



ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

**COFFEE DUST EXPOSURE AND RESPIRATORY HEALTH AMONG
WORKERS IN PRIMARY COFFEE PROCESSING FACTORIES IN
ETHIOPIA**

SAMSON WAKUMA ABAYA



DISSERTATION FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
(PhD) IN PUBLIC HEALTH

ADDIS ABABA UNIVERSITY, ETHIOPIA

MAY 2019



ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

**Coffee dust exposure and respiratory health among workers
in primary coffee processing factories in Ethiopia**

**A Dissertation submitted to the School of Graduate Studies of
Addis Ababa University in partial fulfillment of the
requirements for the Degree of Doctor of Philosophy (Ph.D.)
in Public Health**

By SAMSON WAKUMA ABAYA

Advisors: Dr ABERA KUMIE (PhD)

Dr WAKGARI DERESSA (PhD)

PROFESSOR BENTE E. MOEN (PhD)

PROFESSOR MAGNE BRÅTVEIT (PhD)

ADDIS ABABA UNIVERSITY, COLLEGE OF HEALTH SCIENCES,

SCHOOL OF PUBLIC HEALTH

MAY, 2019

EXAMINATION BOARD DESSERTATION APPROVAL FORM

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

**DISSERTATION TITLE: COFFEE DUST EXPOSURE AND
RESPIRATORY HEALTH AMONG WORKERS IN PRIMARY COFFEE
PROCESSING FACTORIES IN ETHIOPIA**

BY: SAMSON WAKUMA ABAYA

SCHOOL OF PUBLIC HEALTH, ADDIS ABABA UNIVERSITY

APPROVED BY THE EXAMINING BOARD

Chairman, Examining Board

Signature and Date

Dr Abera Kumie
Supervisor (Primary)

Signature and Date

Dr Wakgari Deressa
Supervisor (Secondary)

Signature and Date

External Examiner

Signature and Date

Internal Examiner

Signature and Date

Internal Examiner

Signature and Date

List of original papers

This dissertation is based on the following original research papers, which will be referred to in the text by their Roman numerals (I-IV):

- I. Abaya S.W., Bråtveit M., Deressa W., Kumie A., Moen B.E. Personal Dust Exposure and Its Determinants among Workers in Primary Coffee Processing in Ethiopia. *Annals of Work Exposures and Health* 2018, 62 (9): 1087–1095.
- II. Abaya S.W., Bråtveit M., Deressa W., Kumie A., Moen B.E. Reduced Lung Function among Workers in Primary Coffee Processing Factories in Ethiopia: A Cross Sectional Study. *International Journal of Environmental Research and Public Health* 2018, 15, (2415); doi:10.3390/ijerph15112415.
- III. Abaya S.W., Bråtveit M., Deressa W., Kumie A., Moen B.E. Respiratory Health among Hand pickers in Primary Coffee Processing Factories in Ethiopia. *Journal of Occupational and Environmental Medicine* 2019,61(7): 565-571; DOI: 10.1097/JOM.0000000000001613
- IV. Abaya S.W., Bråtveit M., Deressa W., Kumie A., Tenna A., Moen B.E. Microbial Contamination of Coffee during Post-harvest on Farm Processing: a Concern for the Respiratory Health of Production Workers. *Archives of Environmental and Occupational Health* 2018. DOI: <http://dx.doi.org/10.1080/19338244.2019.1592094>

Acronyms/Abbreviations

AM	Arithmetic Mean
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
ATS	American Thoracic Society
AD	Aerodynamic Diameter
BMI	Body Mass Index
CFU	Colony Forming Unit
FDA	Food and Drug Administration
FEV₁	Forced Expiratory Volume in first second
FEF_{25-75%}	The mean forced expiratory flow between 25% and 75% of the FVC
FVC	Forced Vital Capacity
GDP	Growth Domestic Product
GM	Geometric Mean
GSD	Geometric Standard Deviation
MOLSA	Ministry of Labour and Social Affairs
BOLSA	Bureau of Labour and Social Affairs
NORHED	The Norwegian Programme for Capacity Development in Higher Education and Research for Development
OEL	Occupational Exposure Limit
OSHA	Occupational Safety and Health Administration
RPD	Respiratory Protective Devices
SD	Standard Deviation
SEG	Similar Exposure Group
SKC	Side Kick Casella
SNNPR	Southern Nations, Nationalities and People's Region
SPC	Standard Plate Count

Glossary

Dry processing method: refers when unpulped coffee cherries are allowed to dry in the sun under natural conditions by spreading on ground, mats, cemented floor or raised dry bed

Hand pickers: are girls and women who are engaged in sorting or separating defective coffees and discoloured coffees (i.e. black, yellow and red coffees) from the sound coffee beans.

Machine room workers: these are people working in the machine room with a radius 5 meter from the hulling machine and includes operator work, mechanic work, feeding hopper and cleaning

Occupational Exposure Limit: is an eight hours time weighted average concentration which is considered to have no adverse effect to the person exposed

Organic dust: is dust particles originated from vegetable, animals and microbes

Primary coffee processing factories: refers to mechanical cleaning of debris from parchment coffee from the farms, and includes hulling, grading, hand picking, and packing of green coffee beans

Secondary coffee processing factories: referes to coffee factories where polishing, roasting, and grinding coffee take places

Wet coffee processing: when harvested cherries are pulped immediately after harvesting, followed by fermentation and washing with clean water to remove mucilage cover

Table of Contents

List of original papers.....	iv
Acronyms/Abbreviations	v
Glossary.....	vi
List of Tables	xi
List of Figures	xii
Abstract.....	xiii
1. Introduction	1
1.1 Background	1
1.2 Statement of the problem	2
1.3 Rationale and significance of the study	4
2. Literature review.....	6
2.1. General overview about coffee production.....	6
2.1.1. Coffee.....	6
2.1.2. Coffee in Ethiopia.....	6
2.1.3. Coffee production in Ethiopia.....	7
2.1.4. Harvest and processing of coffee at the farm in Ethiopia.....	7
2.2. Coffee processing factories in Ethiopia.....	8
2.2.1. Primary coffee processing factories.....	8
2.2. 2. Secondary coffee processing factories.....	10
2.3. Task related activities in primary coffee processing factories in Ethiopia.....	11
2.3.1. Handling low quality coffee	11
2.3.2. Husk handling.....	12
2.3.3. Sweeping, collecting and stamping on coffee bags	12
2.3.4. Loading and unloading in coffee processing factories.....	12
2.3.5. Machine room workers.....	13
2.3.6. Hand pickers.....	13

2.4. General overview about dust particles.....	14
2.4.1. Definition of dust and types of dust.....	14
2.4.2. Organic dust and its constituent.....	14
2.4.3. Dust sampling methods at work places	15
2.4.4. Characteristics of dust exposure in coffee factories.....	16
2.5. Coffee dust exposure and its health problems.....	16
2.5.1. Acute and chronic respiratory symptoms.....	16
2.5.2. Reduced lung function	17
2.6. The Conceptual Framework.....	18
3. Research questions and objectives.....	20
3.1. Research questions	20
3.2. Research objectives	20
3.2.1. General objectives	20
3.2. 2. Specific objectives.....	20
4. Methods.....	21
4.1. Study areas and setting.....	21
4.2. Study design and period	22
4.3. Source population.....	22
4.4. Study population.....	22
4.5. Inclusion criteria.....	23
4.5. Exclusion criteria	23
4. 6. Selection of coffee and control factories	23
4.7. Sample size determination	24
4.8. Study participant sampling procedure.....	27
4.9. Data collection	30
4.10. Data management	33
4.11. Data quality assurance.....	33

4.12. Data description and analysis	34
4.13. Study variables.....	38
4.13.1. Dependent variables	38
4.13.1. Independent variables	38
4.14. Operational definition.....	39
4.14. Ethical considerations	40
4.15. Summary of dissertation work by objective and methods.....	41
5. Results.....	42
5.1. Personal dust exposure.....	44
5.2. Task and factory determinants	46
5.3. Exposure determinant models.....	47
5.4. Chronic respiratory symptoms among coffee worker (Paper II & III).....	48
5.5. Lung function reduction among coffee workers (Paper II & III)	51
5.6. Microbial contamination of coffee on farm processing (Paper IV).....	52
6. Discussion.....	56
6.1. Personal dust exposure.....	56
6.2. Determinants of exposure	57
6.3. Lung function reduction among coffee workers.....	58
6.4. Chronic respiratory symptoms.....	59
6.5. Microbial contamination of coffee on farm processing	61
7. Methodological Discussion	63
7.1. Validity and Generalizability	63
7.1.1. Internal validity	63
7.1.2. External validity.....	65
8. Strengths and limitations of the study.....	66
8.1. Strengths of the study.....	66
8.2. Limitations of the study	66

9. Conclusions and Recommendation.....	68
9.1. Conclusions	68
9.2. Recommendation.....	68
10. Acknowledgements.....	71
11. Refences	72
Annexes.....	79

List of Tables

Table 1: Distribution of dust sampling by regions (Oromia, SNNPR & Addis Ababa) and task, 2016.....	25
Table 2: Summary of the methods for each paper	41
Table 3 : Characteristics of participants, Ethiopia, May 2016 to January 2017	43
Table 4: Personal total dust exposure in the 12 coffee factories stratified by factory and main job group, Ethiopia, May 2016 to January 2017.....	45
Table 5:Factory related determinants of total dust exposure for machine room workers and transporters in 12 primary coffee processing factories in Ethiopia, May 2016 to January 2017	46
Table 6:Linear mixed effect model of ln-transformed total dust levels in 12 primary coffee processing factories in Ethiopia, May 2016 to January 2017	48
Table 7:Prevalence of chronic respiratory symptoms among male coffee workers and controls, Ethiopia, May 2016 to January 2017	49
Table 8: Prevalence of chronic respiratory symptoms among two groups of hand pickers of coffee and a low dust exposed control group, Ethiopia, May 2016 to January 2017	50
Table 9:Lung function among male coffee workers in primary coffee processing factories and control groups stratified by age (three age groups), Ethiopia, May 2016 to January 2017	51
Table 10: Lung function among hand pickers in primary coffee processing factories and control, Ethiopia, May 2016 to January 2017	52
Table 11: Microbial load in different stages of wet and dry coffee processing in Ethiopia, May 2016 to January 2017.....	53
Table 12: Presence of gram negative bacteria in different stages of postharvest on farm coffee processing, Ethiopia, May 2016 to January 2017	54
Table 13 : A summary of key findings from papers (I-IV), Ethiopia, May 2016 to January 2017.....	55

List of Figures

Figure 1 : Steps in primary coffee processing factories.....	10
Figure 2 Steps in secondary coffee processing factory.....	11
Figure 3. Mixing rejected coffee.....	11
Figure 4: Transporting coffee	12
Figure 5: Hand pickers without table (a) and hand pickers with table (b).....	13
Figure 6 Conceptual Framework for determinants of coffee dust exposure and its effect on respiratory health	19
Figure 7: Location of map of the study area in Jimma zone (Goma and Mena woreda), Sidama zone (Shebediono and Aleta wondo woerda) and Addis Ababa city administration (Akaki kality and Nefasilk lafto sub city).	21
Figure 8:Stages of wet and dry processes and sampling of coffee beans	29
Figure 9: Personal total dust sampling method from breathing zone, right hand person	30
Figure 10: : A picture showing lung function measurement.....	32

Abstract

Background: Dust exposure is one of the major risk factors for health in many work places including coffee processing factories. Dust generates at different stages of coffee handling and processing. Excessive exposure to coffee dust can cause respiratory health problems. Coffee workers in Ethiopia are exposed to coffee dust, but the level of exposure and the magnitude of its health effect have not been widely investigated.

Objectives: The aims of this study were to assess the level of personal total dust exposure, factors affecting dust exposure, the prevalence of respiratory symptoms and lung function reduction among coffee workers. In addition, assessing microbial contamination of coffee at different stages of both wet and dry method on farm coffee processing was a part of this dissertation.

Methods: Comparative cross-sectional studies were conducted in primary coffee processing factories involving 3 regions: Oromia Regional State; Addis Ababa City Administration; and Southern Nations, Nationalities and Peoples' Region. The study also included a comparative population in 3 water bottling factories, one from each region mentioned above. A total of 360 dust samples were collected from 12 primary coffee processing factories for dust exposure assessment. In addition, 60 total dust samples were collected from the 3 water bottling factories. Dust samplings were collected from breathing zone of workers using 25-mm three piece, closed-faced conductive cassettes with a cellulose acetate filter attached to Side Kick Casella pumps with a flow rate of 2 liter/ minute. Observational checklist was used to identify possible determinants for dust exposure.

Lung function tests were performed for a total of 420 participants (120 male coffee workers, 120 male controls, 60 hand pickers with tables, 60 hand pickers without tables and 60 female controls) using a portable spirometer (SPIRARE 3 sensor model SPS 320). Lung function parameters such as Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), the mean forced expiratory flow between 25% and 75% of the FVC ($FEF_{25-75\%}$) and ratio FEV_1/FVC were measured. Prevalence of chronic respiratory symptoms were assessed with an interview, using a standardized questionnaire adopted from the American Thoracic Society.

Coffee cherries each weighing about 25 grams were sampled from each stage of the wet and dry processes for microbial contamination assessment. Standard Plate Count agar was used

to grow total bacteria and gram stain technique were used to identify gram negative and gram positive bacteria.

Data were entered into an electronic database using EpiData version 3.1 and exported to SPSS version 22 for analysis. Missing values and outliers were checked using frequency tabulation, and then were managed accordingly. The results were described as arithmetic mean, standard deviation, geometric mean (GM), and geometric standard deviation (GSD).

A one-way analysis of variance was performed to compare the GM of personal total dust exposure level between different job groups and between tasks. Linear mixed effect regression models were developed to identify significant determinants for personal total dust exposure. Independent t-tests were used to compare the mean values for the continuous variables. The Pearson Chi-square test or Fisher's exact test, if the expected value was less than 5, were used to test the difference between the groups regarding the categorical variables. Poisson regression analysis with a robust variance was used to determine the prevalence ratio of the different respiratory symptoms between the coffee workers and controls. Analysis of covariance and linear regression were used to compare the mean lung function parameters between the coffee workers and controls while adjusting for confounders.

Results: The GM dust exposure among machine room workers ranged from 4.09 to 34.40 mg/m³, among transport workers from 3.51 to 24.19 mg/m³, and among hand pickers from 0.26 to 5.87 mg/m³. Overall the GM personal dust exposure was significantly higher ($P = 0.001$) for the machine room (12.54 mg/m³) and transport workers (12.30 mg/m³) than for the hand pickers (1.08 mg/m³). In these three groups, 84.6%, 84.1%, and 2.6% of the samples exceeded the occupational exposure limit of 5 mg/m³ respectively. The result also indicated that pouring coffee vigorously from a dropping height was the determinant with the highest impact on personal total dust exposure with 3.2-fold increase compared to gradually pouring coffee from a very short height.

Coffee workers had significantly higher prevalence of most of the chronic respiratory symptoms compared with the controls. For most of the chronic respiratory symptoms, hand pickers without tables displayed a significantly higher prevalence ratio than in hand pickers with tables.

Male coffee workers in the age groups 28–39 years and ≥ 40 years, had a significantly lower FVC and FEV₁ compared to the controls in the similar age groups. There were statistical differences in FEF_{25-75%} between hand pickers and controls. In addition, FVC and FEV₁ were significantly lower among hand pickers without tables than among hand pickers with tables. The results also indicated the presence of gram negative bacteria in dried and stored beans from both the wet and dry process.

Conclusion: About 84% of the dust samples among machine room and transport workers in primary coffee processing factories were above the occupational exposure limit value for organic dust. Machine and transport workers in primary coffee processing factories had a higher prevalence of chronic respiratory symptoms and lower FVC and FEV₁ than the controls. Pouring coffee beans vigorously from a dropping height, mixing coffee and feeding hopper were the main determinants for increased personal dust exposure level. The dust exposure was related to reduced lung function and higher prevalence of chronic respiratory symptoms among coffee workers. Gram negative bacteria found in dried and stored coffee beans, might release endotoxin which may cause respiratory health problems among coffee production workers.

Recommendations: Coffee workers should be provided with efficient respiratory protective device and training on its importance prior to employment and regularly afterwards as necessary. Changing process of pouring coffee beans from vigorously to gradual could reduce personal dust exposure level in the coffee factories.

1. Introduction

1.1 Background

Dust is air-borne and small solid particles that ranged from $1\mu\text{m}$ to $100\mu\text{m}$ formed from disintegration of large solid materials during cutting, crushing and grinding (1). There are two types of dusts; inorganic and organic dusts. Inorganic dusts are dusts that come from stone, chemicals and metals such as cement coal and asbestoses (2). Organic dusts are dust particles originated from plants, animals and microbes (3). Most of the time organic dusts are released into the environment from industrial processing and agricultural activity such as grain processing, sugarcane processing, coffee processing and cotton processing (4).

Dust is one of the components present in coffee processing that originates at different stages of coffee handing and processing and is regarded as organic dust as it is derived from coffee plant. Dust in primary coffee processing factories contains particles that ranged from $5\mu\text{m}$ to $400\mu\text{m}$ (5, 6). Primary coffee processing, refers to green coffee processing that include mechanical cleaning of debris from parchment coffee, hulling, grading, hand picking, and packing of green coffee beans (7). Primary coffee processing occurs often in coffee growing countries, seldom in other countries. Secondary coffee processing refers to coffee processing that involve polishing, roasting and grinding (7).

Ethiopia is a major producer of coffee in Africa by producing about 500 000 tonnes every year (8). Ethiopia is believed to be the birth place of *Coffea arabica*, which obtained its name from Kaffa where coffee was first discovered in the south-western highlands of Ethiopia (9). Coffee contributes to about 10% of the Ethiopian growth domestic product and accounts for more than 25% of the foreign currency income (10, 11). Ethiopia produces exclusively Arabica Coffee, which is grown in three regional states: Oromia, Southern Nations, Nationalities and Peoples' Region (SNNPR) and Gambella. About 99% of the coffee production comes from the Oromia and SNNPR regions (12).

Coffee production by its nature is labour intensive, as a result a large number of people are involved in this sector. In Ethiopia, about 15 million people depend on coffee production directly or indirectly for their living (13). Often these coffee workers are exposed to coffee dust at different stage of coffee processing and handling, but the extent of their exposure is unknown and the magnitude of its health effect is also not known in Ethiopia.

1.2 Statement of the problem

Dust exposure is one of the major risk factors for health of coffee workers (14). Studies conducted in primary coffee processing factories in Papua New Guinea, Uganda, and Tanzania have shown levels of total dust exposure ranging 0.7–10 mg/m³, 1–58 mg/m³, and 0.24–36 mg/m³, respectively (5, 15, 16). Dust exposure in primary processing factories varied with processes, tasks, ventilation system, type of coffee, and method of pre processing at the farm (5, 16). For instance, a study in Tanzania indicated that personal dust exposure was higher when handling dry processed coffee than wet processed coffee (16). Dry processing method at the farm refers to a method where unpulped cherries are allowed to dry in the sun under natural condition after harvesting (17). In the wet processing method, harvested cherries are pulped immediately after harvesting, followed by fermentation and washing with clean water to remove mucilage cover (17, 18).

In preparatory field visits at primary coffee processing factories in Ethiopia, we observed that more dust seemed to be generated from old processing machines compared to new machines, and that dust levels appeared to be lower in coffee factories with mechanical ventilation and good natural ventilation compared to factories without such ventilation.

The primary coffee processing factories in Ethiopia are different from the primary coffee processing factories in Tanzania, Uganda, and Papua New Guinea where previous dust exposure measurements were conducted. Although Tanzania, Uganda, and Papua New Guinea grow both Arabic and Robusta coffee types, Ethiopia produces only Arabic coffee. Also the processing method at the farms in Ethiopia is different from these countries. For example, in Tanzania, Arabica coffee is mostly wet processed whereas Robusta coffee is dry processed. In Ethiopia, Arabica coffee is processed as dry or wet method based on the individual farmer interest. As coffee types and the processing method differ from one country to another, results from previous studies may not represent the dust exposure level in primary coffee processing factories in Ethiopia.

Several studies have indicated an association between working in coffee factories and respiratory health problems. Allergies have been suggested to be related to the problems (6, 19-24). A few studies conducted in primary coffee processing factories have indicated that exposure to coffee dust is likely to cause acute and chronic respiratory symptoms in these

factories as well (5, 7, 15, 25). Studies in primary coffee processing factories in Uganda and Sri Lanka indicated that exposure to coffee dust is associated with acute respiratory symptoms (15, 25) whereas an increased prevalence of chronic respiratory symptoms was reported among primary coffee factory workers in Tanzania and Papua New Guinea (5, 7).

Furthermore, studies indicated that exposure to coffee dust is likely to decrease lung function (24, 26-28). For instance study conducted in Papu New Guinea also found low mean Forced Expiratory Volume in first second (FEV₁) among coffee workers compared to soft drink factory workers (5). However, the study in Tanzania did not find difference in lung function parameters between the coffee workers and the controls (28).

Hand pickers are mainly women involved in manual sorting and removal of defective and discoloured coffee beans (29). Although the tasks of all hand pickers in Ethiopia are the same, the working conditions vary between factories. In general, hand pickers in the country can be classified into two groups: hand pickers with and without sorting tables. Hand pickers with tables are for instance work in primary coffee processing factories in Addis Ababa. The hand pickers sit on chairs with heights ranging from 40 to 50 cm, inside the processing machine room, and they sort both wet and dry processed coffee beans on a long table or a conveyor belt. Hand pickers without tables are found in Oromia and SNNPR primary coffee processing factories. These hand pickers perform their work while sitting on the ground, either outdoors on a veranda or in a separate room. They sort only dry processed coffee from piles of green coffees.

Studies have also indicated that coffee dust can contain endotoxin that can cause respiratory health problem (30-34). Endotoxin are released to the working environment when agricultural products contaminated with dust containing gram negative bacteria are processed (35-38). Sakwari et al. found high levels of endotoxin in primary coffee processing of Tanzania (16, 28). This finding indicate that coffee can be contaminated with gram negative bacteria like any other agricultural products during on farm processing of coffee and storage (28). Furthermore, Sakwari et al. found an association between exposure to endotoxin and respiratory symptoms and reduced lung function among the coffee processing factory workers in Tanzania (28). The same author suggested that poor storage and drying coffee on

ground might have increased bacterial contamination of the beans (28), but this suggestion has not been verified.

To our knowledge no previous studies assessed the difference between the two types of hand pickers in terms of respiratory health problem and dust exposure. Furthermore, the findings related to lung function were not clear, and more studies were needed for conclusive information regarding the respiratory health of coffee workers. The respiratory health impact of working in coffee processing factories of Ethiopia has not yet been explored.

Therefore, the aims of this study were to assess personal total dust exposure level, factors that influence dust exposure level and its effect on respiratory health of coffee workers. In addition this study assessed microbial contamination of coffee in different stages of both wet and dry method on farm coffee processing.

1.3 Rationale and significance of the study

The coffee sector in Ethiopia provides job opportunities for a significant number of people in different chain of coffee production. It is the source of income for many poor people and women. It is estimated that 15 million people in Ethiopia depend on coffee production directly or indirectly for their living (13). Often, these coffee workers are exposed to coffee dust at different stage coffee processing and handling, however, no study has been conducted to assess the coffee dust exposure level and factors affecting dust exposure level. So, this study will help to know the dust exposure level among workers in primary coffee processing factories in Ethiopia which is important to develop coffee dust exposure limit and preventive methods to reduce dust exposure in coffee factories.

Furthermore, previous studies conducted in primary coffee processing factories in other countries indicated that dust exposure can cause the development of acute and chronic respiratory symptoms. Therefore, data gathered by the this study will add more knowledge about respiratory health and dust exposure and this can aid health planners and other relevant stakeholders to implement preventive strategies. Generally, this study has an important contribution that may have an impact on improving workplace conditions in Ethiopia. Above all, this study can serve as baseline data for further studies.

Studies from Tanzania have also indicated that coffee dust can contain endotoxin when it is contaminated by bacteria. This might also be the case in Ethiopia but little effort has been made to assess coffee contamination by microbes at the farm, therefore this study assessed microbial contamination of coffee in different stages of both wet and dry method on farm coffee processing. Thus, this study can help to identify points of coffee contamination, and could provide new information on how to prevent and control bacterial contamination of coffee beans.

2. Literature review

2.1. General overview about coffee production

2.1.1. Coffee

Coffee is one of the most important beverages in the world. The two most known coffee species in the world with economic significant are coffee Arabica and coffee Robusta; which together accounts for 99% of the global coffee market. Arabica accounts for 70% while coffee Robusta accounts for 30% (39, 40). Coffee is produced in many countries in the world and major coffee producing regions are South America, South East Asia and Africa (40-42).

Coffee is the main source of foreign exchange in many coffee producing countries. For instance, more than 25 countries in Africa depend on coffee export to earn foreign currency (43). Coffee production by its nature, is labour intensive and as a result a large number of people are involved in this sector worldwide.

2.1.2. Coffee in Ethiopia

Coffee Arabica has originated from Ethiopia. In fact, coffee got its name from Kaffa where coffee was first discovered in the South Western region of Ethiopia. Ethiopia produces about 3% of world coffee and is a major producer in Africa, with about 500, 000 metric tons every year (44). About half of the coffee produced in Ethiopia is consumed locally. Currently, coffee accounts for more than 25% of foreign currency income (10).

Coffee grows in three regional states of Ethiopia namely Oromia, SNNPR and Gambella regional state. Oromia and SNNPR are the two regions that constitute the main coffee growing areas. About 64, 35 and 1% of coffee production comes from Oromia, SNNPR and Gambella regions respectively (45). In Ethiopia, more than 90% of the coffee is produced by small- scale farmer that owns in average 0.5 hectare (12). Coffee from different growing regions of Ethiopia has different varieties of coffee Arabic each with its own unique liquor attributes: aroma, taste, and flavor (46). The most popular coffee varieties in Ethiopia are Sidama, Yirgacheffe, Jimma and Harar coffee beans (9). Arabic coffee grows best at altitude, ranging from 1300 to 1800 meters above sea level and with annual rainfall and temperature ranging from 1500 to 2500mm and 15 to 25⁰C, respectively (47).

2.1.3. Coffee production in Ethiopia

There are various coffee production types in Ethiopia: forest coffee, semi forest coffee, garden coffee and plantation coffee (43). Forest coffees refer to wild coffees that grow in the dense rainforest of south western highlands of Ethiopia and regenerate naturally assisted by wild animals (9). In this system there is no any kind of human interference except collecting the ripened coffee cherry and there is no personal owner, everyone in the community has the right to collect the coffee cherries. It accounts about 10% of Ethiopia coffee production (9).

Semi forest coffee refers to coffee that grows in light forest of south western region and often located near to rural towns, villages and crop lands. This system is owned and managed by personal owners and it contribute to about 35% of Ethiopian coffee production (9).

Garden coffee refers to coffee developed from planting of seedlings from forest or nurseries. Garden coffee trees have little shades and often grow together with other annual and perennial crops. It accounts about 35% of coffee production of Ethiopia (9).

Plantation coffee production system refers to highly intensified coffee plantations that are owned by private investors and modern small scale farmers. This system contributes to about 20% of the coffee production in Ethiopia (9).

2.1.4. Harvest and processing of coffee at the farm in Ethiopia

Coffee plant in Ethiopia matures in about 5 years after planting the seedlings (42). It takes eight months for coffee cherries to ripe after flowering. Coffee harvesting in Ethiopia occurs only once in a year and the harvesting period is from August to January (42). In Ethiopia, coffee cherries are harvested when most of the cherries are ripen, and most of the time the harvest is done by handpicking in specially designed baskets. After the harvest the cherries are processed on farm (17). There are two types of coffee processing at the farm in Ethiopia: dry and wet coffee processing method. In Ethiopia, about 71 percent of the coffee is processed by the dry method and the rest is processed by wet method (12).

In dry processing method, after sorting out unnecessary things like leafs and unripe cherries from the harvested cherries, the unpuled coffee cherries are allowed to dry in the sun under natural conditions by spreading on ground, mats, cemented floor or raised dry bed (17, 18). The spread coffee is heaped in the night and respread each morning. This process continued

for about three to four weeks depending on the weather condition of the area until the moisture content gets about 11.5 percent (17). Dry processed coffee is also called natural coffee or unwashed coffee (12).

In wet coffee processing, unlike the dry processing coffee, harvested cherries are sorted and depulped the same day they are harvested. Then, the pulped coffee is allowed to ferment naturally in different tanks for about 16-18 hours depending on the weather condition (17, 18). This process is monitored carefully to avoid over or under fermentation. When fermentation is completed, the coffee is washed with running water to remove the remaining mucilage and acids and to improve the colour of the beans. Finally, the wet coffee beans are spread on raised drying table and allowed to dry by sun until the moisture content gets 11.5 % (17, 18). This process is also called washed coffee or wet method and produce coffee with parchment. There were about 1024 wet processing facilities at the farm in Ethiopia (12).

2.2. Coffee processing factories in Ethiopia

2.2.1. Primary coffee processing factories

After the coffee has been processed at the farms, it is processed in primary coffee processing factories. These are of two types of primary coffee processing factories. The first one is coffee factories that process only coffee processed by dry method in the farm. They are normally located near the farm. These type of coffee processing factories are found in Oromia and SNNPR. There were about 696 coffee factories in both Oromia and SNNPR (48).

The second one is coffee factories found in Addis Ababa and Dire- Dawa that process coffee beans that have been processed by wet method. In addition, these coffee factories process green coffee beans that have been processed in Oromia and SNNPR coffee factories to meet the export standard. In total, there were about 50 coffee factories of these type (49). More than 95% of these coffee processing factories are located in Addis Ababa. The processing steps are more or less the same in the two coffee processing factories except polishing is absent in coffee factories in Oromia and SNNPR. Generally, the following are the steps in coffee processing factories in Ethiopia (Figure 1):

From warehouses, coffee cherries or parchments are manually conveyed to the intake hopper where it is stored temporarily to ensure continuous supply of coffee in the processing line and

also to mix coffee at equal ratio. From the hopper coffee is conveyed to the pre-cleaner via an elevator. The pre-cleaner is used to separate dust, and large things from the coffee (7). From the pre-cleaner the coffee is conveyed via an elevator to the destoner where heavy stones are removed (7).

There is a magnet between the pre-cleaner and the destoner that remove metals from the coffee. From the destoner coffee is conveyed via an elevator to the Huller machine where husks are removed from the coffee. An Aspirator is used to blow dust from the Hulling machine to outside via a pipe. From the Huller machine coffee is conveyed to the polisher where more skin covers (silver skin) are removed from the coffee (7).

From the polisher coffee is conveyed via elevators to the grader where coffees are separated based on their size. From the grader via an elevator coffee is conveyed to the catador to separate broken and light coffee from normal coffee (7). From the catador coffee is conveyed to the gravity separator where the lighter coffees are separated from heavier ones. From the gravity separator coffee is conveyed to colour sorter where discoloured coffees are separated from green coffee and finally coffee is conveyed to the hand pickers.

Coffee from the hand pickers is conveyed via elevator to the Silo where they are stored temporarily and then weighed and sewn in 60 kg jute bag. The packed coffee is transported to the warehouse until quality control and other procedural things are finished. Finally, the processed coffees are loaded to the trucks for shipping.

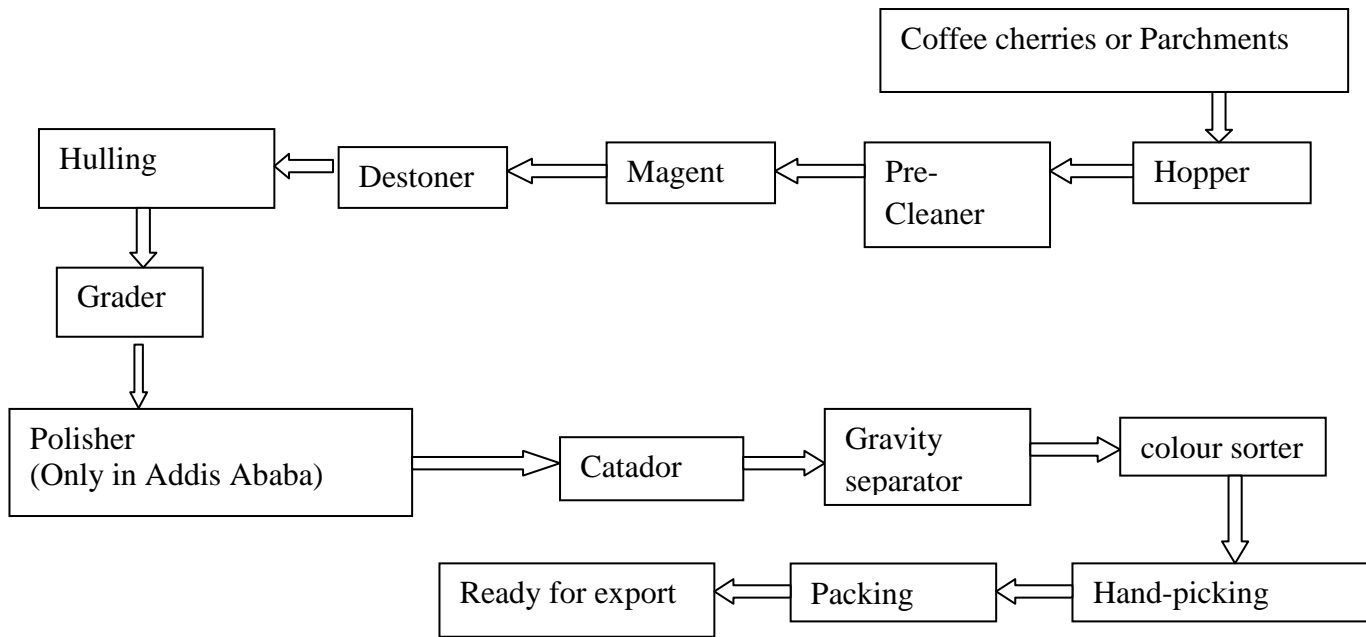


Figure 1 : Steps in primary coffee processing factories

2.2. 2. Secondary coffee processing factories

Secondary coffee roasting plants involves three different processes: roasting, grinding and packing (7). There are limited number of secondary coffee processing factories in Ethiopia. They have small in size and capacity. The cleaned coffee is first manually added to coffee hopper where it will be stored temporarily until the coffee is conveyed to the roasting hopper using air conveyer (blower). From roasting hopper coffee discharged to the roasting drum where coffee is roasted at adjusted temperatures to get the desired colour.

Then coffee is discharged into the cooling bin where it is cooled by air cooling (blower) to room temperature. Cooled roasted coffee is sorted by hand pickers to remove beans that are too light, too dark and defected coffee. Cleaned roasted coffee beans will be transported manually to the grinding machine where it is grinded to desired size. Finally the grinded coffee is weighed, packed and sent for local market and for export (Figure 2).

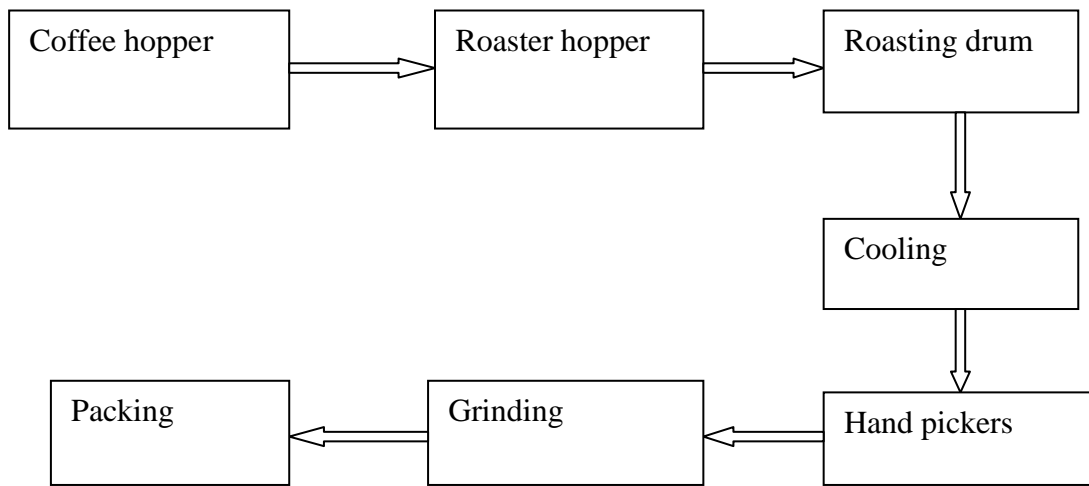


Figure 2 Steps in secondary coffee processing factory

2.3. Task related activities in primary coffee processing factories in Ethiopia

2.3.1. Handling low quality coffee

Small size coffee, lighter coffee and broken coffee from the grader, gravity separator and catador are collected and stored in the warehouse as a reject coffee and later will be sold in local markets (Figure 3). Sometimes based on the request of the buyer or the wish of the owner, the rejected coffee of different types and grades are mixed together to get a homogenous mixture. The mixing is done manually, first the sewn bags of rejected coffees are cut and the coffee is poured out on the cemented floor. Then, six to seven workers use shovels to mix the coffees until the required homogeneity is reached. The mixing process produces a lot of dust.



Figure 3. Mixing rejected coffee

2.3.2. Husk handling

Husks from hulling machine are conveyed via a pipe to the storage house in the back yard. Husks are sold for cooking purpose to the community in auction. The winner of the auction comes with a group of people to load the husk in to the bags and load it in to the trucks. Those people who are involved in loading husk in the bags and on trucks are exposed to dust.

2.3.3. Sweeping, collecting and stamping on coffee bags

There are people who clean the floor and the machine frequently. Sweeping is done manually by using dry brooms. There are also people who are collecting emptied bags and put it in order for selling. There are also people printings labels on the new coffee bags. The above mentioned task can expose workers to dust.

2.3.4. Loading and unloading in coffee processing factories

When coffee arrives to the primary coffee processing factories, they are transported manually to the warehouse (Figure 4). From warehouse the coffees are transported manually to hopper intake where they are stored temporarily. Coffee after cleaned by hand pickers, are weighed and put in 60 kg jute bag manually. The packed coffee is transported manually to the warehouse. When order come from the buyers the 60 kg jute bags are loaded manually to truck for shipping or further process to meet export standards. Workers involved in loading and unloading activities can be exposed to dust.



Figure 4: Transporting coffee

2.3.5. Machine room workers

These are people working in the machine room with in radius of 5 meter from the hulling machine and includes operator work, mechanic work, feeding hopper and cleaning.

Operators are involved in monitoring proper coffee processing procedures. Mechanics ensure the smooth running of the machines and involved in maintenance work. Feeding hopper is adding the coffee beans in to hopper gradually or vigorously.

2.3.6. Hand pickers

Hand pickers are girls and women who are engaged in sorting or separating defective coffees and discoloured coffees (i.e. black, yellow and red coffees) from the sound coffee beans. Although, the tasks of all hand pickers in Ethiopia is the same, their working condition varies significantly from factories to factories. In general, the hand pickers in Ethiopia can be classified in to two groups; hand pickers with table and hand pickers without table.

Hand pickers with table are found in Addis Ababa primary coffee processing factories and sit on chair and sort coffee beans from a long table or moving belt. They also sit inside the machine room and sort both wet and dry processed coffee beans (Figure 5a). On the other hand, hand pickers without table found in Oromia and SNNPR primary coffee processing factories and sit on the ground and sort coffee beans from small grass reed plate. They sit outside the machine room either in Veranda or separated room and sort only dry processed coffee (Figure 5b).



Figure 5: Hand pickers without table (a) and hand pickers with table (b)

2.4. General overview about dust particles

2.4.1. Definition of dust and types of dust

Dust is air borne and small solid particles that ranged from 1µm to 100 µm formed from disintegration of large solid materials during cutting, crushing, grinding etc (1). For many years dusts were classified as total dust and respirable dust. Total dust refers to all sizes airborne particles while respirable refers to fine airborne particles.

To define the size of a particle, a diameter of a particle is used based up on its aerodynamic properties specifically considering the settling velocity of a particle in the still air. Aerodynamic diameter (AD) is the diameter of a unit density sphere that drops at the same velocity with particle concerned (1). The Aerodynamic diameter plays important role in determining how the particles deposit in the lung. Based on this definition the dust particle size can be categorized in to three parts: inhalable dust fractions , thoracic dust fractions and respirable dust fraction (14).

Inhalable dust fractions are dust particles that can be breathed in by mouth and nose (50% cut point at 100 microns) (1). Dust from hardwood and grinding of lead containing material can be categorized as inhalable dust (14). Thoracic dust consists of dust particles that can reach middle respiratory tract like the trachea and bronchial regions (50% cut point at 10 microns) (1). Cotton and other dust causing airway disease are best example for this group. Respirable dust -these are dust particles that can penetrate in the lower respiratory tract or alveoli (50% cut point at 4 microns) (1). Examples of respirable dust includes quartz, free crystalline silica, cobalt and other hard metal dust produced by grinding masonry drill bits; and many others (14).

2.4.2. Organic dust and its constituent

Organic dust are dust particles originated from vegetable, animals and microbes (3). They are released into the environment from industry and agricultural activity such as grain, sugarcane, coffee and cotton processing, swine and dairy buildings (30, 33, 35-37). Often organic dust contains biological factors such as bacteria and mold, endotoxins, (1→3) - β-D-glucans and mycotoxins (37).

Endotoxin is a toxin found in the cell wall of all gram negative bacteria (31). Studies have indicated that endotoxin are released to the working environment when agricultural products contaminated with dust containing gram negative bacteria are processed (35-38). High concentration of endotoxines have been detected in many occupational settings where organic dust are found such as in swine confinements (50) textile factories (51) and hemp processing plant (52).

Like many other agricultural products coffee can be contaminated with bacteria that release endotoxin (41). Sakwari et al. found high levels of endotoxin in primary coffee processing of Tanzania (16, 28). This finding indicate that coffee can be contaminated with gram negative bacteria like any other agricultural products during processing of coffee at the farm and storage (28). Poor storage and drying coffee on ground might increase the chance of coffee contamination by bacteria and mold (39). A study conducted in Yemen found an average total bacteria count of 4.47×10^4 colony forming unit (CFU), while the average total fungi (mold & yeast) count was 6.17×10 CFU from all coffee samples collected from the local market (41).

2.4.3. Dust sampling methods at work places

There are different methods of dust sampling at work places (1). One method is static measurements (area measurement) –in this case an instrument for sampling is located in one place in the work area and indicate the concentration of dust in that working area. Another method is to use in personal measurements. Here a sampling instrument is mounted on the individual workers and they carry it with them whenever they move from place to place. This indicates personal dust exposure level.

All dust measurement methods have their own advantage and disadvantage. For example static can be considered as a simple and cost effective method. It can be used when there is fairly uniform distribution of dust in all section of the work place (53). Static measurement provides low concentration of dust compared to personal measurements (1). Personal measurement is more labour intensive and require more instruments but this method provide reliable concentration of dust exposure by individual worker although they have been moving around in different areas (1). Personal measurements are useful for compliance purpose.

