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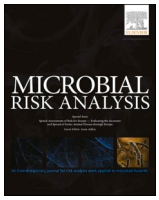

Full length article

Assessing urban street food safety among youth: The impact of road dust on potential microbial contamination risks to student health

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ABSTRACT

This study investigates the potential impact of air pollution on street food safety within educational environments, highlighting how airborne pollutants contribute to the microbial contamination of food, beverages, and environmental dust. A mixed-method approach was employed, combining microbial analyses with a survey of 200 students using the Theory of Planned Behavior (TPB) to assess attitudes, social pressures, and control over food safety practices. The findings reveal significant contamination levels: dust samples showed Coliform and E. coli concentrations of 3×10^3 CFU/g and 2×10^3 CFU/g, respectively, while food samples exhibited even higher microbial loads, with Coliform levels reaching 6.4×10^6 CFU/g and E. coli up to 1×10^4 CFU/g. SPSS 20 analysis reflects substantial concerns among students regarding the safety of street foods, emphasizing the need for increased public awareness. By establishing a clear link between air pollution and the microbial risks associated with street food, the study advocates for enhanced consumer education and regulatory measures to mitigate health risks and protect public health.

1. Introduction and literature review

Air pollution and its impact on humans and the environment have become one of the most pressing issues of the 21st century, especially in major urban areas (Liu et al., 2023). The continuous increase in traffic activity not only contributes to the rise in toxic emissions but also serves as a source of road dust, which harbors a plethora of microorganisms potentially harmful to human health (Deak et al., 2023). In addition to the health burden, the cost of mitigating the consequences of air pollution is also substantial (Piracha & Chaudhary, 2022), necessitating attention not only from regulatory bodies but also from the scientific community.

The situation of air pollution in major cities like Hanoi and Ho Chi Minh City is becoming increasingly severe, with $PM_{2.5}$ (Particulate Matter) concentrations exceeding the safe threshold set by the WHO by more than twice (Minh et al., 2021; Sheng et al., 2019). Vietnam, with a preference for personal transportation, had over 3553,700 vehicles and more than 45 million motorcycles in circulation as of February 2020. In Ho Chi Minh City alone, more than eight million motorcycle trips are made daily. Vehicles that do not meet emission standards and are not regularly maintained have led to a significant increase in $PM_{2.5}$ levels in recent years (Ho et al., 2022; Tran et al., 2024). Fine particulate matter, consisting of small airborne particles, can cause various diseases and affect the respiratory tract (Mohammed & Shehasen, 2020).

Road dust is not only a health concern but also directly impacts the quality of street food, an integral part of the culinary culture in many countries. Containing various bacteria and toxic chemicals, road dust can easily adhere to street food due to direct exposure to polluted air (Chenery et al., 2020). The impact of road dust on displayed food not only increases the risk of contamination but also affects food quality and safety for consumers (Mensah et al., 2012). This risk is particularly high for students and individuals who frequently consume street food, as they are more exposed to harmful microorganisms and toxic compounds. The contamination of street food by microorganisms from road dust elevates food safety risks and poses significant health concerns for students and young adults—a group that regularly consumes these foods (Mamun et al., 2020; Tran et al., 2021). This necessitates a deep understanding and awareness of the link between living environments, air quality, food

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safety, and public health.

Food safety and air pollution are closely linked, creating a complex interaction chain that impacts public health (Sun et al., 2017). Air pollution, through dust particles and toxic gases, can contaminate food, reducing the quality and safety of street food (Domingo et al., 2021). This not only increases the risk of exposure to foodborne diseases but also harms long-term health. Young people need to pay attention to this issue as they frequently consume street food and are a group capable of spreading information and changing consumption habits, contributing to promoting both food safety and improving air quality (Ho et al., 2020).

The issue of food safety, especially for street food, is becoming increasingly urgent globally and particularly in Asia (Jeaheng & Han, 2020). Street food is not only an indispensable part of daily life, with an estimated 2.5 billion people consuming street food every day worldwide, but it is also the main source of livelihood for many families, contributing significantly to the culinary culture and economy in developing countries (Jaffee et al., 2018; Loukieh et al., 2018). However, previous studies have shown that the food safety knowledge of street food vendors is poor (Choudhury et al., 2011; Omemu & Aderoju, 2008). Most street vendors lack comprehensive information about hygiene rules in food preparation, processing, and preservation (A. C. Sezgin & N. J. J. o. H. S. Şanlıer, 2016). A study on the knowledge, attitudes, and behaviors of street food vendors regarding food safety revealed poor food handling practices, and most operate in unsanitary conditions (Ma et al., 2019; Tran et al., 2023).

Surveying the perspectives and awareness of youth regarding environmental issues and food safety plays a pivotal role in shaping policy and management strategies (Ahmed et al., 2021). While existing literature acknowledges the potential of youth to propagate awareness about environmental and health consciousness (Anna Shutaleva et al., 2021), there remains a critical gap in understanding how these perceptions translate into practical behavioral changes, particularly in the context of street food safety. Youth, as both consumers and agents of change, are positioned to influence consumption habits, which can foster broader community participation in addressing environmental challenges (Ahmed et al., 2021). Yet, a limited number of studies have examined how youth perceptions of environmental pollution, specifically air pollution, intersect with food safety concerns (Tan et al., 2022). This intersection is essential to comprehend as it offers a more holistic view of how these two areas affect daily life and public health.

A comprehensive approach that integrates both environmental and food safety concerns is required to fully capture this dynamic (Haslberger, 2006; Stoyanova, 2020). Most existing research addresses these areas in isolation, thereby missing the critical interactions between environmental contamination and food hygiene, especially in developing countries where street food is a primary source of nutrition (Mohammed & Shehasen, 2020). By examining youth perspectives on both fronts, this study contributes to filling the existing research gap and highlights how awareness can be leveraged to promote safer food consumption behaviors and environmental responsibility (A Shutaleva et al., 2021). Conducting simultaneous surveys on food safety and environmental pollution allows for a deeper exploration of how these factors interact and inform consumer priorities and behaviors (Ahmed et al., 2021).

