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Sick Building Syndrome symptoms and perceived indoor air quality among home based food business operators

Eliani Ezani[1,2*], Akmal Khuzaifi Khairuddin[1], Muhammad Yasir Iman Mohd Yusri[1], Darpan Das[3] and Mimi H. Hassim[4]

*Correspondence:
Eliani Ezani
elianiezani@upm.edu.my
[1]Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia
[2]Institut Ekosains Borneo (IEB), Universiti Putra Malaysia Sarawak, Jalan Nyabau, 97000 Bintulu, Sarawak, Malaysia
[3]Department of Environment and Geography, University of York, York, UK
[4]Safety and Health Research Group/UTM-MPRC Institute for Oil and Gas, Universiti Teknologi Malaysia, UTM Johor Bahru, 81310 Johor Bahru, Johor, Malaysia

Abstract

Objective This study examines Sick Building Syndrome (SBS) symptoms and their associations with socioeconomic factors, housing conditions, and perceived indoor air quality (IAQ) among home-based food business operators.

Methods A cross-sectional survey was conducted among 262 home-based food business operators in the Klang Valley, Malaysia, using convenience sampling through community networks and online platforms. The validated MM040 questionnaire was used to assess three SBS symptom domains (general, mucosal, and dermal), along with demographic characteristics, household conditions, socioeconomic status, and perceived IAQ indicators (dry air, humid air, dusty air, and mouldy smell). Associations were examined using chi-square tests, Spearman correlations, and multivariable logistic regression.

Results Participants had a mean age of 36 years (SD 10.9), and 61.5% were women. The majority reported at least one SBS-related symptom. Fatigue (67.2%) and heavy headache (66.4%) were the most common general symptoms, while dry throat (65.3%) and eye irritation (64.1%) were the most frequently reported mucosal symptoms; dermal symptoms were less common. Women, married operators, and those in the lower-income (B40) group reported higher rates of mucosal symptoms, while participants in the middle-income (M40) group had a higher prevalence of dermal symptoms. Smaller households were associated with an increased prevalence of mucosal complaints. Selected perceived IAQ indicators, particularly indoor humidity, were significantly associated with SBS symptom domains.

Conclusion To our knowledge, this study is one of the first to examine SBS symptoms among home-based food business operators, a rapidly expanding yet understudied segment of the informal economy. The findings indicate a notable burden of SBS-related symptoms associated with gender, socioeconomic position, and residential environmental conditions. Given their reliance on domestic kitchens repurposed as workspaces, these operators constitute a previously under-recognised occupationally exposed population. Improving ventilation practices and strengthening occupational health measures are important for reducing exposure-related health risks in this workforce.

Keywords Home-based food business, Housing conditions, Indoor air quality (IAQ), Cooking, Socioeconomic factors, Sick Building Syndrome (SBS)

1 Introduction

People spend approximately 90% of their time indoors, where exposure to pollutants is influenced not only by emission sources, ventilation, and building characteristics, but also by individual demographic factors and occupants' behaviours. These conditions have been linked to Sick Building Syndrome (SBS), a term first described by the World Health Organization in 1983 [40]. SBS can be experienced by individuals in a specific indoor environment, with symptoms that typically improve or disappear once they leave. These symptoms are commonly classified into three categories: general symptoms, including headaches and fatigue; respiratory symptoms, such as sore throat and nasal congestion; and skin-related symptoms, including rashes and irritation [7].

In addition to physical and behavioural factors, social determinants have been identified as significant contributors to the SBS risk [1]. Specifically, Barmark [6] found that education level and employment status play important roles in determining the likelihood of developing SBS in residential settings. Moreover, disadvantaged housing conditions, such as public rental housing in Singapore, have been shown to directly affect health outcomes, including increased hospital re-admissions and healthcare utilization [25]. Poor indoor air quality (IAQ) has also been closely linked to SBS, as various indoor pollutants can directly affect the respiratory and mucosal systems. Key contaminants such as particulate matter (PM), volatile organic compounds (VOCs), formaldehyde, carbon monoxide nitrogen dioxide and bioaerosols are known to cause mucosal irritation, inflammatory responses and oxidative stress [33]. These physiological reactions contribute to the development of SBS symptoms, including headaches, eye and throat irritation, fatigue and difficulty concentrating [47].

Occupants' perceptions of indoor air quality (IAQ) are important, as they influence how individuals interpret and experience the indoor spaces they inhabit. These perceptions are shaped by routine, repetitive daily activities within households or workplaces, where indoor air pollutants can be generated across varying temporal and spatial scales, potentially contributing to adverse health effects [54]. Building on this, previous studies have examined the association between IAQ perception and SBS across a range of settings, including residential environments [46], schools [4] and office buildings [39]. These studies commonly rely on respondents' subjective ratings of IAQ using perceptual indicators as practical qualitative proxies when objective measurements are unavailable [22]. Typically, the MM040 Questionnaire has been used as a qualitative tool to assess perceptions of IAQ in previous studies [22, 32, 46].

SBS has been extensively studied in offices [56], hospitals [44], and schools [27], but little is known about other indoor settings. Cooking is a major contributor to indoor air pollution in residential environments, with studies showing that pollutant concentrations in domestic kitchens can exceed health-based guidelines. Previous research on indoor exposures from food preparation has primarily focused on commercial kitchens, where high cooking volumes and limited ventilation contribute to elevated concentrations of PM and VOCs [31, 11]. However, domestic kitchens are increasingly recognised as important sources of exposure, particularly when these spaces are used intensively for food production. In Malaysia, Mahamud et al. [26] found that indoor $PM_{2.5}$ during cooking reached 75 μg/m³ and exhibited higher cytotoxicity than outdoor particles, while Tang and Pfrang [48] demonstrated that cooking in compact student studio flats exposed residents to prolonged PM emissions, with deep-frying generating the highest PM_{10} concentrations (up to 236 μg/m³). These findings highlight that small or poorly ventilated kitchens can create significant exposure risks.