2.4.4. Characteristics of dust exposure in coffee factories

Dust generates from coffee at different stages of coffee handling and processing (54). As a result coffee workers are exposed to a varied level of coffee dust depending on the task performed (16, 23, 55). To date, there is no internationally agreed occupational exposure limit for coffee dust, however, as coffee dust is an organic dust, studies have used the occupational exposure limit for organic dust $5\text{mg}/\text{m}^3$ as occupational exposure limit for coffee dust (7, 23). The occupational exposure limit is an eight hours time weighted average concentration which is considered to have no adverse effect to the person exposed (14).

A study conducted in Tanzania found that personal total dust concentration ranging from $0.24\text{-}36\text{mg}/\text{m}^3$ (16). This study also indicated that a higher dust exposure when handling dry pre-processed coffee ($3.68\text{mg}/\text{m}^3$) than when handling wet pre-processed coffee ($1.90\text{mg}/\text{m}^3$). In similar study a higher level of dust exposure was found for sweeping than for tasks with less green coffee contact (16).

Studies conducted in Papua New Guinea and Uganda indicated concentration of total dust exposure ranging from $0.7\text{-}10\text{mg}/\text{m}^3$ and $1\text{-}58\text{mg}/\text{m}^3$, respectively (5, 15). Another study conducted in a coffee haulage company also found a high level of inhalable dust at coffee discharge ranged from $10.1\text{-}15.7\text{mg}/\text{m}^3$ (54). Several reports also indicated relatively a higher dust concentration level when processing green coffee beans compared to roasted coffee (24, 26, 56).

2.5. Coffee dust exposure and its health problems

Several studies have indicated that exposure to coffee dust is likely to cause acute and chronic respiratory symptoms and reduced lung function

2.5.1. Acute and chronic respiratory symptoms

Acute respiratory symptoms may result from short time exposure to coffee dust and includes: cough, dyspnea, throat, irritation, dryness, eye irritation, headache, nose secretion, nose dryness and nose bleeding (57). A study conducted in Sri Lanka in people who are exposed to coffee dust intermittently showed acute respiratory symptoms; cough (84.2%), sputum (76.3%), sneezing (73.7%), difficulty in breathing (63.2%) and running nose (55.3%) (20). Another study conducted in primary coffee factories of Uganda also indicated a higher

prevalence of acute respiratory symptoms among coffee workers (9.3 %) than controls (3.9%) (15) .

A study conducted among workers in green coffee and roasted coffee found a high prevalence of acute symptoms among green coffee workers (cough 38.7 % and dyspnea 41.9%) (6). Several case studies in secondary coffee processing indicated an association between coffee dust exposure and acute symptoms such as asthma, rhinitis, conjunctivitis (6, 58).

A study conducted in Tanzania found a significantly higher prevalence for almost all chronic respiratory symptoms when compared to controls. This study found prevalence of morning cough (24%), morning cough with sputum (22%), breathlessness (12%), wheezing (16%), chest tightness (28%) and chronic bronchitis (3.6%) among coffee workers (28). A study conducted in Papua New Guinea reported a higher prevalence of chronic productive cough (8.7%) among coffee workers than control (1.5%) (5). Another study also showed a high prevalence of chronic cough (29.3%) chronic phlegm (24.4%), chronic bronchitis (17.1), dyspnoea (29.3%) among female coffee workers (57).

Several studies have indicated that exposure to endotoxin can cause respiratory health problems (30-33). Sakwari et al. found an association between exposure to endotoxin and respiratory symptoms (28).

2.5.2. Reduced lung function

The study conducted in primary coffee processing factories in Papua New Guinea found no significant difference in the mean forced vital capacities and FEV₁/FVC ratio between coffee workers and controls. However, the mean FEV₁ of coffee workers was less than that of the soft drink factory workers (5).

On the other hand study conducted in primary coffee processing factories in Tanzania found significant difference in FEV₁/FVC ratio before age adjustment between coffee workers and controls, however, there was no significant difference in the FVC and FEV₁ between coffee workers and controls (28).

Another study conducted in primary coffee processing factories that compared exposed and unexposed workers found post-shift drop in mean FEV₁ and it was statistically significant after adjusting for age, gender and cigarette smoking (15).

A study in secondary coffee processing factories found a significant acute reductions in ventilatory capacity during work on Mondays in workers processing either roasted or green coffee (24). It is not only the coffee dust that may cause reduced lung function, it might also be exposure to endotoxin that leads to reduced lung function (28).

2.6. The Conceptual Framework

To better understand the the relationships between dust exposure and respiratory health a conceptual framework (Figure 6) was developed based on literature review. Exposure to coffee dust and endotoxin is likely to cause respiratory problem. In addition to dust exposure, other factors such as smoking and indoor cooking can cause respiratory problem. Proper protective equipments like masks can reduce exposure to dust which in turn can reduce respiratory health problem.

The level of dust exposure is also affected by factory related determinants or task related determinants. Factory related determinants includes ventilation type, the design of the machineries, type coffee processing, processing capacity, production rate, number of machine in the room. Task related activities are tasks performed at the time of sampling such as feeding hopper, cleaning, mixing coffee, loading and unloading and mechanic work.

Often organic dust such as coffee dust contains biological factors such as bacteria. This is because like many other agricultural products coffee can be contaminated with bacteria during processing coffee at the farm. During further coffee processing, endotoxin may possibly released in to the working environment from coffee contaminated by gram negative bacteria which might affect coffee workers respiratory health. Poor storage and drying coffee on ground might increase the chance of coffee contamination by bacteria.

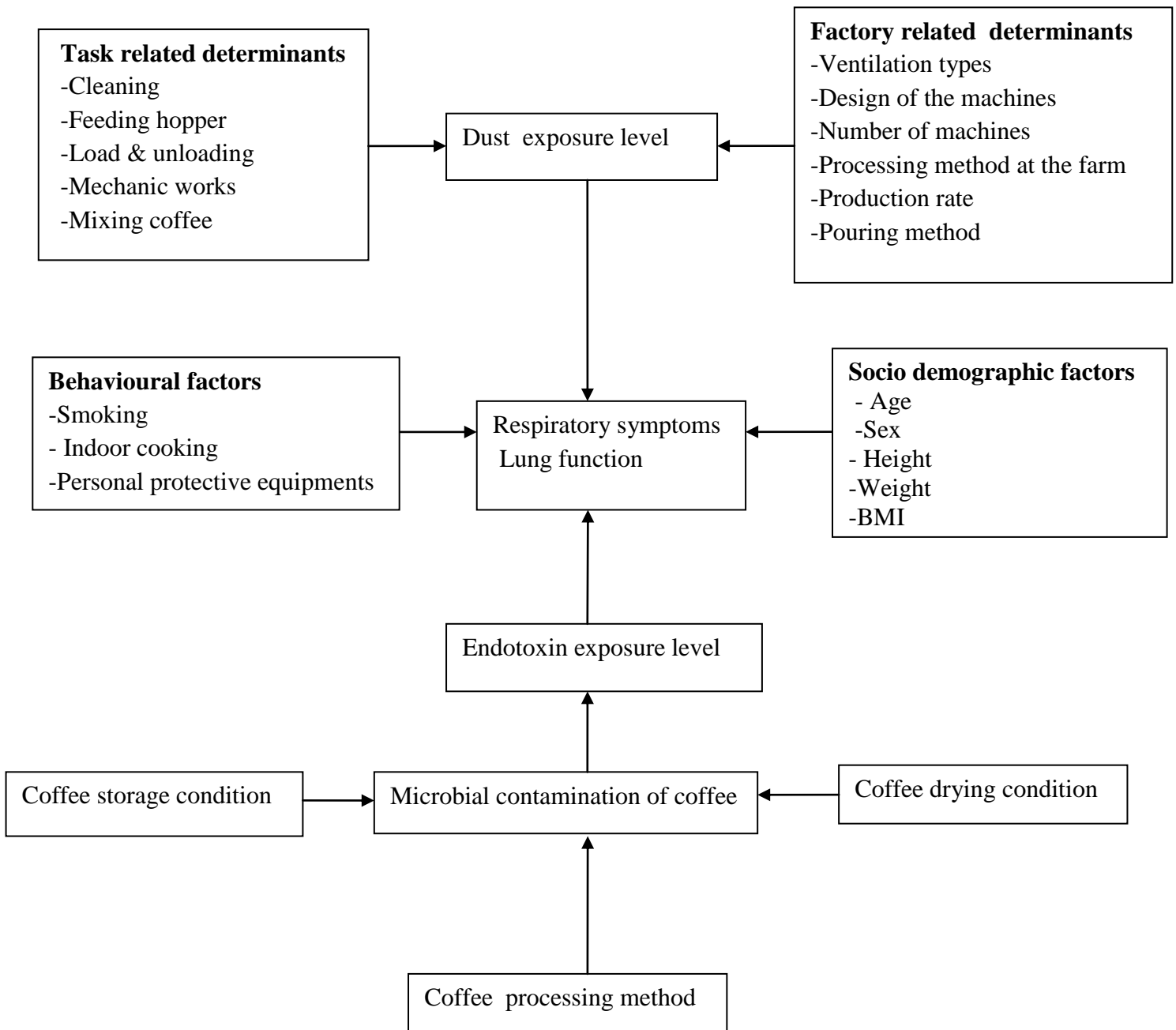


Figure 6 Conceptual Framework for determinants of coffee dust exposure and its effect on respiratory health

3. Research questions and objectives

3.1. Research questions

1. What is the personal total dust exposure level among workers in primary coffee processing factories in Ethiopia?
2. What are the factors affecting dust exposure level in primary coffee processing factories?
3. Is there lung function reduction and chronic respiratory symptoms among workers in primary coffee processing factories in Ethiopia?
4. Is there a difference in respiratory health problem between hand pickers with tables and without tables in primary coffee processing factories in Ethiopia?
5. At which stage of coffee processing on farm coffee contaminated by gram negative bacteria?

3.2. Research objectives

3.2.1. General objectives

To assess personal total dust exposure level, factors affecting dust exposure and respiratory health among workers in primary coffee processing factories and also to assess microbial contamination of coffee in different stages of coffee processing at the farm.

3.2. 2. Specific objectives

1. To assess the personal total dust exposure level and evaluate their determinants of exposure among workers in primary coffee processing factories in Ethiopia (paper I)
2. To examine lung function reduction and chronic respiratory symptoms among workers in primary coffee processing factories in Ethiopia (Paper II)
3. To compare the prevalence of chronic respiratory symptoms and lung function among hand pickers with table and without tables in primary coffee processing factories of Ethiopia (Paper III)
4. To assess microbial contamination of coffee at different stages coffee processing at the farm in Ethiopia (Paper IV)

4. Methods

4.1. Study areas and setting

The study was conducted in Goma, and Mena woredas of Jimma zone, Oromia region and Aleta Wondo and Shebedino woredas of Sidama zone, SNNPR (Figure 7). In addition, the study was conducted in Addis Ababa City Administration. Southern Nations, Nationalities and Peoples' Region and Oromia Regional States are the two regions that constitute the main coffee growing areas with about 64% and 35% respectively (45). Jimma and Sidama zones are the two zones with highest coffee production in their respective regions. There were about 746 primary coffee processing factories in Ethiopia (i.e 550 in Oromia region, 146 in SNNPR and 50 in Addis Ababa) (48, 49). There were about 405 and 616 wet method processing facilities at the farm in Oromia and SNNPR, respectively (31).

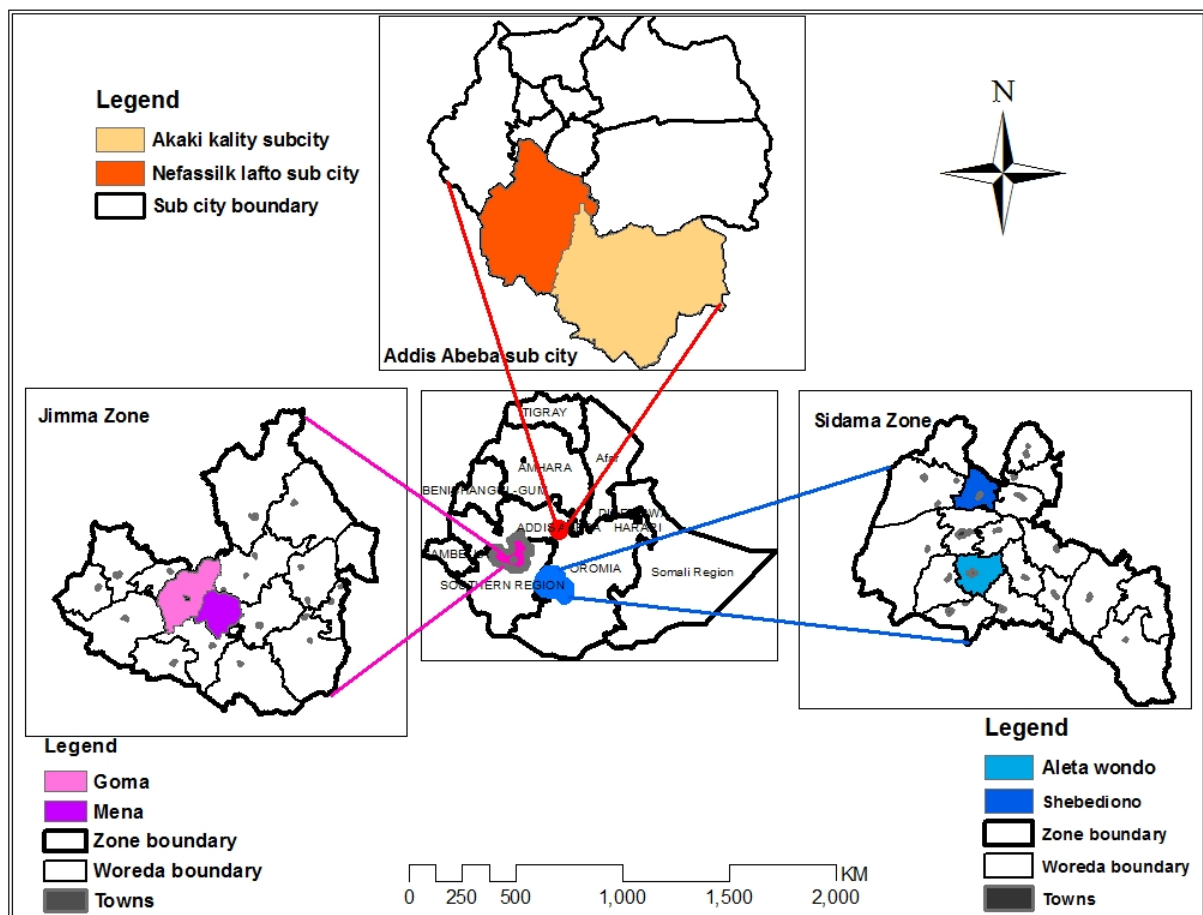


Figure 7: Location of map of the study area in Jimma zone (Goma and Mena woreda), Sidama zone (Shebediono and Aleta wondo woerda) and Addis Ababa city administration (Akaki kality and Nefasilk lafto sub city).

4.2. Study design and period

A comparative cross sectional study design was used to compare lung function reduction and chronic respiratory symptoms between coffee workers and control groups for paper II & III. A cross sectional study design was used to assess personal dust exposure among coffee workers and microbial contamination of coffee for paper I & IV. The whole study project was conducted from May, 2016 to January, 2017.

4.3. Source population

For paper I : All workers (machine room workers, transporters and hand pickers) in primary coffee processing factories found in Addis Ababa, SNNPR and Oromia regions were the source population.

For paper II: All machine room and transporters workers in primary coffee processing factories found in Addis Ababa, SNNPR and Oromia regions were the source population. All male workers in water bottling factories of the three regions were used as source of population for controls.

For paper III: All hand pickers in primary coffee processing factories found in Addis Ababa, SNNPR and Oromia regions were the source population. All female workers in water bottling factories of the three regions were used as source of population for controls

For paper IV: All wet and dry method coffee processing plant found in SNNPR and Oromia region

4.4. Study population

For paper I: Machine room workers, transporters and hand pickers in the selected twelve primary coffee processing factories found in Addis Ababa city, SNNPR and Oromia region.

For paper II: Machine room and transporters workers in the selected twelve primary coffee processing factories found in Addis Ababa city, SNNPR and Oromia region. Male workers in the three water bottling factories from each of the three regions were study population for control group.

For paper III: Hand pickers in the selected twelve primary coffee processing factories found in Addis Ababa city, SNNPR and Oromia region. Female workers in the three water bottling factories from each of the three regions were study population for control group.

For paper IV: 2 wet and 2 dry method processing plant in Yebu and Shebedino woreda in Oromia and SNNPR regions of Ethiopia, respectively.

4.5. Inclusion criteria

This study included both old and new coffee factories as well as small and large size primary coffee factories. Only workers aged 18 years and above were included in this study for ethical reason. Workers worked for at least one year at the factory were included in the study.

4.5. Exclusion criteria

Coffee processing factories that process other agriculture products were excluded in this study because the result may not represent the majority coffee factories of Ethiopia. Participants were excluded from lung function test, if they had eye surgery, open chest or abdominal surgery, stroke, or heart attack specifically in the past 3 months.

4.6. Selection of coffee and control factories

Taking into consideration the available resources and after consulting experts on exposure assessment, 12 primary coffee processing factories were included in this study. The twelve primary coffee processing factories were divided equally to the three regions (i.e., four factories for each of the three regions: Addis Ababa, SNNPR and Oromia regions). These regions were selected because almost all primary coffee processing factories are located in these regions.

Jimma Zone from Oromia region and Sidam Zone from SNNPR region were selected, because they have the highest number of primary coffee processing factories in their respective regions. In field visits at primary coffee processing factories in different part of Ethiopia, we observed that coffee processing and handling are more or less similar for all primary coffee processing plants found within the region. Two woredas were randomly selected from each zone. Thus, Goma and Yebu woredas from Jimma zone and Aleta Wondo and Shebedino woredas from Sidam zone were selected. In the final stage two primary coffee

processing factories were randomly selected from each woreda. In addition, four primary coffee processing factories were randomly selected from Akaki kality and Nefasilk Lafto sub city in Addis Ababa city Administration (i.e 2 coffee factories from each sub city).

Furthermore, three water bottling factories from each of the three regions: Addis Ababa, SNNPR and Oromia regions were selected as a control group. Water bottling factories were chosen as their workers experience less dust exposure at work.

4.7. Sample size determination

Sample size for dust exposure (paper I): The number of personal dust samples was calculated based on Rappaport and Kupper (2008) who suggested repeated samples from 5 to 10 randomly selected individuals per Similar Exposure Group (59). Similar exposure groups compose workers with similar tasks sharing the same working environment (59). In primary coffee processing factories of Ethiopia three main job groups (hand pickers, transporters, and machine room workers) had distinct characteristics in terms of tasks performed and were assumed to constitute three similar exposure groups.

In each factory, five coffee workers were randomly selected for dust sampling from each of the three main job groups. Thus, 15 persons were involved from each factory, and a total of 180 individuals from the 12 primary coffee processing factories were participated in this study. Since sampling was performed on two consecutive days for each worker, a total of 360 dust samples were taken in the 12 factories (Table 1).

Similarly, sample size for dust sampling for control group was also calculated based on Rappaport and Kupper (2008) (59). It was assumed that there were two similar exposure groups in the water bottling factories (i.e. loading bottled water (male) and light inspection (female)). Five individuals were randomly selected from each group. That means a total of 15 female and 15 male workers from the three water bottling factories. Since sampling was performed on two consecutive days for each worker, a total of 60 dust samples (i.e 30 dust samples from male and 30 dust samples from female) were collected from the 3 water bottling factories (Table 1).

Table 1: Distribution of dust sampling by regions (Oromia, SNNPR & Addis Ababa) and task, 2016

Regions	Male coffee workers				Hand pickers (Female)				Controls from water bottling factories			
	Machine room workers		Transporters		Handpickers with table		Handpickers without table		Male		Female	
	NW	NS	NW	NS	NW	NS	NW	NS	NW	NS	NW	NS
Addis Ababa	20	40	20	40	20	40	-	-	5	10	5	10
SNNPR	20	40	20	40	-	-	20	40	5	10	5	10
Oromia	20	40	20	40	-	-	20	40	5	10	5	10
Total	60	120	60	120	20	40	40	80	15	30	15	30

NW: number of workers; NS: number of dust samples

Sample size for paper II: Sample size for lung function was calculated using the mean difference formula. Lung function with mean and standard deviation for FEV₁/FVC was 83.3±6.3 among Arabic coffee workers and 85.7±5.2 among controls (28). Significance level of 0.05 and 80% power were used to calculate the sample size. After considering 15% for non-response, a total of 105 from coffee factories and 105 from water bottling were required.

$$n = \frac{2\sigma^2 (Z_{\alpha/2} + Z_{\beta})^2}{(d)^2}$$

Where

n= sample for one group

σ= standard deviation (the variability of the difference between sample means)

d=mean difference between exposed (coffee workers) and non exposed (controls)

Z_β= corresponds to power

The sample size for respiratory symptoms was calculated using a double population formula considering that the prevalence of wheezing among the primary coffee workers in Tanzania

was 16% and 4.3% among the controls (28). An 80% power was set to detect a difference in the wheezing between the two groups at significance level of 0.05. After considering 15% for non-response, a total of 120 from coffee factories and 120 from water bottling were required.

$$n1 = \frac{(Z\alpha/2 + Z\beta)^2 * (P_1(1-P_1) + P_2(1-P_2))}{(P_1 - P_2)^2}$$

Where

P₁= prevalence of respiratory symptoms among exposed to coffee dust

P₂=prevalence respiratory symptoms among non exposed

Zβ= corresponds to power (the probability of detecting a significant difference in morning cough between the two groups).

Since the sample size for respiratory symptoms produce the higher number, 120 individuals from each group were included in this study.

Sample size for paper III: The sample size for prevalence of assessment among hand pickers was calculated using double population formula considering the prevalence of morning cough with sputum among coffee workers 23% and controls 10% (7). A 90% power was used to detect the difference in morning cough between the two groups at significance level of 0.05.

$$n1 = \frac{(Z\alpha/2 + Z\beta)^2 * (P_1(1-P_1) + P_2(1-P_2))}{(P_1 - P_2)^2}$$

Where

P₁= prevalence of respiratory symptoms among exposed to coffee dust

P₂=prevalence respiratory symptoms among non exposed

Zβ= corresponds to power (the probability of detecting a significant difference in morning cough with sputum between the two groups)

Thus, 190 participants from each hand pickers and controls needed. However, the prevalence of chronic respiratory symptoms were compared among three groups (i.e. Hand pickers with tables, Hand pickers without tables and women from water bottling factories). Thus, 190 participants from each of the three groups were included.

Sample size for lung function was calculated using the mean difference formula. We expected 0.027 mean difference and 0.05 standard deviation for FEV₁/FVC among female coffee workers and controls in water bottling factories. Significance level of 0.05 and 80% power were used to calculate the sample size (28). After considering 10% non-response, we needed 60 hand pickers and 60 controls. As the lung function parameters were planned to be compared among three groups (i.e. hand pickers with tables, hand pickers without tables and controls) 60 participants from each of the three groups were included, making the total number of participants 180.

$$n = \frac{2\sigma^2 (Z_{\alpha/2} + Z_{\beta})^2}{(d)^2}$$

Where

n= sample for one group

σ = standard deviation (the variability of the difference between sample means)

d=mean difference between exposed (coffee workers) and non exposed (controls)

Z_{β} = corresponds to power

Sample size for paper IV: A total of four different farms (2 wet and 2 dry coffee processing) were included. Coffee sampled twice from each stages of wet coffee procesing (i.e. red cherries, pulped beans, fermented beans, washed beans, dried beans and stored beans). Thus, a total of 24 coffee samples were collected from the 2 wet coffee processing farms. Similarly coffee sampled twice from each stages of dry methods (i.e. coffee cherries, dried beans and stored beans). That means, a total 12 coffee sampled from the 2 dry coffee processing farms. Therefore, in total 36 coffee samples were collected for microbial examination (Figure 8).

4.8. Study participant sampling procedure

For dust exposure (paper I): Five workers from each of the tree main job group (i.e machine room, transporters and hand pickers) were selected by systematic sampling method, using the workers' registration list as a sampling frame from each coffee factories. Similarly, 5 workers from each of the two departments (i.e loading and light inspection) were selected by systematic random sampling method, using the workers' registration list as a sampling frame from each water bottling factories.

For paper II: Five machine room workers and 5 transporter workers were selected by systematic sampling method from each of the 12 primary coffee processing factories, using the workers' registration list as a sampling frame from each coffee factories.

The 120 male controls were allocated proportionally to the size of the 3 water bottling factories. Then, workers were selected by systematic sampling method, using the workers' registration list as a sampling frame from each water bottling factories.

For paper III: The 190 samples for hand pickers without tables were allocated proportionally to the size of the 8 primary coffee processing factories found in Oromia and SNNPR. Similarly, 190 samples for hand pickers with tables were allocated proportionally to the size of the 4 primary coffee processing factories found in Addis Ababa. In addition, 190 samples for controls were allocated proportionally to the size of the 3 water bottling factories. Then, workers were selected by systematic sampling method, using the workers' registration list as a sampling frame from each factories.

For paper IV: Coffee samples were collected two times on different days from different batches of coffee from each stage of both the wet and the dry method process. (Figure 8).

On farm postharvest processing of coffee

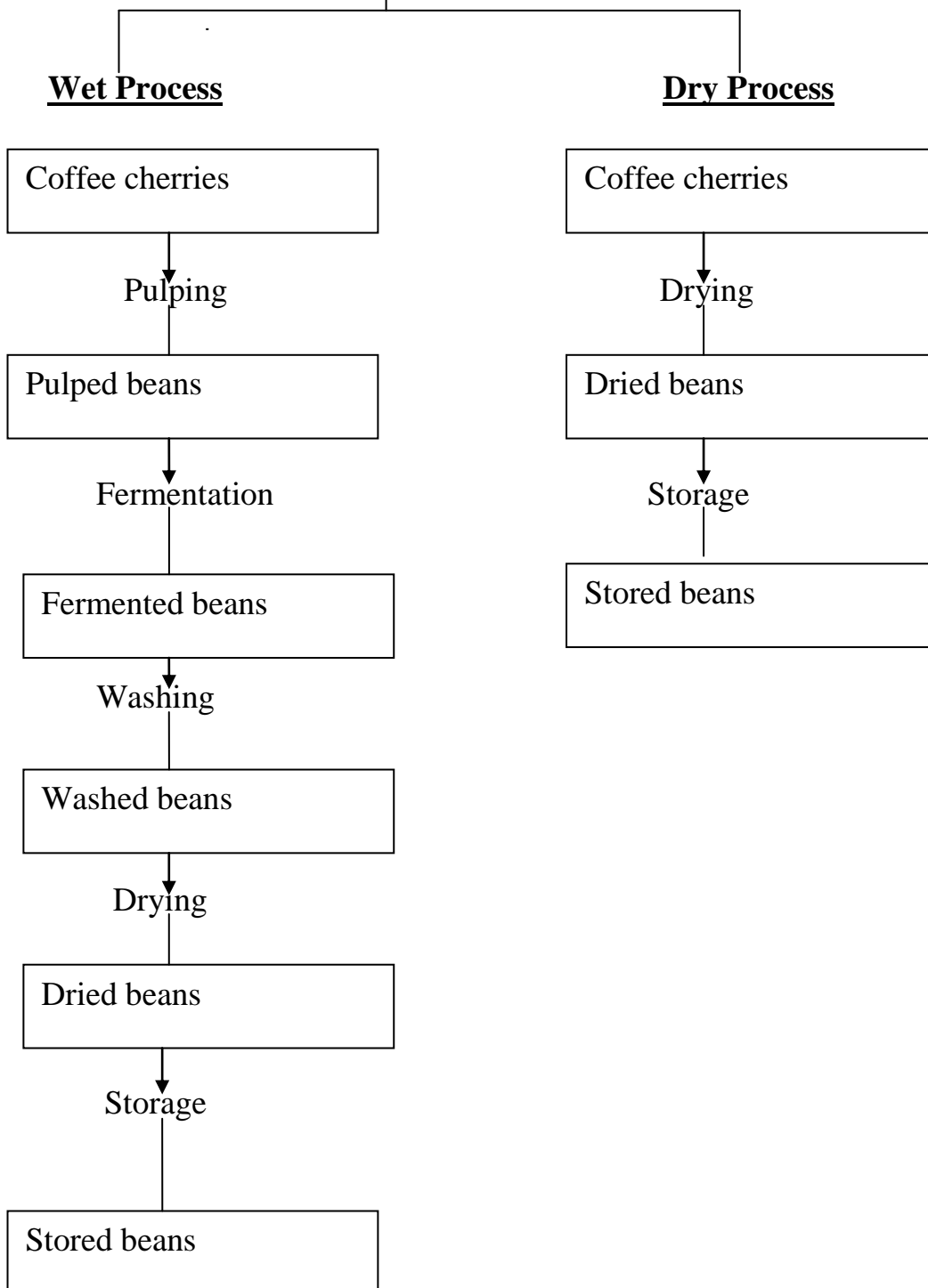


Figure 8: Stages of wet and dry processes and sampling of coffee beans

4.9. Data collection

For personal dust collection: Personal dust samples were taken in the workers breathing zone (about 3 inches from the workers mouth) using 25-mm three piece, closed-faced conductive cassettes (Millipore MAWP 025 AC) with a cellulose acetate filter (Millipore AAWP02500) attached to Side Kick Casella pumps with a flow rate of 2 l/min (60) (Figure 9). This sampling head has the same geometry (except for the cassette diameter) and orifice diameter as the 37 mm three-piece cassette used for ‘total’ dust sampling, and has also been assumed to sample ‘total’ dust at a flow rate of 2 l/min (61).

The pumps were paused during lunch breaks. Full-shift exposure measurements (8 hrs work) were conducted on randomly chosen days of the week and repeated sampling was conducted the next day. Data collection took 4–6 days in each factory.



Figure 9: Personal total dust sampling method from breathing zone, right hand person

For determinants of exposure: An observational checklist to collect information about possible determinants of dust exposure was filled in by the principal investigator during the sampling days. The checklist included task-related determinants for machine room workers (machine operator work, mechanic work, feeding hopper, and cleaning) and for transport workers (loading and unloading, mixing coffee, and feeding coffee). The major job task performed by the respective workers was recorded during the sampling day to be linked with the associated dust sample.

The checklist also included factory-related, dichotomized determinants such as the design of the machineries; hopper, huller, and graders (open or closed top); the production rate (less or more than 50 tonnes per day); type of processing method at the farm (dry or wet processing method); mechanical ventilation system (present or absent); pouring method (pouring coffee to the hopper or ground (vigorously pouring coffee from a dropping height or gradually poured from short height), and natural ventilation [adequate ventilation with the windows and openings area greater than or equal to 10% of the floor area of the machine room or inadequate ventilation with the windows and openings area less than 10% of the floor area of the machine room (62).

For lung function test: Lung function tests were performed according to the ATS recommendation for spirometry (63). A portable spirometer (SPIRARE 3 sensor model SPS 320) was used to measure the lung function (Figure 10). The standing height and weight of the participants was measured using standard weight and height measure. The test was performed during the day shift between 08:00 and 16:00, with the workers in a sitting position. The participants were asked to inhale deeply to maximum lung capacity and exhale forcefully into the device (64). Three acceptable maneuvers with consistent (“repeatable”) results were retained and the best of all of these was recorded.

Only the absolute values for the lung function are given in the results, as there are currently no reference equations for the Ethiopia population for obtaining predicted values. The lung function parameters included were FVC and FEV₁, as well as the percentage ratio of FEV₁/FVC. The participants with FEV₁/FVC < 0.70 were considered to have airflow limitations (65).



Figure 10: : A picture showing lung function measurement

For chronic respiratory symptoms interview: Standardized questionnaire adopted from ATS were used to assess chronic respiratory symptoms among the participants (63). Chronic respiratory symptoms was chosen because the aim was to assess long term dust exposure and its effect on respiratory health which is better characterized by chronic respiratory symptoms. The questionnaire was translated from English to Amharic and Afan Oromo languages and translated back to English. The questionnaire included socio-demographic data (age, height, weight and Body Mass Index (BMI)), occupational history (years of work experience in the present and other dusty factories), past respiratory diseases (pneumonia, tuberculosis, bronchitis, asthma, and chest injury), use of respiratory protective devices while working (yes/no) and smoking habits (current smoker, ex- smoker and never smoker (yes/no)).

The questionnaire also included questions about chronic respiratory symptoms; cough, cough with sputum, breathlessness, work related shortness of breath, wheeze and chronic bronchitis. Participants were considered to have cough and cough with sputum if they answered " yes" to at least one of the four questions assessing cough and cough with sputum respectively; breathlessness if "yes" to at least one of the three questions for breathlessness. Work-related shortness of breath and wheezing were defined as present if the participants answered "yes" to a single question assessing work-related shortness of breath and wheezing respectively.

For microbial contamination assessment: Coffee cherries and beans, each weighing about 25 grams were sampled from each stage of the wet and dry processes. Coffee samples were collected two times on different days from different batches of coffee from each stage of both the wet and the dry process. The principle investigator together with one senior

microbiologist collected the samples from each stages in sterile plastic bag, labeled with types of sample, location, name of stages and sites and transferred to ice boxes (triple package). The samples were transported within 6 hrs of collection to Addis Ababa City Administration Health Bureau Laboratory (Public Health Microbiology Laboratory). Sampling was conducted in the dry season of the year (from October 2016 to January 2017).

4.10. Data management

For paper I: For each sample, the identity of the sample, the time when the flow rate was on and off and the volumetric flow rate was recorded. The code list as well as the data were kept confidential, and were accessed only by the research team.

For paper II & III: The collected data were checked for completeness and consistencies by the principal investigator through a close follow up during the data collection period. The data were coded, and no names were included in the database. The code list as well as the data were kept confidential, and were accessed only by the research team. EpiData 3.1 was be used to enter the data and exported to SPSS version 22 for analysis. Missing values and outliers were checked using frequency tabulation and residual plotting, and managed accordingly.

For paper IV: The principal investigator was responsible to check if the sample collection forms were filled properly such as the date and time, types of sample, location, name of stages and sites. The lab results were entered to EpiData 3.1 and exported to SPSS version 22 for analysis.

4.11. Data quality assurance

For paper I: During sampling, the pumps were checked every second hour to ensure that the equipment is still working. Field blanks were used to correct for any weight changes during sampling. The calculated duration of sampling period were checked against the recorded time on the reading from the pump. If the two sampling times differ by more than 5% were considered as invalid, since this may indicate that the pump did not operate for the entire period.

After sampling, the cassettes were capped and transported as hand luggage by aeroplane to the laboratory in a box suitable to prevent damage or disturbance. The dust samples were

analysed gravimetrically using a standard microbalance scale AT261 Mettler Toledo with a detection limit of 0.01 mg m/m³ in the accredited laboratory SINTEF MOLAB in Norway.

For paper II & III: To assure the data quality, parts of a standardized questionnaire adapted from ATS were used. A pre-test was conducted prior to the actual data collection for the validation of the data collection tool. Questions that were not easy for the participants to understand were rephrased to make them more easily understood.

The lung function tests were also performed according to the ATS recommendation for spirometry. The standing height and weight of the participants was measured using standard weight and height measure. The participants had training measurements before the actual measurements. Both the volume-time and flow-volume curves were evaluated for evidence of technical errors. If erroneous curves are detected, additional manoeuvres were done. Three acceptable maneuvers with consistent (“repeatable”) results were retained and the best of all of these was recorded. Repeatability means that the difference between the largest and second largest values for both FVC and for FEV₁ are within 150 ml (66).

For paper IV: All equipment and materials were sterilized prior to use. The samples were collected using sterile plastic bag, labeled with types of sample, location, name of stages and sites and transferred to ice boxes (triple package). The samples were transported within 6 hrs of collection to the Laboratory and analysed as soon as possible after receipt in the laboratory. Senior microbiologist from Addis Ababa City Administration Health Bureau Laboratory were involved in identification of micro organisms. All the stained slides were cross checked by another microbiologist from the Ethiopian Public Health Institute.

4.12. Data description and analysis

For paper I: The distribution of dust exposure levels was skewed and therefore ln-transformed before analysis. The results were described using arithmetic mean, geometric mean (GM), and geometric standard deviation. Independent *t* tests were used to test differences within the potential dichotomous exposure determinants. A one-way ANOVA was performed to compare the GM of personal total dust exposure level between main job groups and between tasks. Tukey honest significant difference tests were used to explore the

difference between each job group and Games–Howell post hoc tests were used for tasks when equal variances assumption was not met.

Two separate linear mixed effect regression models were developed to identify significant determinants for personal total dust exposure among the machine room workers and the transport workers, respectively. Two separate models developed for these job groups because they were mainly working in different rooms/ areas. In the random and mixed-effect models, the ln-transformed personal total dust exposure level was used as the dependent variable. In the random model, employee and factory were entered as random effects.

In the mixed-effect model, possible factory and task-related determinants (*Det*) with significance value $P \leq 0.2$ in preparatory univariate analysis were entered as fixed effects, and employee and factory were entered as random effects. The task machine operator work was the reference category in the model for machine room workers whereas loading and unloading was the reference task category for the transport workers. The final model contained only determinates with P -value ≤ 0.05 . The linear mixed model is given by van Tongeren *et al.*, 2000; Rappaport and Kupper, 2008 (59, 67).

$$Y_{ifjk} = \ln(X_{ifjk}) = \mu_i + \sum_{l=1}^p \alpha_{il} Det_{ifl} + \gamma_{if} + \beta_{ifj} + \epsilon_{ifjk}$$

for $i=1, \dots, g$ denotes group; $f=1, \dots, F$ denotes factory (same number of factories for each group); $j = 1, \dots, n_{if}$ denotes worker within group * AND* factory; $k=1, \dots, n_{ifk}$ denotes measurements within worker (and within group/factory,) where n_{ifk} is 1 or 2; $l=1, \dots, p$ denotes determinant; μ_i represents the true underlying mean of log- transformed exposure level for group i ; Det_{ifl} represent the l th determinants in the i th group in the f th factory;

$$\sum_{l=1}^p \alpha_{il} Det_{ifl} \text{ represent, the fixed effects of the } p \text{ determinants;}$$

β_{ifj} is the random effect of the worker within group and factory and ϵ_{ijk} is the random error of the i th group in the f th factory; γ_{if} is the random effect of the factory; ϵ_{ifjk} is the

random error of the j th worker in i th group in the f th factory on the k th measurements. X_{ifjk} represent the exposure level on the k th measurements for j th worker in i th group in the f th factory and Y_{ifjk} is the natural logarithm of the individual measurements X_{ifjk}

Variance component structure was used in the model. Explained within-worker ($ww\delta$), between- worker ($bw\delta$), between-factory ($bf\delta$) variances, respectively were calculated as the percentage change in the respective variances between the random and the mixed effects models. Total variance explained by the fixed effects was calculated as the percentage change in the sum of the three variance components between the random and the mixed effects model. The effects of the significant fixed factors in the mixed models were calculated as e^β , where β is the regression coefficient.

Design of huller correlated significantly with design of grader so design of grader was dropped from the analysis. The analysis was done using SPSS version 22 (SPSS, Chicago, IL, USA).

For paper II: Independent t-tests were used to compare mean values for the continuous variables. The Pearson chi-square test or Fisher's exact test, if the expected value was less than 5, were used to test the difference between the groups regarding the categorical variables. Poisson regression analysis with a robust variance was used to determine the prevalence ratio of the different respiratory symptoms between the coffee workers and controls, with a corresponding 95% confidence interval, and the statistical significance level was set to a p-value less than 0.05. As the prevalence of the chronic respiratory symptoms was high, we chose the prevalence ratio over the odds ratio, because the odds ratio overestimated the strength of association (68).

Analysis of covariance (ANCOVA) were used to compare the mean lung function parameters between the coffee workers and controls when adjusting for height and education level. We adjusted for education level, because there was a significant difference in the educational level between the coffee workers and the controls.

For paper III: Independent t - tests were used to compare continuous variable between the three groups. Pearson chi-square test or fisher's exact test if the expected value was less than

5 were used to test differences in respiratory symptoms and other categorical variables between the groups. A linear mixed effects regression model with variance component structure was used to analyse for any difference in dust exposure level between hand pickers with and without tables. In this model employee ID was entered as a random factor and exposure group as a fixed factor.

Poisson regression analysis with robust variance was used to determine the prevalence ratio of different respiratory symptoms between hand pickers and controls with 95% confidence interval and p-value less than 0.05 considered as statistical significance level while adjusting for age, education level, previous respiratory disease and kitchen located inside the house.

Linear regression analyses were used to compare the mean lung function parameters between hand pickers and controls while adjusting for age, height, education level previous respiratory disease and cooking inside the living room.

For paper IV: The samples were analyzed for heterotrophic plate count. The coffee cherries were transferred to a flask containing 225ml of sterile buffered peptone water (1% peptone, 5% weight per volume NaCl) and swirled gently for 20 min using orbit shaker (lab-line instruments.inc, Model 3521, USA) (39). The orbit shaker was used to detach microorganism from coffee bean surfaces. Peptone water was used to make a serial dilution (1:10) for each samples. Then serial dilution was made to 10^{-3} for each samples to get appropriate number of colony which ranges from 30-300. From each dilutions, 1ml of sample was pour plated on plate count agar (PCA) (Park Scientific (USA) as described in the Food and Drug Administration Bacteriological Analytic Manual (69).

Then the plates were incubated at 37°C for 72hrs (296, South Africa). Fresh media was utilized and its sterility was checked by overnight incubation. Quality control was used in each batch of the samples. Colony count was made by YLN-30 lab colony counter magnifying digital display apparatus (UK) and undistinguished colonies were ignored. All distinguishable colonies were counted. The best two consecutive dilutions were used, as n_1 and n_2 to calculate the results. Total bacteria colony count was presented as organisms per milliliter of Coffee Colony Forming Unit (CFU/ml). The average plate count was calculated using this formula:

$$N = C/V (n_1 + 0.1n_2) d$$

Where

C = is the sum of colonies on all plates counted

V = is the volume applied to each plate

n₁= is the number of plates counted at first dilution.

n₂= is the number of plates counted at second dilution,

d = is the dilution from which first count was obtained.

Bacteria were identified as gram negative and gram positive bacteria based on standard Gram-stain technique and microscopic observation (70). Yeast and Filamentous fungi were identified based on their morphology from gram stain via microscopic observation (3H30RF200, Germany). When gram negative bacteria identified in the coffee process the result was presented as "Yes" and when it was absent it was reported as "No".

The data were presented using descriptive statistics. Independent t-test was used to compare mean microbial load between the two types of on farm postharvest processing of coffee and between the two study areas. Statistical significance level was set to a p-value less than 0.05.

4.13. Study variables

4.13.1. Dependent variables

- Dust exposure level
- Lung function reduction
- Respiratory symptoms
- Gram negative bacteria

4.13.1. Independent variables

- Socio-demographic factors (age, sex, height, weight & BMI)
- Behavioural factors (smoking, indoor cooking, PPE)
- Task related factors (cleaning, feeding hopper, loading & unloading, mechanic work, mixing coffee,
- Factory related factors (ventilation types, design of the machines, number of machines, processing method at the farm, production rate & pouring method)
- Coffee contamination (coffee storage and drying condition)

4.14. Operational definition

Current smoker: participants who smoke currently or those who stopped smoking less than one year ago.

Ex-smoker: participants who had stopped smoking more than one year ago.

Never smoker: participants who had never smoked.