The current mixed-method study addresses this gap by combining empirical microbial analyses with a survey-based approach grounded in the Theory of Planned Behavior (TPB). While microbial contamination has been frequently measured (Chawla et al., 2023; Ferrari et al., 2021; Moloi et al., 2021; Szczotko et al., 2022), the novel contribution of this study lies in how it integrates quantitative microbial data with qualitative insights into consumer attitudes and behaviors. This combination reveals a more robust understanding of the risks associated with street food consumption, especially in areas with high levels of air pollution (Mamun et al., 2020). Through the collection of dust samples and microbial analysis, the study assesses the concentration of pathogenic microorganisms in both the environment and food samples, thus providing direct evidence of how air pollution impacts food safety. Concurrently, surveying the youth population about their attitudes, perceived behavioral control, and subjective norms concerning street food safety elucidates the behavioral aspect of food consumption in a polluted environment (Mohammed & Shehasen, 2020).

This mixed-method design complements the quantitative findings with qualitative behavioral insights, offering a comprehensive view of the problem (Petticrew et al., 2013). By connecting microbial contamination to consumer behavior, this study not only addresses the immediate public health risks posed by air pollution but also informs the development of targeted educational and regulatory interventions aimed at reducing these risks. Ultimately, the study contributes to the broader discourse on sustainable food safety and environmental health by proposing actionable solutions based on both scientific evidence and social behavior (Hutter, 2011). This integrated approach fills a crucial gap in the literature, where the intersection of air pollution and street food safety has been underexplored, despite its significant implications for public health in urban areas of developing countries (Tacardon et al., 2023).

This study systematically investigates the intersection between students' awareness of food hygiene, safety, and air pollution, exploring how their perceptions and attitudes correlate with the microbial risks present in their living environments. While existing literature has often examined these issues in isolation, this research addresses a critical gap by integrating both environmental and food safety concerns. The mixed-method approach combining quantitative microbial analysis with perception-based surveys rooted in the Theory of Planned Behavior (TPB) provides a more holistic understanding of the problem. Through this design, the study bridges the empirical findings of air pollution's direct impact on street food contamination with behavioral insights from youth, revealing how attitudes, social norms, and perceived control influence consumption behavior in polluted environments. By employing both experimental and survey methods, the study offers robust, complementary findings that not only identify the microbial risks but also inform targeted strategies for public health interventions and education. This approach engages young individuals in environmental and food safety efforts, underlining their crucial role in improving community health and sustainability. In doing so, this research contributes to the development of effective solutions aimed at enhancing food safety and the quality of the living environment, emphasizing the importance of youth participation in addressing these public health challenges.

2. Materials and methods

2.1. Surveying the youth's perspective on street food and environmental issues

2.1.1. Theory on hypothesis formulation and questionnaire design

This study concurrently evaluates the concern for air pollution and food hygiene and safety among students and pupils at school entrances in Ho Chi Minh City. The proposed research models indicate that the Theory of Planned Behavior (TPB) (Ajzen, 2020) is ideal for predicting or explaining behavior, particularly the youth's concerns about air pollution and food hygiene and safety issues (Lin & Roberts, 2020). By applying this approach, it is possible to assess existing limitations in individual beliefs and perceptions regarding air pollution and food hygiene and safety. This evaluation helps in understanding how these perceptions correlate with the actual conditions in areas in front of schools. The aim is to propose solutions to enhance consumer health and establish a sustainable street food business model (Anna Shutaleva et al., 2021). This not only creates more livelihood opportunities for the people, develops the essence of street food culture but also ensures safety factors for public health.

From the Theory of Planned Behavior (TPB), the study proposes a

hypothetical model, Fig. 1. The questionnaire is designed to gather information on consumers' attitudes, perceived behavioral control, and social pressure related to air pollution and food hygiene and safety issues at school entrances. The main sections of the questionnaire are as follows: (1) habits and frequency of street food consumption (Abrahale et al., 2019); (2) survey on attitudes, perceptions, and social pressure regarding air pollution and food hygiene and safety issues (A. C. Sezgin & N. Şanlıer, 2016); (3) survey on the level of concern about air pollution affecting food hygiene and safety for street snacks (Li et al., 2021); (4) some perspectives on the decision to consume street food and coping with food hygiene and safety; (5) demographic characteristics of the participants. A 5-point Likert scale was used for data analysis. To ensure the effectiveness of the survey and identify the main issues, a preliminary survey was conducted with about 20 participants. From there, redundant, distracting, inappropriate questions were eliminated, and based on the participants' feedback, the official questionnaire was developed.

2.1.2. Sample size and survey conduct

Through the survey, a total of 200 valid questionnaires were obtained. The minimum sample size was ensured according to the formula: N (total sample) = 5 × m, where m = 29 represents the total number of questions (Hair et al., 1998). This sample size is suitable for studies using factor analysis (Comrey et al., 1973). The samples were collected both directly (the survey respondents were interviewed face-to-face by our research collaborators at snack stalls and shops near school gates) and indirectly (survey responses collected through online questionnaires). The sampling was simultaneously conducted using random sampling at snack stalls, shops near school gates, and online via Google Sheets (in Vietnamese). These online participants were primarily from the educational institutions included in the study and were recruited through various student organizations. Especially, the survey was conducted with the support of the local Youth Union and educational institutions. The Youth Union, which is an active youth organization in schools (under the supervision of schools and governments through activity programs), collaborated closely in supervising the data collection process and provided volunteers to assist with the survey completion. This support ensured that the survey was conducted seriously and confidentially, adhering to ethical research principles. Thanks to the supervision by the schools and the involvement of these organizations, the survey process proceeded smoothly, particularly with participants under the age of 18.

The survey targeted high school students (aged from 15 to 18) and university students (over 18 but under 25 years old), as this demographic frequently moves around and gathers near school entrances, where the density of street food vendors is high. The sensitivity of this age group to food safety issues is heightened due to the prevalent consumption of street food, which often lacks proper hygiene standards. This demographic frequently experiences health issues like allergic reactions and gastrointestinal problems due to inadequate food safety controls (Vazquez-Ortiz et al., 2020). This underscores the urgency of this investigation.

2.1.3. Data analysis and processing

Survey data analyses were entered using Microsoft Excel 2023. Statistical analyses, including EFA and regression, were performed using IBM SPSS 20 with a 95% confidence level. These comprehensive methods ensured a thorough analysis of the data, providing a solid foundation for the study's conclusions and recommendations.

