria by Tosho et al. [1] where the difference between mean PEFR of flour mill workers and mean PEFR of control was also found to be statistically significant ($p < 0.05$). Hosseinabadi et al. [8] also reported a significant difference between mean PEFR value of flour factory workers and controls. Similarly, Wagh et al. [6] reported a significant difference between mean PEFR value of flour mill workers and controls. The PEFR provides an objective assessment of functional changes associated with environmental and occupational exposures and indicates acute or chronic disease process [32]. The low PEFR values observed in this study when compared with those that had been reported in other studies might be because of variation in exposure levels as regards the differences in working environment and years/duration of working. Local grain millers are frequently and directly exposed to flour dust and diesel fumes without any form of engineering controls as compared to industrial flour mill workers where exposure might be less as a result of improved milling practices.

Stratification of the results showed that as duration of exposure increased, the lung function values decreased. There was a significant ($p < 0.05$) reduction in mean values of FEV_1 and PEFR as the duration of exposures increased, though the mean FEV_1 for exposure period of <5 years was found to be nonsignificant ($p > 0.05$); all others were significant for all work durations in comparison with the control group.

Similarly, Meo [33] also reported a significant decrease in the mean values of FEV_1 and PEFR as duration of exposure increased; however, workers who had worked between 0–4 years showed no significant ($p > 0.05$) reduction in mean values of FEV_1 and PEFR. Zodpey and Tiwari [34] in their study among flour mill workers reported that the PEFR was significantly ($p < 0.05$) reduced in flour mill workers as compared to their comparison group. They reported that the decline in lung function was significantly associated with duration of exposure. However, in their study, the lung function of workers exposed for <5 years was not significantly different ($p < 0.05$) from that of controls.

Wagh et al. [6] also compared the pulmonary function of flour mill workers according to duration of exposure; they reported a significant ($p < 0.05$) reduction in pulmonary function as duration of exposure increased. All the findings as well as that of this study are in support of Gimenez et al. [35] who had earlier reported that exposure to grain/flour dust induced chronic respiratory manifestations as well as lowering of pulmonary function values when compared to unexposed/referents, and the effect was very much dependent upon the extent of exposure, both in the form of duration of daily working hours and number of years they had worked in the mill.

In conclusion, the findings in this study reveal that exposure to grain dust and diesel engine exhaust results in reduced FEV_1 and PEFR values among grain millers as compared with the controls.

Improved milling practices and engaging cleaner milling facilities should be adopted to minimize exposure.

Disclaimer

We would like to state that we are solely responsible for all contents of the article including the accuracy of data, statement, facts etc.

Conflicts of interest

All authors have no conflicts of interest to declare.

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