This evidence is particularly relevant in the context of the growing gig economy and informal food sector, which has driven a surge in home-based food businesses, especially in the Global South [9, 38]. These businesses, often operated by women, retirees, or low-income households, rely heavily on residential kitchens where work and living spaces overlap [8, 17, 37]. Converting domestic kitchens into commercial workspaces may intensify exposure to environmental and occupational hazards, yet this population has been largely overlooked in research and policy. To address this gap, this study surveyed 262 home-based food business operators in the Klang Valley, Malaysia, to examine Sick Building Syndrome (SBS) symptoms and their associations with socioeconomic factors, housing conditions and perceived indoor air quality (IAQ).

2 Methodology

2.1 Study design and study location

This cross-sectional study examined indoor air quality (IAQ) and Sick Building Syndrome (SBS) symptoms among home-based food business operators in the Klang Valley, Malaysia. The Klang Valley encompasses Kuala Lumpur, Putrajaya, and Selangor (Fig. 1), representing Malaysia's most urbanised region, with reported urbanisation rates of 100% in Kuala Lumpur and Putrajaya, and 95.8% in Selangor [12]. The region was selected for its high concentration of home-based food businesses and diverse urban residential environments, making it a suitable setting for investigating IAQ in mixed residential-commercial settings. Data from the Ministry of Health Malaysia show a substantial number of registered home-based food operators across Kuala Lumpur, Putrajaya, and Selangor [30].

2.2 Participants and recruitment

The study population consisted of primary operators of home-based food businesses that utilised residential kitchens for commercial purposes. Inclusion criteria were: (1) age ≥ 18 years; (2) business operations from a residential kitchen ≥ 5 days per week; and (3) business established for >6 months. Exclusion criteria were (1) businesses operating exclusively from commercial kitchens and (2) operators with pre-existing respiratory or cardiovascular diseases that could confound SBS symptom reporting. The minimum required sample size was calculated using G*Power 3.1 for logistic regression, assuming a medium effect size (odds ratio ≈ 1.5), a significance level of $\alpha = 0.05$, and a power of 0.80 ($1 - \beta$). This calculation indicated a minimum of 196 respondents. To account for potential non-responses, a larger sample was targeted through community networks and online platforms, resulting in 262 completed surveys and ensuring adequate statistical power. Participants were recruited using a convenience sampling approach through community networks and online platforms. Specifically, study invitations were disseminated via widely used social media applications in Malaysia, including *Telegram*, *WhatsApp* and *Facebook* targeting groups and pages related to home-based food businesses.

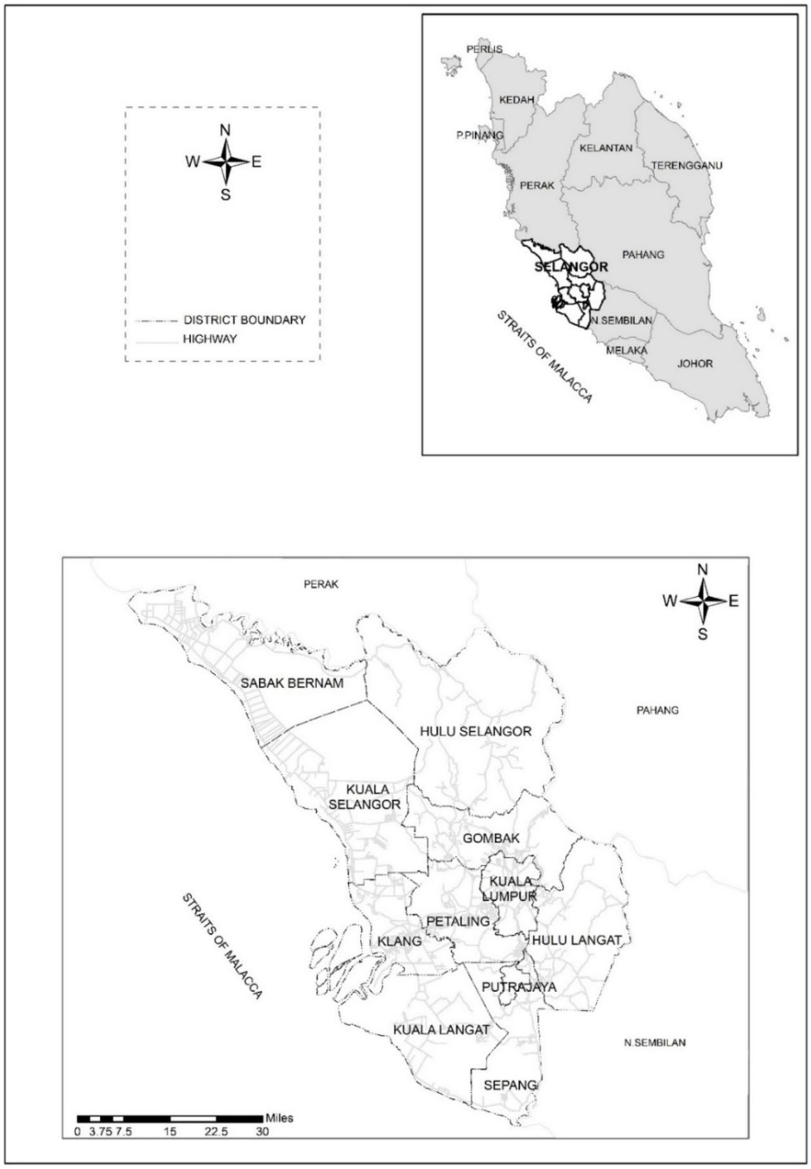

Fig. 1 Klang Valley study region (top), covering Kuala Lumpur, Putrajaya, and Selangor (bottom), where all 262 home-based food business operators were recruited

Interested participants accessed the survey through an online link via Google form and provided informed consent prior to participation.