In assessing the reliability of the measurements, we employed

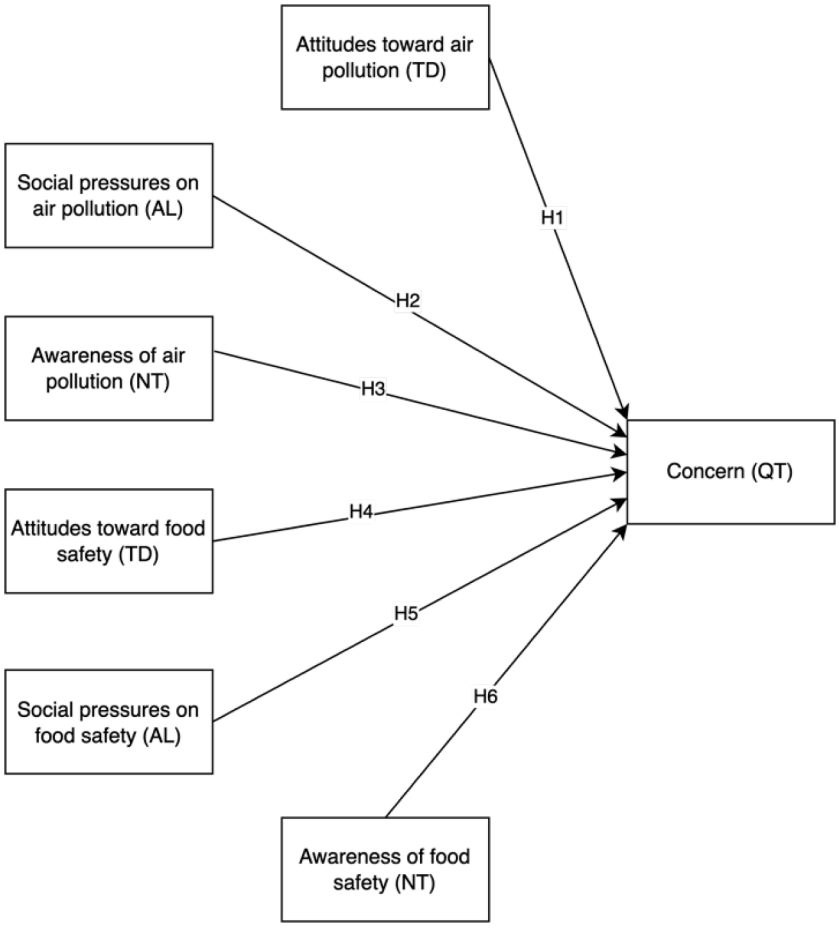

Fig. 1. Proposed research model based on the Theory of Planned Behavior (TPB).

Cronbach's Alpha (α) coefficient and the total-item correlation based on the criteria outlined by (Bonett & Wright, 2015). A range of $0.6 \leq \alpha \leq 0.95$ is considered acceptable, with α values above 0.95 suggesting redundancy among survey items and values below 0.3 indicating potential issues with item validity. An item-total correlation greater than 0.3 signifies that an item is relevant. Cronbach's Alpha helps evaluate the consistency of measurements by minimizing random errors. In our study, we used it to ensure the reliability of each scale and to screen for unsuitable variables before conducting Exploratory Factor Analysis (EFA) (Liu et al., 2021).

2.2. Sampling and assessing the level of pathogenic microbial contamination in street food, dust and investigating the possibility of exposure to dust on street food

2.2.1. Sampling locations

The study aims to assess the presence of pathogenic microorganisms in the air and in street food samples in areas in front of school entrances. Furthermore, the study examines the correlation and impact of air pollution on food hygiene and safety. Four educational institutions, including two universities and two high schools, were selected for air quality and food sampling surveys. The sampling sites are presented in Fig. 2. The universities in the area are respectively designated as "A" and "B". Additionally, "C" and "D" represent the two selected high school institutions for this study. These locations were methodically chosen to provide a comprehensive overview of the environmental conditions affecting students at different educational levels.

Alongside, the study selected various types of food and beverages for sampling to analyze the quality of street food. This includes two frequently consumed food items: Rice paper salad (T01) and Banh mi (B02), and two popular beverages: Kumquat tea (R03) and Soy milk (S04). These items were chosen based on survey data indicating a high consumption rate among students, reflecting the deep concern for ensuring their safety and quality.

2.2.2. Methods of sampling and analyzing microorganisms in street food

To ensure the credibility of the microbial testing, a detailed and systematic approach was implemented for collecting and analyzing food samples. The study focused on four types of street foods: rice paper salad, Vietnamese bread, kumquat tea, and soy milk. Over five weeks, samples were collected every wednesday at 8 AM during the dry season, ensuring consistency and minimizing variability. The sampling was conducted at fixed vendor locations in front of four educational institutions, as described in the research location section, to control for environmental differences. Regarding the sampling process, food samples were collected by purchasing one serving as a typical customer. More details can be found in the supplementary images. In total, 40 food samples and 40 beverage samples were collected and analyzed.

Weekly food sampling, conducted on wednesdays, allowed for consistent and comparable microbial analysis over time. Each sample was processed according to stringent protocols to ensure accuracy and reliability. By following national standards and maintaining consistent sampling procedures, the microbial testing results were credible and scientifically robust.

The food sampling process adhered to circular 14/2011/TT-BYT by the ministry of health and the national standard TCVN 8129:2019 (ISO 18,593:2018) for microorganisms in the food chain, with an emphasis on surface sampling. Samples were collected to ensure they remained fresh and were immediately preserved in a cold styrofoam box. This method maintained the appropriate temperature to prevent microbial

Fig. 2. Study area for sampling street dust at near school gates location, Ho Chi Minh city.

growth during transportation to the laboratory.

After the food samples were collected, they were taken to the laboratory for analysis on the same day. The parameters to be analyzed in food and beverages include *E.Coli* and *Coliform* according to the Vietnamese standard TCVN 9975:2013 for quantifying *Coliform* and *Escherichia Coli* using the PETRIFILM™ count plate method, and TCVN 11,039–3:2015 for detecting and quantifying *Coliform* and *E.Coli* using the most probable number (MPN) technique. Microbial results were read and carefully recorded 2 days after analysis.

This rigorous sampling strategy, combined with adherence to recognized standards, provides a solid foundation for the reliability and validity of the findings. The systematic approach in sampling and analysis underscores the thoroughness and credibility of the microbial testing, offering valuable insights into the microbial contamination of street foods.