Cough: participants were considered to have coughed if they answered “yes” to at least one of the following four questions; cough first thing in the morning, cough during the day or night, cough as much as four to six times a day in a week, or cough for most days for as much as three consecutive months during the year.

Cough with sputum: participants were considered to have cough with sputum if they answered “yes” to at least one of the four questions: cough with sputum first thing in the morning, cough with sputum during the day or night, cough with sputum as much as four to six times a day in a week, or cough with sputum for most days for as much as three consecutive months during the year.

Breathlessness: participants were considered to have breathlessness if he/she was troubled by a shortness of breath when hurrying on level ground or walking up a slight hill, or get shortness of breath when walking at his/her own pace on the level ground or get shortness of breath when walking with other people of your own age on level ground?.

Work-related shortness of breath participants were considered to have work-related shortness of breath if he/she usually experience chest tightness while at work or just after work.

Wheezing: participants were considered to have wheezing if his/her chest ever sounded wheezy (whistling sound)

FEV₁ is the maximal volume of air exhaled in the first second of a forced expiration from a position of full inspiration

FEF_{25-75%} is the mean forced expiratory flow between 25% and 75% of the FVC

FVC is the maximal volume of air exhaled with maximally forced effort from a maximal inspiration

Past dust exposure: any work experience on dusty environment before the current working position.

Past respiratory illness: respiratory disease likes TB, chronic bronchitis, lung cancer, and heart disease that could be developed before and identified by physicians.

Chronic respiratory symptoms: the development of one or more of the symptoms of cough, Cough with sputum, wheezing, breathlessness and work related shortness of breath which lasts at least three months in one year.

Acute respiratory health effects refer to acute changes in respiratory health status immediately following an exposure

Adequate natural ventilation with the windows and openings area greater than or equal to 10% of the floor area of the machine room

Inadequate natural ventilation with the windows and openings area less than 10% of the floor area of the machine room

Vigorously pouring coffee refers dropping coffee from a very tall height

Gradually pouring coffee refers pouring coffee from a very short height slowly

Utilization of PPE: - availability and wearing of personal protective equipment

4.14. Ethical considerations

The Institutional Review Board of the College of Health Sciences of Addis Ababa University (Protocol number:051/15/SPH) and the National Research Ethical Review Committee of the Federal Ministry of Science and Technology (NRERC-3/10/110/2016), approved the study. In addition, the Addis Ababa City and SNNPR and Oromia Region Health Bureau approved the study. Permission to conduct the study was obtained from the factory managers. Written informed consent was obtained from each participant, and participation in the study was voluntary. Confidentiality was ensured by not using the names of the workers in any reports. Participants with lung function impairments were advised to consult the nearest health centre.

4.15. Summary of dissertation work by objective and methods

The summary of the methods used for each specific objectives is shown in Table 2 below.

Table 2: Summary of the methods for each paper

Objective	Study design	Study subject	Sample size	Data collection	Analysis
To assess personal total dust exposure and to evaluate determinants of dust exposure in primary coffee processing factories in Ethiopia (Paper 1)	Cross-sectional	Workers in 12 primary coffee processing factories in Addis Ababa, Oromia & SNNPR	360 dust samples from primary coffee factories	-Personal dust samples from workers breathing zone using 25-mm three piece, closed-faced conductive cassettes with a cellulose acetate filter attached to Side Kick Casella pumps with a flow rate of 2 l/ min -Observational check list	-Arithmetic mean (AM) -Geometric mean(GM) -Geometric standard deviation (GSD) - T-test - A one-way ANOVA - Linear mixed effect regression models
To examine lung function reduction and chronic respiratory symptoms among workers in primary coffee processing factories in Ethiopia (Paper 2)	Comparative cross sectional	Workers in primary coffee processing and water bottling factories in Addis Ababa, Oromia & SNNPR	120 coffee workers 120 controls (water bottling) - 30 dust samples from controls	-Chronic respiratory symptoms were assessed with an interview, using a standardized questionnaire from the American Thoracic Society - Lung function tests were performed according to the American Thoracic Society recommendation for spirometry using a portable spirometer (SPIRARE 3 sensor model SPS 320)	Descriptive Analysis (AM, GM, GSD) - Independent t-tests Pearson chi-square test Fisher's exact test - Poisson regression analysis for prevalence ratio - Analysis of covariance (ANCOVA)
To compare the prevalence of chronic respiratory symptoms and lung function among hand pickers with table and hand pickers without tables in primary coffee processing factories of Ethiopia (Paper 3)	Comparative cross-sectional	Hand pickers with table and without table in primary coffee processing and water bottling factories in Addis Ababa, Oromia & SNNPR	190 hand pickers with table 190 hand pickers without table 190 controls (women) 30 dust samples from controls	Chronic respiratory symptoms were assessed with an interview, using a standardized questionnaire from the American Thoracic Society - Lung function tests were performed according to the American Thoracic Society recommendation for spirometry using a portable spirometer (SPIRARE 3 sensor model SPS 320)	Descriptive Analysis (AM, GM, GSD) - Independent t-tests Pearson chi-square test Fisher's exact test - Poisson regression analysis for prevalence ratio - Linear regression model -Linear mixed effect regression models
To assess microbial contamination of coffee at different stages coffee processing at the farm in Ethiopia (Paper 4)	Cross-sectional	Coffee samples from wet and dry process from four farms in Yebu and Shebedion Woreda in Oromia & SNNPR respectively	24 coffee samples from wet process 12 coffee samples from dry process	Coffee cherries each weighing about 25 grams were collected two times on different days from different batches of coffee from each stage of both the wet and the dry process. using sterile plastic bag, labeled with types of sample, location, name of stages and sites and transferred to ice boxes . The samples were transported within 6 hrs of collection to Addis Ababa City Administration Health Bureau Laboratory .	-Gram-stain technique and microscopic observation -Descriptive statistics -Independent t-test

5. Results

Characteristics of the study participants

A total of 179 coffee workers from the three departments participated in the dust exposure assessment (paper I) making the response rate 99.4 %. Similarly, a total of 115 male coffee workers and 110 male controls from water bottling factories participated in the assessment of respiratory symptoms and lung function test (Paper II), making the response rate 98.8% for male coffee workers and 91.6% for controls. In addition, a total of 374 hand pickers and 175 female control participated in paper III, making the response rate 98.4% for hand pickers and 92.1% for controls. Both male coffee workers and hand pickers were older and had a lower educational level compared to their respective control groups. None of the hand pickers and female controls were current or former smokers (Table 3). However, 3(2.6%) male coffee workers and 4(3.6%) male controls were current smokers. The result indicates no statistical difference was found in terms of the duration of previous work in dusty factories or in use of biomass for cooking, in both male coffee workers and hand pickers comparing compared to their respective controls groups (Table 3).

Table 3 : Characteristics of participants, Ethiopia, May 2016 to January 2017

Variables	All hand pickers n=374	Female controls n=175	Significance level	Male coffee workers n =115	Male controls n =110	Significance level
			All hand pickers versus controls			Male coffee workers versus controls
Age (years): AM (range)	29.6 (18.0-60.0)	25.7 (18-46)	<0.001†	35.1 (18.0-75.0)	30.9 (18.0-71.0)	0.008†
Height (m): AM (range)	1.6 (1.3-1.8)	1.6 (1.4-1.7)	0.03†	1.7 (1.5-1.9)	1.7 (1.5-1.8)	0.5†
Weight (kg): AM (range)	51.9 (35.1-94.3)	53.0 (39.2-95.1)	0.14†	59.8 (43.0-88.0)	60.0 (45.0-90.0)	0.9†
BMI (kg/m ²): AM (range)	21.2 (14.2-36.7)	21.4 (14.8-32.9)	0.59†	20.8 (15.4-30.5)	20.7 (16.6-29.1)	0.8†
Duration of employment at present work years: AM (range)	5.3 (1.0-38.0)	3.97 (1.0-15.0)	<0.001†	6.5 (1.0-30.0)	3.4 (1.0-6.0)	0.001†
Education						
Unable to read and write	122 (32.6)	1 (0.5)	<0.001\$	14 (3.5)	3 (2.7)	0.007 ^{\$}
Primary education and above	252 (67.4)	174 (99.4)		101 (87.8)	107 (97.3)	0.001 ^{\$}
Cooking						
Cooking food at home: n (%)	369 (98.7)	172 (98.3)	0.71±	103 (89.6)	97 (82.2)	0.74 ^{\$}
Kitchen located inside the living room: n (%)	118 (32.0)	57 (33.1)	0.79\$	34 (33)	31 (32)	0.87 ^{\$}
Use biomass for cooking: n (%)	357 (96.7)	164 (95.3)	0.42\$	96 (93.2)	86 (88.7)	0.26 ^{\$}
Previous respiratory disease						
Bronchitis: n (%)	10 (2.7)	0	N	3 (2.6)	1(0.9)	0.62
Pneumonia: n (%)	18 (4.8)	5 (2.9)	0.29\$	7 (6.1)	5(4.5)	0.61 ^{\$}
Pleurisy: n (%)	1 (0.3)	1(0.6)	N	0	0	N
Tuberculosis: n (%)	7 (1.9)	0	N	4 (3.5)	2 (1.8)	0.68 [±]
Asthma: n (%)	11 (2.9)	5 (2.9)	0.95\$	8 (7)	4 (3.6)	0.27 [±]
Chest injury: n (%)	5 (1.3)	1 (0.6)	N	0	0	N
Participants who have had at least one of the respiratory diseases: n (%)	44 (11.8)	11 (6.3)	0.04\$	22 (19.1)	12 (10.9)	0.09 ^{\$}

n: number of study participants; † Independent t test; \$ Pearson chi-square test; ± Fisher's exact test to compare coffee workers with controls, N: not calculated, owing to low numbers

5.1. Personal dust exposure

Personal dust exposure within the three main job groups (i.e. machine room workers, transport workers and hand pickers) varied considerably between the coffee factories (Table 4). The geometric mean (GM) dust exposure among machine room workers ranged from 4.09 to 34.40 mg/m³, among transport workers from 3.51 to 24.19 mg/m³, and among hand pickers from 0.26 to 5.87 mg/m³. Overall the GM personal dust exposure was significantly higher ($P = 0.001$) for the machine room (12.54 mg/m³) and transport workers (12.30 mg/m³) than for the hand pickers (1.08 mg/m³). In these three groups, 84.6%, 84.1%, and 2.6% of the samples exceeded the OEL of 5mg/m³, respectively (Table 4). Personal total dust exposure GM was 1.4 mg/m³, 1 mg/m³, and 0.30 mg/m³ among hand pickers with table, hand pickers without table and controls, respectively.

Table 4: Personal total dust exposure in the 12 coffee factories stratified by factory and main job group, Ethiopia, May 2016 to January 2017

Region	Factory	Sampling time (min) AM (range)	Total dust exposure (mg/m ³)																	
			Machine room workers						Transporters						Hand pickers					
			NW	NS	AM	Range	GM(GSD)	% OEL >5mg/m ³	NW	NS	AM	Range	GM(GSD)	% OEL >5mg/m ³	NW	NS	AM	Range	GM(GSD)	% OEL >5mg/m ³
Addis Ababa	A	412 (382-473)	5	9	18.86	3.59-26.32	16.60 (1.88)	89	5	10	17.51	2.76-53.22	12.84 (2.34)	90	5	10	2.57	0.90-4.58	2.12(1.97)	0
	B	418(309-464)	5	10	9.13	1.12-36.87	4.09 (3.39)	20	5	9	14.17	3.90-49.74	9.63 (2.38)	78	5	10	0.90	0.65-1.23	0.88(1.24)	0
	C	378(319-466)	5	10	9.77	6.07-14.78	9.45 (1.31)	100	5	10	28.65	10.63-64.60	24.19 (1.85)	100	5	10	1.71	1.31-2.11	1.69(1.17)	0
	D	346(246-403)	5	9	21.06	5.96-53.51	15.97 (2.21)	100	5	9	23.04	7.54-64.56	17.80 (2.10)	100	5	10	1.31	0.74-3.36	1.19(1.51)	0
Oromia	E	441(392-494)	5	9	27.90	7.09-73.77	21.31 (2.20)	100	5	10	19.11	5.25-41.37	15.96 (1.88)	100	5	10	2.15	0.94-3.53	1.98(1.55)	0
	F	442(376-480)	5	10	18.47	11.95-26.96	17.88 (1.31)	100	5	9	16.87	4.38-28.78	14.91 (1.79)	89	5	5	6.49	2.71-9.74	5.87(1.70)	60
	G	410(363-435)	5	10	39.81	11.66-77.28	34.40 (1.80)	100	5	10	20.21	5.35-81.61	13.45 (2.33)	100	5	10	1.90	1.03-3.86	1.79(1.44)	0
	H	391(315-433)	5	10	21.50	2.69-45.57	15.70 (2.65)	80	5	9	32.17	3.52-78.81	20.31 (3.30)	78	5	10	1.66	1.03-2.22	1.63(1.25)	0
SNNPR	I	451(409-493)	5	10	8.63	2.11-15.25	7.54 (1.81)	80	4	8	3.68	2.51-6.79	3.51 (1.36)	13	5	10	1.07	0.48-2.96	0.92(1.69)	0
	J	418(320-465)	5	10	18.34	10.96-26.88	17.96 (1.29)	100	5	10	11.61	3.93-22.37	10.41 (1.67)	90	5	10	0.34	0.19-0.58	0.31(1.50)	0
	K	407(342-465)	5	10	5.25	3.32-8.59	4.97 (1.41)	50	5	10	11.07	2.88-20.61	9.22 (1.99)	80	5	10	0.73	0.23-1.53	0.63(1.84)	0
	L	418(364-455)	5	10	12.44	7.29-19.77	11.91 (1.37)	100	5	9	9.50	3.41-19.8	8.36 (1.75)	78	5	10	0.29	0.12-0.51	0.26(1.67)	0
Each main job group			60	117	17.47	1.12-77.28 P95=45.79	12.54 (2.37)	84.6	59	113	17.46	2.51-81.61 P95=50.69	12.30 (2.32)	84.1	60	115	1.55	0.12-9.74 P95=3.90	1.08(2.42)	2.6

NW, number of workers; NS, number of samples; AM, arithmetic mean; GM, geometric mean; geometric standard deviation; SNNPR, Southern Nations, Nationalities & Peoples' Region; P95, 95th percentile; %OEL >5mg/m³, percent of Occupational Exposure Limit above 5mg/m³

5.2.Task and factory determinants

Personal total dust exposure among both machine room and transport workers was significantly increased when pouring coffee vigorously from a height in factories that had more than one huller machine in the room and when the hopper had open top (Table 5). For machine room workers also the state of the mechanical ventilation and the design of the huller had impact on dust exposure. For transport workers, a production rate with more than 50 tonnes per day was associated with a higher dust exposure compared with production rate less than 50.

Table 5:Factory related determinants of total dust exposure for machine room workers and transporters in 12 primary coffee processing factories in Ethiopia, May 2016 to January 2017

Potential determinants	Definitions	Machine room workers			Transporters	
		NS	GM (mg/m ³)	p-value	GM (mg/m ³)	p-value
Process at the farm	0=Wet pre-processed coffee	63	9.87	0.191	11.82	0.902
	1=Dry pre-processed coffee	282	13.20		12.30	
Production rate	0=Less than 50 tonnes/day	258	12.30	0.640	10.80	0.006
	1=More than 50 tonnes/day	87	13.46		17.64	
Number of huller machine in the room	0=One huller machine in the room	146	10.49	0.042	8.41	0.001
	1=More than one huller machine in the room	199	14.30		16.12	
Pouring method	0=Gradual pouring of coffee	32	5.05	0.001	6.55	0.039
	1=Vigorous pouring coffee	313	14.30		12.81	
Factory establishment year	0=New (after year 2010)	58	7.92	0.07	11.25	0.597
	1=Old (Before year 2010)	287	13.74		12.55	
Design of hopper	0=Closed top	87	8.33	0.003	11.25	0.04
	1= Open top	258	14.30		16.28	
Natural ventilation	0=Adequate ventilation	116	12.06	0.789		
	1=Inadequate ventilation	229	12.81			
Mechanical ventilation	0=Working in a good condition	29	4.10	0.01		
	1=Not working or absent	316	13.87			
Design of huller	0=Closed top	116	9.78	0.033		
	1= Open top	229	14.15			

NS=number of samples; GM= geometric mean; p- value -Independent t-test

5.3.Exposure determinant models

For the machine room workers, the linear mixed effects model that included the pouring method of coffee beans and mechanic work explained about 34% of between-factory variance, and 21% of the total variance. Vigorously pouring coffee from a dropping height was associated with 1.7 time increase in personal total dust exposure. For the transport workers, the mixed-effects model that included pouring method of coffee beans, number of huller machine in the room, mixing coffee, and feeding the hopper explained about 83% of the between-factory variance, but considerably less of the between-worker and the day-to-day variance. These fixed factors explained 32% of total variance in personal total dust exposure for the transporters.

The result indicated that pouring coffee vigorously from a dropping height was the determinant with the highest impact on personal total dust exposure with 3.2-fold increase compared to gradually pouring coffee from a very short height. More than one huller machine in the room contributed to a 2.1-fold increase in total dust level compared to having only one huller machine in the room (Table 6).

Table 6: Linear mixed effect model of ln-transformed total dust levels in 12 primary coffee processing factories in Ethiopia, May 2016 to January 2017

Fixed factors	Machine room workers (“Total” dust in mg/m ³)				Transport workers (“Total” dust in mg/m ³)			
	Random effects Model β (SE)	Mixed effects model β (SE)	Effect (e ^{β})	p	Random effects model β (SE)	Mixed effects model β (SE)	Effect (e ^{β})	P
Intercept	2.53(0.18)	2.08(0.30)		0.001	2.50(0.14)	0.74(0.36)		0.05
Coffee pouring method; Vigorously(1) vs. gradually (0)		0.56(0.31)	1.7	0.05		1.17(0.34)	3.2	0.002
Mechanic work; Yes(1) vs. no(0)		-1.26(0.43)	0.3	0.006				
Huller machines; More than one(1) vs. one(0)						0.73(0.17)	2.1	0.002
Mixing coffee; Yes(1) vs. no(0)						0.53(0.15)	1.7	0.001
Feeding hopper; Yes(1) vs. no(0)						0.67(0.26)	2.0	0.013
Variance components								
Ww δ	0.32(0.06)	0.32(0.06)			0.49(0.09)	0.42(0.08)		
Bw δ	0.13(0.07)	0.08(0.06)			0.05(0.08)	0.04(0.07)		
Bf δ	0.32(0.16)	0.21(0.11)			0.18(0.10)	0.03(0.04)		
Explained variance by the fixed factors								
Within-worker		0%				14%		
Between -worker		38%				20%		
Between-factory		34%				83%		
Total		21%				32%		

Notes: β = regression coefficients, SE = standard error of the regression coefficients, ww δ = within-worker variance, bw δ = between-worker variance; bf δ = between factory variance; Effect e β = the effect contributed by each determinants; P = P-value

5.4. Chronic respiratory symptoms among coffee worker (Paper II & III)

The prevalence of chronic respiratory symptoms was in the range of 5.2–55% and 2.7–12.7% among the male coffee workers (i.e. machine room and transport workers) and controls respectively (Table 7). The prevalence ratio of all of the respiratory symptoms was significantly higher for the coffee workers compared to the controls after adjusting for age, education, years worked in other dusty factories, and previous respiratory disease.

Table 7: Prevalence of chronic respiratory symptoms among male coffee workers and controls, Ethiopia, May 2016 to January 2017

Variable	Coffee workers N=115	Control N= 110	Prevalence Ratio, 95% CI	P-value
Cough; n (%)	52 (46.4)	8 (7.5)	5.6 (2.9-11.7)	<0.001
Cough with sputum; n(%)	26 (23.2)	2 (1.9)	11.4 (2.7-47.8)	<0.001
Breathlessness; n(%)	40 (35.7)	12 (11.3)	2.9 (1.6-5.3)	<0.001
Work-related shortness of breath; n(%)	22 (19.6)	6 (5.5)	3.7 (1.6-8.7)	0.003
Wheezing; n(%)	20 (17.9)	5 (4.7)	3.3 (1.3-8.4)	0.01
Chronic bronchitis; n(%)	6 (5.2)	0	-	-

CI, confidence interval while adjusting for age, education, years worked in other dusty factories and previous respiratory disease; p-value when comparing coffee workers vs. controls

For most of the chronic respiratory symptoms hand pickers had significantly higher prevalence ratio of most chronic respiratory symptoms compared to controls, for instance cough with prevalence ratio 3.0, 95% CI 1.4-6.2). Hand pickers working on the ground had higher prevalence ratio of cough without sputum (PR=3.9, 95% CI: 1.6-9.5) and wheezing (PR=2.3, 95% CI 1.3-4.3) compared to hand pickers with tables (Table 8).

Table 8: Prevalence of chronic respiratory symptoms among two groups of hand pickers of coffee and a low dust exposed control group, Ethiopia, May 2016 to January 2017

Variables	All hand pickers n=374	Controls n=175	All hand pickers versus controls	Hand pickers with tables n=185	Hand pickers without tables n=189	Comparing hand pickers without tables and With hand pickers with tables
	n(%)		Prevalence ratio (95% confidence interval)	n(%)		Prevalence ratio (95% confidence interval)
Cough	78 (20.9)	12 (6.9)	3.0 (1.4-6.2)	28 (15.1)	50 (26.5)	2.0 (1.3-3.1)
Cough with sputum	26 (7)	4 (2.3)	-	7 (3.8)	19 (10.1)	3.9 (1.6-9.5)
Breathlessness	130 (34.8)	37 (21.1)	1.7 (1.1-2.5)	63 (34.1)	67 (35.4)	1.2 (0.9-1.6)
Wheezing	47 (12.6)	8 (4.6)	2.1 (0.9-4.8)	13 (7.0)	34 (18)	2.3 (1.3-4.3)
Work- related shortness of breath	69 (18.4)	13 (7.4)	2.5 (1.1-5.6)	25 (13.5)	44 (23.3)	1.8 (1.1-2.8)
Chronic bronchitis	3 (0.80)	0	-	0	3 (1.6)	-

n: number of participants; Prevalence ratio adjusted for age, education level, cooking inside the living room and previous respiratory diseases; Prevalence ratio was calculated when number of symptoms in the control group was higher than 5.

5.5. Lung function reduction among coffee workers (Paper II & III)

The coffee workers in machine room and Transport in the age group 28–39 years and ≥ 40 years, had significantly lower FVC and FEV₁ compared with the controls in the similar age category. The FEV₁/FVC-ratio was significantly lower among these coffee workers compared to the controls in the oldest age group. The prevalence of airflow limitation (FEV₁/FVC < 0.7) was higher among these coffee workers compared to the controls in all of the age categories (Table 9).

Table 9: Lung function among male coffee workers in primary coffee processing factories and control groups stratified by age (three age groups), Ethiopia, May 2016 to January 2017

Lung function parameters	Age group	No of participants		Absolute value Mean (SD)		p-value
		Coffee workers N=104	Controls N=103	Coffee workers	Controls	
FVC (l)	18-27	35	57	4.60 (0.43)	4.70 (0.49)	0.35
	28-39	35	23	4.08 (0.47)	4.43 (0.46)	<0.001
	≥ 40	34	23	3.38 (0.53)	3.67 (0.51)	0.05
	All age group	104	103	4.03 (0.69)	4.41 (0.63)	<0.001
FEV ₁ (l)	18-27	35	57	3.74 (0.46)	3.87 (0.39)	0.15
	28-39	35	23	3.29 (0.58)	3.63 (0.47)	0.02
	≥ 40	34	23	2.60 (0.50)	3.05 (0.51)	< 0.001
	All age group	104	103	3.22 (0.69)	3.63 (0.54)	<0.001
FEV ₁ /FVC	18-27	35	57	0.81 (0.08)	0.83 (0.05)	0.43
	28-39	35	23	0.80 (0.09)	0.82 (0.07)	0.48
	≥ 40	34	23	0.77 (0.09)	0.83 (0.06)	0.02
	All age group	104	103	0.80 (0.09)	0.83 (0.06)	0.01
FEV ₁ /FVC<0.7; n(%)	18-27	35	57	3 (8.60)	0	-
	28-39	35	23	2 (5.70)	1 (4.30)	1*
	≥ 40	34	23	9 (26.50)	0	-

Analysis of Covariance between coffee worker and controls while adjusting for height and education level * fisher exact test between coffee workers and controls; P-value: Significance level

There were no statistical differences in FVC, FEV₁, FEV₁/FVC or in the prevalence of airflow limitation between controls and hand pickers (Table 10). However, there was significant difference in FEF_{25-75%} between hand pickers and controls. Furthermore, FVC, FEV₁ and FEF_{25-75%} were significantly lower among hand pickers without tables than among hand pickers with tables, after adjusting for age, height, educational level, cooking inside the living room and previous respiratory disease (Table 10). The prevalence of airflow limitation among hand pickers without tables was also higher (12.5%) than among hand pickers with tables (7.3%), but not significant (Table 10).

Table 10: Lung function among hand pickers in primary coffee processing factories and control, Ethiopia, May 2016 to January 2017

Lung function parameters	All hand pickers n=111	Controls n=54	All hand pickers vs Controls		Hand pickers with table n=55	Hand pickers without table n=56	Hand pickers with table vs hand pickers without table	
			B(SE)	P-value			B(SE)	p-value
FVC – mean (SD)	3.08 (0.59)	3.33 (0.50)	-0.07 (0.11)	0.52 [†]	3.20 (0.63)	2.96 (0.51)	-0.32 (0.10)	0.002 [†]
FEV1 - mean (SD)	2.43 (0.55)	2.69 (0.41)	-0.07 (0.09)	0.46 [†]	2.53 (0.57)	2.33 (0.51)	-0.29 (0.08)	0.001 [†]
FEV1/FVC - mean (SD)	0.78 (0.07)	0.81 (0.07)	-0.01 (0.02)	0.57 [†]	0.79 (0.07)	0.78 (0.07)	-0.02 (0.01)	0.18 [†]
FEF ₂₅₋₇₅ mean (SD)	2.08 (0.63)	2.72 (0.73)	-0.40 (0.12)	0.001	2.16 (0.50)	2.01 (0.73)	-0.26 (0.09)	0.01 [†]
FEV ₁ /FVC<0.70 n; (%)	11 (9.9)	2 (3.7)	-	0.23 [±]	4 (7.3)	7 (12.5)	-	0.36 [*]

n; number of participants, HPWT- Hand pickers with Table; HPWOT- Hand pickers without table † Linear regression while adjusting for age, height, education level; cooking inside the living room and previous respiratory disease, * Chi-square test ; ± fisher exact test; B: Beta Coefficient; SE: Standard Error

Use of respiratory protective device (Paper II& III)

The majority of the 112 (97.4%) male coffee workers did not use any type of respiratory protective devices (RPD). Among the non-users of RPD, 109 (97.3%) of the male coffee workers indicated that the reason for not using RPD was because it was not available or not provided at the work place. Only 3 hand pickers (2 with table and 1 without table) used any type of Respiratory Protective Devices (RPD). The majority of those not using RPD (n=368; 99%) indicated that the reason for not using RPD was that it is not available or not provided at the work place. From our observation some hand pickers used a piece of cloth to cover their mouth and nose.

5.6. Microbial contamination of coffee on farm processing (Paper IV)

When merging the two regions the mean microbial load in the dry process (2.0×10^5 CFU/ml; range 6.9×10^2 to 7.2×10^5 CFU/ml) did not differ significantly ($p=0.22$) from the microbial

load in the wet process (9.0×10^4 CFU/ml; range 2.5×10^2 to 4.6×10^5 CFU/ml). Furthermore, there was no significance difference in microbial load between the two regions (1.7×10^5 CFU/ml versus 8.4×10^4 CFU/ml; $p = 0.18$) or between the wet and dry processes within the SNNPR ($p = 0.74$) or within the Oromia region ($p = 0.16$) (Table 11).

Table 11: Microbial load in different stages of wet and dry coffee processing in Ethiopia, May 2016 to January 2017

Regions	Types of post-harvest on farm processing of coffee	n	Coffee samples from stages of coffee processing	Aerobic plate count (CFU/ml)	P-value comparing dry and wet types of post-harvest on farm processing of coffee
SNNPR	Dry process	2	Coffee cherries	1.8×10^5	0.74
		2	Dried beans	1.7×10^4	
		2	Stored beans	1.9×10^4	
		6	Mean for the 3 dry process	7.3×10^4	
	Wet process	2	Coffee cherries	1.0×10^5	
		2	Pulped beans	8.6×10^4	
		2	Fermented beans	2.7×10^4	
		2	Washed beans	1.2×10^2	
		2	Dried beans	1.4×10^5	
		2	Stored beans	1.9×10^5	
		12	Mean for the 6 wet process	9.0×10^4	
Oromia	Dry process	2	Coffee cherries	1.8×10^4	0.16
		2	Dried beans	3.6×10^5	
		2	Stored beans	6.2×10^5	
		6	Mean for the 3 dry process	3.3×10^5	
	Wet process	2	Coffee cherries	8.4×10^4	
		2	Pulped beans	2.1×10^4	
		2	Fermented beans	3.7×10^4	
		2	Washed beans	2.6×10^5	
		2	Dried beans	1.1×10^4	
		2	Stored beans	1.4×10^5	
		12	Mean for the 6 wet process	9.1×10^4	
Both regions	Dry process	4	Coffee cherries	1.0×10^5	0.22
		4	Dried beans	1.9×10^5	
		4	Stored beans	3.2×10^5	
		12	All in dry process	2.0×10^5	
	Wet process	4	Coffee cherries	9.5×10^4	
		4	Pulped beans	5.4×10^4	
		4	Fermented beans	3.2×10^4	
		4	Washed beans	1.3×10^5	
		4	Dried beans	7.4×10^4	
		4	Stored beans	1.6×10^5	
		24	All in wet process	9.0×10^4	

Independent t-test were used to compare mean difference between types of postharvest processing of coffee and between regions

Gram negative identified in different stages of wet and dry methods

The results indicated the presence of gram negative bacteria in almost all stages of dry process in both regions. In the wet process, gram negative bacteria were identified in coffee cherries and stored beans in both sampling periods and regions. Gram negative bacteria were identified in dried beans in one of the samples in both regions (Table 12).

Table 12: Presence of gram negative bacteria in different stages of postharvest on farm coffee processing, Ethiopia, May 2016 to January 2017

Types of post-harvest on farm processing of coffee	Stages of coffee processing	Presence of Gram negative bacteria in the sample from Shebedino woreda SNNPR		Presence of Gram negative bacteria in the sample from Yebu woreda Oromia	
		1st round	2nd round	1st round	2nd round
Dry process	Coffee fruits		x	x	x
	Dried beans	X	x	x	x
	Stored beans	X	x	x	x
Wet process	Coffee fruits	X	x	X	x
	Pulped beans			X	x
	Fermented beans				
	Washed beans	X			
	Dried beans		x	X	
	Stored beans	X	x	X	x

Note: "x" refers the presence of gram negative and the blank cells indicate the absence of gram negative

The key findings from each paper (I-IV) were described in Table 13 below.

Table 13 : A summary of key findings from papers (I-IV), Ethiopia, May 2016 to January 2017

Objective	Main finding
To assess personal total dust exposure and to evaluate determinants of dust exposure in primary coffee processing factories in Ethiopia (Paper 1)	<ul style="list-style-type: none"> ▪ The geometric mean (GM) dust exposure among machine room workers ranged from 4.09 to 34.40 mg/m³, among transport workers from 3.51 to 24.19 mg/m³, and among hand pickers from 0.26 to 5.87 mg/m³. ▪ Overall the GM personal dust exposure was significantly higher ($P = 0.001$) for the machine room (12.54 mg/m³) and transport workers (12.30 mg/m³) than the for the hand pickers (1.08 mg/m³). ▪ From the samples 84.6%, 84.1%, and 2.6% of the machine room workers, transport workers and hand pickers exceeded the OEL, respectively.
To examine lung function reduction and chronic respiratory symptoms among workers in primary coffee processing factories in Ethiopia (Paper 2)	<ul style="list-style-type: none"> ▪ The male coffee workers (machine room and transport workers) had significantly higher prevalence of coughing, coughing with sputum, breathlessness, work-related shortness of breath, and wheezing compared with the controls. ▪ The prevalence ratio of cough (PR=5.6, 95% CI: 2.9-11.7), work-related shortness of breath (PR = 3.7, 95% CI: 1.6–8.7) and wheezing (PR = 3.3, 95% CI: 1.3–8.4) was significantly higher for the coffee workers compared to the controls. ▪ The coffee workers in the age groups 28–39 years and >40 years, had a significantly lower forced vital capacity and forced expiratory volume in 1 s compared to the controls in the similar age groups.
To compare the prevalence of chronic respiratory symptoms and lung function among hand pickers with table and hand pickers without tables in primary coffee processing factories of Ethiopia (Paper 3)	<ul style="list-style-type: none"> ▪ Hand pickers without table had significantly the highest prevalence ratio of almost all chronic respiratory symptoms compared to hand pickers with table and controls. ▪ Similarly, hand pickers without table had significantly lower Forced Vital Capacity and Forced Expiratory Volume in one second compared to hand pickers with table and controls. ▪ There was a significant difference in FEF_{25-75%} between hand pickers and controls
To assess microbial contamination of coffee at different stages coffee processing at the farm in Ethiopia (Paper 4)	<ul style="list-style-type: none"> ▪ The results indicate the presence of gram negative bacteria in dried and stored beans from both the wet and dry process. During further coffee processing possible release of endotoxin from coffee contaminated by gram negative bacteria might affect coffee workers respiratory health.

6. Discussion

This study indicated that about 84% of the dust samples among machine room and transport workers were above the occupational exposure limit value of 5 mg/m³. The dust exposure was considerably lower for the hand pickers. This study report that coffee workers in the machine room and transport had a significantly lower FVC and FEV₁ and higher prevalence for chronic respiratory symptoms compared with the controls. Hand pickers without table had significantly the highest prevalence ratio of almost all chronic respiratory symptoms compared to hand pickers with table and controls. The microbial assessments of coffee at the farm indicated the presence of gram negative bacteria in dried and stored beans from both the wet and dry process.

6.1. Personal dust exposure

The GM personal total dust exposure among the machine room workers and the transporters in this study (12.4 mg/m³) was higher than reported among comparable job groups in Tanzanian primary coffee factories (GM 2.5 mg/m³ (16)). The difference in the results could have several explanations. For example, dust exposure in the Tanzanian study was measured in processing both Robusta and Arabica coffee whereas in our study, only Arabica coffee was processed. Furthermore, the number of machines in the room could also be a reason for the difference in exposure. In all visited coffee factories in Ethiopia, all machines were located in one room whereas in two out of four of the studied coffee factories in Tanzania, the machines were located in different halls. Differences in machine design and practice in processing coffee might also have contributed to the difference in personal total dust exposure levels between these studies. The range of personal total dust exposure in our study (0.12–81.61 mg/m³) was broader than in primary coffee factories of Papua New Guinea [(0.7–10 mg/m³ and Uganda [(10.8–58 mg/m³ (15). The difference from our study is difficult to explain, as both the Papua New Guinea and the Uganda studies reported only the range of the exposure levels, and did not include any measure of central tendency. Furthermore, the Papua New Guinea study did not describe the factories in any detail, and in Uganda both Robusta and Arabica coffee were processed.

The presently found personal total dust exposure GM of 1.4 mg/m³ and 1 mg/m³ among the two groups of hand pickers is comparable with a previous study conducted among hand pickers in primary coffee processing factories in Tanzania (0.9 mg/m³) (29).

6.2. Determinants of exposure

In this study, the exposure level varied across the task, which is consistent with the studies conducted in Tanzania and Papua New Guinea (5, 16). In our study, feeding coffee caused the highest exposure for the transporters, which is different from the study conducted in Tanzania in which sweeping was associated with the highest personal total dust exposure (16). Differences in how these tasks were performed might have caused such discrepancies. In our study, sweeping was carried out only for short periods, whereas feeding coffee was carried out for a long period of time.

The mixed-effect model indicated that the method of pouring coffee beans vigorously from a dropping height was the main determinant for increased personal total dust exposure for both machine room workers and transporters. Furthermore, among the transporters increased dust exposure level was associated also with feeding coffee and mixing coffee. Both these tasks are in most factories performed by vigorously pouring coffee from a dropping height, thus further enhancing the emission of dust from these tasks. Thus, the exposure models indicate that changing the pouring process could reduce personal dust exposure level in the coffee factories as it seems to contribute to a high background concentration of dust in the general working atmosphere.

Among the transporters, the fixed factors in the exposure model mainly explained the between-factory variance (83%). This seems reasonable for the two factory-related determinants, pouring method and number of huller machines, which alone explained 61% of the between-factory variance. The two task-based determinants, feeding hopper and mixing coffee, contribute to explain part of the within worker variance 9% probably because some of the workers changed between these tasks between the two measurement days. For machine room workers, mechanic work was the only task identified as a significant determinant in the exposure model. However, the few samples from this task were taken from a factory that had one of the lowest exposure levels.

The small difference in exposure levels between the other three tasks for the machine room worker could be due to a high background concentration of dust emitted from the processing machinery. Even after adjusting for the pouring method of coffee none of the other potential task-based determinants were found to be significant. One cannot exclude that a more refined

categorization of the task-related determinants, for instance a detailed recording of time spent on the respective tasks could have explained more of the exposure variability in the exposure models.

6.3. Lung function reduction among coffee workers

The present study's results showed that in the two oldest age groups of coffee workers in machine room and transports, the FVC and FEV₁ were lower than among the controls, while FEV₁/FVC was lower in the oldest age group of coffee workers than among the controls. In the Tanzanian study, there were no difference in the FVC and FEV₁ between coffee workers and controls (28). The considerably higher dust exposure in the Ethiopian study (GM = 12.3 mg/m³) (71) compared to the levels reported for the processing of Arabica coffee in Tanzania (GM = 2.1 mg/m³) (16) may have contributed to the difference in findings related to lung function. Also, the study conducted in Papua New Guinea, where the dust levels were lower than in the present study, did not find significant differences in FVC and FEV₁/FVC between the coffee workers and controls.

Both FEV₁ and FVC were reduced among the coffee workers, indicating both obstructive and restrictive lung effects. However, in the oldest age group, the FEV₁/FVC ratio was less than 0.70 for about 27% of the coffee workers, which indicates the presence of an obstructive lung disease (66). It is noteworthy that such a result was found, even though these workers were present at the workplaces in physically demanding work. A limitation of the present study is that coffee workers with impaired lung function might have quit their job because of the demanding nature of coffee processing. Thus, a healthy worker effect cannot be excluded

The lung function parameters measured among hand pickers were not significantly different than among controls. However, there was significant difference in FEF_{25-75%} between hand pickers and controls. This might be due to that inhaling this type of dust will at first cause inflammation in the small airways and this may not be picked up by FEV₁ (72). The Tanzanian study found a significant difference in FEV₁/FVC between coffee workers and controls, and suggests that work in coffee factories is associated with small but significant lung function impairment (28). However, the study did not study hand pickers, and the production workers were engaged in other parts of the coffee processing. Also, the workers

examined were males. In addition, the findings from this Tanzanian study might be related to differences in type of coffee, post harvest processing method at the farm, working conditions and dust exposure level than we have in Ethiopia.

In our study, among male coffee workers (i.e machine room and transport workers), we found that coffee workers in the age groups 28–39 years and ≥ 40 years, had a significantly lower FVC and FEV₁ compared to the controls in the similar age groups, this might be related to a higher dust exposure level in machine room and transport departments (73).

The present study found a lower FVC and FEV₁ among hand pickers without tables compared to those with tables. This might be related to dust content, as there are differences in the type of coffee these two hand picking groups process. Hand pickers without tables handle coffee beans processed by the dry method in the farms, while hand pickers with tables handle coffee beans processed by either the wet or the dry method. The methods may influence the content of the dust inhaled during the hand picking work (28). Future studies should assess the content of the dust; bacteria, fungi and endotoxin, in addition to the total dust levels.

6.4. Chronic respiratory symptoms

This study found a significantly higher prevalence of respiratory symptoms among the coffee workers (i.e. machine room and transports workers) compared to controls. Our results are consistent with studies conducted in primary coffee processing factories in Papua New Guinea, Tanzania and Uganda (5, 7, 15). All of these studies show that coffee workers have high prevalence of respiratory health problems. However, our present study found a higher prevalence of some of the respiratory symptoms compared with the studies conducted among Arabica coffee workers in Tanzania, where the prevalence of breathlessness was 14%, wheezing 13%, and chronic bronchitis 3.1% (28).

One of the reasons for this difference could be the higher personal total dust exposure in Ethiopian coffee factories ($GM = 12.3 \text{ mg/m}^3$) compared with the comparable job groups in Tanzanian primary coffee factories ($GM = 2.1 \text{ mg/m}^3$) (16). The different methods of coffee pre-processing could be another reason; the Arabica coffee is pre-processed only by a wet-method in the Tanzanian factories, whereas in Ethiopia, Arabica coffee is pre-processed either by dry or wet method, based on the individual farmers' interests.

In addition, only 3% of the workers used RPD in Ethiopia, compared to 33% in the coffee workers in Tanzania. The lack of RPD use makes it more likely that the workers actually were exposed to the dust levels measured in the factories. There may have been other additional factors that were not identified in the present study that may also have influenced the respiratory health of the workers.

Similarly, the prevalence of a cough with sputum and wheezing in our study was higher than in the study in Uganda; where the prevalence was 5.2% and 13.5%, respectively (15). This might be due to the different types of coffee species between the two countries; the Robusta and Arabic coffee were processed in Ugandan factories, whereas only Arabica coffee was processed in Ethiopia. For a cough with sputum, we found a higher prevalence than reported in the study in Papua New Guinea (8.7%) (5). This difference might be due to higher dust exposure in the present study compared with what was measured in Papua New Guinea (0.7–10 mg/m³).

In addition, the difference in working environments, coffee processing methods, and level of awareness among the coffee workers about the impact of dust exposure on their health might be the reason for the difference in the symptom prevalence. In addition, there may be differences between these countries regarding the presence of, for instance, lung infections or sequela after lung infections. Infections may cause respiratory symptoms and influence lung function. This possibility is not very likely, as the examined workers are performing hard physical work, but this factor needs to be considered, because of the high prevalence of tuberculosis as well as HIV in East-African countries (74). However, it is not likely that this type of health problem is different among the workers in the two factory types included in our study.

The prevalence of respiratory symptoms such as cough, shortness of breath, chest tightness and wheezing were higher among coffee workers compared to among security and supermarket workers in Ethiopia which were assumed to have less dust (75,76). This substantiates our argument that coffee workers respiratory symptoms might be related to higher level of dust exposure.

The prevalence of almost all respiratory symptoms for the hand pickers was higher than among controls. Our findings were consistent with previous studies conducted in Papua New

Guinea, Tanzania, Uganda and Ethiopia that reported a higher prevalence of respiratory symptoms among coffee processing workers compared to controls (5, 7, 15, 73). However, it is difficult to compare the findings as previous studies assessed male workers in the processing areas and did not include female hand pickers. In the present study the prevalence of respiratory symptoms such as wheezing and work-related shortness of breath for both groups of hand pickers were lower than among Ethiopian male coffee production workers; where the prevalence was 17.9% and 19.6%, respectively (73). This difference in symptom prevalence might be related to the difference in dust exposure level (71).