2.3 Questionnaire

SBS-related symptoms were assessed using the MM040 questionnaire, adapted from the Swedish Miljömedicin Questionnaire [5]. Participants were asked: "*Over the past three months, have you experienced any of the following symptoms while indoors*?" The questionnaire included 12 symptoms grouped a priori into three symptom domains: general symptoms (fatigue, heavy headache, nausea, difficulty concentrating), mucosal symptoms (eye irritation, irritated nose, dry throat, cough), and dermal symptoms (dry facial skin, itching scalp, dry hands). Only the symptom-related items from the MM040 questionnaire were used in this study. Demographic characteristics, job-related information, and perceived IAQ indicators were collected using additional questionnaire items developed for this study. Responses were recorded on a three-point scale ("often every week", "sometimes", "never"), and responses of "often every week" or "sometimes" were classified as positive for symptom presence within the respective domain. The assessed symptoms correspond to symptom types widely recognised in the literature as clinically relevant indicators of SBS [5, 20]. However, the analyses were based on domain-level symptom reporting rather than on a clinical diagnosis of SBS. The primary outcomes of the study were pre-specified as the prevalence of symptoms within each symptom domain, while individual symptoms were examined descriptively to characterise symptom patterns. For analysis, prevalence was defined as reporting one or more symptoms within each SBS symptom domain during the three-month recall period and does not represent a clinical diagnosis. The questionnaire collected demographic characteristics, job-related information, kitchen-related characteristics (including type of cooking appliance [electric, LPG, electric–LPG] and cooking device [oven, stove, mixed]), and perceived IAQ, including key variables such as age, gender, housing characteristics, type of food business, experience, and cooking-related activities, with IAQ assessed using a five-point Likert scale (dry, humid, stuffy, dusty, and mouldy air). Perceived IAQ indicators were treated as ordinal variables, with higher scores reflecting poorer perceived indoor air quality. These indicators were selected to operationalise indoor air conditions in domestic kitchens, where objective monitoring was not feasible within the study scope.

Socioeconomic status was measured using Malaysia's nationally recognised household income classification system. Households are stratified into three income tiers: the Bottom 40% (B40), Middle 40% (M40), and Top 20% (T20), based on national household income distribution. The B40 group comprises households earning ≤ RM4,360 per month (≈ USD 930), the M40 group earns RM4,361–RM9,619 per month (≈ USD 930–2,050), and the T20 group earns ≥ RM9,620 per month (≈ USD 2,050). The B40 group represents lower-income households, generally associated with more constrained resources and increased vulnerability to environmental exposures. The M40 group reflects middle-income households with moderate but stable resources, while the T20 group represents higher-income households with greater financial security and living standards [50]. This classification is widely used in Malaysian health and social research to identify socioeconomic disparities and was adopted in this study to examine potential links with SBS symptoms.

2.4 Statistical analysis

All analyses were conducted using SPSS version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics summarised demographic characteristics and the prevalence of SBS symptoms. Chi-square tests were used to examine unadjusted associations between SBS symptom domains and participant characteristics. Spearman correlation was used to assess relationships among perceived IAQ indicators. Binary logistic regression models were applied separately for each SBS symptom domain (general, mucosal, and dermal) to estimate adjusted independent associations. Variables with $p < 0.10$ in bivariate analyses were included in the initial models, and backward stepwise elimination was used to identify significant predictors ($p < 0.05$).

The dependent variables were defined as the presence or absence (yes/no) of SBS-related symptoms within each domain (general, mucosal, and dermal). Independent variables included sociodemographic characteristics (age, gender, marital status, household size, and socioeconomic status), occupational characteristics (type of food business, years of experience, cooking duration and frequency), kitchen characteristics (type of cooking appliance and kitchen setup), lifestyle factors (smoking status), and perceived IAQ indicators (dry, humid, stuffy, dusty, and mouldy air). These variables were considered potential predictors and confounders in the regression models.

3 Results

3.1 Participant characteristics

A total of 262 home-based food business operators completed the survey. Table 1 summarizes the sociodemographic data of our respondents. The sample was predominantly female (61.5%) with a mean age of 36 ± 10.9 years. Most participants were Malay (68.3%) and resided in urban areas of Kuala Lumpur (39.3%) and Selangor (41.9%). The majority lived in high-rise apartments (55.7%) and in households with 3–5 occupants (48.5%). For the occupational characteristics, 54.2% operated bakeries, while 45.8% managed other Asian-cuisine businesses. Most participants (73.7%) had less than five years of experience running a home-based food business, and only 10.3% had more than 15 years of experience. Regarding cooking duration, 50.4% of participants reported cooking more than 4 h per day, while 37.4% cooked between 2 and 4 h and 12.2% cooked 1 to 2 h per day. Additionally, 75.2% reported cooking more than three times per day. Socioeconomic classification indicated that 59.3% belonged to the lower-income B40 group, 36.1% to the middle-income M40 group, and 4.6% to the higher-income T20 group.

3.2 Prevalence of SBS symptoms

Overall, SBS-related symptoms were commonly reported (Fig. 2). Among general symptoms, fatigue (67.2%) and heavy headache (66.4%) were the most frequently reported. Mucosal symptoms were also prevalent, particularly dry throat (65.3%) and eye irritation (64.1%). Dermal symptoms were less frequently reported overall, although dry hands (59.9%), dry facial skin (35.9%), and itchy scalp (30.9%) were notable.