2.2.3. Methods of sampling and analyzing microorganisms in the street dust

For the analysis of background environment and air quality control indicators such as $PM_{1.0}$ and $PM_{2.5}$, the Dienmern DM502 device and the FCC-5000G dust sampler along with an Air Quality Monitor were used. These devices include a sampling pump, a rubber tube connecting the sampling head to the suction pump, a sample collection head containing a 25mm diameter filter paper, and other auxiliary tools such as flat-nose pliers for picking up the filter paper and a pad. The collected dust samples were then analyzed based on QCVN 02:2019/BYT for the permissible exposure limit of dust at the workplace. The air analysis method follows the national standard TCVN 5067:1995, aiming to determine the dust content by the gravimetric method, and according to the guidelines of circular 24/2017/TT-BTNMT. Air sampling will take place on thursdays each week, providing periodic data on air quality and dust pollution levels.

The microbial content in street dust was also collected at sampling locations in front of school gates and roadside areas as indicated in Fig. 2. Dust sample collection was conducted at 8 AM to avoid fluctuations and potential inaccuracies in air composition that could occur during the day. The dust sampling process lasted for 4 hours to obtain approximately 2 g of sample, and the dust sample was then preserved in a sterilized petri dish and placed in a styrofoam box capable of maintaining sample preservation conditions throughout transportation to the laboratory. The quantification of pathogenic microorganisms *Coliform* and *Escherichia Coli* in dust samples was based on the Vietnamese standard TCVN 9975:2013.

2.2.4. Methods of data analysis

The data analysis for this study involved a structured approach to ensure the reliability and validity of the results. Information on air quality and microbial content in food samples was meticulously collected and entered into Microsoft Excel 2023. This software facilitated thorough statistical analysis and visualization.

Firstly, the collected data was entered and cleaned to ensure accuracy and consistency. Descriptive statistics, including means, medians, and standard deviations, were calculated to summarize the data. Correlation analysis was then performed to identify potential relationships between air quality indicators (such as PM1.0 and PM2.5) and microbial contamination levels in the food samples.

To visualize the data, boxplots and correlation plots were generated using Microsoft Excel 2023. These visual tools provided clear insights into the distribution and variability of the microbial content in both food and dust samples, highlighting significant findings.

3. Results and analysis

3.1. Statistics on participants' demographic information and frequency of street food consumption

In this survey, a total of 200 participants were included, with 52% female and 48% male, enhancing the representativeness and diversity of the data, providing a comprehensive view for both genders on the research issue. The distribution among age groups and educational levels was also even, with high school students and university students each accounting for 50%. Monthly income distribution among respondents showed that the majority (83 responses) had an income below 41.67 USD. Additionally, 67 responses indicated an income range of 41.67–125 USD, 35 responses reported an income of 125–208.3 USD, and 8 responses indicated an income above 292 USD.

Since students are the main consumer group for snacks, this reinforces the reliability of the study (Beniwal & Mogra, 2023). Our survey found that 77% of students snack occasionally or frequently, with monthly spending on snacks ranging from under 2.083 USD to over 20.83 USD. Specifically, 95 responses indicated a spending range from 2.083 to 8.33 USD.

In the context of Vietnam, students' income mainly comes from allowances provided by their parents. High school students typically receive pocket money from their parents, while university students might receive monthly allowances or earn additional income from part-time jobs. This income affects their consumption habits and awareness of food safety (Jovanovic, 2016), as students with higher allowances can afford more expensive snacks or various combo meals. These findings indicate the impact of income on snack consumption habits and highlight the importance of raising awareness about food hygiene and safety, as well as air pollution, among the youth community (Mamun et al., 2020).

These results reinforce the reliability and relevance of the study, particularly important for targeting interventions to improve food safety awareness and practices among students.

3.2. Evaluating the awareness and behavior of students towards food safety and air pollution

In the context of challenges related to food safety and air pollution, survey results on students' attitudes towards food hygiene and safety issues in Fig. 3 show significant concern for the organization and control of food quality (Sanlier et al., 2018). Food hygiene refers to the conditions and practices that ensure the safety of food during preparation, handling, and storage, aiming to prevent foodborne illnesses and contamination (Kamboj et al., 2020). In fact, up to 74% of respondents agree that grouping vendors in a specific area is necessary, reflecting the need for a better-managed selling environment, which could facilitate easier hygiene control (Sepadi & Nkosi, 2023). Similarly, 74% of respondents expressed a high level of agreement on the importance of controlling the state of food hygiene and safety.

Regarding the importance of unverified food information, it also shows a clear consciousness about issues related to the widespread presence of ingredients of unknown origin in the market (Ochulor et al., 2022). Furthermore, 77% of respondents expressed fear regarding information about contaminated food, which further confirms the deep concern about health and food safety issues and emphasizes the urgency of improving the hygiene and safety quality of vendors (Samapundo et al., 2015). However, only 62.5% of survey participants responded to the food safety and hygiene campaign, which may indicate that although awareness of the issue is high, there is a need for more specific and effective measures to encourage positive action from students. This represents a difference from previous research that found awareness, attitude, and action all received high percentages (Ellinda-Patra et al., 2020).

The survey results on the awareness of students towards food hygiene and safety issues at snack bars and street food in Vietnam reflect significant concerns about food safety as shown in Fig. 4. Notably, the majority of respondents agree that the food quality at snack bars is not guaranteed (72%), and the preparation of food directly on the street poses a high risk of contamination (70%) (Eley et al., 2022). This not only highlights public health concerns but also reflects an increased

