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Airborne Particulate Matter Density in Traditional Bakeries of Saveh, Central of Iran, in 2020

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ABSTRACT

Introduction: High concentration of inhalable airborne particles can increase the risk of lung disease in exposed people. This study aimed to determine the respirable particulate matter (PM_5) concentration in traditional bakeries of Saveh in 2020.

Materials and Methods: This cross-sectional descriptive study was conducted among 25 bakeries where the samples were collected by cyclone and teflon filter equipped by air sampling pump. Later, the respirable particulate matter concentration was measured using gravimetric method. The collected PM_5 was scanned using a FTIR (Fourier-transform infrared spectroscopy) with regard to flour dust. In addition, size and shape of the collected PM_5 were analyzed using a scanning electron microscope (SEM).

Results: Findings showed that the Lavash bakery had the highest PM_5 concentration (9.15 mg/m^3) in comparison with two other bakeries (Sangak and Barbari). However, an inverse relationship was observed between RH and particle concentration. In addition, the results demonstrated that increasing RH decreased the particle concentration, but the relationship was not significant ($P = 0.052$, Spearman's rho = -0.393). Furthermore, Lavash bakery had the lowest average size of PM_5 (0.63 ± 0.32 µm). However, the FTIR scans confirmed that the flour dust had the predominant amount of PM_5.

Conclusion: Based on the findings, the density of respirable PM_5 has a high level in Saveh bakeries and workers are exposed to high levels of PM.

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Introduction

The inhalation of organic and non-organic airborne particles, as one of the important pollutants, leads to chronic lung diseases and affects lung function adversely [1]. Considering the importance of this issue, the research showed that that such indoor air pollution has become one of the five main threats to human health [2, 3]. Flour particles are organic particles with a complex structure including a wide range of allergic and antigenic components [4]. Many workers in various occupations such as agriculture, flour industries, pasta, silo, bakery, and confectionery industry are exposed to flour particles[4-6] that can cause serious damage to workers' respiratory system [4]. The health effects of exposure to flour dust depend on the size and concentration of the flour particles directly [7, 8]. By reducing the dimensions and increasing the concentration of flour particles, they can affect the respiratory system more significantly [8, 9]. The impact of dust on the respiratory system depends on the dust particles' type, size,

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concentration, and movability by the air [4, 6, 8]. Therefore, the impact of different types of dusts can be different in various environments [4, 10]. Bakery is a place with airborne flour particles, so the workers are frequently exposed to them [7, 8]. Exposure to wheat flour particles can lead to lung complications from simple stimulus symptoms to allergic rhinitis and occupational asthma [8, 11]. According to the American Conference of Governmental Industrial Hygienists (ACGIH)[10], the allowable density of inhaled flour particles is set at 0.5 mg/m^3 (8-h TWA) in the working environment. However, the studies conducted by the Technical Committee of Iran's Occupational Health showed that exposure to concentrations less than this recommended level could cause allergies in workers. The presence of these particles in the bakery's indoor air increases the possibility of developing different diseases in the long run. Given the central role of occupational health in sustainable development, these particles should be measured in the air of bakeries [8, 10, 12]. Khodadadi et al. studied the exposure of workers in flour mills of Hamadan province, western Iran, to the flour dust[13]. The results of this study showed that the density of inhalable particles was high in all flour factories of Hamadan province and the exposure rate was higher among workers of the flour bagging units. Soltanzadeh et al. investigated the respiratory problems caused by job exposure to flour dust among the flour mills workers in Khorasan Razavi and South Khorasan provinces [14]. The results of their study indicated that the critical factors in the prevalence of respiratory symptoms and decrease of the lung capacity—included the strategies applied by people to encounter the flour dust according to their age. Furthermore, bakery workers are often exposed to high levels of dust from flour particles, especially in the units where dough is prepared. Karjalainen et al. determined the size and concentration of airborne particles in the air of traditional Finnish bakeries [15]. They found that the number of inhalable particles was 9-15% in the nano range. Various working conditions, design, and operation of the applied equipment, such as stove/oven, dough maker, etc., can affect the number and size distribution of the airborne particles.