Stratified analyses by sociodemographic characteristics identified several differences in symptom prevalence (Table 2). Women and married respondents reported a higher prevalence of mucosal symptoms ($p = 0.024$ and $p = 0.026$, respectively). Dermal symptoms were reported more frequently among respondents in the M40 group (32.8%) than in the B40 group (16.1%; $p = 0.014$). Household size was also associated with mucosal symptoms, with 85.4% of respondents living in smaller households (1–2 occupants) reporting at least one mucosal symptom ($p = 0.009$).

No significant differences in symptom prevalence were observed by business type (bakery versus homemade; $p > 0.05$). In contrast, kitchen characteristics were associated with symptom reporting. Symptom prevalence varied across cooking appliance categories, with a higher prevalence of mucosal symptoms among respondents using electric appliances (91.5%) than among those using LPG (67.4%; $p < 0.001$). Dermal symptoms also varied across cooking device categories ($p = 0.011$), with a higher prevalence among respondents using mixed cooking devices (25.1%) than among stove-only users (6.9%). Smoking status was inversely associated with general symptom reporting in descriptive analyses, with smokers reporting fewer general symptoms than non-smokers (27.9% vs. 44.3%, $p = 0.022$).

Table 1 Demographic of the food business operators in Klang Valley, Malaysia ($n = 262$)

Demographic	Total, *n* (%)
Gender	
Male	101 (38.5)
Female	161 (61.5)
Age groups	Mean = 36 ± 10.9
18–30	95 (36.3)
31–45	106 (40.5)
46 and above	61 (23.3)
Ethnicity	
Malay	179 (68.3)
Non-Malay	83 (31.7)
Residence	
Kuala Lumpur	103 (39.3)
Selangor	126 (41.9)
Putrajaya	33 (12.6)
Type of housing	
High rise	146 (55.7)
Low rise	116 (44.3)
Number of occupants	
1–2	82 (31.3)
3–5	127 (48.5)
6 and above	53 (20.2)
Type of food business	
Bakery	142 (54.2)
Asian	120 (45.8)
Years of working experience	
Less than 5 years	193 (73.7)
5–15 years	42 (16.0)
More than 15 years	27 (10.3)
Cooking time (per day)	
1 to 2 h	32 (12.2)
2 to 4 h	98 (37.4)
More than 4 h	132 (50.4)
Number of cooking activities (per day)	
Less than 3 times	65 (24.8)
More than 3 times	197 (75.2)
Socioeconomic status[1]	
RM 4, 360 and below per month (B40)	155 (59.3)
Between RM4, 361 - RM 9, 619 (M40)	95 (36.1)
RM 9, 620 and above (T20)	12 (4.6)

[1]Household income groups in Malaysia are classified by the Department of Statistics Malaysia (DOSM) into three categories: Bottom 40% (B40), with a monthly household income of RM4,360 and below (≈USD 930); Middle 40% (M40), RM4,361–RM9,619 (≈USD 930–2,050); and Top 20% (T20), RM9,620 and above (≈USD 2,050).

To contextualise the observed prevalence of SBS symptom domains, comparisons were made with previous studies conducted in distinct indoor environments, including commercial settings [22] and residential populations [32], which employed comparable symptom-based assessment approaches. Table 3 presents a comparative baseline of SBS symptom-domain prevalence between our study and previous research. General symptoms were reported by 36.6–50.7% of participants, which is lower than the 50–70% range reported by Kim et al. [22] among store workers in underground shopping centres, but higher than the 8.0% prevalence reported by Nakayama et al. [32] in a residential pre-SBS risk population. Mucosal symptoms were reported by 67.4–100% of participants,

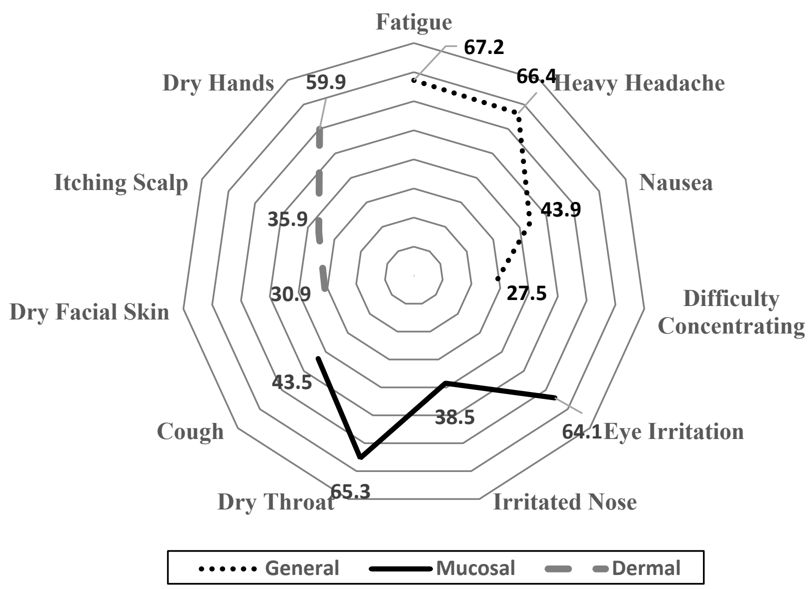

Fig. 2 Prevalence of Sick Building Syndrome (SBS) symptoms among home-based food business operators ($n = 262$)

exceeding the ranges reported in both Kim et al. [22] (40–70%) and Nakayama et al., (7.2–13.1%). Dermal symptoms were reported by 16.1–32.8% of participants, which is lower than the 30–45% range reported by Kim et al. [22]. These comparisons indicate that mucosal symptoms were reported more frequently among home-based food business operators than in the reference studies.