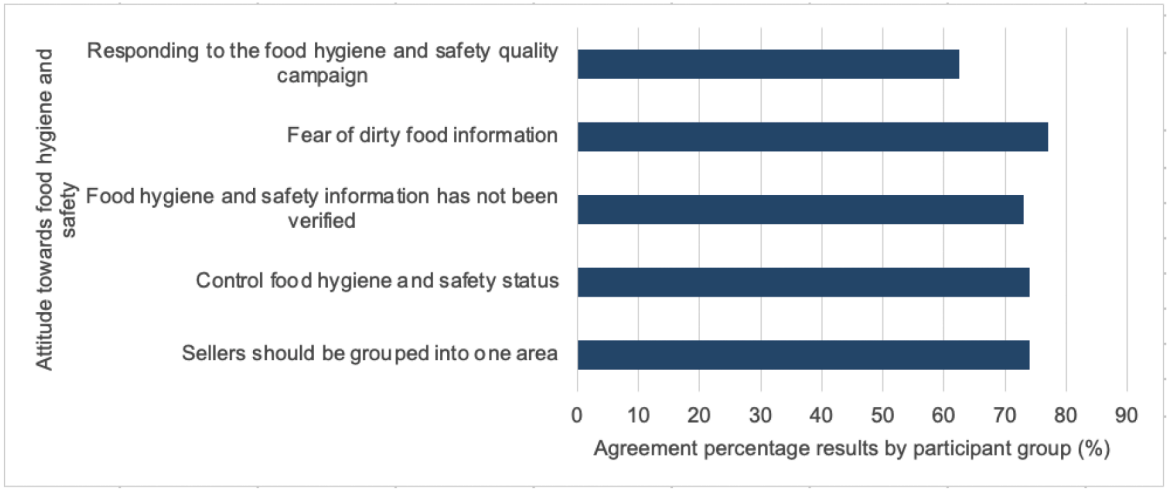

Fig. 3. The attitudes towards food hygiene and safety of student.

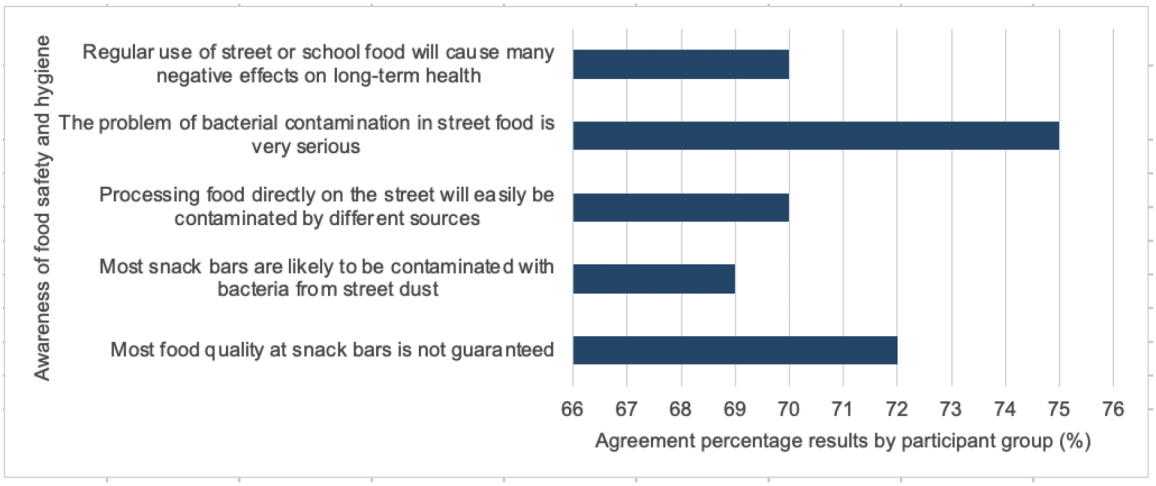

Fig. 4. The awareness of food safety and hygiene of student.

awareness of the need for strict food quality control measures not only by vendors but also by local authorities (Dwumfour-Asare, 2015). The acknowledgment that street food contamination is a serious issue (75%) and that regular consumption could harm long-term health (70%) is a positive sign indicating high awareness among students about street food contamination and its health risks (Madilo et al., 2023). This shift in consumption awareness may stem from strong education and communication campaigns or personal experiences in recent years

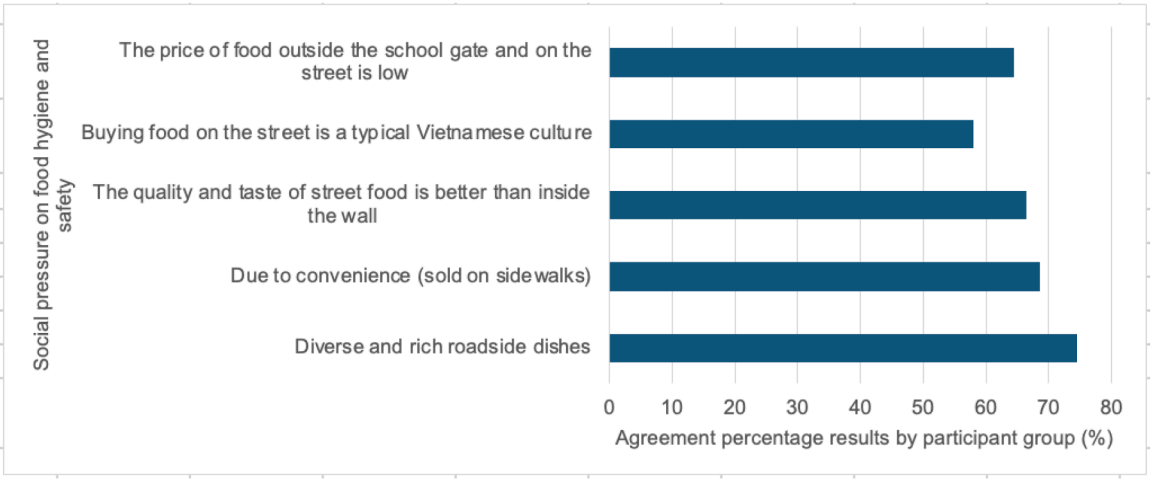

Fig. 5. The social pressure on food hygiene and safety of student.

(Losasso et al., 2012).

The factor of social pressure is also significant in assessing the interest of students in this issue, as survey results presented in Fig. 5 show strong consensus on the diversity and richness of street food (74.5%), as well as recognition of it as a part of Vietnam's unique culture (83%), reflecting a cultural pride and preference for the convenience and uniqueness of street cuisine. At the same time, the level of agreement is also quite high regarding the diversity of tastes (66.5%) and the low cost (64.5%) of street food, which may indicate the appeal of this type of food. Students are attracted not only by the delicious flavors but also by the affordability (Herman et al., 2022). This poses a challenge for policymakers and the social science community in seeking a balance between preserving cultural beauty and ensuring public health (Stutter, 2017).