The present study found a higher prevalence of almost all respiratory symptoms, among hand pickers without tables than in pickers with tables. As the dust exposure level for both group were below the occupational exposure limit, the difference could be associated with other factors than dust such as endotoxin. This argument is supported by Sakwari et al. finding who found an association between exposure to endotoxin and respiratory symptoms among workers in primary coffee processing factory in Tanzania (28).

6.5. Microbial contamination of coffee on farm processing

In this study, gram negative bacteria was identified in the final stages of dried and stored beans in both the wet and the dry method. This finding is consistent with Bruyn et al. who found relative abundances of gram negative bacteria over the course of drying (77). However, in principle gram negative bacteria are not expected in the final stages of dried and stored beans due to the expected low moisture level at this last stage that do not favour microbial growth, particularly gram negative bacteria as they are less resistant to low moisture content (78). This can be explained by the possibility of higher moisture content of the beans than recommended. The recommended moisture range of coffee beans is 11 to 12%. According to a study conducted in the southern part of Ethiopia more than 94.4% of the coffee farmers do not determine the exact moisture content of coffee beans for storage (46). Thus, a higher moisture content than recommended might be the reason for the observed gram negative bacteria development in the dried and stored beans in the present study.

A second reason could be related to environmental contamination. Generally, coffee beans should be stored in clean areas to prevent contamination of coffee beans (79). However, a previous study conducted in Ethiopia indicated that 54% of coffee farmers did not have proper storage facilities (46). This might increase the contamination of coffee beans by gram

negative bacteria. This assumption was supported by Balows et al. who found that 38.6% of the bacteria were actual or opportunistic pathogens from coffee beans (80). Belay et al suggested that coffee beans should be stored in a place free from potential contaminants, such as cow dung, soils and chickens (47).

The presence of gram negative bacteria in dried beans and stored beans might not pose a risk to public health because of the high temperatures used during roasting. However, the presence of gram negative bacteria in dried and stored beans might affect the coffee workers respiratory health due to endotoxin exposure when the coffee beans are further processed. Thus, endotoxin exposure in coffee processing factories can be prevented by reducing contamination of coffee beans during drying and storage.

7. Methodological Discussion

7.1. Validity and Generalizability

7.1.1. Internal validity

An observation is considered to have internal validity, if it accurately represent the true information of the particular group under investigation. There are several factors such as random error, bias and confounders that may affect the internal validity of our study finding. However, in this study we tried to minimize the role of chance, bias and confounders which may affect our findings.

7.1.1.1. Random error

To minimize the role of chance we tried to include relatively large number and repeated dust sampling was performed on two consecutive days for each worker. Furthermore, dust sampling time were representative of the working periods of individuals exposed. Similarly, larger number of sample size than was required were included for lung function reduction and respiratory symptoms assessment. The 95% CI were used for most of the variables to compare the outcomes between coffee workers and controls, this helped us to assess the effect of the chance.

7.1.1.2. Bias

To minimize the role of selection bias, we included factories that were representative of primary coffee processing factories in the country in terms of size, machine type, type of coffee being processed, and design of the factory. In addition, participants were randomly selected and representative of the production workers in each factory. Participants health status were not known during selection. Coffee workers with impaired lung function or respiratory health problem might have quit their job because of the demanding nature of coffee processing. Thus, a healthy worker effect cannot be excluded. However, the demanding nature of coffee processing task is similar to all primary coffee processing factories present in Ethiopia and this may indicate that participants in this study were representative of all primary coffee processing factories of Ethiopia. Furthermore, to minimize the health worker effect, participants from equally demanding task in water bottling factories were used as a control.

Moreover, the participation rate in our study were high for both coffee workers and controls. The reason for high response rate could be due to close co-operation between the investigators and factory management and workers. The high response rate may also indicate that our study findings have high validity within the coffee workers and controls.

To reduce measurement bias in dust exposure concentration a great care were taken at each stage of dust sampling that included checking the required flow rate, position of the sampling head, pump failure, tube twisting, dirty filters and covering full shift dust sampling. Furthermore for gravimetric analysis we used standard microbalance scale in the accredited laboratory SINTEF MOLAB in Norway. In addition for lung function measurements the standing height and weight of the participants were measured using standard weight and height measure. Three acceptable maneuvers with consistent (“repeatable”) results were retained and the best of all of these was recorded.

However, we cannot rule out measurement bias, especially in the lung function tests as some of the coffee workers and control workers did not know their exact birth date specifically the date and months, and we used national holidays and religious days to approximate the date and months for these participants. As this problem was present only for a few workers and in both group, it is unlikely to have major impact on the results.

This study used a questionnaire-based interview to assess the respiratory symptoms that might result in recall and interviewer bias. However, similar questions were used to assess respiratory symptoms in both coffee workers and control groups and also we used standardized questionnaire and well-trained interviewer with close supervision were involved to interview both groups to minimize interviewer bias.

7.1.1.3. Confounders

To control for the effect of confounding factors, information on potential confounders such as age, height, weight, education level, cooking habit, smoking habit, duration of employment in other dusty factory and previous respiratory diseases were collected and adjusted for using Poisson regression, multivariate regression, Analysis of Covariance (ANCOVA) and mixed effects model analysis. Furthermore, during the designing phase, we classified the coffee

workers as male coffee production workers (Paper II) and hand pickers (female coffee workers in paper III). This may eliminate or control gender from being a confounder.

7.1.2. External validity

External validity (generalizability) refers whether the results apply to those not involved in this study (81,82). This study included workers from the three major coffee growing and processing regions of Ethiopia (i.e Oromia, SNNPR and Addis Ababa), and the factories included in this study were representative of primary coffee processing factories in the country in terms of size, machine type, type of coffee being processed, and design of the factory. The results are believed to be representative for all coffee production workers in Ethiopia. That means, this study can be generalized to all primary coffee processing factories in Ethiopia. Similar results might also be expected by any African coffee factory with a similar dust exposure level and similar production type of Arabica coffee beans.

8. Strengths and limitations of the study

8.1. Strengths of the study

As far as we are aware, this is the first study of personal dust exposure in primary coffee processing factories that included large number of coffee factories, and dust samples. Most of the previous studies in coffee factories did not address the factors that affect dust exposure.

Further more, to date, no study has investigated microbial contamination of coffee at the farm which might affect coffee workers respiratory health during coffee processing in the factories. However, this study assessed microbial contamination of coffee in different stages of both wet and dry post-harvest on farm coffee processing. Thus, this study provided useful information to prevent and control bacterial contamination of coffee beans in the farm. In addition, unlike many previous studies in coffee factories, this study used mixed effect regression model to identify significant determinates for dust exposure in primary coffee processing factories which is important to introduce effective preventive and control measures.

8.2. Limitations of the study

There were some limitations throughout the process of the study. One of the limitation this study was, the use of closed-face cassettes for dust sampling which are known to underestimate the inhalable dust levels, especially for large particles size (83-85). Because the coffee processing involves a lot of manual tasks including carrying sacks on shoulder, we chose this method, to protect the filters better than if other sampling heads were used. They were also cost effective.

In addition, the control group in the present study was from another production factory, with very low dust levels. In principle controls from general populations would have been best, but this would have introduced other types of bias in the study, related to socioeconomic differences between the factory workers and the population.

Furthermore, a longitudinal study is best method to characterize the association between dust exposure and lung function reduction. However, it was difficult to perform this design in this study, as the methods for tracing persons over longer periods is challenging. Case-control studies are also difficult to perform in Ethiopia, as the population does not have easy access to hospitals, and are treated at a large number of small health units. Therefore, a comparative

cross-sectional study design was chosen, where the coffee factory workers were compared to a control group.

The other limitation of this study was it didn't analysis the association between cumulative dust exposure or years of working in the factory and lung function reduction. This could have been good to the see cumulative dust exposure influence on lung function reduction. One reason why we didn't analysis the association between cumulative dust exposure and lung function, because we measured total dust exposure in a relatively short time period, and this might not represent the cumulative dust exposure level. This is because the dust exposure level might have varied from year to year due to several factors such as coffee production rate, length of coffee harvesting season, factory maintenance and other process interventions. In addition there was a significant correlation between age and years of working in the factory.

Above all, this study used only the absolute values results for the lung function tests, as there are currently no reference equations for the Ethiopia population for obtaining predicted values.

Other limitations of this study were the coffee sampling number for microbial contamination were low, with few sampling days. Repeated sampling was conducted only on two different days from different batches of coffee. However, this study collected samples from the two main coffee growing regions of Ethiopia, and the results are likely to be representative to Ethiopian on farm postharvest processing of coffee.

9. Conclusions and Recommendation

9.1. Conclusions

This study indicated that about 84% of the dust samples among machine room and transport workers were above the occupational exposure limit value. The dust exposure was considerably lower for the hand pickers. This study found no significant difference in exposure level between hand pickers with tables and those without. Pouring coffee beans vigorously from a dropping height, mixing coffee and feeding hopper were the main determinants for increased personal dust exposure level. Both male coffee workers and handpickers had significantly higher prevalence of most of the chronic respiratory symptoms compared with their respective controls. For most of the chronic respiratory symptoms, hand pickers without tables had significantly a higher prevalence ratio than in hand pickers with tables.

The dust exposure was related to reduced lung function and higher prevalence of chronic respiratory symptoms among coffee workers. Majority of coffee worker didn't use any respiratory protective device. Gram negative bacteria found in dried and stored coffee beans, might release endotoxin which may affect respiratory health of coffee workers in primary coffee processing factories.

9.2. Recommendation

For policy makers/ MOLSA

- Our findings indicate high level of dust exposure and respiratory health problem in coffee factories of Ethiopia. However, currently Ethiopia does not have occupational exposure limit generally for organic dust and particularly for coffee dust. In Ethiopia, there are about 15 million people who depend on coffee production directly or indirectly for their living. Therefore, our findings calls for setting occupational exposure limit for organic dust in the standard.

For regional BOLSA

- Regular inspection and assessment of dust exposure in coffee factories to ensure good working environment (i.e. proper ventilation, lighting and safety) for coffee workers

To coffee authorities and coffee farm unions

- As coffee contamination by gram negative bacteria might cause respiratory health problem to workers in coffee factories, coffee farmers should be trained on proper handling of coffee during drying and storage at the farm to reduce gram negative bacterial contamination
- Strengthen coffee quality monitoring at the farm to reduce bacterial contamination of coffee.

For coffee factory managers

- Coffee workers who are exposed to high dust level such as machine room and transport workers should be provided with efficient personal respiratory protective equipments like P3 filter (i.e. particle filter with high efficiency)
- Pouring coffee beans vigorously from a dropping height such as during feeding coffee and mixing coffee was the main determinant for increased personal total dust exposure for both machine room workers and transporters. Therefore, changing the pouring process, from vigorous to gradual, could reduce personal dust exposure level in the coffee factories.
- In the long term, more targeted engineering dust control measures such as closing the top of huller and hopper and installing mechanical ventilation should be undertaken to reduce dust exposure particularly in machine room.
- Provide training on dust exposure and its health effect and importance of RPEs for workers in coffee factories prior to employment and regularly afterwards as necessary

For health practitioners

Regular medical examination should be conducted to detect early sign of respiratory diseases in primary coffee processing factories.

Further research directions

- This is the first study to assess dust exposure, prevalence of respiratory symptoms and lung function reduction among coffee workers in Ethiopia. However, as this study is a cross sectional study, the cause and effect cannot be drawn based on our findings. Although, longitudinal studies could be difficult, we would recommend a repeated study that includes large number of factories and workers should be undertaken at least for three to four years in order to characterize the association between dust exposure and lung function reduction.

- The present study considered only bacterial contamination on farm. However, coffee can also be contaminated during transport of coffee from the farm to the processing factories, or even in the coffee factories coffee can be contaminated during storage, handling and processing. Therefore future studies should consider all chains of coffee processing to get clearer picture of coffee contamination.
- During further coffee processing possible release of endotoxin from coffee contaminated by gram negative bacteria might affect coffee workers respiratory health. Further studies should assess the relation between bacterial contamination of coffee and endotoxin level.

10. Acknowledgements

First of all, I would like to give my sincere gratitude to the almighty God for giving me strength and endurance throughout my PhD training.

I am sincerely grateful for the financial support from Norwegian Agency for Development Cooperation (Norad) through the Norwegian Programme for Capacity Building in Higher Education and Research for Development (NORHED) through a research project "Reduction of the burden of injuries and occupational exposures through capacity building in low income countries"

I would like to extend my sincere gratitude to my supervisor Professor Bente Elisabeth Moen and Professor Magne Bratveit. Words cannot express, how I feel about you. Without your constant guidance, support, patience and inspiration I would never have succeeded in fulfilling my tasks. I really thank you for everything you have done for me during my PhD work.

I wish to express my deepest and sincere gratitude to my supervisor Dr. Abera Kumie and Dr Wakgari Deressa for their constant guidance, unconditional support, fruitful comments and encouragements during my PhD work. Thank you so much for believing in me! Your role were instrumental in my academic carrier, this project wouldn't have been possible without you. I was really privileged working beside you.

I am extremely grateful to my wife, Hirut Basha, for her love, understanding, prayers and continuing support during the entire PhD work. I am very much thankful to my children, Kiya and Lewi, for allowing me to focus on my study, for their valuable prayers and patience despite my long absence from home.

My special thanks goes to College of Health Sciences drivers, Tesfaye, Fikire, Frew, and Desta, for their hard work during data collection. To my friends Desaaegn, Ashenafi, Teshome and Karesa, thank you for your assistance during data collection.

Finally, my sincere gratitude goes to my study participants and farm managements for their cooperation and willingness to participate in the study.

11. References

1. Gardiner K, Harrington M. Occupational Hygiene. Main Street Malden Massachusetts USA: Wiley-Blackwell; 2005.
2. Koren H, Bisesi M. Handbook of Environmental Health Pollutant Interactions in Air Water and Soil. 4 ed. Mortimer Street London: CRC Press; 2002.
3. Simpson J, Niven R, Pickering C, Flecher A, Oldham L. Prevalence and predictors of work related respiratory symptoms in workers exposed to organic dusts. Occupational Environmental Medicine. 1998;55:668–72.
4. Christian D. Organic Dust Exposure and Chronic Airway Disease. American Journal of Respiratory and Critical Care Medicine. 1996;154:833-4.
5. Smith D, Brott K, Kokisource G. Respiratory Impairment in Coffee Factory Workers in the Asaro Valley of Papua New Guinea. British Journal of Industrial Medicine. 1985;42(7):495-8.
6. Larese F, Fiorito A, Casasola F, Molinari S, Peresson M, Barbina P, et al. Sensitization to green coffee beans and work-related allergic symptoms in coffee workers. American Journal of Industrial Medicine. 1998;34:623–7.
7. Sakwari G, Bråtveit M, Mamuya S, Moen B. Dust exposure and chronic respiratory symptoms among coffee curing workers in Kilimanjaro: a cross sectional study. BMC Pulmonary Medicine. 2011;11(54):1-8.
8. Amamo AA. Coffee production and marketing in Ethiopia. European Journal of Business and Management 2014;6:109--21.
9. Wiersum KF, Gole TW, Gatzweiler F, Vokmann J, Bognetteau E, Wirtu O. Certificate of wild coffee in Ethiopia: experience and challenges. Forest, Trees and Livelihood. Forest, Trees and Livelihood. 2008;18:9-21.
10. Chauhan R, Hooda MS, Tanga AA. Coffee: the backbone of Ethiopian economy. International Journal of Economic Plants. 2015;1:082-6.
11. Gebreyesus T. Determinants of coffee export performance in Ethiopia. Journal of Economic and Sustainable Development 2015;6:147-57.
12. Musebe R, Agwanda C, Mekonen M. Primary coffee processing in Ethiopia: patterns, constraints and determinants. African Crop Science Conference Proceedings. 2007;8:1417–21.
13. United State AID. Ethiopian Coffee Industry Value Chain Analysis: Profiling the actors , their interactions, costs, constraints and opportunities. USAID; 2010.
14. World Health Organization. Hazard Prevention and Control in the Work Environment: Airborne Dust. Geneva, Switzerland: WHO; 1999.

15. Sekimpi DK, Agaba DF, Okot-Nwang M. Occupational coffee dust allergies in Uganda. . African Newsletter on Occupational and Safety. 1996;6:6-9.
16. Sakwari G, Mamuya SH, Bratveit M, Larsson L, Pehrson C, E MB. Personal exposure to dust and endotoxin in Robusta and Arabica coffee processing factories in Tanzania. Annals of Occupational Hygiene. 2012;57:173–83.
17. Schwan R, Silva C, Batista L. Coffee fermentation. In: Hui Y, editor. Plant Based Fermented Food and Beverage Technology. 2 ed. London: CRC press; 2012.
18. Schwan R, Fleet G. Microbial Activity during Coffee Fermentation. In: Nout R, Sarkar P, editors. Cocoa and Coffee Fermentations. London: CRC Press; 2015.
19. Figley KD, Rawling FA. Castor bean an industrial hazard as a contaminant of green coffee dust and used burlap bags. Journal of Allergy. 1950;21:545–53.
20. Karr RM, Lehrer SB, Butcher BT, Salvaggio JE. Coffee worker's asthma: A clinical appraisal using the radio allergosorbent test. Journal of Allergy and Clinical Immunology. 1978;62:143-8.
21. Bruun E. Allergy to coffee: An occupational diseases. Acta Allergologica. 1955;11:150-4.
22. Kaye M, Freedman S. Allergy to Raw Coffee—An Occupational Disease. Canadian Medical Association Journal 1961;84:469-71.
23. Osterman K, Zerterstrom O, Johansson GO. Coffee Worker's Allergy. Allergy. 1982;37:313-22.
24. Zuskin E, Vali F, Skuri Z. Respiratory function in coffee workers. British Journal of Industrial Medicine. 1979;36:117-22.
25. Uragoda C. Acute symptoms in coffee workers. Journal of Tropical Medicine and Hygiene. 1998;91:169-72.
26. Zuskin E, Vali F, Skuri Z. Immunological and respiratory changes in coffee workers. Thorax. 1981;36:9-13.
27. Zuskin E, Duncan P, Douglas J. Pharmacological characterisation of extracts-ofcoffee dusts. British Journal ofIndustrial Medicine. 1983;40:193-8.
28. Sakwari G, Mamuya S, Bråtveit M, Moen B. Respiratory Symptoms, Exhaled Nitric Oxide, and Lung Function Among Workers in Tanzanian Coffee Factories. Journal of Occupational and Environmental Medicine. 2013;55:544-51.
29. Moen B, Kayumba A, Sakwari G, Mamuya S, Bråtveit M. Endotoxin, dust and exhaled nitrogen oxide among hand pickers of coffee; a cross-sectional study. Journal of Occupational Medicine and Toxicology. 2016;11(17).

30. Schwartz DA, Thorne PS, Yagla SJ, Burmeister LF, Olenchock SA, Watt JL, et al. The role of endotoxin in grain dust induced lung disease. *American Journal of Respiratory and Critical Care Medicine*. 1995;152:603-8.
31. Thorn J, Rylander R. Inflammatory response after inhalation of bacterial endotoxin assessed by the induced sputum technique. *Thorax*. 1998;53:1047-52.
32. Castellan RM, Olenchock SA, Hankinson JL, Millners PD, Cocke JB, Bragg CK, et al. Acute bronchoconstriction induced by cotton dust: Dose-related responses to endotoxin and other dust factors. *Annals of Internal Medicine*. 1984;101:157-63.
33. Haglind P, Rylander R. Exposure to cotton dust in an experimental cardroom. *British Journal of Industrial Medicine*. 1984;41:340-5.
34. Rylander R, Haglind P, Lundholm M. Endotoxin in cotton dust and respiratory function decrement among cotton workers in an experimental cardroom. *American Review of Respiratory Disease*. 1985;131:209-13.
35. Lane S, Nicholls P, Sewell R. The Measurement and Health Impact of Endotoxin Contamination in Organic Dusts from Multiple Sources. *Industry Inhalation Toxicology*. 2004;16:217-29.
36. Smit L, Wouters I, Hobo M, Eduard W, Doekes G, Heederik D. Agricultural seed dust as a potential cause of organic dust toxic syndrome. *Occupational and Environmental Medicine*. 2006;63:59-67.
37. Gora A, Mackiewicz B, Krawczyk P, Golec M, Skorska C, Sitkowska J, et al. Occupational exposure to organic dust, microorganisms endotoxin and peptidoglycan among plants processing workers in Poland. *Annals of Agricultural and Environmental Medicine*. 2009;16:143-50.
38. Ingalls S. An endotoxin exposure in the food industry. *Applied Occupational and Environmental Hygiene*. 2003;18:318-20.
39. Silva C, Schwan R, Dias E, Wheals E. Microbial diversity during maturation and natural processing of coffee cherries of *Coffea arabica* in Brazil. *International Journal of Food Microbiology*. 2000;60:251-60.
40. Teressa A, Crouzillat D, Petizard V, Brouhan P. Genetic diversity of Arabica coffee (*Coffea arabica* L.) collections. *Ethiopian Journal of Applied Sciences and Technology*. 2010;1:63-79.
41. Nogaim Q, Thabet H, Al-Qudami M, Nagi A, Al-Awdy B. Determination of Microbial Contamination in Yemeni Green Coffee. *Advanced Journal of Biological Sciences Research*. 2013;1(2):22-9.
42. Coffee and Tea Authority Ethiopia. *Ethiopian Coffee handbook a Practical Guide for Subject Matter Specialists and Development Agents*. Addis Ababa, Ethiopia 1995.

43. Food and Agriculture Organization. Medium term prospects for Agriculture commodities projection to the year 2010 Rome coffee. Rome: FAO; 2010.
44. Ethiopian coffee exporter Association. Ethiopian's coffee perspective from 2009/10-2011/12 season and the long term vision of the sector. Addis Ababa, Ethiopia2012.
45. Federal Democratic Republic of Ethiopia Ministry of Trade Coffee Opportunities in Ethiopia. Addis Ababa Ethiopia2012.
46. Garo G, Shara S, Mare Y. Assessment of harvest and post-harvest factors affecting quality of Arabica coffee in Gamo Gofa Zone, Southern Ethiopia. African Journal of Agriculture Research. 2016;11:2157-21-65.
47. Belay S, Mideksa D, Gebrezgiabher S, Weldemariam S. Factors affecting Coffee (Coffee Arabica L) quality in Ethiopia: A review. Journal of Multidisciplinary Scientific Research 2016;4:22-8.
48. Federal Democratic Republic of Ethiopia Ministry of Agriculture. Distribution of primary dry processing factories and wet pre processing facilities. Addis Ababa, Ethiopia2013.
49. Federal Democratic Republic of Ethiopia Ministry of Trade. The distribution of primary wet coffee processing factories in Ethiopia. Addis Ababa, Ethiopia2013.
50. Lyngen B, Buhagen M, Qvenild T, Svendsen K, Tufvesson HE. Short term exposure to low amounts of airway irritants in a swine confinement building and inflammatory markers in blood and exhaled air. Annals of Agricultural and Environmental Medicine. 2004;21(3):479-84.
51. Astrakianakis G, Seixas N, Camp J, Smith T, Bartlett K. Cotton Dust and Endotoxin Exposure Levels in Three Shanghai Textile Factories A Comparison of Samplers. Journal of Occupational and Environmental Hygiene. 2006;3:418-27.
52. Fishwick D, Allan L, Wright A, Curran A. Assessment of Exposure to Organic Dust in a Hemp Processing Plant. Annals of Occupational Hygiene. 2001;45(7):577-83.
53. Mehta J, Wang R, Eisen A, Dai L, Astrakianakis G. Work Area Measurements as Predictors of Personal Exposure to Endotoxin and Cotton Dust in the Cotton Textile Industry. Annals of Occupational Hygiene. 2008;52(1):45-54.
54. Suphioglu C. Coffee Anyone, Are You at Risk of Allergy? International Archives of Allergy and Immunology 2012;159:213-5.
55. Oldenburg M, Bittner C, Baur X. Health Risks due to Coffee Dust. CHEST. 2009;136:536-44.
56. Thomas K, Trigg C, Baxter P, Topping M, Lacey J. Factors relating to the development of respiratory symptoms in coffee process workers. British Journal of Industrial Medicine. 1991;48:314-22.

57. Zusikin E, Schachter EN, Kanceljak B, Witek TJ, Fein E. Organic dust disease of airways. *International archives of Occupational and Environmental Health*. 1993;63:135-40.
58. Romano C, Sulotto F, Piolatto G, Ciacco C, Capellaro E, Falagiani P, et al. Factors related to the development of sensitization to green coffee and castor bean allergens among coffee workers. *Allergy*. 1995;25:643-50.
59. Rappaport SM, Kupper L. *Quantitative exposure assessment: El Cerrito, CA*; 2008.
60. Occupational Safety and Health Administration. OSHA technical manual: section ii, chapter 1: personal sampling for air contaminants USA: United State Department of Labor; 2014 [Available from: https://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_1.html#total_dust].
61. Skaugset NP, Ellingsen DG, Noto H, Jordbekken L, Thomassen Y. Intersampler field comparison of RespiconR, IOM, and closed-face 25-mm personal aerosol samplers during primary production of aluminium. *Annals of Occupational Hygiene*. 2013;57:1054-64.
62. Nemerow N, Agardy F, Salvato J. *Environmental engineering: environmental health and safety for municipal infrastructure, land use and planning and industry*. 6 ed: Hoboken, NJ: John Wiley & Sons, Inc; 2009.
63. American Thoracic Society-Division of Lung Diseases. Recommended Respiratory Disease Questionnaires for Use with Adults and Children in Epidemiological Research: ATS; 1978 Available from: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.607.2516&rep=rep1&type=pdf>
64. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R. ATS/ERS Task force: Standardisation of lung function testing. *European Respiratory Journal*. 2005;26:319-38.
65. National Institute for Occupational Safety and Health. Spirometry Quality Assurance: Common Errors and Their Impact on Test Results In: *Health and human service*. USA: U.S. Department of Health & Human Services; 2012.
66. Pauwels A, Buist S, Calverley A, Jenkins R, Hurd S. Globally Strategy for the diagnosis management and prevention of Chronic Obstructive Pulmonary Disease: NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD) Workshop Summary. *American Journal of Respiratory and Critical Care Medicine*. 2001;163:1256-76.
67. Van Tongeren MJ, Kromhout H, Gardiner K. Trends in levels of inhalable dust exposure, exceedance and overexposure in the European carbon black manufacturing industry. *Annals of Occupational Hygiene*. 2000;44:271-80.
68. Tamhane AR, Westfall AO, Burkholder GA, Cutter GR. Prevalence odds ratio versus prevalence ratio: Choice comes with consequences. *Statistics in Medicine* 2016;35:5730-5.
69. U. S. Food and Drug Administration. Bacteriological Analytical Manual FDA; 1998 [Available from: <https://www.fda.gov/food/foodscienceresearch/laboratorymethods/ucm2006949.htm>].

70. Holt J, Krieg N, Sneath P, Stanley J, Williams S. In: Bergey's Manual of Determinative Bacteriology: Williams & Wilkins, Baltimore, MD.
71. Abaya WS, Bråtveit M, Deressa W, Kumie A, Moen BE. Personal dust exposure and its determinants among workers in primary coffee processing in Ethiopia. *Annals of Work Exposure and Health*. 2018;62(9):1087-95.
72. Burgel P, Bergeron A, Blic J, Bonniaud P, Bourdin A, Chanez P, et al. Small airways diseases, excluding asthma and COPD: an overview. *Eur Respir Rev*. 2013; 22(128): 131–147
73. Abaya SW, Bråtveit M, Deressa W, Kumie A, Moen B. Reduced Lung Function among Workers in Primary Coffee Processing Factories in Ethiopia: A Cross Sectional Study. *International Journal of Environmental Research and Public Health*. 2018;15(2415):1-9.
74. Belay M, Bjune G, Abebe F. Prevalence of tuberculosis, HIV, and TB-HIV co infection among pulmonary tuberculosis suspects in a predominantly pastoralist area, northeast Ethiopia. *Global Health Action* 2015;8.
75. Zeleke Z. Moen B. Bråtveit M. Lung function reduction and chronic respiratory symptoms among workers in the cement industry: a follow up study. *BMC Pulmonary Medicine*. 2011; 11:50
76. Hassen V. Nigatu A. Zeleke Z. Moen B. Bråtveit M. High Prevalence of Respiratory and Dermal Symptoms Among Ethiopian Flower Farm Workers. *Archives of Environmental & Occupational Health*. 2015; 70, 204–213
77. De Bruyn F, Zhang SJ, Pothakos V, Lambot C, Moroni AV, Callanan M, et al. Exploring the Impacts of Postharvest Processing on the Microbiota and Metabolite Profiles during Green Coffee Bean Production. *Applied and Environmental Microbiology*. 2017;83.
78. Silva F, Batista R, Abreu M, Dias S, Schwan F. Succession of bacterial and fungal communities during natural coffee (*Coffea arabica*) fermentation. *Food Microbiology*. 2008b;25:951-7.
79. Techale B, Musema A, Kasahun M. Prevalence of some coffee quality problems in Gomma Woreda, Jimma Zone. *International journal of Agriculture Sciences*. 2013;3:621-7.
80. Balows A, Truiper HG, Dworkin M, Harder W, Schleifer KH, editors. *The Prokaryotes*. Berlin: Springer; 1992.
81. Hennekens CH, Buring JE. *Epidemiology in Medicine*. Mayrent SL, editor. Philadelphia: Lippincott Williams&Wilkins; 1987.
82. Bonita R, Beaglehole R, Kjellström T. *Basic epidemiology*. 2 ed. Geneva: World Health Organization; 2006.

83. Martin RJ, Zalk MD. Comparison of total dust/inhalable dust sampling methods for the evaluation of airborne wood dust. *Applied Occupational Environmental Hygiene*. 1998;13:177-92.
84. Harper M, Muller B. An evaluation of total and inhalable samplers for the collection of wood dust in three wood products industries. *Journal of Environmental Monitoring* 2002;4:648-56.
85. Gorner P, Simon X, Wrobel R, Kauffer E, Witschger O. Laboratory study of selected personal inhalable aerosol samplers. *Annals of Occupational Hygiene*. 2010;54:165-87.

Annexes

Annex1: Participant information sheet in English

Title: "Assessing coffee dust exposure and respiratory health among workers in primary coffee processing factories of Ethiopia"

Principal Investigator: Samson Wakuma

Sponsoring Organization: NORHED

Introduction: Excessive exposure to coffee dust can cause different respiratory health problems. Coffee workers in Ethiopia are exposed to coffee dust but the level of exposure and the magnitude of its health effect is not known. Therefore, you have been chosen to participate in this study which is an assessment of dust exposure and respiratory health among coffee workers in Ethiopia primary coffee processing factories.

Purpose of the study

The aim of this study is to assess the dust exposures level and associated respiratory health problems among workers and evaluate determinants of dust exposure in primary coffee processing factories of Ethiopia. This study will help us come up with recommendations on how to improve the work environment.

What participation involves

If you agree to join the study you will be required to participate in an interview which will be on your personal back ground, respiratory symptoms and information on your previous job experiences. For some of the workers we will also take some measurements on lung function by a non invasive machine. You will be also asked to carry dust sampling pump in your breathing zone for the whole shift.

Confidentiality

All information obtained from you will be kept confidentially in a computer using the identification number. The information will only be used for the purpose of this research. Your employer will have neither access to any of the information you gave us nor the results of your lung function test.

Risk and /or discomfort

The study does not have any inhumane treatment of research participants and any physical harm, social discrimination, psychological trauma and economic loss. In general for dust sampling and respiratory assessment we do not expect that any harm will happen to you because of joining this study. For lung function test there is a small risk of syncope so you will be seated while performing the procedure to reduce the risk which is greater if you are standing.

Inducement, incentive and compensation

This study process has no any harm form of inducement, coercion and the study does not bring any risks that incur compensation.

Result Dissemination

The researcher is responsible for dissemination of findings. Maximum effort will be done to publish the findings in scientific reputable journal.

Right to withdraw

Your participations in the interview and every aspect of this study is completely voluntary. you have the choice to participate or not to. Your employer will have no access to your decision to participate or not.

Benefits

If you are found to have respiratory problems you will be referred to the hospital. The study does not have a short term financial and capacity building benefit to the research participants as individual or as a group but in the long run it will help the concerned organization and policy makers to have a policy consideration and direction and formulation of strategy and will help to come up with recommendations on how to improve the work environment.

In case of injury

We do not anticipate that any harm will occur to you in the course of this study.

Person to Contact

The participant has the right to ask information that is not clear about the research context and content before and or during the research work. you can contact the principal invesitgator and his advisor. moreover this research undergone ethical reviewed and approved by Addis Ababa University College of Health Sciences (IRB). The main task of this board is to make sure that the ethical principles is adhered or not and the research participants are protected from harm.

If you need clarification on the study you can contact the following people

Addis Ababa University College of Health Sciences IRB secretary office Tel: 0115512876

Principal Invesitgator: Samson Wakuma: Phone: +251923940998 ; E-mails-samson_wakuma@yahoo.com

Primary Supervisor: Abera Kumie; School of Public, College of Health Science, Addis Ababa University. Mobile: 0911882912

Annex2: Amharic version participant information sheet (የሰራተኞች የተሳታፊነት መረጃ ፎርም)

የጥናቱ ረዕስ: ከቡና ማቀነባበሪያ የሚወጣ ብናኝና የሰራተኛው የመተንፈሻ ጤና ችግርን ለማጥናትና የችግሩን መጠን ለመለካት

የጥናቱን ዋና ተመራማሪ: ሳምሶን ዋቁማ

ስፖንሰር ያደረገው ድርጅት: የኖረዌይ የልማት ድርጅት

መግቢያ: ከቡና ማቀነባበሪያ የሚወጣ ብናኝ ከመጠን በላይ ከሆነ በሰራተኞች መተንፈሻ ላይ የጤና ችግር የመጣል:: በኢትዮጵያ ውስጥ በተለየ ሰራተኞች በቡና ማቀነባበሪያ ውስጥ ይሰራሉ እናም እነዚህ ሰራተኞች ለብናኝ ይጋለጣሉ ሆኖም ግን በምን የህል እና ምን አይነት የጤና ችግር እና በምን መጠን የሚለወድ አይታወቅም:: ስለዚህ እርሶ በቡና ማቀነባበሪያ የሚወጣ ብናኝና የሰራተኛው የመተንፈሻ ጤና ችግርን የሚያጠና ጥናት ላይ እንድትሳተፉ ተመርጠዋል::

የጥናቱ አላማ : ከቡና ማቀነባበሪያ የሚወጣ ብናኝና የሰራተኛው የመተንፈሻ ጤና ችግርን ለማጥናትና የችግሩን መጠን ለመለካት ያለመ ነው :: ይህ ደግሞ የሰራ ቦታዎችን ደህንነትን ለማሻሻል ይረዳል ::

ለተሳታፊዎች መመሪያ: በዚህ ጥናት ለመሳተፍ ፍቃደኛ ከሆኑ በቃለ መጠይቅ እንዲሳተፉ እጠይቃለሁ:: ቃለ መጠይቅ አጠቃላይ ስለ ራስ የመተንፈሻ አካል የጤና ችግርና ከዚህ በፊት የሰራ ሁኔታ ይመለከታል :: አንዳዶቻችሁን የሳንባ ጤንነት ምንም ዓይነት ጉዳት በሚያመጣ መሳሪያ እንለካለን :: በተጨማሪ የብናኝ መለኪያ ፓምፕ እንዲይዙ ይደረጋል::

ሚስጥርን መጠበቅ: ሁሉም መረጃ ከርሶ የሚገኘው በሚስጥር ኮድ አማካኝነት በሚስጥር በኮምፒዩተር ውስጥ ይቀመጣል :: የተገኘው መረጃ ለዚህ ጥናት ብቻ ይውላል :: አሰሪዎ ከርሶ የተገኘውን ማንኛውንም መረጃና የሳንባ ምርምር ውጤት ማየት ወይም ማግኘት አይችልም ::

በተሳታፊዎች የሚደርሱ ጉዳት ወይም ምችት ማጣ: ይህ ጥናት ምንም አይነት ሰብአዊነት የሚነካ ነገር የለውም አካልን አየንዳም ከህብረተሰብ መንገድ አያመጣም የስነልቦና ችግር አያመጣም እንዲሁም ኪሳራ አያመጣም ባጠቃላይ በዚህ ጥናት ጊዜ ምንም ዓይነት አደጋ ይከሰታል ብለን አንጠብቅም::

በጥናቱ ያለመሳተፍ መብት: በዚህ ቃለ ምልልስ ወይም በዚህ ጥናት መሳተፍ ወይም አለመሳተፍ ሙሉ መብት አለዎት :: አሰሪዎ በርሶ ውሳኔ ላይ ምንም ዓይነት ውሳኔ መስጠት አይችልም ::

ማበረታቻ/ ገቢ ወይም ካሳ : ይህ ጥናት ምንም አይነት ማበረታቻ ወይም ካሳ ወይም ገቢ አይሰጥም ::

ዉጤትን ማሰራጨት: የጥናቱ ተመራማሪ ሙሉ መጠቀሙ ሃላፊነቱን ወስዶ ወጤቱን ያሰራጫል:: እንዲሁም ወጤቱን በታወቀ የሳይንስ ጆርናል ላይ ያሳትማል ::

የተሳታፊዎች ጥቅም: የመተንፈሻ ችግር ከተገኘበት ወደ ሆስፒታል እንድትሄዱ ያደርጋሉ :: ይህ ጥናት የሰራ ቦታ ደህንነት እንዲሻሻል ያደርጋል :: ይህ ጥናት ምንም አይነት የአጭር ጊዜ ገቢ እና የአቅም ግንባታ ለግለሰብ ወይም ለህብረት የለውም :: ግን ለወደፊት ለሚመለከተው ክፍል እና ለፕሊሲ አዉጪ ወች አቅታጫ ና ስትራቴጂ ለማዘጋጀት ይረዳል::

በአደጋ ጊዜ: በዚህ ጥናት ጊዜ ምንም ዓይነት አደጋ ይከሰታል ብለን አንጠብቅም::

የሚያነጋግሩት ሰዉ: ተሳታፊዎች ስለ ጥናቱም ሆነ ስለሌላ ነገር ግልድ ያልሆነ ካለ ጥያቄ ለመጠየቅ ሙሉ መብት አላቸው:: ጥያቄ ካሎት ዋና ተመራማሪ ወይም ዋና አማካሪ ማግኘት ይችላሉ:: በተጨማሪ ይጥናት በአዲስ አበባ ዩኒቨርሲቲ የጤና ሳይንስ ኮሌጅ የህብረተሰብ ጤና ሳይንስ ት/ቤት የሰነ ምግባር ኮሚቴ የታየና የጸደቀ ነዉ:: የኢንስቲትዩሽናል ረቪዉ ቦረድ ዋናዉ አላማ ጥናቱ ስነ ምግባር በተሞላበት ሁኔታ አንዲካሄድና የተሳታፊዎችን ከአደጋ ለመከላከል ነዉ ::

ተጨማሪ ማብራሪያ ወይም ጥያቄ ካሎት በሚከተለው አድራሻ መጠየቅ ይችላሉ::

ሳምሶን ዋቁማ፤ ስልክ 09-23 94 09 98 ፤ ኢ.ሜል Samson_wakuma @ yahoo .com

ዋና አማካሪ፤ አበራ ኩሚ: ስልክ 09-11-88-2912

ኢንስቲትዩሽናል ረቪዉ ቦረድ: ስልክ 01-18-96-13-9

Annex3: Oromifa version participant information sheet (Waraqaa Odeeffannoo Hirmaataa Afaan Oromiffaatiin)

Qorannoo dhukkeef saaxilamuufi Fayyaa hargansuu hojjetoota bunaa warshaalee Itiyoophiyaa buna qopheessan kessa hojjetanii irratti godhamu irratti akka hirmaattuuf filatamteetta. Hirmaachuuf walii galuu keetiin dura Ibsawwan armaan gadii dubbisuun gaaffiiwwan ifa hin taane kamiyyuu gaafadhu.

Kayyoo Qorannichaa

Kaayyoo qorannoo kanaa sadarkaa saaxilamawwan dhukkee fi rakkoowwan fayyaa hargansuu hojjetoota gidduu jirru gamaggamuufi warshaalee Itiyoophiyaa kan buna qopheessan akka dhukkeef saaxilaman kan murteessu maal akka ta'e qorachuu. Qorannoon kun akkamitti akka naannoo hojji fooyyassu danda'ammu irratti hubannoo akka argannu nu gargaara.

Wanta Hirmaachuun of keessa qabu

Qorannoo kana irratti hirmaachuuf yoo walii galte gaaffii fi deebii seenaa jireenyaa kee, mallattoowwan hargansuu keetii fi odeeffannoo muuxannoowwan hojii kee duraanii irratti xiyyeffatee adeemisfamu irratti hirmaachuun isin barbaachisa. Hojjetoota muraasaaf dalagaawwan sombaa irratti safarawwan muraasa maashinaan ni adeemsifna. Yeroo dabaree hojji guutuu keetiif saampilii dhukkee goggoogaa meeshatti akka baattan ni gaafatamtu.

Iccitummaa

Odeeffannoo isin irraa argame hundu lakkoofsa adda baasaa fayyadamuun iccitiidhaan koompitara keessa kaa'ama. Odeeffannoon kan fayyadu kaayyoo Qorannoo kanaa qofaafidha hojjechiisan keessan odeeffannoo isin nuuf kennitan kamiyyuu yookan bu'aawwan qorannoo hojii somaba kee akka beekuu ni taasifama.

Miidhaamawwan

Sababa qorannoo kanatti seenuu keetiif miidhaan isin irra ga'u ni jira jennee hin eegnu.

Mirga addaan kutuu

Hirmaannawwan ati gaaffii fi deebii akkasumas kallattii kamiinuu qorannoo kana irratti gootu guutumatti Fedhii/tola/irratti kan hundaa'edha hirmaachuu yookan dhiisuuf filannoo qabdu. Hirmaachuuf yookan dhiisuuf murteessuu keetiif hojjechiisan kee keessa in galu.

Bu'aawwan/Faayidaawwan

Rakkoo hargansuu akka qabdu yooo argame gara hospitaalaatti ni ergamta (isiniif bareeffama)

Dhimma balaa madaa'uu

Miidhaan qorannoo kana irratti isin irra ni ga'a jennee hin yaannu. Qorannoo irratti ibsa yoo barbaadde lakk. Bilbilaa 0923940998 yookan toora intarneetii samson_wakuma@yahoo.com tiin Saamson Waaqumaa qunnami.

Too'ataa/suppeyaayizara /jalqabaa

Abarraa Kumee moobaayila 0911882912

Lakk. Bilbilaa IRB 0911896136

Annex4: English version of Consent Form

Title: "Assessing coffee dust exposure and respiratory health among workers in primary coffee processing factories of Ethiopia"

Name of industry _____ Name of the department _____

Name of the working section _____

Hello, I am _____. I am working in the research team of Addis Ababa University, College of Health Sciences, School of Public Health, Department of Preventive Medicine. I would like you to participate in a research study related dust exposure and respiratory health problem. No harm will happen to you because of joining this study instead your participation will help to improve working environment. Your name will not be written in this form, and will never be used in connection with any information you tell us. All information given by you will be kept strictly confidential and will be anonymously used in this research and only accessed by principal investigator. Your participation is voluntary and you are not obliged to answer any question you do not wish to answer. If you feel discomfort with the interview please feel free to drop it any time you want. This interview will take about 25 minutes.