Considering that working with flour in traditional or hand-made bakeries can lead to flour particle suspension, the present study aimed to determine flour airborne particles in Saveh bakeries. To the best of our knowledge, no similar study has ever investigated this issue in Saveh. Hence, the present study can provide basic information on the amount of particles inhaled by the bakery workers.

Materials and Methods

Study area

Saveh city, (35.0236° N, 50.3585° E) with a height of 995 m above the sea level, is located in Markazi Province, center of Iran. The weather pattern of Saveh is warm and semi-arid with 6 to 32 °C air temperature variation; the annual average temperature is 18°C. The maximum precipitation occurs during October to May with an average of 213 mm. This city is 100 Km far from Tehran (the capital of Iran) and is the largest Industrial town in Iran. Based on the latest census (performed at 2011), 259,030 live in this city. Approximately, all people use traditional bread in forms of Lavash, Sangak, and Barbari; so, plenty of traditional bakeries exist in Saveh that make breads.

Sampling strategy

This research was conducted on 25 bakeries from 137 active bakeries of Saveh in 2020. Considering that the bakeries were located in different geographical areas of the city, the cluster sampling method was used and the air sampling was done at various time intervals and the collected particles measured gravimetrically [3]. To conduct sampling, researchers referred to bakeries at different days and hours (in the bakery shifts when referring to the air pollution laboratory was possible) randomly.

Particulate matter sampling

In the pretest, a number of bakeries were sampled (5 bakeries) to determine the concentration range of suspended particles in bakeries. A mobile sampling system and a

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gravimetrical method were used to measure the concentration of particles [6, 8, 9]. For sampling PM_5 (particles with an aerodynamic diameter ≤ 5 µm), a SKC pump (Universal PCXR4 Pump) with a flow rate of 2 liters per minute (L/m), a cyclone (Bahar Afshan Co.) with 5 µm cut-off to remove larger particles, and Teflon filters were used. To measure the indoor inhalable particles, a sampling set was placed at the breathing zone of workers (i.e., 1.5m). Concentration of the collected particles was calculated using Equation (1).

$$C = \frac{W_2 - W_1}{V} \times 10^6 \quad (1)$$

In here, C represents the concentration of particles in µg/m^3; W_1 and W_2 are the initial and secondary weight of the filter, respectively; and V is the volume of taken air in m^3. The sampling volume was standardized according to the temperature and pressure of the sampling site as well as the standard temperature and pressure. To prevent sampling errors, the pump flow rate was measured and corrected before and after each sampling series. Temperature, relation humidity (RH), and air velocity were measured on-site using a digital hygro thermometer instrument (Testoterm, Germany) and an anemometer, respectively. The filters were photographed and the size of collected particle were measured using the Nikon light microscope (model MA200).

Infrared spectrum (FTIR) and scanning electron microscopy (SEM)

In order to find the similarity of collected particles on the filters with flour particles, surface morphology and size of the FTIR and SEM were considered. The FTIR scan was performed in the range of 400-4,000 cm^{-1} using the FTIR spectrometer. The collected PM_5 on the filters were scanned without any fixation steps before FTIR scanning. All samples were placed in a desiccator to avoid interference from water-related bands. The SEM (NIKON MA200) and FTIR were located in Islamic Azad University-Saveh Branch, Saveh, Iran.

Data Analysis

Initially, the normality of data was assessed by the Kolmogorov-Smirnov and the Shapiro-Wilk tests. Since the data were not normal (Sig. value < 0.05), Spearman and Kruskal–Wallis nonparametric tests were applied to analyze the relationship between variables and bakery types, respectively. All statistical analyses were conducted using SPSS (version 21) at the significant level of 0.05.