The profound relationship between food safety and concerns about air pollution does not exist independently but is closely intertwined, as the consequences of air pollution directly impact and complicate the issue of food hygiene and safety (Sun et al., 2017). This connection is clearly reflected in Fig. 6, which illustrates students' attitudes towards the impact of air pollution on human health and food hygiene and safety. The survey results on students' attitudes have shown significant environmental and community health concerns among students (Tan et al., 2022). There is a relatively high consensus on the view of the impact of air pollution on human health (72.5%), and the effect leading to the contamination of street food is clearly recognized by the student community (73.5%). Similarly, the agreement rate of 73.5% on the difficulty of controlling air pollution and the level of concern about pollution information (73%) indicates that although information about air pollution is widely discussed, there is also a pessimistic view of the effectiveness of current preventive and remedial measures. Furthermore, the lower agreement rate on the current issue of air pollution (64.5%) may reflect the relative priority of this issue in public opinion. A similar result was also found in previous research (Dong et al., 2019).

The findings from the survey on students' awareness related to the relationship between air pollution, weather conditions, and food hygiene and safety, presented in Fig. 7, provide a noteworthy picture of environmental and public health concerns. The awareness that hot weather increases the dispersion of dust into the air (73.5%), and the view that food contaminated with dust has a severe impact on consumer health (73.5%), not only highlight the concern for the link between living environments and health but also show opportunities to improve understanding and practices of food hygiene and safety. This result is similar to previous research results (Pérez et al., 2006; Anna Shutaleva et al., 2021) However, only 65% agree that the air quality around street food stalls is not guaranteed (Mamun et al., 2020), which may indicate fluctuating perceptions or in assessing actual environmental risks. It may also reflect uncertainty or a lack of specific information about pollution levels in particular areas.

The aspect of social pressure cannot be ignored when discussing the impact of air pollution on food hygiene and safety, suggesting a clear awareness of the relationship between the environment and food quality. The results obtained in Fig. 8 show that 72.5% of respondents agree that air quality at food establishments with glass doors is higher than at roadside stalls. This indicates a recognition of better air quality in sheltered environments compared to open-air, unsheltered eateries (Bellizzi et al., 2021). While this does suggest a concern about the impact of open-air pollution, it does not necessarily imply a preference for sheltered environments over traditional street vendors. Participants may acknowledge the air quality differences but still prefer traditional street vendors for various reasons, such as the cultural experience, convenience, or affordability. The link between food quality and taste with street dust contamination (68.5%) also emphasizes the awareness that students today are increasingly conscious of the origin and processing of the food they consume, as well as concerned about potential impacts from polluted air, highlighting the need to enhance food hygiene and safety in all aspects of life (Ochulor et al., 2022). Additionally, the acknowledgment that areas with heavy traffic have poorer air quality (74%) shows an understanding of pollution sources and awareness of how air pollution can spread. Finally, the impact of low air quality on food choices (62.5%) reflects a consideration in consumption decisions based on the surrounding environment (Domingo et al., 2021).

The data collected from the survey, as shown in Fig. 9, indicate a significant level of concern among students about issues related to food hygiene, safety, and air pollution (Kamboj et al., 2020). A relatively high proportion of young people have expressed an understanding of food safety regulations (67.5%) and have shown the habit of discussing this issue with friends and family (73%), reflecting not only awareness but also proactivity in disseminating information (Tuglo et al., 2021a). The strong interest in news about the impact of air pollution (77%) also demonstrates that students are concerned not only with what they consume but also with their surrounding environment (Ahmed et al., 2021).. However, only 63% agree that air pollution severely affects food hygiene and safety, indicating hesitation or a lack of specific information about the relationship between the two issues. Information about contaminated food investigated and published by authorities, although only receiving 62% agreement on its relevance, remains important in improving public awareness (Samapundo et al., 2015; A. C. Sezgin & Şanlıer, 2016).

Price is also acknowledged as a factor affecting the quality of street food (66%), an undeniable reality in the current socio-economic context

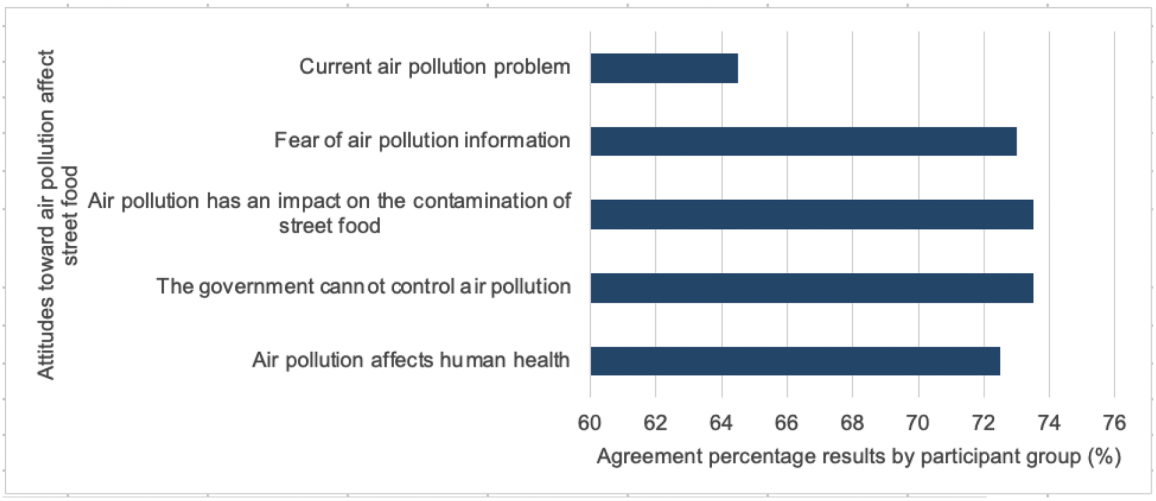

Fig. 6. The attitudes towards air pollution affect street food of student.