3.3 Perceived Indoor Air Quality

Several perceived indicators of indoor air quality were weakly but significantly correlated (Table 4). Dry air showed significant correlations with stuffy air ($r = 0.16$, $p < 0.05$), dusty air ($r = 0.15$, $p < 0.05$), and mouldy air ($r = 0.23$, $p < 0.01$). Humid air was weakly correlated with mouldy air ($r = 0.15$, $p < 0.05$). Stuffy air, used as an indicator of inadequate ventilation, was significantly associated with perceived dry air but showed no meaningful correlations with other IAQ indicators.

3.4 Associations between perceived IAQ, sociodemographic and SBS symptoms

The regression models included perceived IAQ indicators (dry, humid, stuffy, dusty, and mouldy air), adjusted for sociodemographic, occupational, kitchen-related, and lifestyle variables as potential confounding factors. Multivariable logistic regression analyses (Fig. 3) showed that perceived indoor humidity was independently associated with higher odds of general symptoms (AOR = 3.10, 95% CI = 1.22–7.91, $p = 0.017$). Socioeconomic status was also independently associated with general symptoms, with respondents in the M40 group having higher odds compared with those in the B40 group (AOR = 1.95, 95% CI = 1.06–3.62, $p = 0.033$). Although descriptive analyses indicated lower reporting of general symptoms among smokers, adjusted analyses showed that smoking status was independently associated with higher odds of general symptoms after controlling for potential confounders (AOR = 2.30, 95% CI = 1.17–4.51, $p = 0.015$).

Table 2 Characteristics of home-based food business operators and prevalence of Sick Building Syndrome (SBS) symptom domains ($n = 262$)

Demographic	Total	General Symptoms	*p*	Mucosal Symptoms	*p*	Dermal symptoms	*p*
Gender							
Male	101	47(46.5%)	0.112	85(84.2%)	**0.024**	22(21.8%)	0.804
Female	161	59(36.6%)		116(72.0%)		33(20.5%)	
Age							
18–40	165	68(41.2%)	0.781	124(75.2%)	0.736	38(23.0%)	0.473
41–55	87	35(40.2%)		69(79.3%)		16(18.4%)	
56 and above	10	3(30.0%)		8(80.0%)		1(10.0%)	
Marital							
Married	166	67(40.4%)	0.967	120(72.3%)	**0.026**	35(21.1%)	0.962
Single	96	39(40.6)		81(84.4.%)		20(20.8%)	
Socioeconomic							
B40	180	66(36.7%)	0.134	134(74.4%)	0.078	29(16.1%)	**0.014**
M40	67	34(50.7%)		52(77.6%)		22(32.8%)	
T20	15	6(40.0%)		15(100%)		4(26.7%)	
Household size							
1–2	82	31(37.8%)	0.787	70(85.4%)	**0.009**	20(24.4%)	0.575
3–5	127	54(42.5%)		86(68.5%)		26(20.5%)	
6 and above	53	21(39.6%)		44(83.0%)		9(17.0%)	
Type of business							
Bakery	142	61(43.0%)	0.370	114(80.3%)	0.138	26(18.3%)	0.246
Homemade	120	45(37.5%)		87(72.5%)		29(24.2%)	
Type of kitchen							
Electric	117	45(38.5%)	0.225	107(91.5%)	**0.000**	30(25.6%)	0.130
LPG	138	56(40.6%)		93(67.4%)		25(18.1%)	
Electric-LPG	7	5(71.4%)		1(14.3%)		0 (0.0%)	
Cooking device							
Oven	29	13(44.8%)	0.747	24(82.8%)	0.248	7(24.1%)	**0.011**
Stove	58	25(43.1%)		40(69.0%)		4(6.9%)	
Mix	175	68(38.9%)		137(78.3%)		44(25.1%)	
Smoking status							
Yes	61	17(27.9%)	**0.022**	47(77.0%)	0.944	14(23.0%)	0.668
No	201	89(44.3%)		154(76.6%)		41(20.4%)	

Prevalence reflects reporting of one or more symptoms within each SBS symptom domain during the three-month recall period and does not represent a clinical diagnosis

Table 3 Comparative baseline prevalence of Sick Building Syndrome (SBS) from previous studies and our study

Study	Study population	General (%)	Mucosal (%)	Dermal (%)	Key findings/summary
Ezani et al. [14] Present study	Home-based food business operators (Malaysia)	36.6–50.7	67.4–100	16.1–32.8	Higher prevalence of mucosal symptoms compared with previous studies, with general symptoms at intermediate levels and dermal symptoms lower than those reported in commercial indoor settings
Kim et al. [22]	Underground shopping centre workers (Korea)	50.0–70.0	40.0–70.0	30.0–45.0	Higher prevalence of general and dermal symptoms reported in enclosed commercial environments, with comparatively lower mucosal symptom prevalence
Nakayama et al. [32]	General population (Japan)	8.0	7.2–13.1	–	Lower prevalence of SBS-related symptoms across domains in a general population residential setting

Table 4 Spearman correlation coefficients among perceived indoor air quality (IAQ) indicators among home-based food business operators ($n = 262$)

Perceived IAQ	Dry air	Humid air	Stuffy air	Dusty air	Mouldy air
Dry air	1.00	0.10	0.16*	0.15*	0.23**
Humid air	0.10	1.00	0.05	−0.04	0.15*
Stuffy air	0.16*	0.05	1.00	0.04	0.02
Dusty air	0.15*	−0.04	0.04	1.00	0.07
Mouldy air	0.23**	0.15*	0.02	0.07	1.00