Ethical issues

This research was approved at the research ethics committee of Saveh University of Medical Sciences, Iran with the Ethics Code of IR.SAVEHUMS.REC.1398.018.

Results

In this study, temperature, air velocity, RH, and particle concentration were measured. The measured values for each parameter are represented in Table 1. According to the table, the means of temperature, air velocity, RH, and concentration of particles were 36.69 °C, 0.16 m/s, 25.90%, and 8.08 mg/m^3, respectively. In 19 bakeries, the air velocity was zero at sampling sites. In other six bakeries, the value of this parameter was ≥ 0. Since the data were not normal, the statistical test of Spearman was used to investigate the relationship between the studied variables (particle concentration, temperature, RH, and air velocity). The Mann–Whitney test showed no significant relation between air velocity and particle concentration ($P = 0.7$). However, an inverse relationship was observed between RH and particle concentration. In addition, the results showed that increased RH decreased the particles' concentration, but it was not significant ($P = 0.052$, $r_s = -0.4$).

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Table 1: The parameters of temperature, air velocity, RH, and particle concentration

Parameters	Samples	Min	Max	Mean ± SD
Temperature (°C)	25	29.9	39.6	39.69 ± 2.43
Air velocity (m/s)	25	0.00	2.6	0.16 ± 0.53
RH (%)	25	2.42	16	25.9 ± 7.06
Particle(mg/m^3)	25	0.52	13.75	8.07 ± 3.81

A direct relationship was found between the particle concentration and temperature. Conversely, an inverse and significant relationship was observed between particle concentration, air velocity, and RH. As Table 2 illustrates, a positive correlation was observed between particle concentration and temperature (correlation value = 0.21), while a negative correlation was observed between particle concentration, air velocity, and RH (-0.12 and -0.4, respectively). Additionally, the relationship of particle concentration with temperature, air velocity, and RH was not significant.

Table 2: The correlation between the measured parameters using the Spearman test

Parameters	particle(mg/m^3)	Temperature (°C)	Air velocity (m/s)	RH (%)
Particle(mg/m^3)	1 -	0.21 0.314	-0.12 0.574	-0.4 0.052
Temperature (°C)	0.214 0.31	1 -	-0.009 0.97	-0.79** 0.00
Air velocity (m/s)	-0.12 0.57	-0.009 0.97	1 -	-0.206 0.32
RH (%)	-0.4 0.052	-0.79** 0.00	-0.21 0.32	1 -

**The level of 0.01 select as the correlation level

Table 3 shows the concentration of particles regarding the type of bakery. The Kruskal–Wallis test indiacted that the particle concentration among the bakeries have not significant difference.

Table 3: The concentration of suspended particles (mg/m^3) in bakeries regarding bread type

Bakery type	samples	Particle concentration(mg/m^3)	Particle diameter (µm)
Barbari	10	7.36 ± 4.61	2.26 ± 2.98
Sangak	5	7.36 ± 4.47	1.04 ± 0.54
Lavash	10	9.15 ± 2.57	0.63 ± 0.32
Total	25	8.08 ± 3.2	1.31 ± 1.28

Considering Figures 1 a and b, the sampled air particles of Lavash bakeries are more homogeneous in size than the other two types. In addition, they are nearly spherical. However, the air particles in Sangak and Barbari bakeries have irregular and non-spherical shapes.