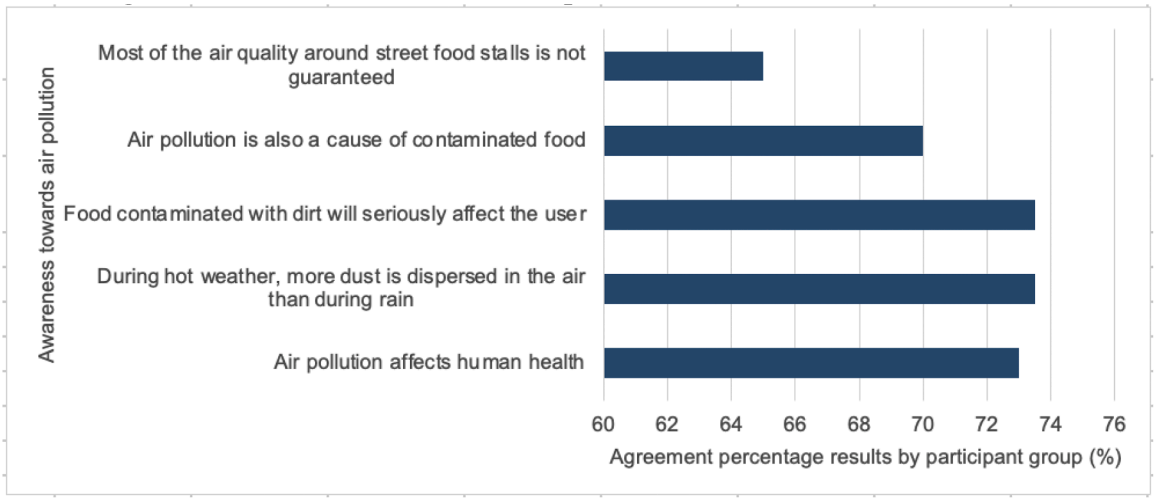

Fig. 7. The awareness of air pollution of student.

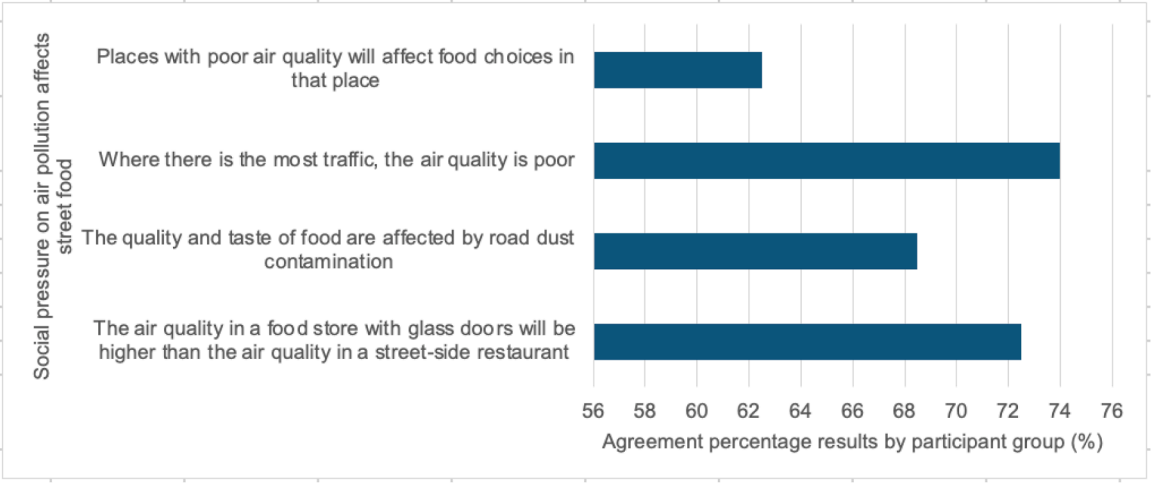

Fig. 8. The social pressure on air pollution affects street food of student.

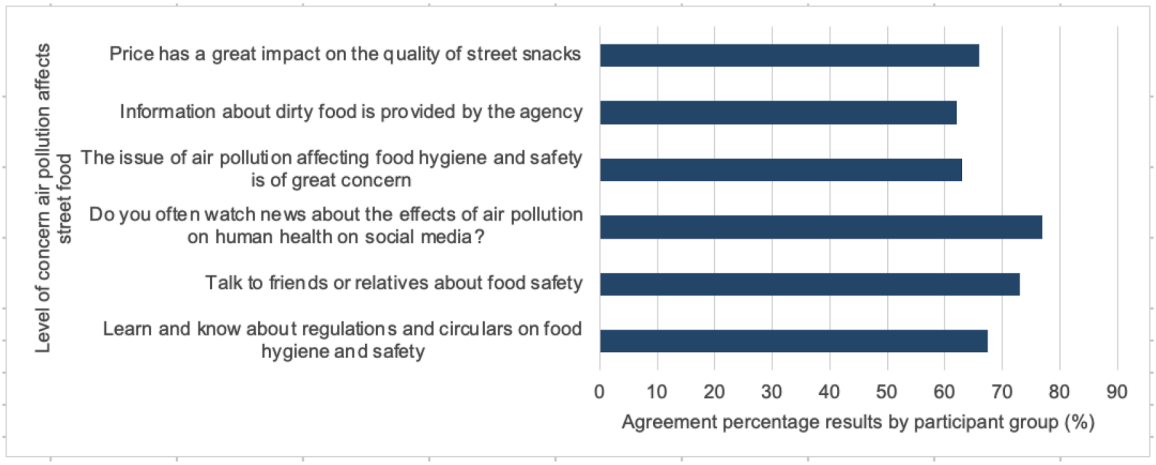

Fig. 9. The level of concern about air pollution affects street food of student.

(Ali & Ali, 2020). Notably, the interest in places selling food, with 75% concerned about pushcarts, street vendors, and areas in front of schools, shows a preference for convenience and attachment to this unique cultural space. In response to concerns about street food being contaminated with dust, 80.5% of respondents reported that they had consciously reduced their consumption of street food to minimize potential health risks. Additionally, 74.5% indicated that they had chosen to completely avoid consuming street food, reflecting a heightened

awareness and proactive approach toward protecting their health. However, 67% continue to use this food despite knowing the harms, reflecting a reality that eating habits and needs can be stronger than health concerns (Chenery et al., 2020).