Do you agree?

Participant agrees-----participant does not agree_____

I -----have read the contents in this form or it has been read to me in the language I comprehend and understood the condition stated above. My questions have been answered. Therefore, I agree to participate in this study and confirm my participation by signing the consent.

Signature of participant _____

Interviewer: Code _____ Name _____ signature _____

Date of interview _____ Time started _____ Time completed _____

Result of interview: 1.Completed 2.Respondent not available 3.Refused 4. Partially completed. For any inconvenience and problem you can contact the following people

Addis Ababa University College of Health Sciences IRB secretary office Tel: 0115512876

Principa investigator: Samson Wakuma: Phone -0923940998;E-mails-samson_wakuma@yahoo.com

Primary Supervisor: Abera Kumie; Mobile: 0911882912

Annex5: Amharic version Consent Form (የተሳታፊዎች ፍቃድኝነት መጠየቅ ቅጽ)

የጥናቱ ረዕስ: ከቡና ማቀነባበሪያ የሚወጣ ብናኝና የሰራተኛው የመተንፈሻ ጤና ችግርን ለማጥናትና የችግሩን መጠን ለመለካት

የኢንዱስትሪ ስም ----- የዲፓርትመንት ስም -----

ክፍል -----

ጤና ይስጥልኝ እኔ ----- እባላለሁ :: እኔ የመጣሁት ከአዲስ አበባ ዩንቨርሲቲ ጤና ሳይንስ ኮሌጅ የሕብረት ጤና ት/ቤት የፕሪቪግጅቲቭ ሜዲሴን ት/ክፍል ቡድን አባል ሆኜ ነው ::

ከዚህ በመቀጠል በቡና ማቀነባበሪያ ፋብሪካ እና የሰራተኞች ጤና የሚያጠና ጥናት ላይ እንዲሳተፍ እንጠይቃለን ::

በዚህ ጥናት ጊዜ ምንም ዓይነት አደጋ ይከሰታል ብለን አንጠብቅም። ከእርሶ የሚገኘው መልስ የሰራ አከባቢ አገልግሎትን ለማሻሻል ከፍተኛ እገዛ ይኖረዋል። ከእርሶ የምናገኛቸው ማንኛውም መረጃ በምስጥር እንጠብቃለን። ከዚህ ጥናት ጋር በተያያዘ በማንኛውም ቦታ እና ጊዜ ስምዎ እንዳይጻፍና እንደማይጠቀስ ልንገልጽለዎ እንወዳለን። በአጠቃላይ መጠይቁ ወደ 25 ደቂቃ ገዳማ የሚወስድ ስሆን በጥናቱ የሚሳተፉት የእርሶን ሙሉ ፍቃድኝነት ስናገኝ ብቻ ነው። በመጠይቁ ሂደት ለመመለስ የማይፈልጉትን ጥያቄዎችን ያለመመለስ ሙብተዎ የተጠበቀ ነው።

በጥናቱ ለመሳተፍ ፍቃደኛ ነዎት

1 አዎ----- 2 የለም -----

እኔ ----- ሙሉ ፀሁፉን አንብቤ ተረድቻለሁ ወይም በሚገባኝ ቋንቋ ተነባልኛል። ስለዚህ ካላይ የተጠቀሱትን ሃሳቦች በደንብ ተረድቻለሁ። ጥያቄዎቼ በሙሉ ተመልሰዋል ስለዚህ በዚህ ጥናት ለመሳተፍ እስማማለሁ ::

የተሳታፊ ፊርማ -----

የጥያቄው ኮድ ----- ስም ----- ፊርማ -----

የቃለመጠይቁ ቀን ----- የተጀመረበት ሰዓት ----- ያለቀበት ቀን -----

ውጤት

- 1. ተጠቃሷል 2. ተጠያቂው አልተገኘም 3. ተጠያቂው ተቃውመዋል 4. በከፊል ተጠናቋል

ምንኛውንም መረጃ ለማግኘት የጥናቱን ዋና ተመራማሪ በሚቀጥለው አድራሻ ማግኘት ይችላሉ።

ሳምሶን ዋቁማ፤ ስልክ 09-23 94 09 98 ፤ ኢ.ሜ.ል Samson_wakuma @ yahoo .com

ዋና አማካሪ፤ አበራ ኩሚ፡ ስልክ 09-11-88-2912

ኢንስቲትዩሽናል ረቪዩ ቦረድ፡ ስልክ 01-18-96-13-96

Annex 6: Oromifa version of Consent Form (Guca Walii galtee)

Maqaa industirii _____

Maqaa Muummee /hojjii _____

Maqaa kutaa hojjii _____

Hayyee, Ani _____ jedhama. Anis Garee qorannoo Yuunivarisiitii finfinnee, koolleejjii saayinsii fayyaa, mana barnoota fayyaa ummataa mumme qoricha ittisaa keessan hojjechaa jira. Qorannoo waa'ee dhukkeef saaxilamuufi rakkoo fayyaa hargansuu irratti qoratamu irratti akka hirmaattan nan brbaada. Qorannoo kanatti galuu keessaniif wanti isin miidhu hin jiru garuu naannoo hojii akka fooyyeessitan isin gargaara.

Maqaan keessan guca kana irratti hin barreefamu akkasumas odeeffannoo nutti himtaniin wal qabaree faayidaa irra hin oolu. Odeeffannoon isiniin kenname hundi iccitii cimaadhaan kaa'ama.

Akkumas eenyu akka dubbate/ ibse osoo hin ibsamin qorannoon kun qorataa qofaan kan dhiyeeffamuudha/qabamuudha/. Hirmaannaan keessaa Feedhiidhaan ta'a. akkasumas gaaffii deebisuu hin barbaannee kamiyyuu deebisuuf hin dirqamamtan. Gaaffii fi deebichi yoo isiniitti hin tollee yeroo barbaaddan kamittuu addaan kutuu ni dandeessu gaaffii fi deebiin kun naannaa daqiiqaa 25 ni fudhata.

Itti walii galtuu?

Hirmaataan/ttuu walii gale/ite _____

Hirmaataan/ttuun walii hin galle _____

Ani _____ kanan jedhamu qabiyyeewwan guca kanaa dubbiseera yookan afaan ani beekuun naaf dubbifameera akkasumas haalli armaan oliitti ibsame naaf galeera. Gaaffiin koo naaf deebi'eera. Kanaafuu qorannoo kana irratti hirmaachuuf waliigaleera. Akkasumas walii galtee kana irratti mallatteessuun hirmaanna koo, nan mirkaneessa mallattoo hirmaataa/ttuu _____

Hirmaataa:- koodii _____ Maqaa: _____ mallattoo guyyaa gaaffii fi deebii _____ sa'aatii jalqabe _____ sa'aatii xumurame _____ bu'aa gaaffii fi deebii.

Annex 7: English - Questionnaire

Questionnaire prepared in Addis Ababa University College of Health Sciences School of Public Health for assessing chronic respiratory health problems among coffee factory workers in Ethiopia

Date: _____

Name of the plant: _____

Section A: Demographic data

No	Questions/ variable	Responses	Skips
1	Name of the respondent		
2	Identification number		
3	Date of birth (day/month/year)in G.C	/ ____/ ____/ ____/	
4	Sex	1 [Male] 2 [Female]	
5	Age in years		
6	Education level	[0]none 1[1-4] 2[5-8] 3[9-10] 4[11-12] 5[University]	

Section B: Occupational history

No	Questions/ variable	Responses	Skips
7	For how long have you been working in this factory (years & months)		
8	How many working hours per day?(hours)		
9	How many working hours' per a week? (hours)		
10	How long have you been working in coffee industry, summarizing all periods?(years & months)		
11	Which section are you working now and for how long? multiple responses are possible	1 Hand picking ____/____ 2 Cleaning ____/____ 3 Husk handling ____/____ 4 Reject coffee handling ____/____ 5 Stamping bags ____/____ 6 Loading & unloading ____/____ 7 Any other _____/____/____	
12	Have you ever worked in other sections	1[Yes] 2[No]	

	in the past in the coffee factory?		
13	If Q 12 answer is "yes" indicate which section and for how long? (in years & months) (Multiple answer is possible)	1 Hand picking ____/____ 2 Cleaning ____/____ 3 Husk handling ____/____ 4 Reject coffee handling ____/____ 5 Stamping bags ____/____ 6 Loading & unloading ____/____ 7 Any other _____/____/____	
14	Have you ever worked in other dusty types of work (years)	1[Yes] 2[No]	
15	If Q 14 answer is "yes", for how long have you worked in any of the following types of work(in years)	1 Foundry ____/____ 2 Stone quarry____/____ 3 Asbestos ____/____ 4 Cotton, Sisal or flax ____/____ 5 Flower industry ____/____ 6 Millet processing ____/____ 7 Mines ____/____ 8 Any others _____/____/____	
16	Do you have your own small coffee farm?	1[Yes] 2[No]	
17	Do you process coffee at home?	1[Yes] 2[No]	
18	Are you normally cooking food at home?	1[Yes] 2[No]	
19	If Q 18 is "Yes" where is cooking normally taking places in your home?	1[inside house] 2[outside house in open area] 3[outside in a kitchen]	
20	What type of fuel do you use in your home for cooking?	1[charcoal] 2[fire wood] 3 [kerosene]	
21	Have you sprayed pesticides in the past years?	1[Yes] 2[No]	
22	If Q 21 answer is "Yes" What type of pesticides did you use?		

Section C: Respiratory symptoms

I am going to ask you some questions mainly about your chest. I would like you to answer yes or no wherever possible

No	Questions/ variable	Responses	Skips
Cough			
23	Do you usually cough first thing in the morning	1.[yes] 2.[no]	
24	Do you usually cough during the day or at night?	1 [yes] 2[No]	
If yes to any of the above go to Q 25			
25	Do you usually cough as much as 4-6 times a day for 4 or more days in a week?	1[yes] 2[No]	
26	Do you cough like this on most of days for as much as 3 consecutive months or more in a years?	1[yes] 2[No]	
27	For how long you had this cough? (years)		
Cough with sputum production			
28	Do you usually cough with sputum first thing in the morning?	1[yes] 2[no]	
29	Do you usually cough with sputum during the day or at night?	1[yes] 2[No]	
30	Do you usually cough with sputum as much as 4-6 times a day, or 4 or more days in a week?	1[yes] 2[No]	If no to the above questions skip this
31	Do you cough with sputum on most of days for as much as 3 consecutive months or more in a year?	1[yes] 2 [No]	If no to the above questions skip this
Breathlessness			
32	Are you troubled by shortness of breath when hurrying on level? ground or walking up slight hill?	1[yes] 2[No]	
33	Do you get shortness of breath walking with other people of your own age on	1[yes] 2 [No]	

	level ground?		
	If yes to any of the above go to Q 34		
34	Do you have to stop for breath walking at your own pace on level ground?	1[yes] 2[No]	
35	For how many years have you had trouble for shortness of breath? (years)		
Wheezing			
36	Have you had attacks of wheezing in your chest at any time?	1[yes] 2[No]	
37	How long do you have wheezing in your chest? (years & months)		
	If yes to any of the above go to Q38		
38	Do you usually experience chest tightness while at work or just after work?	1[yes] 2[No]	
39	If the answer for Q38 is "Yes" For how long do you have this problem?		
Chronic bronchitis			
40	During the past 3 years have you had a period of increased cough with increased sputum production for as long as three weeks or more?	1[yes] 2[No]	

Section D: Previous diseases

No	Questions/ variable	Responses	Skips
Have you ever had any of the following ?			
41	An injury /operation affecting your chest	1[yes] 2[No]	
42	Heart trouble	1[yes] 2[No]	
43	Bronchitis	1[yes] 2[No]	
44	Pneumonia	1[yes] 2[No]	
45	Pleurisy	1[yes] 2[No]	
46	Pulmonary tuberculosis	1[yes] 2 [No]	
47	Bronchial asthma	1[yes] 2[No]	

48	Any other chest trouble (Specify)		
----	-----------------------------------	--	--

Section E: Tobacco Smoking

No	Questions/ variable	Responses	Skips
49	Have you ever smoked cigarettes?	1[yes] 2[No]	
50	Do you now smoke cigarettes?	1[yes] 2[No]	
51	For how long have you been smoking (in years)		If no to question 50 skip this
52	How many cigarettes do you normally smoke per day now? number		If no to question 50 skip this
53	How long ago did you give up cigarette smoking? (in years)		
54	How many cigarettes did you normally smoke when you smoked earlier? number		If no to question 50 skip this

Section F: Respiratory protective devices

No	Questions/ variable	Responses	Skips
55	Do you usually wear respiratory protective devices while at work?	1[yes] 2[No]	
56	If Q 55 answer is "Yes" Which of the respiratory protective device do you use?	1 [Mask respiratory] 2 [Full face pieces respiratory] 3 [Breathing apparatus] 4 [Powered respirator]	
57	If Q56 answer is "No"Select the most appropriate reasons for not using respiratory protective device	1 [Not available] 2 [Not comfortable to wear] 3 [Do not offer enough protection against the dust] 4 [The dust is not harmful] 5 Any other reason _____	

Section G: Physical Measurement

No	Questions/ variable	Responses	Skips
58	Weight (Kg)		
59	Standing height (cm)		

Annex 8: Amharic version questionnaire

በአዲስ አበባ ዩንቨርሲቲ የጤና ሳይንስ የህብረተሰብ ጤና ሳይንስ ክፍል በቡና ማቀነባበሪያ ሰራተኞች የመተንፈሻ አካል ጤና ችግር ለመዳሰስ ለሚደረግ ጥናት የተዘጋጀ መጠይቅ

ቀን -----

የአንድስትሪውም ስም -----

ክፍል አንድ ስነ-ሕዝብ በተመለከተ

ተ.ቁ	ጥያቄ	መልስ	ማሳሰቢያ
1	የተጠየቀው ስም		
2	መለያ ቁጥር		
3	የትውልድ ቀን (ቀን / ወር / ዓ.ም)	/ ____ / ____ / ____ /	
4	ጾታ	1 [ወንድ] 2 [ሴት]	
5	ዕድሜ በዓመት		
6	የትምህርት ደረጃ	[0] አልተማረም 1[1-4] 2 [5-8] 3[9-10] 4 [11-12] 5 [ዩንቨርሲቲ]	

ክፍል ሁለት የስራ ሁኔታ

ተ.ቁ	ጥያቄ	መልስ	ማሳሰቢያ
7	ለምን ያህል ጊዜ ነው እዚህ ፋብሪካ የሰሩት? (ዓ.ም ና ወር)		
8	ለምን ያህል ሰዓት በቀን? (ሰዓት)		
9	ለምን ያህል ሰዓት በሳምንት? (ሰዓት)		
10	ለምን ያህል ጊዜ ነው በቡና ማቀነባበሪያ የሰሩት/ጠቅላላ ጊዜ? (ዓ.ም ና ወር)		
11	የትኛው ክፍል ነው አሁን የሚሰሩት እና ለምን ያህል ጊዜ እንደሰሩ ጥቀሱ (ዓ.ም ና ወር) (ከአንድ በላይ መመለስ ይቻላል)	1 ቡና ለቀማ ____/____ 2 ፅዳት ____/____ 3 ገለባ ክፍል ____/____ 4 ውዳቂ ቡና ____/____ 5 ጆናያላይማህተብ መምታት ____/____ 6 ተሽካሚ (አውራጅ እና ጫኝ ____/____ 7 ከዚህ ውጪ ከሆነ ጥቀሱ	

		____/____/____	
12	ከዚህ በፊት በሌላ ክፍል ሰርተዋል ወይ?	1 (አዎ) 2 (የለም)	
13	ጥያቄ 12 መልሱ አዎን ከሆነ የትኛው ክፍል ሰሩ እና ለምን የህል ጊዜ እንደሰሩ ጥቀሱ (ከአንድ በላይ መመለስ ይቻላል)	1 ቡና ለቀማ ____/____ 2 ፅዳት ____/____ 3 ገለባ ክፍል ____/____ 4 ውዳቂ ቡና ____/____ 5 ጆናያላይ ማህተብ መምታት ____/____ 6 ተሸካሚ(አውራጅ እና ጫኝ) ____/____ 7 ከዚህ ውጪ ከሆነ ጥቀሱ ____/____/____	
14	ከዚህ በፊት አዋራማ በሆነ ቦታ ላይ ሰርተዋል	1 (አዎ) 2 (የለም)	
15	ጥያቄ 14 መልሱ አዎን ከሆነ ለምን ያህል ጊዜ ከዚህ ቦታች በተጠቀሱት ቦታ ሰርተዋል	1 ብረታ ብረት ____/____ 2 ድንጋይ መፍጫ ____/____ 3 አስፒራቶስ ____/____ 4 የጥጥ ቃጫ ወይም ተልባ ማቀነባበሪ ____/____ 5 በአበባ ልማት ____/____ 6 ማሸላ ማቀነባበሪያ ____/____ 7 ማዕድን ____/____ 8 ሌላ ከሆነ ጥቀሱ ____/____/____	
16	የራሱ የሆ የቡና እራሻ መሬት አለት ወይ	1 [አዎ] 2 [የለም]	
17	ቡናን እቤት ውስጥ ያቃነባብራሉ ወይ	1 [አዎ] 2 [የለም]	
18	ምግብ እቤት ውስጥ የምታበስሉት	1 [አዎ] 2 [የለም]	
19	ጥያቄ 18 መልሱ አዎን ከሆነ የት ነው ምግብ የምታበስሉት ወይ	1 [እቤት ውስጥ] 2 [ከቤት ውስጥ በክፍት ቦታ ላይ] 3 [ከቤት ውጭ ኩሽና ውስጥ]	
20	ምግብ ለማብሰል ምን ዓይነት ማገዶ ነው የምትጠቀሙት	1 [ከሰል] 2 [እንጨት] 3 [ጋዝ]	
21	ባለፉት ዓመታት ፀረ ተባይ ረጭተዋል ወይ	1 [አዎ] 2 [የለም]	
22	ጥያቄ 21 መልሱ አዎን ምን ዓይነት ፀረተባይ ነው የረጩት		

ክፍል ሶስት የመተንፈሻ ችግር ምልክቶች

ከዚህ በመቀጠል የተወሰነ ጥያቄዎች ስለደረቶ በተመለከተ ልጠይቆ ነው :: አዎን ወይንም የለም በማለት መልሱ

ተ.ቁ	ጥያቄ	መልስ	መሳሰሉ
	ሳል		
23	ብዙ ጊዜ ጠዋት ላይ ሳል አሎት ወይ	1 [አዎ] 2 [የለም]	
24	በቀን ወይንም በማታ ሳል አሎት ወይ	1 [አዎ] 2 [የለም]	
	ከዚህ በላይ አንዱ አዎን ከሆነ ወደ ጥያቄ 25 ሂድ		
25	ከ4-6 ጊዜ በአንድ ቀን ለአራት ቀን ወይንም ከዛ በላይ በሳምንት ውስጥ ሳል አሎት ወይ	1 [አዎ] 2 [የለም]	
26	ባለፉት ሶስት ወራት ወይንም ከዛ በላይ አብዛኛውን ቀን ሳል ነበሮት ወይ	1 [አዎ] 2 [የለም]	
27	ለምን ያህል ጊዜ ነው ሳሉ የቆየዉ (ዓ.ም)		
	ሳል ከሃክታ ጋር		
28	ብዙ ጊዜ ጠዋት ላይ ሳል ከሃክታ ጋር ነበረብት ወይ	1 [አዎ] 2 [የለም]	
29	ብዙ ጊዜ በቀንና በማታ ሲያስሎት ሳሉ ሀክታ አለው ወይ	1 [አዎ] 2 [የለም]	
30	በቀን ውስጥ ከ4-6 ጊዜ ወይንም ለ4 ቀንና ከዛ በላይ በአንድ ሳምንት ሳል ከሃክታ ጋር ነበሮት ወይ	1(አዎ) 2(የለም)	ከዚህ በላይ ያሉ ጥያቄዎች የለም ካሉ ይህን ጥያቄ ይለፉት
31	ባለፉት ሶስት ወራት ወይንም ከዛ በላይ አብዛኛውን ቀን ሳል ከሃክታ ጋር ነበሮት ወይ	1 (አዎ) 2 (የለም)	ከዚህ በላይ ያሉ ጥያቄዎች የለም ካሉ ይህን ጥያቄ ይለፉት
	ትናፋሽ ማጠር		
32	ስተቸኩሎ ወይንም ትንሽ ዳገት ስትወጡ ትንፋሽ የማጠር ችግር አለብት ወይ	1 [አዎ] 2 [የለም]	
33	ከእድሜ እኩያዎ ጋር ለጥ ባለ መንገድ ላይ ሲሄዱ የትንፋሽ ማጠር ይገጥሞታል ወይ?	1[አዎ] 2 [የለም]	
	ከዚህ በላይ ካሉ ጥያቄ አንዱ አዎን ከሆነ ወደ ጥያቄ 34 ሂድ		
34	ለጥ ባለ መንገድ ላይ ሲጓዙ አየር ለመውሰድ ይቆማሉ ወይ	1[አዎ] 2 [የለም]	
35	ለምን ያህል ጊዜ ነው የትንፋሽ ማጠር የቆየዉ (ዓ.ም)		
	ኩር ኩር የሚል ድምፅ		
36	ሲተነፍሱ ደረት ላይ ኩርኩር ወይንም ሲጥ ሲጥ	1 [አዎ] 2 [የለም]	

	የሚል ድምፅ ይሰማል ወይ		
37	ለምን ያህል ጊዜ ነው ኩርኩር ወይም ሲጥ ሲጥ የሚል ድምፅ ይሰማ የነበረው (ዓ.ም/ወር)		
	ከዚህ በላይ ካሉ ጥያቄ አንዱ አዎን ከሆነ ወደ ጥያቄ 38ሂድ		
38	በስራ ላይ ወይም ከስራ በኋላ ደረት ላይ ክብድ ክብድ የሚል ስሜት አለውት ወይ	1 [አዎ] 2 [የለም]	
39	ጥያቄ 38 መልሱ አዎን ደረት ላይ ክብድ ክብድ የሚለው ነገር ለምን ያህል ጊዜ ቆየላት		
	የቆየ ብሮንካይትስ		
40	ባለፉት ሶስት ዓመታት ጊዜ ውስጥ ሳልና ሃክታ ለ3 ሳምንትና ከዛ በላይ ለሆነ ጊዜ እየጨመረ ነበር ወይ	1 [አዎ] 2 [የለም]	

ክፍል አራት - ከዚህ በፊት በሽታ

ከዚህ በታች ካሉት አንዱ የጤና ችግር ነበረብዎት ወይ

ተ.ቁ	ጥያቄ	መልስ	
41	በደረት ላይ የደረሰ ጉዳት ወይም ቀዶ ጥገና ነበር	1 [አዎ] 2 [የለም]	
42	የልብ ችግር	1 [አዎ] 2 [የለም]	
43	ባሮንካይትስ	1 [አዎ] 2 [የለም]	
44	የሳናባ ምች	1 [አዎ] 2 [የለም]	
45	የሳናባ በሽታ	1 [አዎ] 2 [የለም]	
46	የሳናባ ነቀርሳ	1 [አዎ] 2 [የለም]	
47	አስም	1 [አዎ] 2 [የለም]	
48	ሌላ አይነት ይልብ ሕመም ጥቀሱ		

ክፍል አምስት ሲጋራ ማጨስ

ተ.ቁ	ጥያቄ	መልስ	
49	ከዚህ በፊት ሲጋራ አጨሰዎ የወቃሉ ወይ	1 [አዎ] 2 [የለም]	
50	አሁን ሲጋራ ያጨሳሉ	1 [አዎ] 2 [የለም]	
51	ለምን ያህል ጊዜ አጨሰሱ		ጥያቄ 50 መልስ የለም ከሆነ ይህን ጥያቄ

			እለፈው
52	ምን ያህል ሲጋራ በቀን ያጨሳሉ		ጥያቄ 50 መልስ የለም ከሆነ ይህን ጥያቄ እለፈው
53	ምን ያህል ጊዜ ሆኖት ሲጋራ ማጨስ ካቆሙ (በዓመት)		
54	ምን ያህል ሲጋራ በቀን የጨሳሉ ድሮ ሲያጨሱ	-	ጥያቄ 50 መልስ የለም ከሆነ ይህን ጥያቄ እለፈው

ክፍል ስድስት መከላከያ መሳርያ በተመለከተ

ተ.ቁ	ጥያቄ	መልስ	
55	የመተንፈሻ መከላከያ መሳርያ ይጠቀማሉ በስራ ላይ እያሉ?	1 [አዎ] 2 [የለም]	
56	ለ55 ጥያቄ መልስ አዎ ከሆነ የትኛው መከላከያ መሳርያ ነው የሚጠቀሙት	1 [የመተንፈሻ መከላከያ ማስክ] 2 [ሙሉ በሙሉ ፊትን የሚሸፈን ማስክ] 3 [የመተንፈሻ መሳርያ] 4 [በሀይል የሚሰራ] 5 ሌላ ከሆነ ጠቀስ _____	
57	ለ56 ጥያቄ መልስ አይ ከሆነ ምክንያቱ ምንድነው	1 [ስለሌለ] 2 [ስለማይመቹ] 3 [አባራ ስለማይከላከል] 4 [አባራ አደጋ ስለማይመጣ] 5 [ሌላ ምክንያት ካለ ጥቀሱ]	

ክፍል ስድስት: ቁመት ና ክብደት

ተ.ቁ	ጥያቄ	መልስ	
58	ክብደት (ኪግ)		
59	ቁመት (ሳ.ሚ)		

Annex 9: Afaan Oromo version questionnaire

Questionnaireen kun kan qobaa,ee Yuunivarisiitii Finfinnee, koolleejjii Saayinsii Fayyaa, Mana Barnoota Fayyaa Ummataa qorannoo dhukkeef saaxilamuufi fayyaa hargansuu hojjettoota bunaa warshaalee Itiyoophiyaa buna qopheessan kessa hojjetanii irratti godhamudha.

Guyyaa:_____

Maqaa Industurii:_____

Kutaa A. Odeeffannoo seenaa dhuunfaa

Lakk	Gaffii	Deebii	Darbi
1	<u>Maqaa hirmaataa/ttuu</u>		
2	Lakk. eeyyummaa		
3	Guyyaa dhalootaa (guyyaa/ji.a/bara)	/_____/_____/_____/	
4	Saala	1 [Dhiira] 2 [Dhalaa]	
5	Umurii (waggaadhaan)		
6	Sadarkaa barnootaa	[0] Homaa 1[1-4] 2[5-8] 3[9-10] 4[11-12] 5 [Yuunivarsiitii]	

Kutaa B: Seenaa hojii

Lakk	Gaaffii	Deebii	Darbi
7	Warshaa kana keessa hojjechuu erga jalqqabdani yeroo ammammii ta'a (waggoota fi Ji'ootaa)		
8	Guyyaatti sa'a meeqaaf hojjetu? (sati)		
9	Torbanitti sa'a meeqaaf hojjetu? (sati)		
10	Indastirii bunaa keessa yeroo ammamiif hojjechaa turtan? ,yeroowwan hojjetan hunda dabalatee (waggoota fi Ji'ootaa)		
11	Yeroo ammaa Kutaa kamii hojitu, yeroo ammamiif hojjetani? (waggoota fi Ji'ootaa) Tokko chala dhebessun ni da'endama	1 Harkaan funaanuu ___/___ 2 Kutaa qulqullinaa ___/___ 3 Qola irraa luqqisuu ___/___ 4 Buna ilaalamee sadarkaan isaa kufe qabuu ___/___ 5 Korojoo aasxessuu fi irratti chaappessuu ___/___	

		6 Fe'uu fi buusuu ___/___ 7 Kan biraa _____/___/___	
12	Kanaan dura Warshaa bunaa kutaa biraa keessa hojjettanii beektuu?	1[Eeyyee] 2[Lakki]	
13	Gafi 12 Yoo eeyyee ta'e kutaa kami keessa yeroo ammamiif hojjetan? (waggoota fi Ji'ootaa) Tokko chala dhebessun ni da'endama	1 Harkaan funaanuu ___/___ 2 Kutaa qulqullinaa ___/___ 3 Qola irraa luqqisuu ___/___ 4 Buna ilaalamee sadarkaan isaa kufe qabuu ___/___ 5 Koroojoo aaxessuu fi irratti chaappessuu ___/___ 6 Fe'uu fi buusuu ___/___ 7 Kan biraa _____/___/___	
14	Kanaan dura warshaa biraa kan biyee qabu keessa hojjettanii beektuu?	1[Eeyyee] 2[lakki]	
15	Gafi 14 Yoo eeyyee ta'e kutaa kam keessa yeroo ammamiif hojjetan? (Wagadhan)	1 Sibiila baqsuu _____ 2 Dhagaa bocuu _____ 3 Hojjii soofuu kan dhukkee qabu _____ 4 Warshaa huccuu _____ 5 Warshaa/indastirii Abaaboo _____ 6 Hojii daagussaa (Millet)_____ 7 Hojii Albuuda baasuu _____ 8 kanneen biro _____/___/___	
16	Ooyruu bunaa kan dhuunfaa keessannii qabduu?	1 [Eeyyee] 2[Lakki]	
17	Buna manatti ni qopheessituu?	1[Eeyyee] 2[Lakki]	
18	Nyata manatti ni qopheessituu?	1[Eeyyee] 2 [Lakki]	
19	Gafi 18 Yoo eeyyee ta'e Nyaata eeessatti qopheessitu?	1[Mana keessatti] 2 [Manaa ala bakka banaa ta'etti] 3[Kutaa qofaa keessatti (kanaan mana jiraanyaan alaa)]	
20	Nyaata maaliiti gargaaramuun qopheessitu?	1[Cilee] 2 [Qoraan (muka)] 3[Naafxaa/gaazii]	
21	Waggoota darban keessatti qoricha biqiltootaa biiftanii beektuu?	1[Eeyyee] 2[Lakii]	
22	Gafi 21Yoo eeyyee ta'e Qoricha kam biiftan?		

Kutaa C. Mallatoowwan sirna argansuu

Gaaffii muraasa keessatti waan qoma/laphee keessanii isin gaafachuun barbaada. Bakka danda'amaa ta'e kamittuu eeyyee yookan lakki jettanii akka deebistan isin gaafadha.

Lakk	Gaaffii	Deebii	Darbi
<u>Qufaa</u>			
23	Yeroo baay'ee ganama ganama isin qufaasisaa?	1 [Eeyyee] 2[Lakki]	
24	Yeroo baay'ee guyyaa fi halkan isin qufaasisa?	1 [Eeyyee] 2 [Lakki]	
	Tokkoo gaaffilee oliif deebiin keessaan eeyyee yoo ta'e		
25	Guyyaatti yeroo 4-6 turban afuriif yookiin torbanitti yeroo baay'ee isin qufaasisaa?	1[Eeyyee] 2 [Lakki]	
26	Qufaa akkanaa yeroo baay'ee ji'oottan sadiif yookiin isaa oliif wagga keessatti ni qabattuu?	1[Eeyyee] 2[Lakki]	
27	Qufaan kun yeroo ammamiif isin irra ture? (Waggaa)		
Qufaa akii (waan tufamu) qabu			
28	Yeroo baay'ee ganama barii qufaa akii (waan tufamu) qabu isin qufaasisaa?	1[Eeyyee] 2[Lakki]	
29	Qufaan akii (waan tufamu) qabu guyyaa moo halkan baay'inaan isin qufaasisa?	1[Eeyyee] 2[Lakki]	
30	Torban keessatti guyyoota 4 yookaan sanaa oliif guyyatti si'a 4 hanga 6tti yeroo baay'ee qufaa akii (waan tufamu) tufte isin ni qufaasisaa?	1[Eeyyee] 2[Lakki]	Gaaffiwwan asiin ol jiraniif deebiin keessan lakki yoo ta'e gara itti aanutti darbaa
31	Ji'oota 3 yookan sanaa ol kan walitti aananiif guyyoota baay'ee akkasitti qufaa akii qabu isin ni qufaasisaa?	1[Eeyyee] 2[Lakki]	Gaaffiwwan asiin ol jiraniif deebiin keessan lakki yoo ta'e gara itti aanutti darbaa
Hafuura kutaa			
32	Hanqina hafuura baafachuutiin ni qabdu yeroo daddaftanii deemtan yookiin karaa xinnoo olka'aa yookiin wal-qixxaataa deemta hafuura isin kutaa?	1[Eeyyee] 2 [Lakki]	
33	Lafa wal qixxaataa irra namoota umurii wal giittan waliin gaafa deemtaan hanqinni hafuura baafachuu isin quunnamaa?	1[Eeyyee] 2[Lakki]	
	Tokkoo gaaffilee oliif deebiin keessaan		

	eeyyee yoo ta'e gara gaffii 34 demi		
34	Lafa wal qixxaataa irra yoommuu addemtu rakko hafuura baafachuuf dhaabbachuun boqonnaa fudhachuu qabduu?	1[Eeyyee] 2[Lakki]	
35	Rakkoon hafuura baafana (argansuu) kun ammam isin irra tureera? (wagga)		
Hafuura baafaannaa sagalee qabu/dhageessisu			
36	Yeroo kamittuu laphee keessan irratti sagaleen dhaga'amu isin quunnamee beekaa?	1[eeyyee] 2 [miti]	
37	Rakkoon laphhee keessan irraa yeroo hafuura baafattan dhaga'amu ammam isin irra tureera? (wagga fi Ji'a)		
	Tokkoo gaaffilee osiin ol joraniif deebiin keessan eeyyee yoo ta'e gara gaffi 38		
38	Yeroo baay'ee yeroo hojjetan yookan hojjiin booda miidhaan laphee buusuu isin qunnamee beekaa?	1[Eeyyee] 2[Lakki]	
39	Gafi 38 Yoo eeyyee ta'e rakkoon kun yeroo ammam tureera?		
Dhibee ujummoo qilleensaa ture (Chronic Bronchitis)			
40	Waggootan draban sada keessatti qofaan akii (waan tufamu) baay'ee qabu baay'inaan yoo xiqqaate ji'oottan sadiif ture isin mudatee beekaa? isin qufaasisuunMiidhaawwan qufaa	1[Eeyyee] 2[Lakki]	

Kutaa D. Dhukkuboota kanaan duraa

Lakk	Gaaffii	Deebii	Darbi
Kanneen gaditti tarreeffaman keessaa kan isin quunnamee beeku jiraa?			
41	Madaa/baqaqsanii hodhuu laphee kee miidhu	1.[eeyyee] 2. [miti]	
42	Rakkoo onnee	1[eeyyee] 2 [miti]	
43	Madaa qoonqoo	1[eeyyee] 2[miti]	
44	Dhibee sombaa (pneumonia)	1[eeyyee] 2[miti]	
45	Laphee keessatti dhangala'aan kuufamuu (pleaurisy)	1[eeyyee] 2 [miti]	
46	Dhukkuba sombaa (Tuuberkuloosisii)	1[eeyyee] 2 [Lakki]	
47	Dhukkuba asimaa (rakkina argansuu)	1[eeyyee] 2 [Lakki]	
48	Rakkoo laphee biroo kamiyyuu (Kan		

	birra ibsi)		
--	-------------	--	--

Kutaa E. Tamboo xuuxuu

Lakk	Gaaffii	Deebii	Darbi
49	Tamboo xuuxxanii beektuu?	1[eyyee] 2[Lakki]	
50	Yeroo ammaa tamboo ni xuuxxuu?	1[eyyee] 2[Lakki]	
51	Erga xuuxxuu jalqabdani waggaa meeqa ni ta'a? (waggadhan)		Gaaffi lakkofsa 50 miti yoo ta'e gafi kana dharbi
52	Yeroo ammaa guyyaatti tamboo meeqa ni xuuxu? Lakkoosfaan		Gaaffi lakkofsa 50 miti yoo ta'e gafi kana dharbi
53	Tamboo xuuxuu kan dhaabdan waggaa meeqaan dura ture ? (waggadhan)		
54	Duraan yeroo xuuxaa turte guyyaatti Tamboo meeqa xuuxa turte? (lakkoofsaan)		Gaaffi lakkofsa 50 miti yoo ta'e gafi kana dharbi

Kutaa F. Meeshaalee sirna argansuu miidhaa irraa eegan

Lakk	Gaaffii	Deebii	Darbi
55	Bakka hojii yeroo jirtanitti meeshaalee qaama sirna argansuu miidhaa irraa dhorkan yeroo baay'ee ni fayyadamtuu ?	1[eyyee] 2[miti]	
56	Gafi 55 Yoo eeyyee ta'e Meeshaa qaama aarqansuu miidhaa irraa dhorku keessaa isa kam fayyadamtu?	1[Golga afaanii] 2 [Golga fuula guutuu] 3 [Meeshaa aarqansuu] 4 [Meeshaa arqansuu cimaa]	
57	Gafi 56 Yoo mitti ta'e Sababawwan tarreeffaman keessaa kanneen akka isin meeshaalee qaama sirna argansuu miidhaa irraa eegan hin fayyadamnee isin taasisan kanneen kami?	1[Waan hin jirreef] 2[Uffachuuf/kaawwachuuf namatti hin tolu] 3[Dhukkee irraa haala gaarii dhaan nama hin dhorku] 4 [Dhukkeen nama hin miidhu] 5 Sababa biroo _____	

Kutaa G. Safara qaamaa

Lakk	Gaaffii	Deebii	Darbi
58	Ulfaatina (Kg)		
59	Hojjaa (dheerina qaamaa) (sm)		

Annex 10: Factory work place observation checklist

General

SN	Date of inspection /observation	
1	Name of factory	
2	Established year	
3	Produced item: fabric	
4	How many rooms	
5	Number of workers	
6	Regular working days and hours	
7	Presence of shift	
8	Working hours per day and per week	
9	Production capacity	
10	Seasonal production rate the last 5-10 years	

Number of workers by work type

SN	Work place	Number of employees
1	Feeding coffee to the hopper	
2	Monitoring the pre cleaner	
3	Monitoring the huller	
4	Monitoring the catador	
5	Monitoring the gravity table	
6	Hand picking	
7	Packing	
8	Stamping	
9	Sweeping	
10	Handling husks	
11	Bulking the coffee	
12	Storing green coffee bags	
13	Loading and unloading	

Work place characteristics

SN	Work place characteristic	
14	How is the machines distributed (also make an illustrating map where the production line/machines are placed)	
15	Types of ventilation	
	Natural ventilation system - the ventilation through opening along	1. the roof 2. the doors 3. the window 4. other specify.....
	Artificial ventilation	1. Mechanical air supply/extraction 2. local exhaust from machines

	Both natural and artificial	
	No ventilation system	
16	Provision and observed use of personal protective equipment	
17	Design of Hopper	1. Open top 2. closed top
18	Design of Huller	1. Open top 2. closed top
19	Design of Grader	1. Open top 2. closed top
20	Practices in processing	

Task related activities

SN	Task related activities	
21	Practices in processing	1. Gradual pouring of coffee 2. Vigorous pouring of coffee
22	Types of pre processing coffee	1. wet pre processed coffee 2. Dry pre processed coffee
23	Cleaning methods	1. sweeping with brush, 2. vacuum cleaner, 3. jet air 4. other specify
24	Tasks performed at the time of sampling:	1. Feeding coffee to the hopper 2. Handling husks 3. Bulking the coffee 4. Storing green coffee bags 5. Sweeping 6. Monitoring the huller 7. Monitoring the gravity table 8. Hand picking
25	Provision and observed use of personal protective equipment	1. masks, 2. gloves 3. aprons, 4 others specify
26	Production rate during your survey	
27	Do they rotate between different taske /machines, and if so how often and between which sites?	

ANNEX 11: PROCEDURE FOR AEROSOL SAMPLING.

BEFORE SAMPLING

The pumps have to be charged during the whole night before sampling.

Prepare the sampling form.

SAMPLING;

- Remove the caps from the filterholder and attach the tube end to the filterholder (to the opposite end of inlet).
- **IMPORTANT:** Do not run the pumps without filter attached.
- Turn on the pump and let it run with the filter attached for 1-2 min.
- Read the flowrate through the filter with the flowmeter pressed against the open end of the filterholder (marked inlet). It should read 2.0 l/min. Adjust if necessary.
- Personal sampling starts. Note the starting time.
- Control the flowrate after 4 hours. Stop the sampling if the flowrate has decreased by more than 10% from the start value.
- Control/note the flowrate at the end of the sampling period before stopping the pump.
- Stop the pump, note the time.
- Attach the caps on the filterholders and store them for sampling.
- Charge the pumps for the next days samplings.

Annex 13: Observational note form

Sample ID	Job description

Process
Description _____

Engineering
Controls _____

Work practice
Control _____

Ventilation
Measurements _____

Personal Protective equipments Used _____

Original Article

Personal Dust Exposure and Its Determinants among Workers in Primary Coffee Processing in Ethiopia

Samson Wakuma Abaya^{1,2,3*}, Magne Bråtveit², Wakgari Deressa¹, Abera Kumie¹ and Bente E. Moen^{2,3}

¹Department of Preventive Medicine, School of Public Health, College of Health Sciences, Addis Ababa University, PO Box 9086, Addis Ababa, Ethiopia; ²Occupational and Environmental Medicine, Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway; ³Centre for International Health, Department of Global Public Health and Primary Care, Faculty of Medicine, University of Bergen, Årstadveien 21, 5009 Bergen, Norway

*Author to whom correspondence should be addressed. E-mail: samson_wakuma@yahoo.com

Submitted 14 August 2017; revised 19 July 2018; editorial decision 14 August, 2018; revised version accepted 21 August 2018.

Abstract

Background: Coffee processing has been shown to cause high dust exposure among the workers, but there are few studies from primary processing of coffee, and none of them is from Ethiopia. The aim of this study was to assess dust exposure and its determinants among workers in primary coffee processing factories of Ethiopia.

Methods: A total of 360 personal ‘total’ dust samples were collected from the breathing zone of workers in 12 primary coffee processing factories in Ethiopia. Dust sampling was performed with 25-mm three piece conductive cassettes with cellulose acetate filters attached to pumps with flow rate of 2 l min⁻¹ for an average sampling duration of 410 min. The dust samples were analysed gravimetrically using a standard microbalance scale. An observational checklist was used to collect information about possible determinants of dust exposure in the work environment. Linear mixed effect regression models were used to identify significant determinants of total dust exposure.

Results: Personal total dust exposure levels varied between the three main job groups with a geometric mean (GM) of 12.54 mg m⁻³ for the machine room workers, 12.30 mg m⁻³ for the transport workers, and 1.08 mg m⁻³ for hand pickers. In these three groups, 84.6%, 84.1% and 2.6% of the samples exceeded the occupational exposure limit for organic total dust of 5 mg m⁻³, respectively. The mixed-effects model for the machine room workers explained 21% of the total variance in total dust exposure, and showed that vigorously pouring coffee from a dropping height was associated with an about two times increase in exposure. For the transport workers, the mixed-effects model that included pouring method of coffee beans, number of huller machine in the room, mixing coffee, and feeding hopper explained 32% of total variance in personal total dust exposure.