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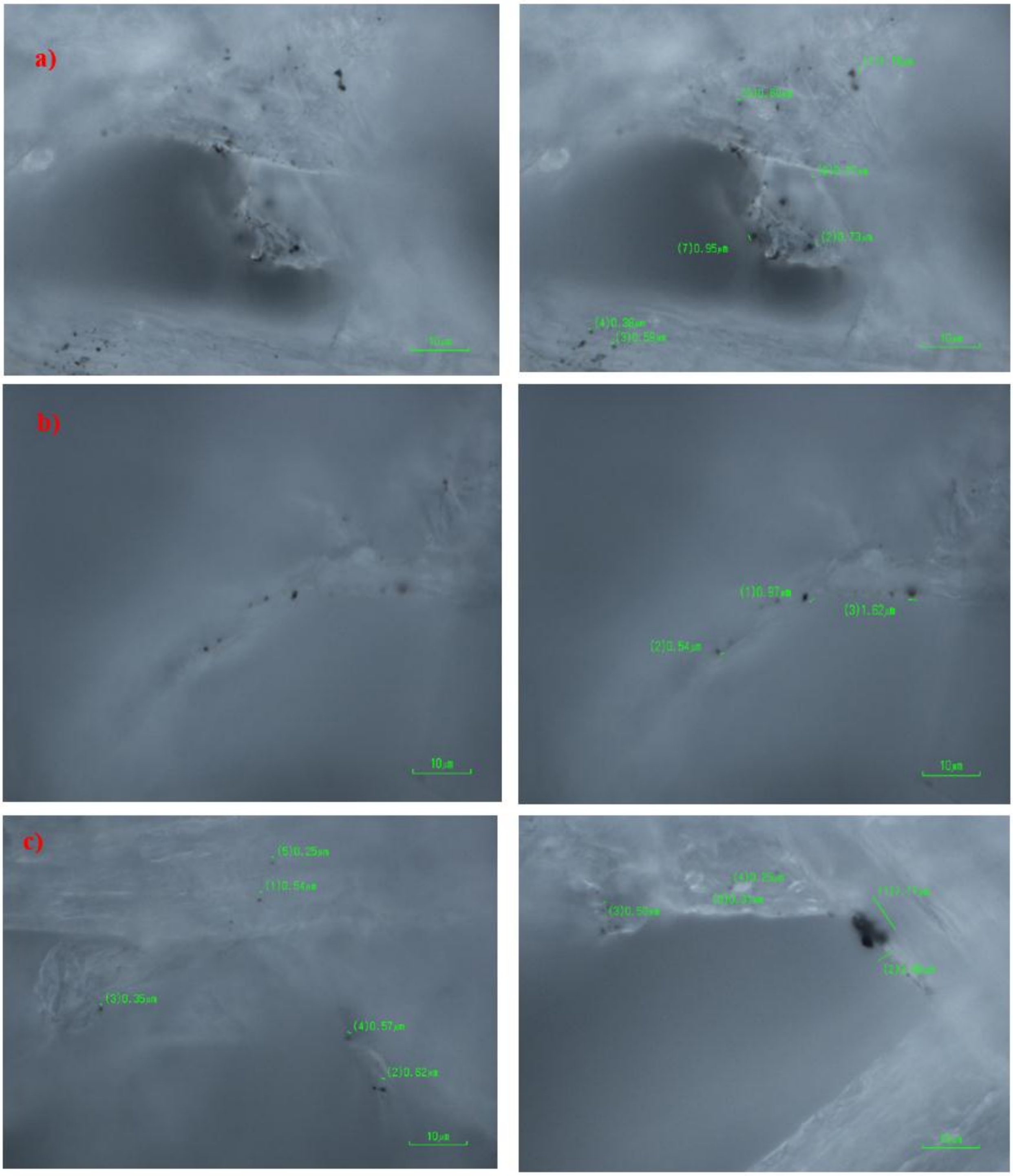

Figure 1: SEM Photos (NIKON MA200 with magnification of X1000) of the collected particles filtered in studied bakeries: a) Lavash, b) Barbari and c) Sangak

Figure 2a shows the FTIR spectra with regard to the particles collected from all three types of bakeries. Given that the flour particles suspend in the air during the baking process, the FTIR of the suspended particles was compared with the FTIR of the flour (Figure 2b). It can be concluded that the FTIR spectrum obtained for Lavash is more in accordance with the flour FTIR spectrum.