*p < 0.05

**p < 0.01

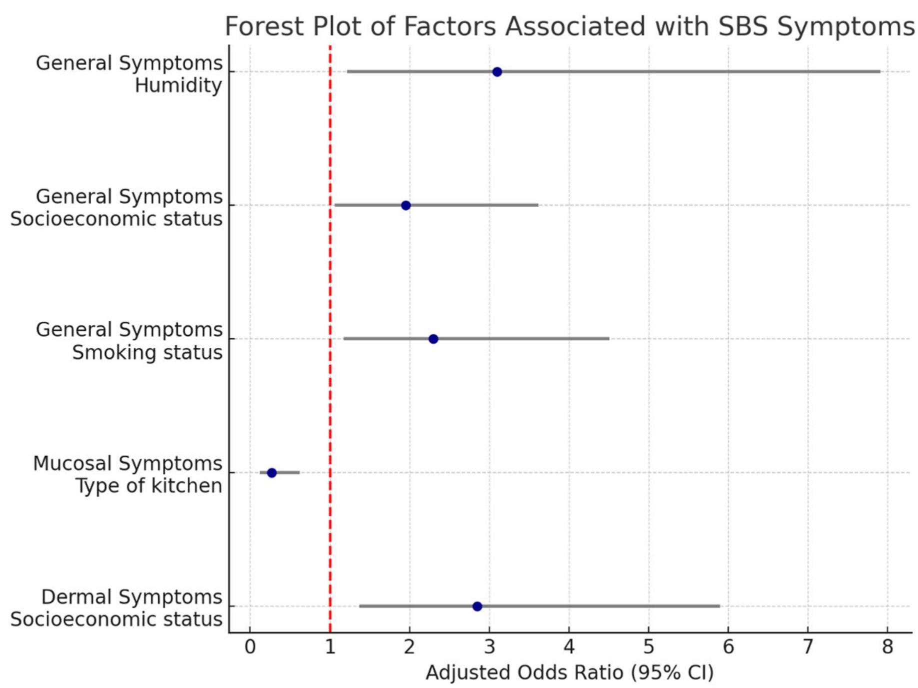

Fig. 3 Adjusted Odds Ratios (AORs) and 95% Confidence Intervals for indoor air quality perceptions and sociodemographic factors associated with general, mucosal, and dermal Sick Building Symptoms (SBS) among home-based food business operators in Klang Valley, Malaysia

For mucosal symptoms, kitchen type was independently associated with symptom occurrence. While electric appliance users exhibited a higher unadjusted prevalence, multivariable analyses showed lower odds of mucosal symptoms among respondents using electric or mixed kitchens compared with LPG kitchens (AOR = 0.27, 95% CI = 0.12–0.62, $p = 0.002$), suggesting the influence of household and socioeconomic confounding factors. Dermal symptoms were independently associated with socioeconomic status, with respondents in the M40 group reporting nearly three times the odds compared with those in the B40 group (AOR = 2.81, 95% CI = 1.38–5.73, $p = 0.004$).

4 Discussion

The demographic profile of our predominantly Malay women respondents reflects both national demographics [12] and the broader informal home-based workforce in Southeast Asia [8, 17]. Occupational characteristics may further contribute to the risk of SBS. In our study, 73.7% had less than 5 years of experience, and 54.2% operated bakeries, suggesting that inexperience and specific food preparation activities may be associated with increased exposure. This highlights the intersection of occupational exposures and social disparities in relation to SBS outcomes. The predominance of bakery operators in this study reflects both long-standing cultural practices and more recent entrepreneurial trends. In Malaysia, home-based baking has been a common practice for years, with individuals preparing cookies, traditional desserts, and other baked goods for festival occasions or local sale. This explains why many operators report several years of experience [36], even though the visibility of home-based food businesses increased during the COVID-19 pandemic. Surveys reported that 74% of Malaysians baked during lockdown, motivated by both necessity and the opportunity to experiment with healthier or more affordable ingredients [49]. Many individuals who developed a passion for baking during this period began producing baked goods for sale within their local communities [3].

SBS symptoms were highly prevalent, with nearly three-quarters of respondents reporting at least one symptom. Mucosal complaints, particularly dry throat (65.3%) and eye irritation (64.1%), were the most common, followed by general symptoms of fatigue (67.2%) and headache (66.4%). Dermal symptoms were generally less frequent, with dry hands, dry facial skin, and itchy scalp reported most often. This pattern is consistent with previous research indicating that occupational kitchen workers, including cooks, kitchen staff, and food handlers, are at elevated risk of hand eczema and diagnosed food allergies [28].

The overall prevalence of SBS symptoms observed in this study was higher than that reported among underground shopping district workers in Korea, where 20–50% of employees experienced at least one symptom [42]. These findings are also higher than reported during COVID-19 quarantine periods in Suzhou, China, where 59.3%, 45.5%, and 49.1% of respondents reported general, mucosal, and dermal symptoms, respectively [41]. Evidence from the Swedish Building Energy, Technical Status and Indoor Environment (BETSI) study further supports the influence of residential indoor environments on SBS, where 23% of adults in single-family houses reported weekly symptoms, and building dampness and poor ventilation were associated with increased mucosal, dermal and general complaints [43]. Women respondents experienced more mucosal symptoms, consistent with global findings indicating female susceptibility to SBS [46, 16]. Women and younger individuals in Japan were more likely to report SBS, whereas in Mexico, females experienced more severe general and mucosal symptoms, exacerbated by outdoor pollutants and airborne pollen. These patterns highlight how demographic characteristics influence the prevalence of SBS in residential and domestic-commercial environments.