Conclusion: About 84% of the dust samples among machine room and transport workers in primary coffee processing factories were above the occupational exposure limit value for organic dust. Proper control measures are necessary to reduce the exposure.

Keywords: coffee dust; coffee Ethiopia; exposure determinants; personal exposure; primary coffee factory

Introduction

Ethiopia is a major producer of coffee in Africa by producing about 500 000 tonnes every year (Amamo, 2014). Ethiopia is believed to be the birth place of *Coffea arabica*, which obtained its name from Kaffa where coffee was first discovered in the south-western highlands of Ethiopia (Wiersum *et al.*, 2008). Coffee contributes to about 10% of the Ethiopian growth domestic product and accounts for more than 25% of the foreign currency income (Chauhan *et al.*, 2015; Gebreyesus, 2015). In Ethiopia, about 15 million people depend on coffee production directly or indirectly for their living (Gray *et al.*, 2013).

Ethiopia produces exclusively Arabica Coffee, which is grown in three regional states: Oromia, Southern Nation's Nationalities and People's Region (SNNPR), and Gambella. About 99% of the coffee production comes from the Oromia and SNNPR regions (Musebe *et al.*, 2007). More than 90% of the coffee is produced by small-scale farmers that on the average owns about 0.5 hectare of land (Mekuria *et al.*, 2004).

Primary coffee processing refers to mechanical cleaning of debris from parchment coffee from the farms, and includes hulling, grading, hand picking, and packing of green coffee beans. Organic dust originates at different stages of this production line. Studies conducted in primary coffee processing factories in Papua New Guinea, Uganda, and Tanzania have shown levels of total dust exposure ranging 0.7–10 mg m⁻³, 1–58 mg m⁻³, and 0.24–36 mg m⁻³, respectively (Smith *et al.*, 1985; Sekimpi *et al.*, 1996; Sakwari *et al.*, 2012). A larger number of studies in Croatia, USA, UK, Italy, and Germany have measured dust exposure in secondary coffee processing factories where polishing, roasting, and grinding take place (Zuskin *et al.*, 1979; Thomas *et al.*, 1991; Larese *et al.*, 1998; Oldenburg *et al.*, 2009). Studies in primary coffee processing factories in Uganda and Sri Lanka indicated that exposure to coffee dust is associated with acute respiratory symptoms (Uragoda, 1988; Sekimpi *et al.*, 1996), whereas an increased prevalence of chronic respiratory symptoms was reported among primary coffee factory workers in Tanzania and Papua New Guinea (Smith *et al.*, 1985; Sakwari *et al.*, 2011). A recent study in a secondary coffee processing factory

in USA indicated that the workers may be at risk of developing obliterative bronchiolitis (Bailey *et al.*, 2015). However, this disease was associated with exposure to diacetyl and 2,3-pentanedione released during the coffee roasting process (Daglia *et al.*, 2007).

Dust exposure in primary processing factories varies with processes, tasks, ventilation system, type of coffee, and method of preprocessing at the farm (Smith *et al.*, 1985; Sekimpi *et al.*, 1996; Sakwari *et al.*, 2012). For instance, a study in Tanzania indicated that personal dust exposure was higher when handling dry preprocessed coffee than wet preprocessed coffee. Dry preprocessing at the coffee farm refers to a method where un pulped cherries are allowed to dry in sun under natural condition after harvesting. In the wet preprocessing method, harvested cherries are pulped immediately after harvesting, followed by fermentation and washing with clean water to remove mucilage cover. Both dry and wet preprocessing methods are used in Ethiopia.

In preparatory field visits at primary coffee processing factories in Ethiopia, we observed that more dust seemed to be generated from old processing machines compared to new machines, and that dust levels appeared to be lower in coffee factories with mechanical ventilation and good natural ventilation compared to factories without such ventilation. However, the levels of exposure have not been documented, as no study has so far been conducted in Ethiopia. Furthermore, factors that may have impact on coffee dust exposure levels have not been studied. The primary coffee processing factories in Ethiopia are different from analogous factories of Tanzania, Uganda, and Papua New Guinea where previous dust exposure measurements were conducted. Although Tanzania, Uganda, and Papua New Guinea grow both Arabic and Robusta coffee types, Ethiopia produces only Arabic coffee. Also the preprocessing method at the farms in Ethiopia is different from these countries. For example, in Tanzania, Arabica coffee is mostly wet preprocessed whereas Robusta coffee is dry preprocessed. In Ethiopia, Arabica coffee is preprocessed as dry or wet preprocessed based on the individual farmer interest. As coffee types and the processing method differ from one country to another, results from previous studies may not represent the dust exposure level in primary coffee

processing factories in Ethiopia. Therefore, the aim of this study was to assess personal dust exposure and to evaluate determinants of dust exposure in primary coffee processing factories in Ethiopia.

Methods

Study area

This study was conducted from May to October 2016. Twelve primary coffee processing factories were included, four factories from each of the three regions: Addis Ababa (factories A, B, C, D); Oromia (E, F, G, H); and SNNPR (I, J, K, L).

Dust sampling strategy

The three main job groups (hand pickers, transporters, and machine room workers) had distinct characteristics in terms of tasks performed and were assumed to constitute three similar exposure groups (SEGs). The number of personal dust samples was calculated based on Rappaport and Kupper (2008) who suggested repeated samples from 5 to 10 randomly selected individuals per SEG. In each factory, five coffee workers were randomly selected for dust sampling from each of the three main job groups. Thus, 15 persons were involved from each factory, and because sampling was performed on two consecutive days for each worker, a total of 360 dust samples were taken in the 12 factories.

The machine room job group included four tasks: machine operator—monitoring the processes; mechanic work—ensure the smooth running of the machines; cleaning—clean the machine and the machine area; and feeding hopper—feeding the hopper that is located inside the machine room. The transport job group included three tasks: loading and unloading—manual transport of coffee beans; mixing—mixing reject coffee; feeding coffee—feeding hopper outside the machine room. Hand picking job group included mainly women involved in manual sorting and removal of defective and discoloured coffee beans. Some of these women sit inside the machine room and picks the coffees from the sorting tables or belts whereas others sit on the floor without table and patiently pick through piles of green coffees.

Due to sampling errors, 15 dust samples were not included in the analysis: 2 samples due to pump failure, 2 samples were taken from a person listed as a transporter but who practised presently as a supervisor, 6 samples were intentionally exposed to dust by the workers and 5 samples were damaged while sampling.

Dust sampling and analysis

Personal dust samples were taken in the workers breathing zone using 25-mm three piece, closed-faced conductive cassettes (Millipore MAWP 025 AC) with a cellulose acetate filter (Millipore AAWP02500) attached to Side Kick Casella pumps with a flow rate of 2 l min⁻¹ (Occupational Safety and Health Administration, 2014). This sampling head has the same geometry (except for the cassette diameter) and orifice diameter as the 37 mm three-piece cassette used for ‘total’ dust sampling, and has also been assumed to sample ‘total’ dust at a flow rate of 2 l min⁻¹ (Skaugset *et al.*, 2013). The pumps were paused during lunch breaks. Full-shift exposure measurements were conducted on randomly chosen days of the week and repeated sampling was conducted the next day. Data collection took 4–6 days in each factory. The mean sampling time was 410 min with standard deviation 43 min and range of 246–494 min. Specific task duration was not recorded. During sampling, the pumps were checked every second hour. Field blanks were used to correct for any weight changes during sampling. After sampling, the cassettes were capped and transported as hand luggage by aeroplane to the laboratory in a box suitable to prevent damage or disturbance.

The dust samples were analysed gravimetrically using a standard microbalance scale AT261 Mettler Toledo with a detection limit of 0.01 mg m⁻³ in the accredited laboratory SINTEF MOLAB in Norway. The results obtained in this work were compared to the Norwegian Occupational Exposure Limit (OEL) for organic total dust of 5 mg m⁻³ (Norwegian Labour Inspection Authority, 2015).

Determinants of exposure

An observational checklist to collect information about possible determinants of dust exposure was filled in by the principal investigator during the sampling days.

The checklist included task-related determinants for machine room workers (machine operator work, mechanic work, feeding hopper, and cleaning) and for transport workers (loading and unloading, mixing coffee, and feeding coffee). The major job task performed by the respective workers was recorded during the sampling day to be linked with the associated dust sample.

The checklist also included factory-related, dichotomized determinants such as the design of the machineries; hopper, huller, and graders (open or closed top); the production rate (less or more than 50 tonnes per day); type of preprocessing method that had been used before the coffee entered the factory (dry or wet preprocessing method); mechanical ventilation system (present or

absent); pouring method (pouring coffee to the hopper or ground (vigorously pouring coffee from a dropping height or gradually poured from short height), and natural ventilation [adequate ventilation with the windows and openings area greater than or equal to 10% of the floor area of the machine room or inadequate ventilation with the windows and openings area less than 10% of the floor area of the machine room (Nemerow *et al.*, 2009)].

Statistical analysis

The distribution of dust exposure levels was skewed and therefore ln-transformed before analysis. The results were described using arithmetic mean, geometric mean (GM), and geometric standard deviation. Independent *t* tests were used to test differences within the potential dichotomous exposure determinants. A one-way ANOVA was performed to compare the GM of personal total dust exposure level between main job groups and between tasks. Tukey honest significant difference tests were used to explore the difference between each job group and Games–Howell *post hoc* tests were used for tasks when equal variances assumption was not met.

Two separate linear mixed effect regression models were developed to identify significant determinants for personal total dust exposure among the machine room workers and the transport workers, respectively. We developed separate models for these job groups because they were mainly working in different rooms/areas. In the random and mixed-effect models, the ln-transformed personal total dust exposure level was used as the dependent variable. In the random model, employee and factory were entered as random effects. In the mixed-effect model, possible factory and task-related determinants (*Det*) with significance value $P \leq 0.2$ in preparatory univariate analysis were entered as fixed effects, and employee and factory were entered as random effects. The task machine operator work was the reference category in the model for machine room workers whereas loading and unloading was the reference task category for the transport workers. The final model contained only determinates with P -value ≤ 0.05 .

The linear mixed model is given as (van Tongeren *et al.*, 2000; Rappaport and Kupper, 2008)

$$Y_{ifjk} = \ln(X_{ifjk}) = \mu_i + \sum_{l=1}^p \alpha_{il} Det_{ifl} + \gamma_{if} + \beta_j f_j + \varepsilon_{ifjk}$$

for $i = 1, \dots, g$ denotes group; $f = 1, \dots, F$ denotes factory (same number of factories for each group); $j = 1, \dots, n_{if}$ denotes worker within group * AND * factory; $k = 1, \dots, n_{fjk}$ denotes measurements within worker (and within group/factory,) where n_{fjk} is 1 or 2; $l = 1, \dots, p$ denotes

determinant; μ_i represents the true underlying mean of log-transformed exposure level for group i ; Det_{ifl} represents the l th determinants in the i th group in the f th factory;

$$\sum_{l=1}^p \alpha_{il} Det_{ifl} \text{ represents the fixed effects of the } p \text{ determinants;}$$

$\beta_j f_j$ is the random effect of the worker within group and factory and γ_{if} is the random effect of the factory; ε_{ifjk} is the random error of the j th worker in i th group in the f th factory on the k th measurements. X_{ifjk} represents the exposure level on the k th measurements for j th worker in i th group in the f th factory and Y_{ifjk} is the natural logarithm of the individual measurements X_{ifjk} .

Variance component structure was used in the model. Explained within-worker (ww δ), between-worker (bw δ), and between-factory (bf δ) variances, respectively, were calculated as the percentage change in the respective variances between the random and the mixed-effects models. Total variance explained by the fixed effects was calculated as the percentage change in the sum of the three variance components between the random and the mixed-effects model. The effects of the significant fixed factors in the mixed models were calculated as e^β , where β is the regression coefficient.

Design of huller correlated significantly with design of grader, so design of grader was dropped from the analysis. The analysis was performed using SPSS version 22 (IBM, 2013).

Ethical considerations

The study was approved by the Institutional Review Board of the College of Health Sciences of Addis Ababa University and the National Ethical Committee of the Federal Ministry of Science and Technology in Ethiopia. Permission to conduct the study was obtained from the factory managers. Written informed consent was obtained from each participant, and participation in the study was voluntary. Confidentiality was ensured by not using the names of the workers in any reports.

Results

Characteristics of the coffee factories

Ten of the 12 coffee factories were established before year 2010. All factories in Addis Ababa, except one, had a production rate more than 50 tonnes per day and more than one huller machine in the room. All coffee processing machines in SNNPR and Oromia regions had open-top design of machines and processed less than 50 tonnes per day, only coffee that had been preprocessed by the dry method. (For detail characteristics of primary

coffee processing factories in Ethiopia, see [Supplementary Table 1](#), available at *Annals of Work Exposures and Health* online).

Personal dust exposure

Personal dust exposure within the three main job groups varied considerably between the coffee factories (for details on personal dust exposure for each main job group in each factory, see [Supplementary Table 2](#), available at *Annals of Work Exposures and Health* online). The GM dust exposure among machine room workers ranged from 4.09 to 34.40 mg m⁻³, among transport workers from 3.51 to 24.19 mg m⁻³, and among hand pickers from 0.26 to 5.87 mg m⁻³. Overall the GM personal dust exposure was significantly higher ($P = 0.001$) for the machine room (12.54 mg m⁻³) and transport workers (12.30 mg m⁻³) than the for the hand pickers (1.08 mg m⁻³). In these three groups, 84.6%, 84.1%, and 2.6% of the samples exceeded the OEL, respectively. None of the workers used any personal protective respiratory devices.

Task-related determinants

Among the machine room workers, there was no significant difference ($P = 0.860$) in personal dust exposure

between cleaning (14.01 mg m⁻³, $n = 25$); machine operator work (13.74 mg m⁻³, $n = 46$); and feeding the hopper (12.68 mg m⁻³, $n = 42$). Mechanic work was associated with lower exposure (1.99 mg m⁻³), but the number of measurements for this task was low ($n = 4$), and the samples were taken from only one of the factories.

Among the transport workers, the highest exposure was associated with feeding coffee (GM of 18.54 mg m⁻³, $n = 12$), followed by mixing coffee (16.44 mg m⁻³, $n = 36$) and loading and unloading (9.68 mg m⁻³, $n = 65$). The exposure when loading and unloading coffee was significantly lower than when mixing coffee and feeding coffee ($P = 0.001$).

Factory-related determinants

Personal total dust exposure among both machine room and transport workers was significantly increased when pouring coffee vigorously from a height in factories that had more than one huller machine in the room and when the hopper had open top ([Table 1](#)). For machine room workers also the state of the mechanical ventilation and the design of the huller had impact on dust exposure. For transport workers, a production rate with more than 50 tonnes per day was associated with a higher dust

Table 1. Factory-related determinants of total dust exposure for machine room workers and transporters in 12 primary coffee processing factories in Ethiopia.

Potential determinants	Definitions	NS	Machine room workers		Transporters	
			GM (mg m ⁻³)	P-value	GM (mg m ⁻³)	P-value
Process at the farm	0 = Wet preprocessed coffee	63	9.87	0.191	11.82	0.902
	1 = Dry preprocessed coffee	282	13.20		12.30	
Production rate	0 = Less than 50 tonnes day ⁻¹	258	12.30	0.640	10.80	0.006
	1 = More than 50 tonnes day ⁻¹	87	13.46		17.64	
Number of huller machine in the room	0 = One huller machine in the room	146	10.49	0.042	8.41	0.001
	1 = More than one huller machine in the room	199	14.30		16.12	
Pouring method	0 = Gradual pouring of coffee	32	5.05	0.001	6.55	0.039
	1 = Vigorous pouring coffee	313	14.30		12.81	
Factory establishment year	0 = New (after year 2010)	58	7.92	0.07	11.25	0.597
	1 = Old (before year 2010)	287	13.74		12.55	
Design of hopper	0 = Closed top	87	8.33	0.003	11.25	0.04
	1 = Open top	258	14.30		16.28	
Natural ventilation	0 = Adequate ventilation	116	12.06	0.789		
	1 = Inadequate ventilation	229	12.81			
Mechanical ventilation	0 = Working in a good condition	29	4.10	0.01		
	1 = Not working or absent	316	13.87			
Design of huller	0 = Closed top	116	9.78	0.033		
	1 = Open top	229	14.15			

NS = number of samples; GM = geometric mean; P-value for Independent *t* test, $p < 0.05$.

exposure compared with production rate less than 50 tonnes per day. Ventilation system and design of huller were relevant only in the machine room, and were not considered as potential determinants for transporters as they work mostly outside the machine room.

Exposure determinant models

In the random-effect model (Table 2) that included employee and factory as random effects, the within-worker variance (day-to-day variance) was higher than the between-worker variance for both machine room workers and transporters. The between-factory variance was also high compared to the between-worker variance.

For the machine room workers, the linear mixed-effects model that included the pouring method of coffee beans and mechanic work explained about 34% of between-factory variance, and 21% of the total variance (Table 2). Vigorously pouring coffee from a dropping height was associated with 1.7 time increase in personal total dust exposure.

For the transport workers, the mixed-effects model that included pouring method of coffee beans, number of huller machine in the room, mixing coffee, and feeding the hopper explained about 83% of the between-factory variance, but considerably less of the between-worker and the day-to-day variance (Table 2). These fixed factors explained 32% of total variance in personal total dust exposure for the transporters. The result indicated that pouring coffee vigorously from a dropping height was the determinant with the highest impact on personal total dust exposure with 3.2-fold increase compared to gradually pouring coffee from a very short height. More than one huller machine in the room contributed to a 2.1-fold increase in total dust level compared to having only one huller machine in the room.

Discussion

Personal total dust exposure level varied both across the coffee factories and between the main job groups in

Table 2. Linear mixed-effect model of ln-transformed total dust levels in 12 primary coffee processing factories in Ethiopia.

Fixed factors	Machine room workers ('Total' dust in mg m ⁻³)				Transport workers ('Total' dust in mg m ⁻³)			
	Random-effects model β (SE)	Mixed-effects model β (SE)	Effect (e ^β)	P	Random-effects model β (SE)	Mixed-effects model β (SE)	Effect (e ^β)	P
Intercept	2.53 (0.18)	2.08 (0.30)		0.001	2.50 (0.14)	0.74 (0.36)		0.05
Coffee pouring method: vigorously (1) versus gradually (0)		0.56 (0.31)	1.7	0.05		1.17 (0.34)	3.2	0.002
Mechanic work: yes (1) versus no (0)		-1.26 (0.43)	0.3	0.006				
Huller machines: more than one (1) versus one (0)						0.73 (0.17)	2.1	0.002
Mixing coffee: yes (1) versus no (0)						0.53 (0.15)	1.7	0.001
Feeding hopper: yes (1) versus no (0)						0.67 (0.26)	2.0	0.013
Variance components								
wwδ	0.32 (0.06)	0.32 (0.06)			0.49 (0.09)	0.42 (0.08)		
bwδ	0.13 (0.07)	0.08 (0.06)			0.05 (0.08)	0.04 (0.07)		
bfδ	0.32 (0.16)	0.21 (0.11)			0.18 (0.10)	0.03 (0.04)		
Explained variance by the fixed factors								
Within-worker		0%				14%		
Between-worker		38%				20%		
Between-factory		34%				83%		
Total		21%				32%		

β = regression coefficients, SE = standard error of the regression coefficients, wwδ = within-worker variance, bwδ = between-worker variance; bfδ = between factory variance; effect e^β = the effect contributed by each determinants; P = P-value.

the respective factories. About 84% of the dust measurements among machine room and transport workers were higher than the OEL value of 5 mg m^{-3} . The dust exposure was considerably lower for the hand pickers. A statistical exposure model including pouring method of coffee beans, number of huller machines, mixing coffee, and feeding hopper explained 32% of total variance in personal total dust exposure for the transporters. For the machine room workers, the pouring method of coffee beans and mechanic work explained about 21% of the total variance in dust exposure.

The GM personal total dust exposure among the machine room workers and the transporters in this study (12.4 mg m^{-3}) was higher than reported among comparable job groups in Tanzanian primary coffee factories (GM 2.5 mg m^{-3} ; (Sakwari *et al.*, 2012). The difference in the results could have several explanations. For example, dust exposure in the Tanzanian study was measured in processing both Robusta and Arabica coffee whereas in our study, only Arabica coffee was processed. Furthermore, the number of machines in the room could also be a reason for the difference in exposure. In all visited coffee factories in Ethiopia, all machines were located in one room whereas in two out of four of the studied coffee factories in Tanzania, the machines were located in different halls. Differences in machine design and practice in processing coffee might also have contributed to the difference in personal total dust exposure levels between these studies.

The range of personal total dust exposure in our study ($0.12\text{--}81.61 \text{ mg m}^{-3}$) was broader than in primary coffee factories of Papua New Guinea [($0.7\text{--}10 \text{ mg m}^{-3}$; Smith *et al.*, 1985)] and Uganda [($10.8\text{--}58 \text{ mg m}^{-3}$; Sekimpi *et al.*, 1996)]. The difference from our study is difficult to explain, as both the Papua New Guinea and the Uganda studies reported only the range of the exposure levels, and did not include any measure of central tendency. Furthermore the Papua New Guinea study did not describe the factories in any detail, and in Uganda both Robusta and Arabic coffee were processed.

In this study, the exposure level varied across the task, which is consistent with the studies conducted in Tanzania and Papua New Guinea (Smith *et al.*, 1985; Sakwari *et al.*, 2012). In our study, feeding coffee caused the highest exposure for the transporters, which is different from the study conducted in Tanzania in which sweeping was associated with the highest personal total dust exposure (Sakwari *et al.*, 2012). Differences in how these tasks were performed might have caused such discrepancies. In our study, sweeping was carried out only for short periods, whereas feeding coffee was carried out for a long period of time.

The mixed-effect model indicated that the method of pouring coffee beans vigorously from a dropping height was the main determinant for increased personal total dust exposure for both machine room workers and transporters. Furthermore, among the transporters increased dust exposure level was associated also with feeding coffee and mixing coffee. Both these tasks are in most factories performed by vigorously pouring coffee from a dropping height, thus further enhancing the emission of dust from these tasks. Thus, the exposure models indicate that changing the pouring process could reduce personal dust exposure level in the coffee factories as it seems to contribute to a high background concentration of dust in the general working atmosphere. On the other hand, low dust exposure level was registered among hand pickers; their task does not involve vigorously pouring of coffee. In one of the primary coffee processing factory, hand pickers had highest dust exposure compared to hand pickers working in other coffee processing factories. During sampling, we observed that these hand pickers were sitting very close to the dust leaking machine, which might have increased their exposure.

Among the transporters, the fixed factors in the exposure model mainly explained the between-factory variance (83%). This seems reasonable for the two factory-related determinants, pouring method and number of huller machines, which alone explained 61% (not shown in Table 2) of the between-factory variance. The two task-based determinants, feeding hopper and mixing coffee, contribute to explain part of the within-worker variance (9%; not shown in Table 2), probably because some of the workers changed between these tasks between the two measurement days.

For machine room workers, mechanic work was the only task identified as a significant determinant in the exposure model. However, the few samples from this task were taken from a factory that had one of the lowest exposure levels. The small difference in exposure levels between the other three tasks for the machine room worker could be due to a high background concentration of dust emitted from the processing machinery. Even after adjusting for the pouring method of coffee, none of the other potential task-based determinants were found to be significant. One cannot exclude that a more refined categorization of the task-related determinants, for instance a detailed recording of time spent on the respective tasks could have explained more of the exposure variability in the exposure models.

Several previous studies have indicated that exposure to total coffee dust is likely to cause acute and chronic respiratory symptoms (Uragoda, 1988; Zuskin *et al.*, 1988; Larese *et al.*, 1998; Sakwari *et al.*, 2011), and our

study indicated that machine room workers and transporters are exposed to even increased levels of coffee dust. Despite this fact, almost none of the workers used proper personal protective devices to reduce dust exposure. Hand pickers had a local piece of cloth to cover their nose and mouth, which will protect them from dust exposure. The reason why workers did not use personal protective device needs to be studied in the future.

As far as we are aware, this is the first study of personal dust exposure that has been conducted in primary coffee processing factories in Ethiopia. The results are believed to be representative for coffee production workers in general in Ethiopia. Repeated and a relatively large number of samples were taken among a well-decided number of workers. Furthermore, the factories included in this study were representative of primary coffee processing factories in the country in terms of size, machine type, type of coffee being processed, and design of the factory.

We did sampling with a recognized dust sampling method. However, the closed-face cassettes are known to underestimate the inhalable dust levels, especially for large particles size (Martin and Zalk, 1998; Harper and Muller, 2002; Görner *et al.*, 2010). Because the coffee processing involves a lot of manual tasks including carrying sacks on shoulder, we chose this method, to protect the filters better than if other sampling heads were used. They were also cost effective.

Conclusion

About 84% of the dust samples among machine room and transport workers in primary coffee processing factories of Ethiopia were above the occupational exposure limit value. Pouring coffee beans vigorously from a dropping height was the main determinant for increased personal dust exposure level. Proper dust control measures are necessary to reduce the dust exposure.

Supplementary Data

Supplementary data are available at *Annals of Work Exposures and Health* online.

Funding

This research was funded by Norwegian Program for Capacity Building in Higher Education and Research for Development (NORHED).

Acknowledgements

We would like to thank the coffee factory management teams and workers for permission to conduct the study and

participating in the study. We thank the Norwegian Program for Capacity Building in Higher Education and Research for Development (NORHED) for financial support for this study.

Conflicts of Interest

The authors declare that they have no competing interest.

References

- Amamo AA. (2014) Coffee production and marketing in Ethiopia. *Eur J Business Manag*; 6: 109–21.
- Bailey RL, Cox-Ganser JM, Duling MG *et al.* (2015) Respiratory morbidity in a coffee processing workplace with sentinel obliterative bronchiolitis cases. *Am J Ind Med*; 58: 1235–45.
- Chauhan R, Hooda MS, Tanga AA. (2015) Coffee: the backbone of Ethiopian economy. *Int J Econ Plants*; 1: 082–6.
- Daglia M, Papetti A, Aceti C *et al.* (2007) Isolation and determination of alpha-dicarbonyl compounds by RP-HPLC-DAD in green and roasted coffee. *J Agric Food Chem*; 55: 8877–82.
- Gebreyesus T. (2015) Determinants of coffee export performance in Ethiopia. *J Econ Sustain Dev*; 6: 147–57.
- Görner P, Simon X, Wrobel R *et al.* (2010) Laboratory study of selected personal inhalable aerosol samplers. *Ann Occup Hyg*; 54: 165–87.
- Gray Q, Tefera A, Tefera T. (2013) Ethiopia: coffee annual report. GAIN Report No. ET 1302. Available at https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Coffee%20Annual_Addis%20Ababa_Ethiopia_6-4-2013.pdf. Accessed 13 Feb 2017.
- Harper M, Muller BS. (2002) An evaluation of total and inhalable samplers for the collection of wood dust in three wood products industries. *J Environ Monit*; 4: 648–56.
- Larese F, Fiorito A, Casasola F *et al.* (1998) Sensitization to green coffee beans and work-related allergic symptoms in coffee workers. *Am J Ind Med*; 34: 623–7.
- Martin RJ, Zalk MD. (1998) Comparison of total dust/inhalable dust sampling methods for the evaluation of airborne wood dust. *App Occup Environ Hyg*; 13: 177–92.
- Mekuria T, Neuhoff D, and Köpke U. (2004) The status of coffee production and the potential for organic conversion in Ethiopia. Conference on International Agricultural Research for Development. Berlin, Germany. Available at <http://www.tropentag.de/2004/abstracts/full/293.pdf>. Accessed 10 Dec 2016.
- Musebe R, Agwanda C, Mekonen M. (2007) Primary coffee processing in Ethiopia: patterns, constraints and determinants. *African Crop Science Conference Proceedings*; 8: 1417–21.
- Nemerow N, Agardy F, Salvato J. (2009) *Environmental engineering: environmental health and safety for municipal infrastructure, land use and planning and industry*. 6th edn. Hoboken, NJ: John Wiley & Sons, Inc. ISBN: 978-0-470-08305-5
- Norwegian Labour Inspection Authority. (2015) Regulations concerning Action and Limit Values. Available at <https://>

- webhms.no/wp-content/themes/new-hms/kursdata/english/704_ENG_final.pdf. Accessed 01 September 2018.
- Occupational Safety and Health Administration. (2014) OSHA technical manual: section ii, chapter 1: personal sampling for air contaminants. *Occupational safety and health administration*. Available at https://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_1.html#total_dust. Accessed 25 November 2017.
- Oldenburg M, Bittner C, Baur X. (2009) Health risks due to coffee dust. *Chest*; **136**: 536–44.
- Rappaport SM, Kupper L. (2008) *Quantitative exposure assessment*. El Cerrito, CA: Stephen Rappaport, ISBN 978-0-9802428-0-5
- Sakwari G, Bråtveit M, Mamuya SH *et al.* (2011) Dust exposure and chronic respiratory symptoms among coffee curing workers in Kilimanjaro: a cross sectional study. *BMC Pulm Med*; **11**: 54.
- Sakwari G, Mamuya SH, Bråtveit M *et al.* (2012) Personal exposure to dust and endotoxin in Robusta and Arabica coffee processing factories in Tanzania. *Ann Occup Hyg*; **57**: 173–83.
- Sekimpi DK, Agaba DF, Okot-Nwang M *et al.* (1996) Occupational coffee dust allergies in Uganda. *Afr Newslett on Occupational and Safety*; **6**:6–9.
- Skaugset NP, Ellingsen DG, Notø H *et al.* (2013) Intersampler field comparison of Respicon®, IOM, and closed-face 25-mm personal aerosol samplers during primary production of aluminium. *Ann Occup Hyg*; **57**: 1054–64.
- Smith D, Brott K, Koki G. (1985) Respiratory impairment in coffee factory workers in the Asaro valley of Papua New Guinea. *Br J Ind Med*; **42**: 495–8.
- IBM. (2013) *SPSS Statistics for Windows, version 22.0*. Armonk, NY: IBM.
- Thomas KE, Trigg CJ, Baxter PJ *et al.* (1991) Factors relating to the development of respiratory symptoms in coffee process workers. *Br J Ind Med*; **48**: 314–22.
- Uragoda CG. (1988) Acute symptoms in coffee workers. *J Trop Med Hyg*; **91**: 169–72.
- van Tongeren MJ, Kromhout H, Gardiner K. (2000) Trends in levels of inhalable dust exposure, exceedance and overexposure in the European carbon black manufacturing industry. *Ann Occup Hyg*; **44**: 271–80.
- Wiersum KE, Gole TW, Gatzweiler F *et al.* (2008) Certificate of wild coffee in Ethiopia: experience and challenges. *Forest, Trees and Livelihood*; **18**: 9–21.
- Zuskin E, Skuric Z, Kanceljak B *et al.* (1988) Effects coffee and tea dust in industrial workers. *Ann Occup Hyg*; **32**: 315–9.
- Zuskin E, Valić F, Skurić Z. (1979) Respiratory function in coffee workers. *Br J Ind Med*; **36**: 117–22.



Article

Reduced Lung Function among Workers in Primary Coffee Processing Factories in Ethiopia: A Cross Sectional Study

Samson Wakuma Abaya ^{1,2,3,*}, Magne Bråtveit ², Wakgari Deressa ¹, Abera Kumie ¹ and Bente E. Moen ^{2,3}

¹ Department of Preventive Medicine, School of Public Health, Addis Ababa University, P.O. Box 90861000 Addis Ababa, Ethiopia; deressaw@gmail.com (W.D.); aberakumie2@yahoo.com (A.K.)

² Occupational and Environmental Medicine, Department of Global Public Health and Primary Care, University of Bergen, 5020 Bergen, Norway; Magne.Bratveit@uib.no (M.B.); Bente.Moen@uib.no (B.E.M.)

³ Centre for International Health, Department of Global Public Health and Primary Care, University of Bergen, 5009 Bergen, Norway

* Correspondence: samson_wakuma@yahoo.com; Tel.: +251-92-394-0998

Received: 13 October 2018; Accepted: 28 October 2018; Published: 31 October 2018



Abstract: Dust exposure is one of the major risk factors for respiratory health in many workplaces, including coffee factories. The aim of this study was to assess the prevalence of respiratory symptoms and lung function reduction among workers in Ethiopian primary coffee processing factories, compared to a control group of workers. A total of 115 coffee workers and 110 water bottling workers were involved in this study, from 12 coffee and 3 water bottling factories in Ethiopia, respectively. The chronic respiratory symptoms were assessed using a structured interview, using a standardized questionnaire adopted from the American Thoracic Society (ATS). The lung function tests were performed according to the ATS recommendation for spirometry. The coffee workers had a significantly higher prevalence of coughing, coughing with sputum, breathlessness, work-related shortness of breath, and wheezing compared with the controls. The prevalence ratio of work-related shortness of breath (PR = 3.7, 95% CI: 1.6–8.7) and wheezing (PR = 3.3, 95% CI: 1.3–8.4) was significantly higher for the coffee workers compared to the controls. The coffee workers in the age groups 28–39 years and ≥ 40 years, had a significantly lower forced vital capacity and forced expiratory volume in 1 s compared to the controls in the similar age groups. The findings indicated the need for longitudinal studies on the possible effect of coffee dust on respiratory health of coffee production workers.

Keywords: coffee workers; dust exposure; Ethiopia; lung function; respiratory symptoms

1. Introduction

Several studies have indicated an association between working in coffee factories and respiratory health problems. Allergies have been suggested to be related to the problems [1–7]. A few older studies conducted in primary coffee processing factories have indicated that exposure to coffee dust is likely to cause acute and chronic respiratory symptoms in these factories as well [8–11].

Recently, studies were conducted in primary coffee processing factories in Tanzania. These demonstrated a higher prevalence of chronic respiratory symptoms in coffee workers than among the controls [11,12]. The primary coffee processing factories are factories that perform mechanical cleaning of the debris from the coffee-making process, such as the hulling, grading, hand picking, and packing of green coffee beans. The lung function parameters were not different between the coffee workers and the controls [12]. The Robusta coffee workers had higher prevalence of asthma

symptoms than Arabica coffee workers [12]. The findings related to lung function were not clear, and more studies are needed for conclusive information regarding the respiratory health of coffee workers. Ethiopia produces exclusively Arabica coffee. The respiratory health impact of working with these coffee beans has not yet been explored. In addition, the coffee pre-processing methods used on the farms in Ethiopia is different from the ones used in Tanzania. Moreover, a recent study conducted in the coffee factories of Ethiopia found much higher levels of personal dust exposure compared with the levels measured in the Tanzanian factories [13].

In Ethiopia, more than 50% of foreign income comes from coffee, with an estimated 15 million people relying on coffee production for their livelihood [14]. Understanding the level of respiratory problems in Ethiopian coffee processing factories can generate information that could aid policy makers and other relevant stakeholders to develop any necessary preventive and control methods.

Studying respiratory disease is difficult in these types of factories, as a healthy worker effect may occur. This means that workers developing an illness may stop working, and may therefore not be found at the work sites. Cohort studies are difficult to perform, as the methods for tracing persons over longer periods is challenging. Case-control studies are also difficult to perform in Ethiopia, as the population does not have easy access to hospitals, and are treated at a large number of small health units. Therefore, a comparative cross-sectional study design was chosen, where the coffee factory workers were compared to a control group.

The aim of this study was to assess the prevalence of respiratory symptoms and to study the lung function among workers in the primary coffee processing factories of Ethiopia, and to compare these findings with a control group of water bottling workers. The methodology can detect early signs of respiratory diseases and is therefore useful in a company setting of relatively healthy workers.

2. Materials and Methods

2.1. Study Site and Period

There are about 746 primary coffee processing factories in Ethiopia. Almost all are found in three regions, Oromia; Addis Ababa; and Southern Nations, Nationalities and Peoples' Region (SNNPR). We did a power calculation before beginning the study in order to estimate the required number of workers. Taking into consideration the available resources, we selected 12 primary coffee processing factories for inclusion in this study. The 12 primary coffee processing factories were divided equally among the three regions (i.e., four factories from each of the three regions), and the factories were selected randomly. The study was conducted from May to October 2016.

2.2. Control Group

The workers from three water bottling factories, one from each of the three study areas, were selected as the control group. Water bottling factories were chosen as their workers experience less dust exposure at work. Water bottling workers' tasks are loading bottled water to the trucks. There are about 38 water bottling factories in Ethiopia.

2.3. Dust Exposure Levels

The personal total dust was sampled in the workers' breathing zone using 25-mm three pieces, conductive cassettes with a cellulose acetate filter attached to a Side Kick Casella (SKC) pump with a flow rate of 2 l min^{-1} [15]. Altogether, 360 full-shift exposure measurements were conducted on randomly chosen days of the week, and repeated sampling was conducted the next day. The sampling process is described in a previous paper [13]. A total of 60 full-shift personal exposure measurements were conducted in the water bottling factories. The arithmetic mean (range) of the personal total dust exposure was 17.36 mg/m^3 ($1.12\text{--}81.61 \text{ mg/m}^3$) and 0.33 mg/m^3 ($0.11\text{--}1.16 \text{ mg/m}^3$) for the coffee workers and controls, respectively. The personal total dust exposure levels among the coffee workers were significantly higher than among the control workers with geometric means (GM) of

12.30 and 0.30 mg/m³, respectively. The dust samples were analyzed gravimetrically using a standard microbalance scale AT261 Mettler Toledo with a detection limit of 0.01 mg/m³, in the accredited laboratory SINTEF MOLAB in Norway.

2.4. Study Population and Sample Size

The sample size for this study was calculated using a double population formula considering that the prevalence of wheezing among the primary coffee workers in Tanzania was 16% and 4.3% among the controls [12]. An 80% power was set to detect a difference in the wheezing between the two groups at significance level of 0.05. After considering 15% for non-response, a total of 240 participants (i.e., 120 from coffee factories and 120 from water bottling) were selected by systematic random sampling method, using the workers' registration list as a sampling frame. All of the participants were male. In the coffee factories, only workers directly related to coffee processing were involved in this study. Office workers and guards were not included in this study.

2.5. Data Collection

2.5.1. Chronic Respiratory Symptoms Interview

The chronic respiratory symptoms among participants were assessed with an interview, using a standardized questionnaire from the American Thoracic Society (ATS) [16]. This questionnaire was chosen because it has been used in previous occupational studies of respiratory health in East-Africa [12], making comparisons possible. The questionnaire was translated from English to Amharic and Afan Oromo languages, and translated back to English. A pre-test was conducted prior to the actual data collection for the validation of the data collection tool. Questions that were not easy for the participants to understand were rephrased to make them more easily understood. The interviews were conducted in an office located at their workplaces in absence of other people, in order to help the interviewee speak freely. The interviews lasted between 25 and 40 min per respondent.

The data were collected by the principal investigator together with an experienced research assistant. The questionnaire included socio-demographic data (age, height, weight, and Body Mass Index (BMI)), occupational history (years of work experience in the present and other dusty factories), past respiratory diseases (pneumonia, tuberculosis, bronchitis, asthma, and chest injury), and smoking habits (current smoker, ex-smoker, and never smoker). The questionnaire also included questions about the use of respiratory protective devices while working (yes/no), and the reason for not using respiratory protective devices (RPD). We asked the workers about this information to see how many of the workers use of RPD. The use of RPD during work might reduce respiratory health problems. The questionnaire also included questions about chronic respiratory symptoms—coughing, coughing with sputum, breathlessness, work related shortness of breath, wheezing, and chronic bronchitis.

2.5.2. Lung Function Test

Lung function tests were performed for a total of 225 participants (i.e., 115 coffee workers and 110 control workers), according to the ATS [17] recommendation for spirometry. A portable spirometer (SPIRARE 3 sensor model SPS 320) was used to measure the lung function. The standing height and weight of the participants was measured using standard weight and height measure. The test was performed during the day shift between 08:00 and 16:00, with the workers in a sitting position. Three acceptable maneuvers with consistent ("repeatable") results were retained and the best of all of these was recorded. Only the absolute values for the lung function are given in the results, as there are currently no reference equations for the Ethiopia population for obtaining predicted values. The lung function parameters included were FVC and FEV₁, as well as the percentage ratio of FEV₁/FVC. The participants with FEV₁/FVC < 0.70 were considered to have airflow limitations [18]. FEV₁ is the maximal volume of air exhaled in the first second of a forced expiration from a position

of full inspiration. FVC is the maximal volume of air exhaled with maximally forced effort from a maximal inspiration.

Eleven spirometer results among coffee workers and seven among the controls were excluded from the analysis because of unacceptable readings.

2.6. Operational Definition of Variables

Current smoker: participants who smoke currently or those who stopped smoking less than one year ago.

Ex-smoker: participants who had stopped smoking more than one year ago.

Never smoker: participants who had never smoked.

Cough: participants were considered to have coughed if they answered “yes” to at least one of the following four questions; cough first thing in the morning, cough during the day or night, cough as much as four to six times a day in a week, or cough for most days for as much as three consecutive months during the year.

Cough with sputum: participants were considered to have cough with sputum if they answered “yes” to at least one of the four questions: cough with sputum first thing in the morning, cough with sputum during the day or night, cough with sputum as much as four to six times a day in a week, or cough with sputum for most days for as much as three consecutive months during the year.

Breathlessness: participants were considered to have breathlessness if he/she was troubled by a shortness of breath when hurrying on level ground or walking up a slight hill, or get shortness of breath when walking at his/her own pace on the level ground.

Work-related shortness of breath participants were considered to have work-related shortness of breath if he/she usually experience chest tightness while at work or just after work.

Wheezing: participants were considered to have wheezing if his/her chest ever sounded wheezy (whistling sound).

2.7. Data Management and Analysis

The collected data were checked for completeness and consistencies by the principal investigator through a close follow up during the data collection period. The data were coded, and no names were included in the database. The code list as well as the data were kept confidential, and were accessed only by the research team.

Independent *t*-tests were used to compare mean values for the continuous variables. The Pearson chi-square test or Fisher’s exact test, if the expected value was less than 5, were used to test the difference between the groups regarding the categorical variables. Poisson regression analysis with a robust variance was used to determine the prevalence ratio of the different respiratory symptoms between the coffee workers and controls, with a corresponding 95% confidence interval, and the statistical significance level was set to a *p*-value less than 0.05. As the prevalence of the chronic respiratory symptoms was high, we chose the prevalence ratio over the odds ratio, because the odds ratio overestimated the strength of association [19].

Analysis of covariance (ANCOVA) were used to compare the mean lung function parameters between the coffee workers and controls when adjusting for height and education level. We adjusted for education level, because there was a significant difference in the educational level between the coffee workers and the controls.

2.8. Ethical Approval

The Institutional Review Board of the College of Health Sciences of Addis Ababa University (Protocol number: 051/15/SPH) and the National Research Ethical Review Committee of the Federal Ministry of Science and Technology (NRERC-3/10/110/2016) approved the study. Permission to conduct the study was obtained from the factory managers. Written informed consent was obtained

from each participant, and participation in the study was voluntary. Participants with lung function impairments were advised to consult the nearest health center.

3. Results

3.1. Characteristics of the Study Participants

All of the participants were men. A total of 115 coffee workers and 111 controls participated in the study, making the response rate 94%. The reasons for non-response were that five workers refused to participate, seven workers were in sick leave, and two had stopped working. The coffee workers were older and had a lower educational level than the controls (Table 1). No difference was found between the groups regarding weight, height, BMI, and past respiratory diseases (Table 1).