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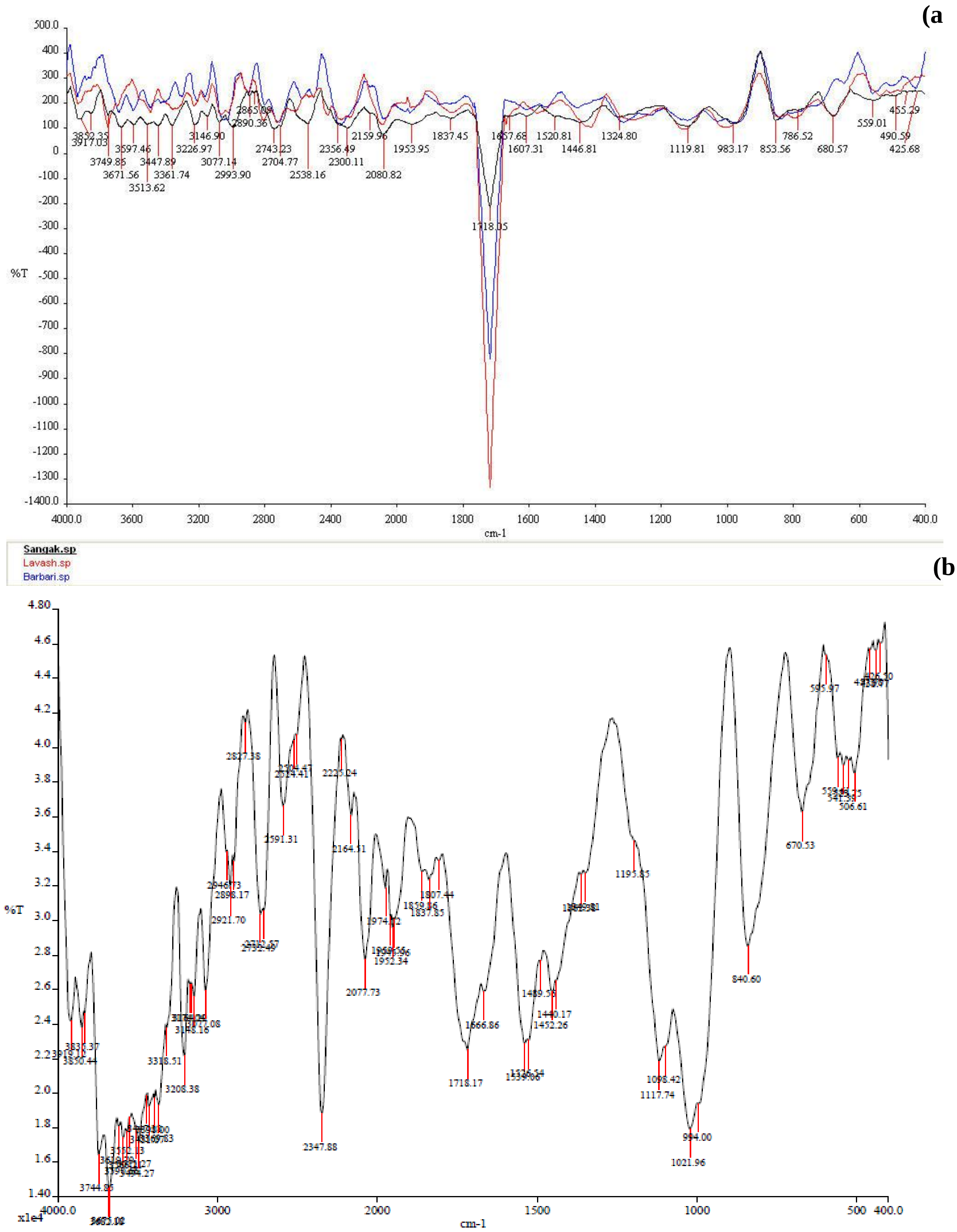

Figure 2: FTIR spectrum (Derkin Elmer_RXI): a) for particles collected on filter for all three bakeries of Sangak, Lavash, and Barbari; b) flour particles