The higher prevalence of mucosal symptoms observed in the present study compared with commercial and residential populations in Korea and Japan may reflect the nature of home-based food preparation, in which domestic kitchens are routinely used for frequent, prolonged cooking. Similar SBS-related concerns have also been reported among food-service workers in Malaysia, where indoor environmental conditions and cooking-related activities were associated with symptom reporting [18]. In residential environments, poor ventilation, fungal growth, and pollutant accumulation from cooking in enclosed living spaces have likewise been associated with SBS symptoms and poorer indoor air quality [7, 45].

Beyond occupational and environmental factors, socioeconomic conditions were also associated with differences in symptom distribution. Middle-income respondents (M40) had higher odds of dermal symptoms, whereas lower-income households (B40) reported more mucosal complaints. This pattern may reflect differences in housing conditions, appliance use, and indoor environmental exposures among M40 households, as well as potential variation in symptom awareness and reporting across socioeconomic groups. Among 180 B40 respondents, 134 (74.4%) reported at least one mucosal symptom, suggesting the potential vulnerability of lower-income households to occupational and environmental exposure. In Malaysia, 83% of the 2.91 million M40 households reside in urban areas [10], where smaller homes and kitchens may intensify exposure to pollutants such as fine particulate matter and VOCs during cooking ([34]; [57]). Smaller households also reported more mucosal symptoms, which may reflect prolonged exposure in confined kitchens. Similar findings have been reported in studies of indoor environmental quality in Malaysian affordable housing, where poor ventilation, noise, glare and lack of privacy negatively affected health and productivity [21]. Within such residential contexts, ventilation constraints become particularly critical when dwellings are repurposed for commercial food preparation. Cooking activities can further impose a substantial load on residential ventilation systems that were not designed for prolonged or high-intensity use [24]. Repeated cooking episodes increase the generation of indoor air pollutants, which can exceed the air-exchange capacity of typical domestic kitchens.

Although environmental and kitchen-related characteristics showed clearer associations with SBS symptoms, differences according to business type were less pronounced. Our analysis did not find a significant association between business type (bakery versus other food preparation) and SBS symptoms, but this finding should be interpreted cautiously. Previous evidence highlights that bakery workers are at risk of respiratory and dermal problems due to occupational exposure to flour dust. Flour particles can become airborne during dough mixing, kneading, and baking, leading to respiratory irritation, asthma, and skin conditions [13]. The absence of a clear association in our study may reflect the small-scale nature of home-based bakeries, which typically operate at lower production volumes than industrial or commercial settings. Additionally, reliance on self-reported symptoms rather than clinical diagnoses may have led to an underestimation of bakery-specific health effects.

In contrast, kitchen type and cooking appliances demonstrated more consistent associations with SBS symptoms. Operators using electric appliances reported significantly higher prevalence of mucosal symptoms than those using LPG kitchens, while mixed-device users had higher odds of dermal complaints. These findings suggest that different cooking energy sources may contribute differently to indoor environmental conditions and symptom reporting. This is possibly due to differences in heat generation, emissions, and ventilation requirements. Although electric appliances do not involve combustion, high-temperature cooking can still generate substantial particulate emissions. Evidence from controlled panel studies indicates that $PM_{2.5}$ source strengths from electric cooking may be comparable to, and in some cases higher than, those from gas appliances for similar cooking methods [35].

Abdullahi et al. [2] also highlight that both electric and gas cooktops emit particles that vary widely in size and composition, depending on cooking practices and ventilation efficiency. These emission characteristics may contribute to mucosal irritation in poorly ventilated domestic kitchens and partly explain the higher prevalence of mucosal symptoms observed among users of electric appliances in our study. However, further studies incorporating direct exposure measurements are needed to clarify these mechanisms. Similar observations have been made in other contexts. For instance, a large population-based survey in Spain reported that the use of electric cooking and heating appliances was associated with a modest but significant increase in the odds of atopic dermatitis among children, even after adjusting for socioeconomic and environmental confounders [52]. Although the health outcomes differ, both studies highlight that indoor energy sources can contribute to adverse health effects, particularly in confined domestic environments.

Perceived indoor air quality was associated with SBS-related symptoms in our study. These indicators reflect occupants' perceptions of indoor conditions rather than direct measurements of pollutant concentrations. Respondents reporting humid, dry, dusty, or mouldy air were more likely to report symptoms, suggesting that subjective experiences of indoor environments are relevant in domestic–commercial kitchens. These perceptions may reflect routine cooking activities, ventilation conditions, and cleaning practices, as described in previous work [54]. The findings align with growing evidence that perceived air quality (PAQ) provides useful contextual information in IAQ research, particularly where objective measurements are not feasible [51]. Perceived sensations of indoor air as humid or dry should not be interpreted solely as reflections of relative humidity, but rather as integrated sensory responses to the indoor pollution load and ventilation conditions. Perceived humidity in the air often indicates insufficient air exchange, leading to the accumulation of airborne pollutants, excess moisture, and microbial byproducts that irritate mucous membranes [53]. In contrast, sensations commonly described as "dry air" or "dry eyes" are increasingly linked to airborne irritants and particulate pollution rather than low absolute humidity itself [23].

Physiologically, inhaled particles and gaseous pollutants interact with the epithelial lining of the eyes and upper airways, activating sensory nerves, inducing local inflammation, and disrupting the tear film and mucosal barrier. These effects depend on particle size and physicochemical properties, which determine deposition and the potential for irritation [55]. Cooking-related emissions are a major source of fine and ultrafine particles in domestic kitchens, and occupational exposure to cooking smoke has been associated with respiratory irritation and symptom burden [15, 29]. This is consistent with experimental evidence showing that exposure to cooking-related particulate matter is strongly influenced by cooking duration and pollutant residence time, particularly in confined residential environments [48]. In the present study, cooking duration may also vary depending on customer demand and order volume, introducing variability in daily exposure levels that is not fully captured by categorical measures. Evidence from Thailand further shows that longer cumulative cooking time, particularly grilling, is associated with increased upper and lower respiratory symptoms [19]. This may partly explain the observed association between perceived indoor air conditions and mucosal symptoms. Stuffy air, included as a proxy for ventilation conditions, showed weak correlations with other IAQ indicators but remained associated with symptoms in adjusted analyses. Although smokers reported fewer general symptoms in unadjusted analyses, higher odds were observed after adjustment, suggesting potential confounding related to demographic or behavioural factors.