Table 1. Characteristics of the participants.

Variable	Coffee Workers (n = 115)	Control (n = 110)	p-Value
Age (years); AM (range)	35.1 (18.0–75.0)	30.9 (18.0–71.0)	0.008 [§]
Weight (Kg); AM (range)	59.8 (43.0–88.0)	60.0 (45.0–90.0)	0.9 [§]
Height (cm); AM (range)	169.3 (148.0–187.0)	169.9 (153.0–183.0)	0.5 [§]
BMI (Kg/m ²); AM (range)	20.8 (15.4–30.5)	20.7 (16.6–29.1)	0.8 [§]
Duration of employment at present work years AM (range)	6.5 (1.0–30.0)	3.4 (1.0–6.0)	0.001 [§]
Years worked in other dusty factories AM (range)	0.23 (0.0–12.0)	0.5 (0.0–12.0)	0.2 [§]
Education			
Illiterate; n (%)	14 (12.2)	3 (2.7)	0.007 [†]
Primary education & above; n (%)	101 (87.8)	107 (97.3)	0.007 [†]
Smoking habits			
Ex smoker; n (%)	4 (3.5)	1 (0.9)	0.37 [±]
Current smoker; n (%)	3 (2.6)	4 (3.6)	0.71 [±]
Cigarettes smoked per day for current smokers AM (range)	3 (2–4)	2 (1–3)	0.2 [§]
Cooking			
Cooking food at home; n (%)	103 (89.6)	97 (82.2)	0.74 [†]
Kitchen located inside the living room; n (%)	34 (33)	31 (32)	0.87 [†]
Use biomass for cooking; n (%)	96 (93.2)	86 (88.7)	0.26 [†]
Previous Respiratory Disease			
Pneumonia; n (%)	7 (6.1)	5 (4.5)	0.61 [†]
Bronchitis; n (%)	3 (2.6)	1 (0.9)	0.62 [±]
Tuberculosis; n (%)	4 (3.5)	2 (1.8)	0.68 [±]
Asthma; n (%)	8 (7)	4 (3.6)	0.27 [±]
Participants who have had at least one of the respiratory diseases, n (%)	22 (19.1)	12 (10.9)	0.09 [†]

AM: arithmetic mean; [§] Independent *t* test between control and coffee workers; [†] Pearson chi square test; [±] Fisher's exact test. BMI—body mass index; “n”: Number of study participants.

3.2. Use of Respiratory Protective Device (RPD)

The majority of the 112 (97.4%) coffee workers did not use any type of respiratory protective devices (RPD). Among the non-users of RPD, 109 (97.3%) of the coffee workers indicated that the reason for not using RPD was because it was not available or not provided at the work place. Others reported that the reasons for not using RPD were because it was not comfortable (one worker) (0.9%), and that the worker experienced that the RPD did not protect from the dust (one worker) (0.9%).

3.3. Chronic Respiratory Symptoms

The prevalence of chronic respiratory symptoms was in the range of 5.2–55% and 2.7–12.7% among the coffee workers and controls respectively (Table 2). Six of the coffee workers (5.2%), and none of the controls had chronic bronchitis. The prevalence ratio of all of the respiratory symptoms was

significantly higher for the coffee workers compared to the controls after adjusting for age, education, years worked in other dusty factories, and previous respiratory disease (Table 2). As the number of current smokers were few, the analysis was also performed after excluding the smokers. This did not change the results substantially.

Table 2. Prevalence of chronic respiratory symptoms among coffee workers and controls.

Variable	Coffee Workers n = 115	Control n = 110	Prevalence Ratio, 95% CI	p-Value
Cough; n (%)	52 (46.4)	8 (7.5)	5.6 (2.9–11.7)	<0.001
Cough with sputum; n (%)	26 (23.2)	2 (1.9)	11.4 (2.7–47.8)	<0.001
Breathlessness; n (%)	40 (35.7)	12 (11.3)	2.9 (1.6–5.3)	<0.001
Work-related shortness of breath; n (%)	22 (19.6)	6 (5.5)	3.7 (1.6–8.7)	0.003
Wheezing; n (%)	20 (17.9)	5 (4.7)	3.3 (1.3–8.4)	0.01

CI, confidence interval while adjusting for age; education, years worked in other dusty factories and previous respiratory disease; p-value when comparing coffee workers vs. controls; “n”: Number of study participants.

3.4. Lung Function

Table 3 shows the result of lung function stratified age among the coffee workers and controls. The coffee workers in the age group 28–39 years and ≥ 40 years, had significantly lower FVC and FEV₁ compared with the controls in the similar age category. The FEV₁/FVC-ratio was significantly lower among the coffee workers compared to the controls in the oldest age group (Table 3). The prevalence of airflow limitation (FEV₁/FVC < 0.7) was higher among the coffee workers compared to the controls in all of the age categories (Table 3). The analyses were also performed again without including education level in the model, and the results were quite similar (data not shown).

Table 3. Lung function among primary coffee processing factories and control groups stratified by age (three age groups).

Lung Function Parameters	Age Group	No of Participants		Absolute Value Mean (SD)		p-Value
		Coffee Workers n = 104	Controls n = 103	Coffee Workers	Controls	
FVC (l)	18–27	35	57	4.60 (0.43)	4.70 (0.49)	0.35
	28–39	35	23	4.08 (0.47)	4.43 (0.46)	<0.001
	≥ 40	34	23	3.38 (0.53)	3.67 (0.51)	0.05
	All age group	104	103	4.03 (0.69)	4.41 (0.63)	<0.001
FEV ₁ (l)	18–27	35	57	3.74 (0.46)	3.87 (0.39)	0.15
	28–39	35	23	3.29 (0.58)	3.63 (0.47)	0.02
	≥ 40	34	23	2.60 (0.50)	3.05 (0.51)	<0.001
	All age group	104	103	3.22 (0.69)	3.63 (0.54)	<0.001
FEV ₁ /FVC	18–27	35	57	0.81 (0.08)	0.83 (0.05)	0.43
	28–39	35	23	0.80 (0.09)	0.82 (0.07)	0.48
	≥ 40	34	23	0.77 (0.09)	0.83 (0.06)	0.02
	All age group	104	103	0.80 (0.09)	0.83 (0.06)	0.01
FEV ₁ /FVC < 0.7; n (%)	18–27	35	57	3 (8.6)	0	-
	28–39	35	23	2 (5.7)	1 (4.3)	1 *
	≥ 40	34	23	9 (26.5)	0	-

Analysis of covariance between coffee worker and controls while adjusting for height and education level. * Fisher exact test between coffee workers and controls; p-value: significance level; “n”: Number of study participants.

4. Discussion

This study found a significantly higher prevalence of respiratory symptoms and lower lung function among the coffee workers compared to controls. Our results are consistent with studies conducted in primary coffee processing factories in Papua New Guinea, Uganda, and Tanzania [8,9,11]. All of these studies show that coffee workers have high prevalence of respiratory health problems. However, our present study found a higher prevalence of some of the respiratory symptoms compared with the studies conducted among Arabica coffee workers in Tanzania, where the prevalence of

breathlessness was 14%, wheezing 13%, and chronic bronchitis 3.1% [12]. One of the reasons for this difference could be the higher personal total dust exposure in Ethiopian coffee factories ($GM = 12.3 \text{ mg/m}^3$) compared with the comparable job groups in Tanzanian primary coffee factories ($GM = 2.1 \text{ mg/m}^3$) [20]. The different methods of coffee pre-processing could be another reason; the Arabica coffee is pre-processed only by a wet-method in the Tanzanian factories, whereas in Ethiopia, Arabica coffee is pre-processed either by dry or wet method, based on the individual farmers' interests. In addition, only 3% of the workers used RPD in Ethiopia, compared to 33% in the coffee workers in Tanzania. The lack of RPD use makes it more likely that the workers actually were exposed to the dust levels measured in the factories. There may have been other additional factors that were not identified in the present study that may also have influenced the respiratory health of the workers.

Similarly, the prevalence of a cough with sputum and wheezing in our study was higher than in the study in Uganda; where the prevalence was 5.2% and 13.5%, respectively [9]. This might be due to the different types of coffee species between the two countries; the Robusta and Arabic coffee were processed in Ugandan factories, whereas only Arabica coffee was processed in Ethiopia.

For a cough with sputum, we found a higher prevalence than reported in the study in Papua New Guinea (8.7%) [8]. This difference might be due to higher dust exposure in the present study compared with what was measured in Papua New Guinea ($0.7\text{--}10 \text{ mg/m}^3$). In addition, the difference in working environments, coffee processing methods, and level of awareness among the coffee workers about the impact of dust exposure on their health might be the reason for the difference in the symptom prevalence. In addition, there may be differences between these countries regarding the presence of, for instance, lung infections or sequela after lung infections. Infections may cause respiratory symptoms and influence lung function. This possibility is not very likely, as the examined workers are performing hard physical work, but this factor needs to be considered, because of the high prevalence of tuberculosis as well as HIV in East-African countries [21]. However, it is not likely that this type of health problem is different among the workers in the two factory types included in our study.

The present study's results showed that in the two oldest age groups of coffee workers, the FVC and FEV_1 were lower than among the controls, while FEV_1/FVC was lower in the oldest age group of coffee workers than among the controls. In the Tanzanian study, there were no difference in the FVC and FEV_1 between coffee workers and controls [12]. The considerably higher dust exposure in the Ethiopian study ($GM = 12.3 \text{ mg/m}^3$) [13] compared to the levels reported for the processing of Arabica coffee in Tanzania ($GM = 2.1 \text{ mg/m}^3$) [20] may have contributed to the difference in findings related to lung function. Also, the study conducted in Papua New Guinea, where the dust levels were lower than in the present study, did not find significant differences in FVC and FEV_1/FVC between the coffee workers and controls.

Both FEV_1 and FVC were reduced among the coffee workers, indicating both obstructive and restrictive lung effects. However, in the oldest age group, the FEV_1/FVC ratio was less than 0.70 for about 27% of the coffee workers, which indicates the presence of an obstructive lung disease [18]. It is noteworthy that such a result was found, even though these workers were present at the workplaces in physically demanding work.

No statistically significant difference was observed in the incidence of past respiratory diseases between the coffee workers and controls; unfortunately, we have no information about when these past respiratory diseases occurred. For example, they could have been before starting work in coffee factories or after starting working in the factories. We only asked the participants if they had ever had any previous respiratory disease.

The control group in the present study was from another production factory, with very low dust levels. Another possibility would have been to choose a control group from the general population, but this would have introduced other types of bias in the study, related to socioeconomic differences between the factory workers and the population.

This is the first study to assess the prevalence respiratory symptoms and lung function among coffee workers in Ethiopia. However, as this study is a cross sectional study, the cause and effect

association between dust exposure, and respiratory symptoms and lung function reduction cannot be drawn based on our findings. Our analyses were adjusted for other factors, including age, which may affect lung function. However, it is worth noting that there may be other variables present, which we have not identified. We would therefore recommend that a longitudinal study is undertaken in order to characterize the association between dust exposure and lung function reduction.

This study used a questionnaire-based interview to assess the respiratory symptoms that might result in recall and interviewer bias. However, similar questions were used to assess the respiratory symptoms in both the coffee workers and control groups. To minimize bias, a well-trained interviewer was involved in interviewing both groups. Also, the reported symptoms agreed with the objective measures from the spirometry. Symptoms such as coughing, wheezing, and breathlessness are often associated with obstructive lung disease [22].

This study included workers from all three coffee growing and processing regions of Ethiopia, and the factories are considered to be representative to all similar primary coffee processing factories in Ethiopia. Similar results might also be expected by any African coffee factory with a similar dust exposure level and similar production type of Arabica coffee beans.

As this study showed that the majority of the coffee workers did not use any type of respiratory protective devices, an immediate action to reduce respiratory health problems among coffee workers would be to provide proper facemasks.

5. Conclusions

Workers in primary coffee processing factories in Ethiopia had a higher prevalence of chronic respiratory symptoms and lower lung function than the controls. This might represent early signs of lung disease. A longitudinal study on the possible effects of coffee dust on respiratory health among coffee production workers is recommended.

Author Contributions: S.W.A. planned the study, collected and analyzed data, and drafted the manuscript in consultation with other authors. M.B., W.D., A.K., and B.E.M. participated in the design, collection and analysis of data, and provided scientific support throughout the project and commented on the manuscript. All of authors have read and approved the final manuscript.

Funding: This research was funded by the Norwegian Program for Capacity Building in Higher Education and Research for Development (NORHED).

Acknowledgments: We would like to thank the coffee factory management teams and workers for their permission to conduct the study and for participating in the study.

Conflicts of Interest: The authors declare that they have no competing interest.

References

1. Figley, K.D.; Rawling, F.F.A. Castor bean an industrial hazard as a contaminant of green coffee dust and used burlap bags. *J. Allergy* **1950**, *21*, 545–553. [[CrossRef](#)]
2. Karr, R.M.; Lehrer, S.B.; Butcher, B.T.; Salvaggio, J.E. Coffee worker's asthma: A clinical appraisal using the radioallergosorbent test. *J. Allergy Clin. Immunol.* **1978**, *62*, 143–148. [[CrossRef](#)]
3. Bruun, E. Allergy to coffee: An occupational diseases. *Acta Allergol.* **1957**, *11*, 150–154. [[CrossRef](#)] [[PubMed](#)]
4. Kaye, M.; Freedman, S. Allergy to Raw Coffee—An Occupational Disease. *Can. Med. Assoc. J.* **1961**, *84*, 469–471. [[PubMed](#)]
5. Larese, F.; Fiorito, A.; Casasola, F.; Molinari, S.; Peresson, M.; Barbina, P.; Negro, C. Sensitization to green coffee beans and work-related allergic symptoms in coffee workers. *Am. J. Ind. Med.* **1998**, *34*, 623–627. [[CrossRef](#)]
6. Osterman, K.; Zetterstrom, O.; Johansson, S.G.O. Coffee Worker's Allergy. *Allergy* **1982**, *37*, 313–322. [[CrossRef](#)] [[PubMed](#)]
7. Zuskin, E.; Vali, F.; Skuri, Z. Respiratory function in coffee workers. *Br. J. Ind. Med.* **1979**, *36*, 117–122. [[CrossRef](#)] [[PubMed](#)]

8. Smith, D.; Brott, K.; Kokisource, G. Respiratory Impairment in Coffee Factory Workers in the Asaro Valley of Papua New Guinea. *Br. J. Ind. Med.* **1985**, *42*, 495–498. [[CrossRef](#)] [[PubMed](#)]
9. Sekimpi, K.; Agaba, E.; Okot-Nwang, M.; Ogaram, D. Occupational coffee dust allergies in Uganda. *Afr. Newsl. Occup. Health Saf.* **1996**, *6*, 6–9.
10. Uragoda, C.G. Acute symptoms in coffee workers. *J. Trop. Med. Hyg.* **1988**, *91*, 169–172. [[PubMed](#)]
11. Sakwari, G.; Bråtveit, M.; Mamuya, S.H.D.; Moen, B.E. Dust exposure and chronic respiratory symptoms among coffee curing workers in Kilimanjaro: A cross sectional study. *BMC Pulm. Med.* **2011**, *11*, 54–61. [[CrossRef](#)] [[PubMed](#)]
12. Sakwari, G.; Mamuya, S.H.D.; Bråtveit, M.; Moen, B.E. Respiratory Symptoms, Exhaled Nitric Oxide, and Lung Function Among Workers in Tanzanian Coffee Factories. *JOEM* **2013**, *55*, 544–551. [[CrossRef](#)] [[PubMed](#)]
13. Abaya, W.S.; Bråtveit, M.; Deressa, W.; Kumie, A.; Moen, B.E. Personal dust exposure and its determinants among workers in primary coffee processing in Ethiopia. *Ann. Work Expo. Health* **2018**. [[CrossRef](#)] [[PubMed](#)]
14. United State AID. Ethiopian Coffee Industry Value Chain Analysis. 2010. Available online: https://agoa.info/images/documents/5157/Ethiopian_Coffee_Industry_Value_Chain_Analysis_2010.pdf (accessed on 22 May 2018).
15. Occupational Safety and Health Administration. OSHA Technical Manual: Section II, Chapter 1: Personal Sampling for Air Contaminants. Occupational Safety and Health Administration. 2014. Available online: https://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_1.html#total_dust (accessed on 20 May 2018).
16. America Thoracic Society-Division of Lung Diseases. Recommended Respiratory Disease Questionnaires for Use with Adults and Children in Epidemiological Research. ATS. 1978. Available online: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.607.2516&rep=rep1&type=pdf> (accessed on 22 May 2018).
17. America Thoracic Society. Standardization of Spirometry, 1994 Update. America Thoracic Society. *Am. J. Respir. Crit. Care Med.* **2005**, *152*, 1107–1136.
18. Pauwels, A.; Buist, S.; Calverley, A.; Jenkins, R.; Hurd, S. Globally Strategy for the diagnosis management and prevention of Chronic Obstructive Pulmonary Disease: NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD) Workshop Summary. *Am. J. Respir. Crit. Care Med.* **2001**, *163*, 1256–1276. [[CrossRef](#)] [[PubMed](#)]
19. Tamhane, A.R.; Westfall, A.O.; Burkholder, G.A.; Cutter, G.R. Prevalence odds ratio versus prevalence ratio: Choice comes with consequences. *Stat. Med.* **2016**, *35*, 5730–5735. [[CrossRef](#)] [[PubMed](#)]
20. Sakwari, G.; Mamuya, S.H.D.; Bråtveit, M.; Larsson, L.; Pehrson, C.; Moen, B.E. Personal Exposure to Dust and Endotoxin in Robusta and Arabica Coffee Processing Factories in Tanzani. *Ann. Occup. Hyg.* **2012**, *57*, 173–183. [[PubMed](#)]
21. Belay, M.; Bjune, G.; Abebe, F. Prevalence of tuberculosis, HIV, and TB-HIV co-infection among pulmonary tuberculosis suspects in a predominantly pastoralist area, northeast Ethiopia. *Glob. Health Action* **2015**, *8*, 27949. [[CrossRef](#)] [[PubMed](#)]
22. Siafakas, N.M.; Vermeire, P.; Pride, N.A.; Paoletti, P.; Gibson, J.; Howard, P.; Yernault, J.C.; Decramer, M.; Higenbottam, T.; Postma, D.S. Optimal assessment and management of chronic obstructive pulmonary disease (COPD). *Eur. Respir. J.* **1995**, *8*, 1398–1420. [[CrossRef](#)] [[PubMed](#)]



Respiratory Health Among Hand Pickers in Primary Coffee-Processing Factories of Ethiopia

Samson Wakuma Abaya, MSc, MPH, Magne Bråtveit, PhD, Wakgari Deressa, MPH, PhD, Abera Kumie, MD, MSc, PhD, and Bente E. Moen, MD, PhD

Objective: The aim of this study was to assess chronic respiratory symptoms and lung function among female hand pickers. **Methods:** A total of 374 hand pickers exposed to coffee dust and 175 female controls from water bottling factories were included. The symptoms were assessed using a standardized questionnaire. Personal total dust exposure and lung function tests were performed. **Results:** Hand pickers experienced a higher dust exposure, displayed a higher prevalence ratio for cough [prevalence ratio (PR) = 3.0, 95% confidence interval (95% CI): 1.4 to 6.2] and work-related shortness of breath (PR = 2.5, 95% CI: 1.1 to 5.6), and had a lower FEF_{25–75} than controls. Hand pickers without tables had a significantly higher prevalence ratio of cough with sputum (PR = 3.9, 95% CI: 1.6 to 9.5) and lower forced vital capacity, forced expiratory volume in 1 second, and mean forced expiratory flow between 25% and 75% of the FVC than hand pickers with tables. **Conclusion:** Hand pickers show a range of adverse symptoms and lung function impairments that warrant efforts to improve working conditions.

Keywords: coffee workers, dust, Ethiopia, hand pickers, lung function

BACKGROUND

In Ethiopia, the coffee beans are grown and processed at the farms before being transported to primary coffee-processing factories. There are two types of post-harvest coffee-bean processing at the farms in Ethiopia.¹ One type is dry processing, where the whole coffee cherries are allowed to dry in the sun under natural conditions.² Wet processing is the second type of on-farm processing, and involves pulping the coffee cherries on the same day as they are harvested, followed by fermentation, washing to remove the mucilage, and drying in the sun.² After processing coffee beans at the

farms, coffee passes through different stages of cleaning in primary coffee-processing factories in order to be sold and shipped to secondary processing factories, where the coffee is roasted. The primary coffee-processing factories perform mechanical cleaning of debris from green coffee beans, as well as sorting, grading, and packing.³ In Ethiopia, almost all primary coffee-processing factories are to be found in three regions: Oromia, Addis Ababa, and the Southern Nations, Nationalities and Peoples' Region (SNNPR). Only Arabica coffee is grown in Ethiopia.

The final stage of coffee cleaning in the primary coffee factories is carried out by hand pickers, and involves separating defective and discolored coffee beans (ie, black, yellow, and red coffees) from the sound coffee beans.⁴ A large number of women work as hand pickers in the primary coffee-processing factories in Ethiopia. This work is the main source of income for many poor women. The hand-picking women might be exposed to coffee dust at their workplace.⁴ Only a few studies of primary coffee-processing factories have been performed, but they all indicate that exposure to coffee dust is likely to cause respiratory health problems.^{3,5–8} Some of the studies are very old,^{5–8} and none of these studies have specifically looked at respiratory health among hand pickers. A study conducted in Tanzania assessed the total dust-exposure level among 10 hand pickers, and showed endotoxin levels higher than recommended standards. This study also indicated an association between exposure to endotoxin and inflammation in the airways measured in terms of exhaled nitrogen oxide. However, this study was based on a small sample size and did not assess respiratory symptoms and lung function among the workers.⁴

Although the tasks of all hand pickers in Ethiopia are the same, the working conditions vary from factory to factory. In general, hand pickers in the country can be classified into two groups: those with sorting tables and those without. The hand pickers in primary coffee-processing factories in Addis Ababa work with tables. The hand pickers sit inside the processing machine room on chairs 40 to 50 cm high, and sort both wet and dry processed coffee beans on a long table or a conveyor belt (Fig. 1).

Hand pickers without tables are to be found in Oromia and SNNPR primary coffee-processing factories. These hand pickers perform their work while sitting on the ground, either outdoors on a veranda or in a separate room. They only sort dry processed coffee from piles of green coffees (Fig. 2). In occupational health settings, there is discussion as to which method is best for the workers: work with or without tables. This is an important topic to be considered for the hand-picking workers, and more knowledge of these issues will have consequences for the working conditions for hand pickers all over the country.

To our knowledge, no previous studies have assessed respiratory health and dust exposure among hand pickers, and consequently, no one has studied such working conditions in the two types of hand pickers.

The aim of this study was to assess respiratory health among hand pickers by using two measures: chronic respiratory symptoms and lung-function parameters. Previous studies of workers exposed to coffee dust have examined lung function parameters such as forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV₁). However, organic dust, such as coffee dust,

From the Department of Preventive Medicine, School of Public Health, Addis Ababa University, Addis Ababa, Ethiopia (Mr Abaya, Dr Deressa, Dr Kumie); Occupational and Environmental Medicine, Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway (Dr Bråtveit); and Centre for International Health, Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway (Dr Moen). SWA planned the study, collected and analyzed data, and drafted the manuscript in consultation with other authors. MB, WD, AK, and BEM participated in the design, collection, and analysis of data, provided scientific support throughout the project, and commented on the manuscript. All authors have read and approved the final manuscript.

This research was funded by the Norwegian Program for Capacity Building in Higher Education and Research for Development (NORHED).

The authors declare that they have no competing interest.

Clinical Significance: Understanding the respiratory health problem among coffee workers in Ethiopia, can help public health professionals and other relevant stakeholders for planning preventive and control strategies.

Address correspondence to: Samson Wakuma Abaya, MSc, MPH, Department of Preventive Medicine, School of Public Health, College of Health Sciences, Addis Ababa University, P.O. Box 9086, Addis Ababa 1000, Ethiopia (samson_wakuma@yahoo.com)

Copyright © 2019 The Author(s). Published by Wolters Kluwer Health, Inc. on behalf of the American College of Occupational and Environmental Medicine. This is an open access article distributed under the terms of the Creative Commons Attribution-Non Commercial-No Derivatives License 4.0 (CCBY-NC-ND), where it is permissible to download and share the work provided it is properly cited. The work cannot be changed in any way or used commercially without permission from the journal.

DOI: 10.1097/JOM.0000000000001613



FIGURE 1. Hand pickers working at coffee-sorting tables (Photo: S. W. Abaya).

may cause asthma-like conditions. We therefore decided to study mean forced expiratory flow between 25% and 75% of the FVC (FEF_{25-75}) as well, as this parameter is known to reflect changes in small airways.⁹ Hand pickers and a control group with low dust exposure were compared. In addition, we compared hand pickers working with and without tables.

METHODS

Study Design and Study Setting

All of the participants included in this study were female. A comparative cross-sectional study was conducted during May to October 2016 among hand pickers with sorting tables working in Addis Ababa, and hand pickers without tables in Oromia and SNNPR primary coffee-processing factories. Hand pickers from 12 primary coffee-processing factories were included, four factories from each of the three regions. The number of hand pickers varied from factory to factory, ranging from 40 to 70. In addition, women from three water-bottling factories—one from each of the three study areas—were selected as a control group. The workers in the water-bottling factories were chosen, as there are no specific dust-emitting processes in this industry, and we thus assumed that they were exposed to less dust at work. The workers in the water bottling factories and the coffee production factories were assumed to have a similar socioeconomic status.

Dust Sampling

The number of personal dust samples was calculated based on Rappaport and Kupper,¹⁰ who suggested repeated samples from 5 to 10 randomly selected individuals per similar exposure group (SEG). We assumed that hand pickers working without tables in each of the eight factories perform similar tasks, and that they were considered to constitute one SEG. Hand pickers working with tables in each of the four factories perform similar tasks, and were assumed



FIGURE 2. Hand pickers working on the ground, without tables (Photo: S. W. Abaya).

to constituent another SEG. However, as we did not know whether there were any differences between the factories, we sampled individuals from each factory. Five hand pickers were thus randomly selected for dust sampling in each factory, for two consecutive days. In total, 40 dust samples were taken from hand pickers with tables and 80 samples from pickers without tables.

Full-shift personal sampling of total dust was performed in the hand picker's breathing zone, using 25 mm three-piece, closed-faced conductive cassettes (Millipore MAWP 025 AC, Millipore Corp., Bedford, MA) with a cellulose acetate filter (Millipore AAWP02500). The filters were attached to Side Kick Casella pumps with a flow rate of 2 L/min.¹¹ In addition, five women were randomly selected from each of the three water-bottling factories chosen as controls for dust sampling. In the water-bottling factories, workers from the light-inspection department were chosen as an SEG. Light inspectors check whether the bottled water is properly filled, cleaned, capped, and labeled. The activities in the light-inspection room do not generate dust. Sampling was also performed on two consecutive days for each worker in the water-bottling factories, giving a total of 30 total dust samples. Owing to sampling errors, five dust samples from hand pickers without tables were not included in the analysis. After sampling, the cassettes were capped, put in a box and flown to Norway as hand luggage. The samples were gravimetrically analyzed in the accredited laboratory SINTEF MOLAB in Norway, where the filters had been pre-weighed before sampling. No damage to the box or the samples was registered.

Study Population and Sample Size

The sample size for the respiratory-symptom assessment was calculated using the double population formula, considering a prevalence of morning cough with sputum among workers exposed to coffee dust of 23% and a prevalence among nonexposed workers of 10%.³ To obtain 90% statistical power for detection of this difference in morning cough with sputum between the two groups, at a significance level of 0.05, we needed 190 hand pickers and 190 controls. As the plan was to compare the prevalence of chronic respiratory symptoms in three groups (ie, hand pickers with tables, hand pickers without tables, and controls), 190 participants from each of the three groups were included, making the total number of participants 570. In the respective groups, the number of participants selected was in proportion to the size of the factories. Lists of workers were available for the researchers who selected the workers, with no knowledge about their health status or dust exposure levels.

The number of hand pickers without tables selected from each factory was in proportion to the size of the eight primary coffee-processing factories in Oromia and SNNPR, to produce the requisite total of 190. Similarly, the selected number of hand pickers with tables was in proportion to the size of the four primary coffee-processing factories in Addis Ababa, to be added up to produce the figure of 190. In addition, 190 controls were selected in proportion to the size of the three water-bottling factories. When the number of workers required from each factory had been settled, the workers were selected from the registration lists of workers in each factory using the systematic random sampling method. Only women were invited to take part in the study, as only women work as hand pickers in Ethiopia. In the control group, too, only women were asked to participate.

DATA COLLECTION

Chronic Respiratory Symptoms Interview

Face-to-face interviews were held. The questionnaire included background data (age, smoking habits (ever smoked: yes/no), occupational history (years of work experience in the present dusty factory and other dusty factories), and past respiratory diseases (pneumonia, tuberculosis, bronchitis, asthma, and chest

injury), as well as questions about the use of respiratory protective devices (RPDs) while working (yes/no) and the reason for not using RPDs. The questionnaire also included questions about the type of fuel used for cooking and the cooking place (kitchen inside or outside living room). Furthermore, the questionnaire included questions about chronic respiratory symptoms using a standardized questionnaire adopted from the American Thoracic Society (ATS),¹² with the following symptoms: cough, cough with sputum, breathlessness, work-related shortness of breath, wheezing, and chronic bronchitis.

The questionnaire was translated from English into Amharic and Afan Oromo languages, then back into English. A preliminary test was conducted before the actual data collection for validation of the data collection tool. The question about wheezing was not easy for the participants to understand, so we rephrased it, using the appropriate local term for the symptom. The data were collected by the principal investigator together with an experienced research assistant who was trained for this task.

Operational Definitions

Cough participants were considered to have cough if they answered "yes" to at least one of the following four questions: cough first thing in the morning, cough during the day or night, cough as much as four to six times a day for a week, or cough on most days for as much as three consecutive months of the year.

Cough with sputum participants were considered to have a cough with sputum if they answered "yes" to at least one of the following four questions: cough with sputum first thing in the morning, cough with sputum during the day or night, cough with sputum as much as four to six times a day for a week, or cough with sputum for most days for as much as three consecutive months of the year.

Breathlessness participants were considered to be experiencing breathlessness if they were troubled by shortness of breath when hurrying on level ground or walking up a slight hill, or got short of breath when walking at their own pace on level ground or when walking with other people of their own age on level ground.

Work-related shortness of breath participants were considered to be experiencing work-related shortness of breath if they usually experienced chest tightness while at work or just after work.

Wheezing participants were considered to be experiencing wheezing if their chest ever sounded wheezy (whistling sound).

Lung-Function Test

The sample size for lung function was calculated using the mean difference formula for FEV₁/FVC. We expected 0.027 mean difference and 0.05 standard deviation among female coffee workers and controls in water-bottling factories.¹³ A significance level of 0.05 and 80% power were used to calculate the sample size. After considering 10% nonresponse, we needed 60 hand pickers and 60 controls. As the plan was to compare lung-function parameters in three groups (ie, hand pickers with tables, hand pickers without tables, and controls), 60 participants from each of the three groups were included, making the total number of participants 180. Ten hand pickers from each of the 12 primary coffee-processing factories and 20 participants from each of the three water-bottling factories were selected by means of the systematic random sampling method, using the workers' registration list as a sampling framework for each factory. Lung-function tests were conducted in accordance with the ATS recommendation regarding spirometry¹⁴ using a portable spirometer (SPIRARE 3 sensor model SPS 320, Diagnostica AS, Oslo, Norway). The standing height and weight of the participants were measured using the Seca 786 weight and height scale (Seca Hamburg, Germany). The test was performed with the worker in a sitting position. The tests were conducted during the day shift from 2 AM to 4 PM.

TABLE 1. Characteristics of Participants

Variables	Significance Level			Significance Level		
	All Hand Pickers <i>n</i> = 374	Controls <i>N</i> = 175	All Hand Pickers Versus Controls	Hand Pickers with Tables <i>n</i> = 185	Hand Pickers Without Tables <i>n</i> = 189	Hand Pickers Without Tables Versus With Tables
Age, years: AM (range)	29.6 (18–60)	25.7 (18–46)	<0.001 [†]	31.9 (18.0–55.0)	27.5 (18.0–60.0)	<0.001 [†]
Height, m: AM (range)	1.6 (1.3–1.8)	1.6 (1.4–1.7)	0.03 [†]	1.6 (1.4–1.8)	1.6 (1.3–1.8)	0.25 [†]
Weight, kg: AM (range)	51.9 (35.1–94.3)	53.0 (39.2–95.1)	0.14 [†]	53.6 (35.2–94.3)	50.2 (35.1–78.8)	<0.001 [†]
BMI, kg/m ² : AM (range)	21.2 (14.2–36.7)	21.4 (14.8–32.9)	0.59 [†]	21.8 (15.2–36.7)	20.7 (14.2–27.6)	<0.001 [†]
Duration of employment at present work years: AM (range)	5.3 (1.0–38.0)	3.97 (1.0–15.0)	<0.001 [†]	5.9 (1.0–38.0)	4.7 (1.0–23.0)	0.06 [†]
Education						
Unable to read and write	122 (32.6)	1 (0.5)	<0.001 [§]	71 (34.6)	51 (22.8)	0.04 [§]
Primary and junior secondary education	205 (54.8)	33 (17.4)		90 (43.9)	115 (51.3)	
Secondary education and above	47 (12.6)	141 (74.2)		24 (11.7)	23 (10.3)	
Cooking						
Cooking food at home: <i>n</i> (%)	369 (98.7)	172 (98.3)	0.71 ±	184 (99.5)	185 (97.9)	0.37 ±
Kitchen located inside the living room: <i>n</i> (%)	118 (32.0)	57 (33.1)	0.79 [§]	48 (26.1)	70 (37.8)	0.02 [§]
Use biomass for cooking: <i>n</i> (%)	357 (96.7)	164 (95.3)	0.42 [§]	178 (96.7)	179 (96.8)	0.99 [§]
Pesticide use						
Sprayed pesticide in the past	2 (0.5)	0	<i>N</i>	0	2 (1.1)	<i>N</i>
Previous respiratory disease						
Bronchitis: <i>n</i> (%)	10 (2.7)	0	<i>N</i>	4 (2.2)	6 (3.2)	0.75 ±
Pneumonia: <i>n</i> (%)	18 (4.8)	5 (2.9)	0.29 [§]	10 (5.4)	8 (4.2)	0.59 [§]
Pleurisy: <i>n</i> (%)	1 (0.3)	1 (0.6)	<i>N</i>	1 (0.5)	0	<i>N</i>
Tuberculosis: <i>n</i> (%)	7 (1.9)	0	<i>N</i>	4 (2.2)	3 (1.6)	<i>N</i>
Asthma: <i>n</i> (%)	11 (2.9)	5 (2.9)	0.95 [§]	7 (3.8)	4 (2.1)	0.34 [§]
Chest injury: <i>n</i> (%)	5 (1.3)	1 (0.6)	<i>N</i>	2 (1.1)	3 (1.6)	<i>N</i>
Participants who have had at least one of the respiratory diseases: <i>n</i> (%)	44 (11.8)	11 (6.3)	0.04 [§]	24 (13)	20 (10.6)	0.47 [§]

n: number of study participants. † Independent t test; § Pearson chi-square test; ± Fisher's exact test to compare hand pickers with table and without table and to compare each hand-picker group with controls; *N*: not calculated, owing to low numbers.

FVC, FEV₁, the ratio FEV₁/FVC, and the FEF_{25–75%} were measured in this study. Three acceptable maneuvers with consistent (“repeatable”) results were retained, and the best one was recorded. Repeatability means that the difference between the largest and second-largest values should be within 150 mL.¹⁵ Participants with a ratio of FEV₁/FVC less than 0.70 were considered to be experiencing airflow limitation.¹⁶

A total of 15 spirometer results (five from hand pickers with tables, four from hand pickers without tables, and six from controls) were excluded from analysis owing to unacceptable readings.

Data Management and Analysis

EpiData 3.1 (EpiData Association, Denmark) was used to enter the data, which was then exported to SPSS Version 22 (IBM Corp., Armonk, NY) for analysis. Data were encoded, and no names were included in the database. The code list and the data were kept confidential. Body mass index (BMI) was calculated for each of the three groups.

Independent *t* tests were used to compare continuous variables in one group with those in the other group. The Pearson Chi-square test was used to test differences in the prevalence of respiratory symptoms and other categorical variables between the groups. Fisher exact test was used for comparisons of categorical variables when the variables had values of less than 5. A linear mixed-effects regression model with a variance component structure was used to analyze for any difference in dust-exposure level between hand pickers with tables and those without. In this model, employee ID was entered as a random factor and exposure group as a fixed factor. Poisson regression analyses with robust variance were used to determine the prevalence ratio of different respiratory symptoms in hand pickers and controls, adjusting for age, education level, previous respiratory disease, and kitchen located inside the house. The variables were included in the analyses, as they showed significant differences between the groups. Multiple linear regression analyses were used to compare the mean lung-function parameters in hand pickers with those in controls, adjusting for age, height, education level, previous respiratory disease, and kitchen located inside the house. In all tests, *P* values of less than 0.05 were considered to be statistically significant.

Ethical Approval

The Institutional Review Board of the College of Health Sciences at Addis Ababa University and the National Research Ethical Review Committee of the Ethiopian Ministry of Science and Technology approved the study. Permission to conduct the study was obtained from the factory managers. Written informed consent was obtained from each participant, and participation in the study was voluntary.

RESULTS

Characteristics of the Study Participants

All participants were females, with a mean age of 28.4 years, ranging from 18 to 60. A total of 549 individuals participated in this study, making the response rate 98.4% for hand pickers and 92.1% for controls. None of the participants were current or former smokers. Control workers had a significantly higher education level and were younger than the hand pickers, but no statistical difference was found in terms of the duration of previous work in dusty factories or in use of biomass for cooking, comparing controls and hand pickers. The mean duration of work as hand picker was 5.3 years (Table 1). There was no significant difference in mean years work experience between hand pickers with tables and without tables.

The group of hand pickers without tables included significantly more people unable to read and write, and they more frequently had a kitchen inside the living room than was the case for hand pickers with tables (Table 1). The weight and BMI of hand pickers with tables was significantly higher than in hand pickers without tables (Table 1).

Use of Respiratory Protective Device

Only three hand pickers used any type of RPD. The majority of those not using RPD (*n* = 368; 99%) indicated that the reason for not using one was that none was available or provided at the workplace. During dust sampling, we observed that some hand pickers used a piece of cloth to cover their mouth and nose, otherwise no RPDs were to be seen.

Dust Exposure Level

Personal total dust exposure was significantly higher among hand pickers (GM = 1.1 mg/m³) than among controls (0.2 mg/m³) (*P* < 0.001) (Table 2). There was no significant difference in exposure level between hand pickers with tables (1.4 mg/m³) and those without (1.0 mg/m³) (*P* = 0.19).

Chronic Respiratory Symptoms

Hand pickers displayed a significantly higher prevalence of most of the chronic respiratory symptoms than controls (Table 3). The highest prevalence ratio for hand pickers relative to controls was for cough [PR = 3.0, 95% confidence interval (95% CI): 1.4 to 6.2], followed by work-related shortness of breath (PR = 2.5, 95% CI: 1.1 to 5.6). For most of the chronic respiratory symptoms, hand pickers without tables displayed a significantly higher prevalence ratio than in hand pickers with tables (Table 3).

TABLE 2. Personal Total Dust Exposure Among Two Groups of Hand Pickers of Coffee and a Control Group From Water-Bottling Factories in Ethiopia

Activity	NW	NS	Sampling Time (min) AM (range)	Total dust exposure (mg/m ³)		No (%) > 5mg/m ³ (OEL)
				AM (range)	GM (GSD)	
All hand pickers	60	115	406 (320–479)	1.6 (0.12–9.74)	1.1 (2.4)	3 (2.6)
Hand pickers with tables	20	40	395 (330–463)	1.6 (0.65–4.6)	1.4 (1.7)	0
Hand pickers without tables	40	75	413 (320–479)	1.5 (0.12–9.74)	1.0 (2.7)	3 (4)
Controls	15	30	421 (337–476)	0.2 (0.11–0.45)	0.2 (1.3)	0

All hand picker, includes both types of hand pickers (hand pickers with table and hand pickers without tables); AM, Arithmetic mean; controls, workers in water bottling factories; GM, Geometric mean; GSD, Geometric Standard Deviations; Hand pickers with table, sort coffee beans on a long table or a conveyor belt while sitting inside the processing machine room on chairs 40 to 50 cm high; Hand pickers without tables, perform their work while sitting on the ground, either outdoors on a veranda or in a separate room; mg/m³, Milligram per meter cube; No, Number of participants; NS, number of dust samples; NW, number of workers; OEL, Occupational exposure limit – 5 mg/m³.

TABLE 3. Frequency of Chronic Respiratory Symptoms Among Two Groups of Hand Pickers of Coffee and a Control Group Exposed to a Low Dust Level

Variables	All Hand Pickers n = 374		Controls n = 175		All Hand Pickers versus Controls		Hand Pickers With Tables n = 185		Hand Pickers Without Tables n = 189		Comparing Hand Pickers Without Tables With Hand Pickers With Tables	
	n (%)		n (%)		Prevalence Ratio (95% confidence interval)		n (%)		n (%)		Prevalence Ratio (95% confidence interval)	
Cough	78 (20.9)	12 (6.9)	3.0 (1.4–6.2)		28 (15.1)	50 (26.5)	2.0 (1.3–3.1)					
Cough with sputum	26 (7.0)	4 (2.3)	–		7 (3.8)	19 (10.1)	3.9 (1.6–9.5)					
Breathlessness	130 (34.8)	37 (21.1)	1.7 (1.1–2.5)		63 (34.1)	67 (35.4)	1.2 (0.9–1.6)					
Wheezing	47 (12.6)	8 (4.6)	2.1 (0.9–4.8)		13 (7.0)	34 (18)	2.3 (1.3–4.3)					
Work-related shortness of breath	69 (18.4)	13 (7.4)	2.5 (1.1–5.6)		25 (13.5)	44 (23.3)	1.8 (1.1–2.8)					
Chronic bronchitis	3 (0.8)	0	–		0	3 (1.6)	–					

n: number of participants; prevalence ratio adjusted for age, educational level, cooking inside the living room and previous respiratory diseases; the prevalence ratio was calculated when the number of symptoms in the control group was over 5.

Lung Function

There were no statistical differences in FVC, FEV₁, FEV₁/FVC, or in the prevalence of airflow limitation between controls and hand pickers (Table 4). However, there was significant difference in FEF_{25–75} between hand pickers and controls, with lower values among the hand pickers. Furthermore, FVC, FEV₁, and FEF_{25–75} were significantly lower among hand pickers without tables than among hand pickers with tables, after adjusting for age, height, educational level, cooking inside the living room, and previous respiratory disease (Table 4). The prevalence of airflow limitation among hand pickers without tables was also higher (12.5%) than among hand pickers with tables (7.3%), but not significant (Table 4).

DISCUSSION

The hand pickers had experienced a higher level of dust exposure, had more respiratory symptoms, and a lower FEF_{25–75} than the controls. Hand pickers without tables displayed a higher prevalence of respiratory symptoms and a lower level of lung function than hand pickers with tables, but there was no difference in dust exposure between these groups.