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Discussion

In this study, PM_5 concentration was determined in Saveh's traditional bakeries. According to the findings, the mean temperature, air velocity, RH, and concentration of particles were 36.69 °C, 0.16 m/s, 25.90%, and 8.08 mg/m^3, respectively. Atabaki et al. showed that precipitation and RH had an inverse effect on the concentration of PM_5. However, increased temperature and wind speed increased the concentration of suspended particles. In the present study, RH and air velocity had an inverse relationship with particulate concentration. By increase of RH, the particles stuck together to form larger particles; as a result, they fell under the force of gravity and were separated from the air stream [10]. According to the measurements, Lavash bakeries had the highest concentration of suspended particles; 9.15 mg/m^3. According to the findings, the amount of suspended particles in Lavash bakeries was more than the other two types of bakeries. In other words, workers of Lavash bakeries are more exposed to particulate matter than Sangak and Barbari bakeries. Based on the results (Table 1), the exposure of bakery staff to inhalable particles was 8.308 mg/m^3, which is higher than the allowable threshold (TLV = 0.5 mg/m^3). The results of a study by Khodadadi et al. indicated that the concentration of inhalable particles was too high in all flour factories of Hamadan province and workers in flour bagging units were more exposed to the particles than other units [13]. Air flow velocity at the sampling site can be considered as one of the protection methods since the suspended particles in the air can be reduced by a proper ventilation system. Moreover, the positive pressure from ventilation can prevent the entry of suspended particles caused by other external processes adjacent to the bakery such as traffic. As Table 3 illustrates, the particles were in different sizes (from about nanometers to microns). The size of the particles collected in the Lavash bakery was smaller than the size of particles in Sangak and Barbari bakeries; so, these particles can easily enter the human respiratory tract. Consequently, workers of the Lavash bakeries may show high respiratory symptoms (cough, sputum, loud breathing, wheezing, and shortness of breath) as well as decreased respiratory capacity. Karjalainen et al. found the most of suspended particles in the nanoscale range. Presence of the suspended particles in the bakeries' air is due to the suspension of flour particles in the air [4, 12, 15]. This can be justified by mentioning that bran is necessary in the flour used in Barbary and Sangaki bakeries. Another reason for obtaining the present result is the regional location of the bakery, which can be affected by the activities performed near the bakery. The particles resulted from other sources could enter the bakery and collected on the filter as a particulate matter. Proximity of the bakery to the traffic can be one of these factors. However, in this study, the source and type of the suspended particles were not investigated and could not be stated with certainty. Soltanzadeh et al, reported that exposure to flour dust and workers' age were among the most effective factors in the prevalence of respiratory symptoms that decreased the workers' lung capacity.

Conclusion

The findings showed the high concentration of PM_5 in the air of Saveh bakeries. Presence of PM_5 was higher in the air of Lavash bakeries than the Sangak and Barbari bakeries, but its size was smaller. The shape of PM_5 in the air of Lavash bakeries was similar to spherical particles and had a higher homogeneous size distribution. In terms of diameter, PM_5 in Lavash bakeries had smaller particles than Sangak and Barbari bakeries. The results showed a positive correlation between PM_5 concentration and air temperature while particle concentration had an inverse relationship with air velocity and RH. Additionally, this study is the first research conducted on the PM_5 of Iranian traditional bakeries. The findings showed that the amount of PM_5 was higher than the threshold level in the air of Lavash bakeries. More studies are required to investigate PM sizes and their associated health effects on humans. Furthermore, clinical examinations, such as chronic obstructive pulmonary disease must be conducted to better understand the effect of airborne flour dusts on the studied population. A proper monitoring and

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correcting surveillance system can be developed in bakeries to establish the workers' safety and the health. In a broad sense, implementing programs such as installing a proper ventilation system is also required to reduce inhalable suspended particles. Moreover, workers should be instructed to use appropriate masks during activity.

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Conflict of interest

The authors declare no competing financial interests or personal relationships that could influence this study.

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