Several limitations should be considered when interpreting the findings of our study. First, indoor air quality was assessed using self-reported perceptual indicators (dry, humid, dusty, stuffy, and moldy air) rather than objective measurements of indoor pollutants. While such perceptual indicators are widely used as qualitative proxies in SBS research when instrumental monitoring is not feasible, they are subject to reporting bias and may not fully capture actual exposure levels. Second, participant recruitment relied on convenience sampling through social media and community networks, which may have preferentially reached younger, more digitally engaged, or healthier home-based food business operators, potentially limiting the generalisability of the findings to the broader population of informal food operators. Third, the exclusion of individuals with pre-existing respiratory or cardiovascular conditions, although intended to reduce symptom misclassification, may have resulted in an underestimation of the overall burden of SBS-related symptoms. This study focused on perceived indoor air quality and self-reported symptoms within the home-based work environment and did not explicitly assess other occupational activities. While participants primarily operated from residential kitchens, additional informal work activities may have contributed to symptom reporting. These factors should be considered when interpreting the reported prevalence of SBS-related symptoms, which may underestimate the burden experienced by home-based food business operators. Although formal sensitivity analyses were limited by the perception-based exposure assessment and cross-sectional study design, the consistency of associations observed across symptom domains and multivariable models supports the robustness of the findings.

5 Conclusion

To our knowledge, this study is among the first to examine SBS-related symptoms and their associations with socioeconomic factors, housing conditions, and perceived indoor air quality among home-based food business operators. A high prevalence of mucosal and general symptoms was observed, with demographic factors (female, married), socioeconomic status (low-income B40 vs. middle-income M40), and occupational characteristics (household size, kitchen type, type of food business) influencing symptom distribution. Perceived indoor air quality (IAQ), including reports of humid, dry, dusty, or moldy air, was significantly associated with symptom prevalence. 74.4% of B40 respondents reported at least one mucosal complaint, highlighting the potential vulnerability of lower-income households. These findings suggest that SBS risk in domestic-commercial kitchens may be influenced by the interplay of occupational exposures, housing conditions, and socioeconomic disparities, indicating potential links between work activities, environmental exposures, and symptom occurrence.

A key strength of this study is its focus on home-based food business operators, a largely under-researched occupational group. Unlike employees in formal commercial or industrial settings, home-based food business operators perform their work in domestic kitchens, where ventilation systems and indoor air quality are not designed for prolonged or intensive food preparation. By examining this population, the study provides observations on SBS symptoms in settings typically excluded from occupational health research, highlighting risks specific to domestic–commercial kitchens that are often overlooked in policy and intervention planning. As with most cross-sectional studies that rely on self-reported data, causal inference is limited, and prevalence estimates should be interpreted cautiously.

The findings of this study have important implications for occupational and public health policy. Local councils and housing authorities should strengthen the monitoring and regulation of residential properties used for commercial cooking activities to improve indoor environmental quality. Home-based food business operators, who often work within informal occupational settings, may benefit from greater access to guidance and support on safe cooking and ventilation practices. In addition, promoting compliance with Occupational Safety and Health (OSH) indoor air quality guidelines may help reduce exposure to particulate matter, volatile organic compounds, and other airborne pollutants generated during cooking activities.

Future research should adopt prospective cohort designs to examine how SBS symptoms develop over weeks or months in home-based food operators. Studies should integrate objective IAQ measurements (i.e., $PM_{2.5}$, VOCs, humidity, and temperature) with self-reported symptoms to better characterise exposure–response relationships. Evaluating the impact of interventions such as safer cooking appliances, improved ventilation, and occupational health training will help identify effective mitigation strategies. Investigating behavioural and operational factors, including cooking duration, cleaning routines, and kitchen layout, can further clarify drivers of SBS-related symptoms. Finally, assessing vulnerable subgroups, such as women and lower-income households, will allow for the development of targeted policies and practices to reduce risk.

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Author contributions
Conceptualization: EE; methodology, EE and AKK; validation: EE and AKK; formal analysis: EE and AKK; investigation, EE, AKK, and MYIMY ; writing—original draft preparation: EE; writing—review and editing: EE, DD, and MHH; supervision: EE. All authors have read and agreed to the published version of the manuscript.

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Data availability
The datasets generated and/or analysed during the current study are available within the article. Additional data are not publicly available due to privacy restrictions but are available from the corresponding author upon reasonable request and with appropriate consent.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and was approved by the Universiti Putra Malaysia Ethics Committee (JKEUPM-2023-646). Digital informed consent was obtained from all participants, and data were anonymised prior to analysis to ensure confidentiality. A Respondent Information Sheet and written Informed Consent Form were provided to all participants in accordance with the requirements of the Universiti Putra Malaysia Ethics Committee (JKEUPM). Participants gave their consent prior to data collection.

Consent for publication
All identifiable participant information was kept strictly confidential and not made publicly available, in accordance with legal and ethical requirements. Data were anonymized prior to publication. Participants were informed that although all reasonable efforts were made to ensure confidentiality, it could not be guaranteed.

Competing interests
The authors declare no competing interests.

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