The personal total dust exposure (GM) of 1.1 mg/m³ among the hand pickers in the present study is comparable to that in a previous study conducted among hand pickers in primary coffee-processing factories in Tanzania (0.9 mg/m³).⁴

The prevalence of almost all respiratory symptoms in the hand pickers was higher than among the controls. Our findings were consistent with previous studies conducted in Ethiopia, Tanzania, Uganda, and Papua New Guinea, which reported a higher prevalence of respiratory symptoms among coffee-processing workers than in controls.^{3,6,7,17} However, it is difficult to compare these findings with those for the present study, as these previous projects studied male workers in the processing areas with considerably higher dust exposure, and did not include female hand pickers. In the present study, the prevalence of respiratory symptoms such as cough and cough with sputum for both groups of hand pickers was lower than among male Ethiopian coffee-production workers, where the prevalence was 46.4% and 23.2%, respectively.¹⁷ This difference in symptom prevalence might be related to the difference in dust exposure level.

The present study found a higher prevalence of almost all respiratory symptoms, as well as a lower FVC, FEV₁, and FEF_{25–75}

TABLE 4. Lung-Function Parameters Among Two Groups of Hand Pickers in Primary Coffee-Processing Factories and Controls Exposed to a Low Dust Level

Lung Function Parameters	All Hand Pickers vs Controls		Hand Pickers With Table n = 55		Hand Pickers Without Table n = 56		Hand Pickers With Table vs Hand Pickers Without Table	
	All Hand Pickers n = 111	Controls n = 54	B (SE)	P-value	B (SE)	P-value	B (SE)	P-value
FVC – mean (SD)	3.08 (0.59)	3.33 (0.50)	–0.07 (0.11)	0.52*	3.20 (0.63)	2.96 (0.51)	–0.32 (0.10)	0.002*
FEV ₁ – mean (SD)	2.43 (0.55)	2.69 (0.41)	–0.07 (0.09)	0.46*	2.53 (0.57)	2.33 (0.51)	–0.29 (0.08)	0.001*
FEV ₁ /FVC – mean (SD)	0.78 (0.07)	0.81 (0.07)	–0.01 (0.02)	0.57*	0.79 (0.07)	0.78 (0.07)	–0.02 (0.01)	0.18*
FEF _{25–75} – Mean (SD)	2.08 (0.63)	2.72 (0.73)	–0.40 (0.12)	0.001	2.16 (0.50)	2.01 (0.73)	–0.26 (0.09)	0.01*
FEV ₁ /FVC < 0.70 n; (%)	11 (9.9)	2 (3.7)	–	0.23 [†]	4 (7.3)	7 (12.5)	–	0.36 [‡]

B, beta coefficient in multiple linear regression; n, number of workers participated in the study; SE, standard error; FEF_{25–75}, mean forced expiratory flow between 25% and 75% of the FVC; FEV₁, forced expiratory volume in 1s; FEV₁/FVC, the ratio of forced expiratory volume in 1s to forced vital capacity; FVC, forced vital capacity; P-value, 95% significance level; SD, standard deviation.

*Linear regression between hand pickers and controls as well as between hand pickers with table and without tables while adjusting for age, height, educational level; cooking inside the living room and previous respiratory disease.

[†]Fisher exact test.

[‡]Chi-square test.

among hand pickers without tables than in pickers with tables. One possible reason could be that there are differences in the type of coffee used in these two hand-picking groups. Hand pickers without tables handle coffee beans processed using the dry method on the farms, while hand pickers with tables handle coffee beans processed using either the wet or the dry method. The methods may influence the content of the dust inhaled during the hand-picking work.¹³ Future studies should assess the content of the dust—bacteria, fungi, and endotoxins—in addition to the total dust levels.

FVC, FEV₁, and FEV₁/FVC measured among hand pickers were not significantly different to those in controls. However, there was significant difference in FEF_{25–75} between hand pickers and controls. This indicates obstruction of small airways among the hand pickers, which is likely to be caused by the organic coffee dust they are exposed to.¹⁸ This parameter has not been studied among coffee workers before. However, a Tanzanian study found a significant difference in FEV₁/FVC between coffee workers and controls,¹³ suggesting that work in coffee factories is associated with a low but significant level of lung-function impairment. The study did not, however, involve hand pickers, and the production workers were engaged in other parts of the coffee processing. Also, the workers examined were males. In addition, the findings from this Tanzanian study might be related to differences in type of coffee, post-harvest processing method at the farm, working conditions, and dust exposure level compared with what we have in Ethiopia. In Tanzania, both Robusta and Arabica coffee were processed, while only Arabica coffee was processed in Ethiopia. Similarly, in Tanzania, Arabica coffee was mostly processed on the farm using the wet method, while Robusta coffee was processed using the dry method. In Ethiopia, Arabica coffee is processed using both the wet and the dry method, depending on the individual farmer. In a previous study among male coffee workers (ie, machine room and transport workers), we found that coffee workers in the age groups 28 to 39 and at least 40 had a significantly lower FVC and FEV₁ than the controls in the similar age groups. This might be related to a higher dust-exposure level.¹⁷

Respiratory symptoms were self-reported, and the method has weaknesses, as the workers might not remember their symptoms or might be biased owing to the focus on dust at their workplace. On the contrary, this was also the situation for the control group, and use of a control group that experienced lower exposure was a strength of this study. The questionnaire method might be a weakness, but it is a good method for obtaining indications of health problems at an early stage, before a serious disease has developed. This is important in studies of workers, as they often represent the “healthy workers,” that is, the ones who have not become ill.

We used validated questions concerning chronic respiratory symptoms, but the answers might also represent acute symptoms. It is often difficult to differentiate between these two categories of symptoms, as they frequently occur at the same time.¹⁹ The results clearly indicate that these workers experience symptoms that should not occur at a workplace, and their work environment should be further examined. However, the design of this study was cross-sectional, and no clear causal relationship between coffee-dust exposure and respiratory symptoms can be concluded. This also means that factors other than dust may be present, and may cause the symptoms registered.

CONCLUSION

Hand pickers had experienced higher dust exposure, displayed a higher prevalence of almost all respiratory symptoms, and lower FEF_{25–75} than the controls. Hand pickers without tables

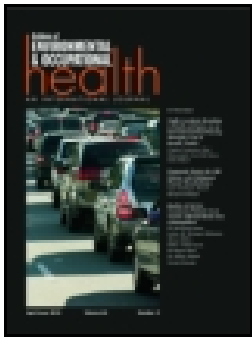
displayed a higher prevalence of almost all respiratory symptoms and a lower level of lung function than hand pickers with tables.

ACKNOWLEDGMENTS

We would like to thank the coffee-factory management teams and workers for their permission to conduct the study and for participating in the study. We thank the Norwegian Program for Capacity Building in Higher Education and Research for Development (NORHED) for their support.

REFERENCES

- Musebe R, Agwanda C, Mekonen M. Primary coffee processing in Ethiopia: patterns, constraints and determinants. *Afr Crop Sci Conf Proc*. 2007; 8:1417–1421.
- Schwan R, Silva C, Batista L. Coffee fermentation. In: Hui Y, editor (s). *Plant-Based Fermented Food and Beverage Technology*. 2nd ed. London: CRC Press; 2012. p. 367–396.
- Sakwari G, Bråtveit M, Mamuya SHD, Moen BE. Dust exposure and chronic respiratory symptoms among coffee curing workers in Kilimanjaro: a cross sectional study. *BMC Pulm Med*. 2011;11:54–61.
- Moen B, Kayumba A, Sakwari G, Mamuya S, Bråtveit M. Endotoxin dust and exhaled nitrogen oxide among hand pickers of coffee; a cross-sectional study. *J Occup Med Toxicol*. 2016;11:17.
- Zuskin E, Vali F, Skuri Z. Respiratory function in coffee workers. *Br J Ind Med*. 1979;36:117–122.
- Smith D, Brott K, Kokisource G. Respiratory impairment in coffee factory workers in the Asaro valley of Papua New Guinea. *Br J Ind Med*. 1985;42:495–498.
- Sekimpi K, Agaba E, Okot-Nwang M, Ogaram D. Occupational coffee dust allergies in Uganda. *Afri News Occup Health Safety*. 1996;6:6–9.
- Uragoda C. Acute symptoms in coffee workers. *J Trop Med Hyg*. 1988; 91:169–172.
- Raji H, Shoushtari MH, Idani E, et al. Forced expiratory flow at 25–75% as a marker for airway hyper responsiveness in adult patients with asthma-like symptoms. *Tanaffos*. 2018;17:90–95.
- Rappaport S, Kupper L. Quantitative Exposure Assessment. El Cerrito, Calif.: S. Rappaport, c2008; ISBN 978-0-9802428-0-5.
- Occupational Safety and Health Administration. OSHA Technical Manual: Section ii, Chapter I: Personal Sampling for Air Contaminants. Occupational Safety and Health Administration; 2014 Available at: https://www.osha.gov/dts/osta/otm/otm_ii/otm_ii_1.html#total_dust. Accessed November 25, 2018.
- American Thoracic Society – Division of Lung Diseases. Recommended Respiratory Disease Questionnaires for Use with Adults and Children in Epidemiological Research. ATS. 1978. Available at: <http://citeserx.ist.psu.edu/viewdoc/download?doi=10.1.1.607.2516&rep=rep1&type=pdf>. Accessed November 15, 2018.
- Sakwari G, Mamuya S, Bråtveit M, Moen B. Respiratory symptoms, exhaled nitric oxide, and lung function among workers in tanzanian coffee factories. *J Occup Environ Med*. 2013;55:544–551.
- American Thoracic Society. Standardization of spirometry, 1994 update. American Thoracic Society. *Am J Respir Crit Care Med*. 2005; 152:1107–1136.
- National Institute for Occupational Safety and Health (NIOSH). Spirometry Quality Assurance: Common Errors and Their Impact on Test Results. Health and human service. 2012. Available at: <https://www.cdc.gov/niosh/docs/2012-116/pdfs/2012-116.pdf>. Accessed November 15, 2018.
- Pauwels A, Buist S, Calverley A, Jenkins R, Hurd S. Globally strategy for the diagnosis management and prevention of chronic obstructive pulmonary disease: NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD) Workshop summary. *Am J Respir Crit Care Med*. 2001;163:1256–1276.
- Abaya S, Bråtveit M, Deressa W, Kumie A, Moen B. Reduced lung function among workers in primary coffee processing factories in Ethiopia: a cross sectional study. *Int J Environ Res Public Health*. 2018;15:pii: E2415.
- Burgel P, Bergeron A, Blic J, et al. Small airways diseases, excluding asthma and COPD: an overview. *Eur Respir Rev*. 2013;22:131–147.
- Lähti MA, Pekkanen J, Koskela H. Defining the risk factors for acute, subacute and chronic cough: a cross-sectional study in a Finnish adult employee population. *BMJ Open*. 2018;8:e022950.



Microbial contamination of coffee during postharvest on farm processing: A concern for the respiratory health of production workers

Samson Wakuma Abaya, Magne Bråtveit, Wakgari Deressa, Abera Kumie, Abiyot Tenna & Bente E. Moen

To cite this article: Samson Wakuma Abaya, Magne Bråtveit, Wakgari Deressa, Abera Kumie, Abiyot Tenna & Bente E. Moen (2019): Microbial contamination of coffee during postharvest on farm processing: A concern for the respiratory health of production workers, Archives of Environmental & Occupational Health, DOI: [10.1080/19338244.2019.1592094](https://doi.org/10.1080/19338244.2019.1592094)

To link to this article: <https://doi.org/10.1080/19338244.2019.1592094>



© 2019 The Author(s). Published with license by Taylor & Francis Group, LLC



Published online: 01 Apr 2019.



Submit your article to this journal [↗](#)



Article views: 90



View Crossmark data [↗](#)

Microbial contamination of coffee during postharvest on farm processing: A concern for the respiratory health of production workers

Samson Wakuma Abaya^{a,b,d}, Magne Bråtveit^b, Wakgari Deressa^a, Abera Kumie^a, Abiyot Tenna^c, and Bente E. Moen^{b,d}

^aDepartment of Preventive Medicine, School of Public Health, Addis Ababa University, Addis Ababa, Ethiopia; ^bOccupational and Environmental Medicine, Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway; ^cAddis Ababa Region Public Health Research and Emergency Management Core Process, Research Department, Addis Ababa, Ethiopia; ^dCentre for International Health, Department of Global Public Health and Primary Care, University of Bergen, Bergen, Norway

ABSTRACT

Coffee workers respiratory health problems, found to be associated with dust exposure in the coffee factories, but the content of the dust is not well known. A cross-sectional survey was conducted to assess the microbial contamination of coffee in dry and wet coffee process, from four farms in two regions of Ethiopia. A total of 36 samples of coffee were collected for laboratory investigation. The microbial load in the dry process ranged from 6.9×10^2 to 7.2×10^5 colony forming units (CFU)/mL while the microbial load in wet process ranged from 2.5×10^2 to 4.6×10^5 CFU/mL. The results indicate the presence of gram negative bacteria in dried and stored beans from both the wet and dry process. During further coffee processing possible release of endotoxin from coffee contaminated by gram negative bacteria might affect coffee workers respiratory health. Further studies are required to assess the relation between bacterial contamination of coffee and endotoxin level in coffee factories.

KEYWORDS

Coffee; gram negative bacteria; postharvest Ethiopia; endotoxin



Background

Coffee is a major export commodity and a source of foreign currency for Ethiopia, and contributes to about 60% of the total export earnings.¹ It is estimated that 15 million people in Ethiopia depend on coffee production directly or indirectly for their living.²

Studies in primary coffee processing factories in Uganda and Sri Lanka have indicated a higher prevalence of acute respiratory symptoms than among controls,^{3,4} while an increased prevalence of chronic respiratory symptoms has been reported among primary coffee factory workers in Papua New Guinea and Tanzania.^{5,6} Studies have also observed reduced lung function among coffee workers compared to controls.^{5,7} These studies are from Papua New Guinea and Tanzania and indicate that the coffee workers might develop respiratory lung diseases due to dust exposure at work. Similarly, a study recently performed in Ethiopia among workers in primary coffee processing factories shows that coffee workers had a

significantly higher prevalence of chronic respiratory symptoms and reduced lung function compared to controls.⁸ This study was performed in the same area as the present study. Primary coffee processing factories refer to mechanical cleaning of debris from parchment coffee and include hulling, grading, hand picking, and packing of green coffee beans. Several studies conducted in coffee roasting factories have also found a higher prevalence of chronic respiratory symptoms and reduced lung function among coffee workers than among controls.^{9–13}

After harvesting, the coffee cherries pass through different processing stages to remove the layers of the coffee cherries (ie, hull, pulp, mucilage, parchments, and silver skin).¹⁴ In Ethiopia, two types of postharvest on farm processing of coffee are used to remove these layers and they are called wet and dry processes. During dry processing the unpulped coffee cherries are allowed to dry in the sun under natural conditions by spreading on ground, mats, cemented floor, or raised dry bed.^{14,15}

CONTACT Samson Wakuma Abaya  samson_wakuma@yahoo.com  Department of Preventive Medicine, School of Public Health, College of Health Sciences, Addis Ababa University, PO Box 9086, Addis Ababa, Ethiopia.

© 2019 The Author(s). Published with license by Taylor & Francis Group, LLC

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (<http://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way.

The spread coffee is heaped in the night and re-spread each morning. This process continues for about two to three weeks depending on the weather condition of the area.¹⁴ During wet processing, the coffee fruits are depulped on the day of harvesting. The pulped coffee beans are allowed to ferment naturally in different tanks for about 16–24 h depending on the weather condition. When fermentation is completed, the coffee beans are washed with running water to remove the remaining mucilage and acids. Finally, the wet coffee beans are spread on a drying table and allowed to dry by sun.² In Ethiopia, about 71% and 29% of coffee is processed by dry and wet process, respectively.¹⁶

Studies have indicated that endotoxin is released to the working environment when agricultural products contaminated with dust containing gram negative bacteria are processed.^{17–20} Endotoxin is known to cause respiratory health problems.^{21–25} Studies conducted in primary coffee processing factories have shown high levels of total dust exposure.^{4,5,26} In our previous study, we indicated that 84% of the dust samples among male coffee workers in primary coffee processing factories in Ethiopia exceeded the occupational exposure limit value,²⁷ but there is little knowledge about the content of the dust. However, Sakwari et al. found high levels of endotoxin in primary coffee processing of Tanzania.^{7,26} This finding indicates that coffee can be contaminated with gram negative bacteria like any other agricultural products during postharvest on farm processing of coffee and storage.²⁸ Furthermore, Sakwari et al. found an association between exposure to endotoxin and respiratory symptoms and reduced lung function among the coffee processing factory workers in Tanzania.⁷ The same author suggested that poor storage and drying coffee on ground might have increased bacterial contamination of the beans,⁷ but this suggestion has not been verified.

The aim of the present study was to assess microbial contamination of coffee in different stages of both wet and dry postharvest on farm coffee processing. Thus, this study will identify points of coffee contamination, and could provide new information on how to prevent and control bacterial contamination of coffee beans.

Materials and methods

Study area

The study was conducted in Yebu woreda of Jimma Zone in Oromia Regional State and Shebedino woreda, Sidama Zone of Southern Nations Nationalities Peoples' Region (SNNPR) of Ethiopia. The two

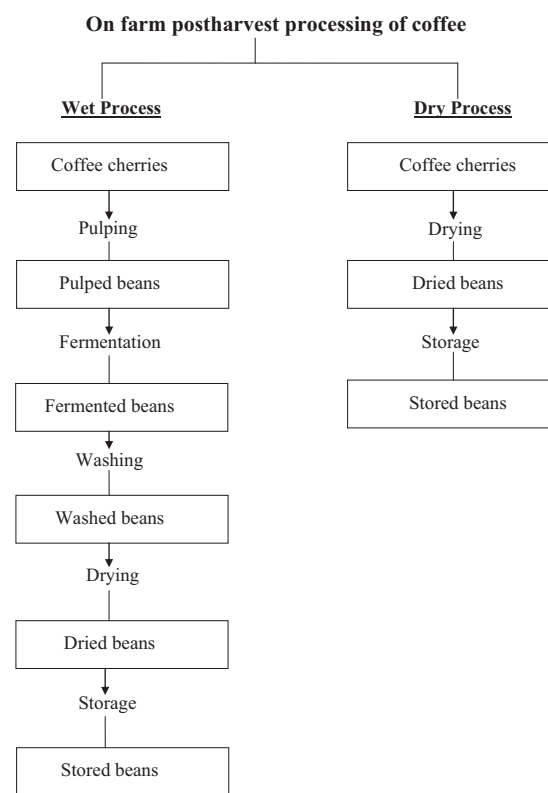


Figure 1. Stages of wet and dry processes and sampling of coffee beans were performed in different stages of dry and wet processing, described inside boxes.

woredas were selected because they are the largest coffee growing areas in their respective regions.

Sampling procedure

This study assessed two wet and two dry coffee processes on four different farms. In wet processing the beans pass through six processing steps, where the dry process comprises three different processing steps (Figure 1). Coffee samples were collected two times on different days from different batches of coffee from each stage of both the wet and the dry process. Thus 24 samples from the two wet processes and 12 samples from the two dry processes were collected for laboratory investigation. Sampling was conducted in the dry season of the year (from October 2016 to January 2017).

Sample collection

The sample collection form contained date and time, types of sample, location, name of stages and sites. All equipment and materials were sterilized prior to use. Coffee cherries and beans, each weighing about 25 g, were sampled from each stage of the wet and dry processes. The principle investigator together with one senior microbiologist collected the samples from each

stage in sterile plastic bag, labeled with types of sample, location, name of stages, and sites and transferred to ice boxes (triple package). The samples were transported within 6 h of collection to Addis Ababa City Administration Health Bureau Laboratory (Public Health Microbiology Laboratory) and analyzed as soon as possible after receipt in the laboratory.

Sample processing and analyses

Three experienced microbiologists at Addis Ababa City Administration Health Bureau Laboratory analyzed the samples. The samples were analyzed for heterotrophic plate count. The coffee cherries were transferred to a flask containing 225 mL of sterile buffered peptone water (1% peptone, 5% weight per volume NaCl) and swirled gently for 20 min using orbit shaker (lab-line instruments.inc, Model 3521, USA).²⁸ The orbit shaker was used to detach microorganism from coffee bean surfaces. Peptone water was used to make a serial dilution (1:10) for each sample. Then serial dilution was made to 10^{-3} for each samples to get appropriate number of colony which ranges from 30 to 300. From each dilutions, 1 mL of sample was pour plated on plate count agar (PCA) (Park Scientific (USA) as described in the Food and Drug Administration Bacteriological Analytic Manual.²⁹ Then the plates were incubated at 37 °C for 72 h (296, South Africa). Fresh media was utilized and its sterility was checked by overnight incubation. Quality control was used in each batch of the samples.

Colony count was made by YLN-30 lab colony counter magnifying digital display apparatus (UK) and undistinguished colonies were ignored. All distinguishable colonies were counted. The best two consecutive dilutions were used, as n_1 and n_2 to calculate the results. Total bacteria colony count was presented as organisms per milliliter of Coffee colony forming unit (CFU/mL). The average plate count was calculated using this formula:

$$N = C/V (n_1 + 0.1n_2)d$$

where C is the sum of colonies on all plates counted; V is the volume applied to each plate; n_1 is the number of plates counted at first dilution; n_2 is the number of plates counted at second dilution; and d is the dilution from which first count was obtained.

Bacteria were identified as gram negative and gram positive bacteria based on standard Gram-stain technique and microscopic observation.³⁰ Yeast and Filamentous fungi were identified based on their morphology from gram stain via microscopic observation (3H30RF200, Germany). All the stained slides

were cross checked by another microbiologist from the Ethiopian Public Health Institute. When gram negative bacteria identified in the coffee process the result was presented as “Yes” and when it was absent it was reported as “No.”

Data analysis

The data were presented using descriptive statistics. Independent t -test was used to compare mean microbial load between the two types of on farm postharvest processing of coffee and between the two study areas. The analysis was performed using SPSS version 22.³¹ Statistical significance level was set to a p -value less than 0.05.

Ethical considerations

The Institutional Review Board of the College of Health Sciences at Addis Ababa University and the National Research Ethical Review Committee of the Ethiopian Ministry of Science and Technology approved the study. Permission to conduct the study was obtained from each on farm postharvest coffee processing owners.

Results

When merging the two regions the mean microbial load in the dry process (2.0×10^5 CFU/mL; range 6.9×10^2 to 7.2×10^5 CFU/mL) did not differ significantly ($p=0.22$) from the microbial load in the wet process (9.0×10^4 CFU/ml; range 2.5×10^2 to 4.6×10^5 CFU/mL). Furthermore, there was no significance difference in microbial load between the two regions (1.7×10^5 CFU/mL versus 8.4×10^4 CFU/mL; $p=0.18$) or between the wet and dry processes within the SNNPR ($p=0.74$) or within the Oromia region ($p=0.16$) (Table 1).

Microbials identified in different stages of postharvest on farm coffee processing

Bacteria, yeast, and fungal filaments were identified in both wet and dry process in the two study regions. In the wet process, yeast cells were dominant among pulped, fermented, washed, and dried beans (Table 2).

The results indicate the presence of gram negative bacteria in almost all stages of dry process in both regions. In the wet process, gram negative bacteria were identified in coffee cherries and stored beans in both sampling periods and regions. Gram negative bacteria were identified in dried beans in one of the samples in both regions (Table 3).

Table 1. Microbial load in different stages of wet and dry coffee processing in Ethiopia.

Regions	Types of postharvest on farm processing of coffee	<i>n</i>	Coffee samples from stages of coffee processing	Aerobic plate count (CFU/mL)	<i>p</i> -value comparing dry and wet types of postharvest on farm processing of coffee
SNNPR	Dry process	2	Coffee cherries	1.8×10^5	0.74
		2	Dried beans	1.7×10^4	
		2	Stored beans	1.9×10^4	
		6	Mean for the 3 dry process	7.3×10^4	
	Wet process	2	Coffee cherries	1.0×10^5	
		2	Pulped beans	8.6×10^4	
		2	Fermented beans	2.7×10^4	
		2	Washed beans	1.2×10^2	
		2	Dried beans	1.4×10^5	
		2	Stored beans	1.9×10^5	
		12	Mean for the 6 wet process	9.0×10^4	
		Oromia	Dry process	2	
2	Dried beans			3.6×10^5	
2	Stored beans			6.2×10^5	
6	Mean for the 3 dry process			3.3×10^5	
Wet process	2		Coffee cherries	8.4×10^4	
	2		Pulped beans	2.1×10^4	
	2		Fermented beans	3.7×10^4	
	2		Washed beans	2.6×10^5	
	2		Dried beans	1.1×10^4	
	2		Stored beans	1.4×10^5	
	12		Mean for the 6 wet process	9.1×10^4	
	Both regions		Dry process	4	Coffee cherries
4		Dried beans		1.9×10^5	
4		Stored beans		3.2×10^5	
12		All in dry process		2.0×10^5	
Wet process		4	Coffee cherries	9.5×10^4	
		4	Pulped beans	5.4×10^4	
		4	Fermented beans	3.2×10^4	
		4	Washed beans	1.3×10^5	
		4	Dried beans	7.4×10^4	
		4	Stored beans	1.6×10^5	
		24	All in wet process	9.0×10^4	

Independent *t*-test were used to compare mean difference between types of postharvest processing of coffee and between regions.

Table 2. Microbial identified in different stages of postharvest on farm coffee processing.

Types of on farm postharvest processing of coffee	Stages of coffee processing	Shebedino woreda SNNPR				Yebu woreda, Oromia region			
		Gram positive	Gram negative	Yeast	Fungi	Gram positive	Gram negative	Yeast	Fungi
Dry process	Coffee fruits	×	×	×		×	×		
	Dried beans	×	×	×		×	×		×
	Stored beans	×	×			×	×	×	
Wet process	Coffee fruits	×	×		×	×			×
	Pulped beans	×	×	×	×	×		×	
	Fermented beans	×		×		×		×	
	Washed beans		×	×				×	
	Dried beans		×	×			×		×
	Stored beans	×	×			×	×		

"×" refers the presence of microorganisms indicated in the column head and the blank cells indicate the absence of microorganisms.

Discussion

This study identified bacteria, yeast, and fungal filaments at different stages of on farm postharvest coffee processing. In the last stage, the stored beans, gram negative bacteria were present in both the wet and the dry process. This is in line with the high endotoxin levels found in primary coffee production in

Tanzania, as the gram negative bacteria may produce endotoxin.

The range of colony count in our study (2.5×10^2 to 7.2×10^5 CFU/mL) was narrower than in previous studies conducted in coffee cherries of *Coffea arabica* in Brazil (3.3×10^4 to 2.2×10^9 CFU/cherry).²⁸ This might be due to differences in the study period in

Table 3. Presence of gram negative bacteria in different stages of postharvest on farm coffee processing.

Types of postharvest on farm processing of coffee	Stages of coffee processing	Presence of gram negative bacteria in the sample from Shebedino woreda SNNPR		Presence of gram negative bacteria in the sample from Yebu woreda Oromia	
		1st round	2nd round	1st round	2nd round
Dry process	Coffee fruits		×	×	×
	Dried beans	×	×	×	×
	Stored beans	×	×	×	×
Wet process	Coffee fruits	×	×	×	×
	Pulped beans			×	×
	Fermented beans				
	Washed beans	×			
	Dried beans		×	×	
	Stored beans	×	×	×	×

“×” refers the presence of gram negative and the blank cells indicate the absence of gram negative.

which both rainy and dry seasons were included in the Brazilian study while only the dry season was considered in the present study. If the present study was conducted in the rainy season of the year the microbial load reported here could also have been higher. Silva et al. found a higher level of microbial load in wet season than the dry season.²⁸ Rain may create favorable condition for proliferation of bacteria.²⁸ In addition the difference could be due to variations in harvesting, transporting, drying, and storage condition.

However, the range of microbial load in the present study was broader than previous studies in Yemeni and Saudi Arabia green coffee (0.6×10^4 to 5.5×10^4 CFU) and (19×10 to 18×10^4 CFU), respectively.^{32,33} The reasons for the difference in counts could be due to only dried beans were involved in previous studies while in this study in addition to dried beans, coffee fruits, fermented beans, and washed beans were included.

The presence of different microorganisms at different stages of wet and dry processing in our study is in line with previous studies.^{34–36} Bruyn et al. indicated that even newly harvested cherries are not free from microorganisms as they contain gram negative bacteria, fungi, and soil microorganisms.³⁷ The type of microorganism present at different stage of coffee processing depends on several factors such as sugar concentration, water activity, availability of oxygen, temperature, acidity, and time.³⁸ The presence of these microorganisms in coffee processing are associated with diverse functionalities such as the degradation of pulp pectin and the depletion of mucilage carbohydrates.^{37–39} In the wet method of coffee production, pulped, washed, and fermented beans were dominated by yeast and gram positive bacteria. This finding is in harmony with several previous studies.^{15,35,36,40} This could be due to the anaerobic or low oxygen conditions created in wet fermentation that could facilitate the development of lactic acid bacteria which in turn cause the pH to drop,

preventing the proliferation of other bacteria and favoring the growth of yeast.⁴¹

In this study, gram negative bacteria were identified in the final stages of dried and stored beans in both the wet and the dry method. This finding is consistent with Bruyn et al. who found relative abundances of gram negative bacteria over the course of drying.³⁷ However, in principle gram negative bacteria are not expected in the final stages of dried and stored beans due to the expected low moisture level at this last stage that do not favor microbial growth, particularly gram negative bacteria as they are less resistant to low moisture content.³⁶ This can be explained by the possibility of higher moisture content of the beans than recommended. The recommended moisture range of coffee beans is 11–12%. According to a study conducted in the southern part of Ethiopia more than 94.4% of the coffee farmers do not determine the exact moisture content of coffee beans for storage.⁴² Thus, a higher moisture content than recommended might be the reason for the observed gram negative bacteria development in the dried and stored beans in the present study.

A second reason could be related to environmental contamination. Generally, coffee beans should be stored in clean areas to prevent contamination of coffee beans.⁴³ However, a previous study conducted in Ethiopia indicated that 54% of coffee farmers did not have proper storage facilities.⁴² This might increase the contamination of coffee beans by gram negative bacteria. This assumption was supported by Balows et al. who found that 38.6% of the bacteria were actual or opportunistic pathogens from coffee beans.⁴⁴ Belay et al suggested that coffee beans should be stored in a place free from potential contaminants, such as cow dung, soils, and chickens.¹⁶

The presence of gram negative bacteria in dried beans and stored beans might not pose a risk to public health because of the high temperatures used during roasting. However, the presence of gram negative

bacteria in dried and stored beans might affect the coffee workers respiratory health due to endotoxin exposure when the coffee beans are further processed. In our previous study in primary coffee processing factories located in the regions where we conducted this study indicated a higher prevalence respiratory symptoms and lower lung function among coffee workers than among controls.⁸ These findings might be associated with release of endotoxin from the gram negative bacteria on the coffee beans that have been contaminated during on farm coffee processing.

Thus, endotoxin exposure in coffee processing factories can be prevented by reducing contamination of coffee beans during drying and storage.

This study assessed the contamination of coffee at different stages of on farm postharvest processing of coffee, but it was not designed to identify potential sources of coffee contamination such as quality of harvesting materials, transporting mechanism, type and quality of drying surfaces, season of the year and quality of water used to wash the coffee. Therefore, future studies should consider all these factors to identify the possible source of microbial contamination of coffee, which is important to prevent and control contamination of coffee.

The present study considered only bacterial contamination on farm. However, coffee can also be contaminated during transport of coffee from the farm to the processing factories, or even in the coffee factories coffee can be contaminated during storage, handling, and processing. Therefore, future studies should consider all chains of coffee processing to get a even clearer picture of coffee contamination. Furthermore, this study did not assess respiratory health of coffee workers at the farm. Future studies should include these health aspects. The coffee samples were not blinded for the microbiologist analyzing them, he knows where they were coming from. However, in this situation, there was no specific hypothesis on which stage or type of coffee processing that was contaminated, and a blinding was not considered necessary.

Other limitations of this study were the sampling numbers which were low, with few sampling days. Repeated sampling was conducted only on two different days from different batches of coffee. However, this study collected samples from the two main coffee growing regions of Ethiopia, and the results are likely to be representative to Ethiopian on farm postharvest processing of coffee.

Conclusion

This is the first study to study microbial contamination of coffee during coffee production. This study

found gram negative bacteria in the final stage of coffee bean production, in both a dry process and a wet process. As these bacteria might release endotoxin which may cause respiratory health problems among coffee production workers, an effort should be made to reduce the presence of these bacteria in the coffee production.

Acknowledgments

We would like to thank the coffee preprocessing facilities management teams and Addis Ababa City Administration Health Bureau Laboratory for permission to conduct the study and allow us to use their laboratory.

Competing interest

The authors declare that they have no competing interest.

Funding

This research was funded by the Norwegian Agency for Development Cooperation (Norad) through the Norwegian Program for Capacity Building in Higher Education and Research for Development (NORHED) through a research project “Reduction of the burden of injuries and occupational exposures through capacity building in low income countries” (project number: 1300646-12).

References

1. Worako TK, Van Schalkwyk HD, Alemu ZG, Ayele G. Producer price and price transmission in a deregulated Ethiopian coffee market. *Agrekon* 2008;47(4): 492–508. doi:10.1080/03031853.2008.9523812.
2. Musebe R, Agwanda C, Mekonen M. Primary coffee processing in Ethiopia: patterns, constraints and determinants. *Afr Crop Sci Conf Proc.* 2007;8: 1417–1421.
3. Uragoda CG. Acute symptoms in coffee workers. *J Trop Med Hyg.* 1988;91(3):169–172.
4. Sekimpi K, Agaba E, Okot-Nwang M, Ogaram D. Occupational coffee dust allergies in Uganda. *Afr News Occup Health Saf.* 1996;6:6–9.
5. Smith D, Brott K, Kokisource G. Respiratory impairment in coffee factory workers in the Asaro Valley of Papua New Guinea. *Br J Ind Med.* 1985;42:495–498. doi:10.1136/oem.42.7.495.
6. Sakwari G, Bråtveit M, Mamuya SHD, Moen BE. Dust exposure and chronic respiratory symptoms among coffee curing workers in Kilimanjaro: a cross sectional study. *BMC Pulm Med* 2011;11:54–61.
7. Sakwari G, Mamuya SHD, Bråtveit M, Moen BE. Respiratory symptoms, exhaled nitric oxide, and lung function among workers in Tanzanian coffee factories. *JOEM* 2013;55:544–551. doi:10.1097/JOM.0b013e318285f453.

8. Abaya S, Bråtveit M, Deressa W, Kumie A, Moen B. Reduced lung function among workers in primary coffee processing factories in Ethiopia: a cross sectional study. *Int J Environ Res Public Health* 2018; 15(11):2415.
9. Thomas K, Trigg C, Baxter P, et al. Factors relating to the development of respiratory symptoms in coffee process workers. *Br J Ind Med*. 1991;48:314–322. doi: [10.1136/oem.48.5.314](https://doi.org/10.1136/oem.48.5.314).
10. Zuskin E, Vali F, Skuri Z. Respiratory function in coffee workers. *Br J Ind Med*. 1979;36:117–122. doi: [10.1136/oem.36.2.117](https://doi.org/10.1136/oem.36.2.117).
11. Žuškin E, Kanceljak B, Skurić Z, Butković D. Bronchial reactivity in green coffee exposure. *Br J Ind Med*. 1985;42(6):415–420.
12. Oldenburg M, Bittner C, Baur X. Health risks due to coffee dust. *Chest* 2009;136(2):536–544. doi:[10.1378/chest.08-1965](https://doi.org/10.1378/chest.08-1965).
13. Žuškin E, Skurić Z, Kanceljak B, Saric M. Effects of coffee and tea dust in industrial workers. *Br Occup Hygiene Soc*. 1988;32:315–319.
14. Schwan R, Silva C, Batista L. Coffee fermentation. In: Hui Y. *Plant-Based Fermented Food and Beverage Technology*. 2nd ed. London: CRC Press; 2012.
15. Schwan R, Fleet G. Microbial activity during coffee fermentation. In: Nout R, Sarkar P. *Cocoa and Coffee Fermentations*. London: CRC Press; 2015.
16. Belay S, Mideksa D, Gebrezgiabher S, Weldemariam S. Factors affecting coffee (*Coffea arabica* L.) quality in Ethiopia: a review. *J Multidiscipl Sci Res* 2016;4: 22–28.
17. Lane S, Nicholls P, Sewell R. The measurement and health impact of endotoxin contamination in organic dusts from multiple sources: Focus on the cotton industry. *Inhalation Toxicol* 2004;16:217–229.
18. Smit L, Wouters I, Hobo M, Eduard W, Doekes G, Heederik D. Agricultural seed dust as a potential cause of organic dust toxic syndrome. *Occup Environ Med*. 2006;63(1):59–67. doi:[10.1136/oem.2005.021527](https://doi.org/10.1136/oem.2005.021527).
19. Gora A, Mackiewicz B, Krawczyk P, et al. Occupational exposure to organic dust, microorganisms endotoxin and peptidoglycan among plants processing workers in Poland. *Ann Agric Environ Med* 2009; 16:143–150.
20. Ingalls S. An endotoxin exposure in the food industry. *Appl Occup Environ Hygiene*. 2003;18(5):318–320. doi: [10.1080/10473220301372](https://doi.org/10.1080/10473220301372).
21. Schwartz D, Thorne P, Yagla S, et al. The role of endotoxin in grain dust-induced lung disease. *AM J Respir Crit Care Med*. 1995;152(2):603–608. doi: [10.1164/ajrccm.152.2.7633714](https://doi.org/10.1164/ajrccm.152.2.7633714).
22. Thorn J, Rylander R. Inflammatory response after inhalation of bacterial endotoxin assessed by the induced sputum technique. *Thorax* 1998;53(12): 1047–1052.
23. Castellan M, Olenchock A, Hankinson L, et al. Acute bronchoconstriction induced by cotton dust: dose-related responses to endotoxin and other dust factors. *Ann Intern Med*. 1984;101(2):157–163. doi:[10.7326/0003-4819-101-2-157](https://doi.org/10.7326/0003-4819-101-2-157).
24. Haglind P, Rylander R. Exposure to cotton dust in an experimental cardroom. *Br J Ind Med*. 1984;41(3): 340–345.
25. Rylander R, Haglind P, Lundholm M. Endotoxin in cotton dust and respiratory function decrement among cotton workers in an experimental cardroom. *Am Rev Respir Dis*. 1985;131:209–213.
26. Sakwari G, Mamuya SHD, Bratveit M, Larsson L, Pehrson C, Moen BE. Personal exposure to dust and endotoxin in Robusta and Arabica coffee processing factories in Tanzania. *Ann Occup Hyg*. 2012;57:173–183.
27. Abaya WS, Bråtveit M, Deressa W, Kumie A, Moen BE. Personal dust exposure and its determinants among workers in primary coffee processing in Ethiopia. *Ann Work Expo Health*. 2018;62(9): 1087–1095. doi:[10.1093/annweh/wxy079](https://doi.org/10.1093/annweh/wxy079).
28. Silva C, Schwan FR, Dias E, Wheals A. Microbial diversity during maturation and natural processing of coffee cherries of *Coffea arabica* in Brazil. *Int J Food Microbiol*. 2000;60(2–3):251–260. doi:[10.1016/S0168-1605\(00\)00315-9](https://doi.org/10.1016/S0168-1605(00)00315-9).
29. U.S. Food and Drug Administration. Bacteriological Analytical Manual (8th Edition) AOAC, Revision A, (1998). FDA Home Page (Bacteriological Analytical Manual Online, January 2001). (Chapter 3: Aerobic Plate Count) and (Chapter 18: Yeasts, Molds and Mycotoxins). FDA 2001
30. Holt JG, Krieg NR, Sneath PHA, Stanley JT, Williams ST. *Bergey's Manual of Determinative Bacteriology*. 9th ed. Baltimore, MD: Williams & Wilkins, 1994
31. SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM. 2013
32. Nogaim Q, Thabet H, Al-Qudami M, Nagi A, Al-Awdy B. Determination of microbial contamination in Yemeni green coffee. *Adv J Biol Sci Res*. 2013;1: 22–29.
33. Nasser AM. Mycotoxins Bacteriological analysis and molecular assay of some bacterial species from coffee beans in Saudi Arabia. *Bull Pharm Sci Assiut Univ*. 2008;31:345373.
34. Avallone S, Guyot B, Brillouet M, Olguin E, Guiraud P. Microbiological and biochemical study of coffee fermentation. *Curr Microbiol*. 2001;42(4):252–256. doi: [10.1007/s002840110213](https://doi.org/10.1007/s002840110213).
35. Masoud W, Cesar B, Jespersen L, Jakobsen M. Yeast involved in fermentation of *Coffea arabica* in East Africa determined by genotyping and by direct denaturing gradient gel electrophoresis. *Yeast* 2004; 21: 549–556. doi:[10.1002/yea.1124](https://doi.org/10.1002/yea.1124).
36. Silva F, Batista R, Abreu M, Dias S, Schwan F. Succession of bacterial and fungal communities during natural coffee (*Coffea arabica*) fermentation. *Food Microbiol*. 2008; 25(8):951–957. doi:[10.1016/j.fm.2008.07.003](https://doi.org/10.1016/j.fm.2008.07.003).
37. Bruyn F, Zhang S, Pothakos V, et al. Exploring the impacts of postharvest processing on the microbiota and metabolite profiles during green coffee bean production. *Appl Environ Microbiol*. 2017;83:e02398-16.
38. Poltronieri P, Rossi F. Challenges in speciality coffee processing and quality assurance. *Challenges* 2016;7:19.
39. Avallone S, Brillouet M, Guyot B, Olguin E, Guiraud P. Involvement of pectolytic micro-organisms in

- coffee fermentation. *Int J Food Sci Tech.* 2002;37(2): 191–198. doi:10.1046/j.1365-2621.2002.00556.x.
40. Masoud W, Jespersen L. Pectin degrading enzymes in yeasts involved in fermentation of *Coffea arabica* in East Africa. *Int J Food Microbiol.* 2006;110(3):291–296. doi:10.1016/j.ijfoodmicro.2006.04.030.
41. Massawe A, Lifa J. Yeasts and lactic acid bacteria coffee fermentation starter cultures. *Int J Postharvest Technol Innov.* 2010;2(1):41–82.
42. Garo G, Shara S, Mare Y. Assessment of harvest and post-harvest factors affecting quality of Arabica coffee in Gamo Gofa Zone, Southern Ethiopia. *Afr J Agric Res.* 2016;11:2157–2165.
43. Techale B, Musema A, Kasahun M. Prevalence of some coffee quality problems in Gomma Woreda, Jimma Zone. *Int J Agric Sci.* 2013;3:621–627.
44. Balows A, Trüper HG, Dworkin M, Harder W, Schleifer KH. (Eds.). *The Prokaryotes*. Berlin: Springer, 1992:4126

LETTER OF DECLARATION

I, the under signed, declared that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation, have been fully acknowledged.

Name of the student: _____

Date: _____ Signature: _____

Approval of the primary Advisor

Name of the primary advisor: _____

Date: _____ Signature: _____