3.3. Testing the reliability of the scale and exploratory factor analysis (EFA)

3.3.1. Assessing the reliability of scales

The results of the Cronbach's Alpha reliability test for the factors of Attitude, Awareness, and Social Pressure regarding food safety are presented in Table 1. Before conducting the EFA analysis, it was found that the Cronbach's Alpha coefficients for these factors were within the acceptable range ($0.5 \leq \alpha \leq 0.95$) (Bonett & Wright, 2015). Specifically, the Attitude factor had a Cronbach's Alpha of 0.685 with four observed variables, the Awareness factor had a Cronbach's Alpha of 0.673 with four observed variables, and the Social Pressure factor had a Cronbach's Alpha of 0.779 with five observed variables. This indicates that the observed variables in these scales meet the reliability requirements and are suitable for further EFA analysis.

Similarly, the Cronbach's Alpha reliability test for the factors of Attitude, Awareness, and Social Pressure regarding air pollution, as shown in Table 2, also demonstrated satisfactory results. The Attitude factor had a Cronbach's Alpha of 0.785 with five observed variables, the Awareness factor had a Cronbach's Alpha of 0.798 with five observed variables, and the Social Pressure factor had a Cronbach's Alpha of 0.809 with four observed variables. These results confirm that the observed variables in the scales for Attitude, Awareness, and Social Pressure regarding air pollution are reliable and appropriate for further EFA analysis.

Furthermore, the Cronbach's Alpha reliability test for the Concern factor showed a Cronbach's Alpha of 0.856 with three observed variables. This coefficient is within the acceptable range ($0.5 \leq \alpha \leq 0.95$), indicating that the observed variables in the Concern scale meet the reliability requirements and are suitable for further EFA analysis.

In conclusion, all observed variables in the scales for the factors of Attitude, Awareness, and Social Pressure regarding food safety and air pollution, as well as the Concern factor, meet the reliability requirements according to the Cronbach's Alpha test. All variables in the group of independent and dependent factors satisfied the requirements to perform Exploratory Factor Analysis (EFA) (Nunnally & Bernstein, 1994). Therefore, they are appropriate for proceeding with the next steps of the EFA analysis. Detailed data of the Cronbach's Alpha test tables are presented in Appendix 2 (Suplementary).

3.3.2. Exploratory factor analysis (EFA)

After entering 27 reliable observation variables from six scales (Attitude, Awareness, and Social Pressure towards food hygiene and safety and air pollution) into EFA twice, and after eliminating unsuitable variables, the results showed a Kaiser – Meyer – Olkin (KMO) coefficient value of 0.725, meeting the condition of $0.5 \leq KMO \leq 1$ (Ayodele, 2023). Bartlett's Test results with a Sig value of 0.000 met the condition of sig ≤ 0.05, indicating that the observation variables are correlated within the population. The total variance explained in the Cumulative % column had a value of 68.709% > 50%, meeting the standard, and the Eigenvalue coefficient had a value of 1.106 > 1, meeting the condition.

Table 1
Cronbach's Alpha Test for Factors Attitude, Awareness, and Social Pressure on Food Safety.

Attitudes toward food safety (TD)		Awareness of food safety (NT)		Social pressures on food safety (AL)	
Cronbach's Alpha	N of Items	Cronbach's Alpha	N of Items	Cronbach's Alpha	N of Items
0.685	4	0.673	4	0.779	5

Table 2
Cronbach's Alpha Test for Factors Attitude, Awareness, and Social Pressure on Air Pollution.

Attitudes toward air pollution (TD)		Awareness of air pollution (NT)		Social pressures on air pollution (AL)	
Cronbach's Alpha	N of Items	Cronbach's Alpha	N of Items	Cronbach's Alpha	N of Items
0.785	5	0.798	5	0.809	4

Results from the rotated component matrix showed that all variables met the condition with factor loadings ≥ 0.5, and after analysis, seven new exploratory factors were identified. Factor A1, named "Perception of Air Pollution and Its Impact on Food Safety," clearly reflects the awareness of the severe risk of air pollution to the quality of street food, particularly regarding dust contamination and the current ability to control air pollution. Factor A2, "Cultural and Practical Preferences for Street Food," expresses a positive attitude towards the utility value of street food such as diversity, affordability, and shopping convenience, while also reflecting the awareness of the role of Vietnam's unique culinary culture in choosing street food. Factor A3, "Perceived Impact of Air Quality on Food Choices," emphasizes concerns about the impact of air pollution on the quality and hygiene of street food, as shown by views on air quality at food selling locations and its influence on consumer food choices. Factor A4, "Awareness of Food Contamination Risks," focuses on concerns about food contamination on streets and sidewalks, where direct street food processing can lead to contamination from various sources. Factor A5, "Concerns About Food Safety Management," addresses awareness of food safety and hygiene information, fear of contaminated food, and the demand for stricter control over street vendors to ensure food hygiene and safety. Factor A6, "General Concerns About Air Pollution," concentrates on the awareness of current air quality and concerns related to its impact on health. Meanwhile, Factor A7, "Health Impacts of Air Pollution," specifically links this awareness by directly associating air pollution with specific health issues such as respiratory diseases and lung cancer.

These factors collectively provide a comprehensive understanding of the various dimensions of awareness and concern related to air pollution and food safety, highlighting the critical areas that need attention to improve public health and food hygiene practices. The EFA results confirm that students are not only aware of the value and utility of street food but also understand environmental factors such as air quality and the risks of infection related to food safety. These perceptions form an important basis for developing environmental and health education strategies, as well as proposing policies to improve the quality of living environments and food safety in areas where students congregate (Ahmed et al., 2021; Eley et al., 2022). The research model was adjusted after EFA analysis, as described in Fig. 10.

3.3.3. Evaluate regression analysis for hypotheses

The analysis results show that the independent factor A4 (Sig ≤ 0.05) has a correlational impact on the dependent factor QT. The results of the linear regression analysis of independence is indicated in Fig. 11. Independent factors A1, A2, A3, A5, A6, A7, with sig > 0.05, were excluded. The correlational analysis results led to an adjusted model that highlights the deep concerns of students about street food contamination and its impact on food hygiene and safety (Eley et al., 2022). The observed variables in group A4 - related to the potential for contamination from street dust, the risks of direct street food processing, the quality of food at snack bars, and the severity of the contamination issue - all focus on environmental factors that could affect health (Alharbi et al., 2020). This means that students are not only aware of the health risks from unsafe food but are also deeply concerned about controlling food hygiene in places where they frequently consume, especially in areas near schools where exposure to street food is common (Kamboj et al., 2020). These results also underscore the urgent need for

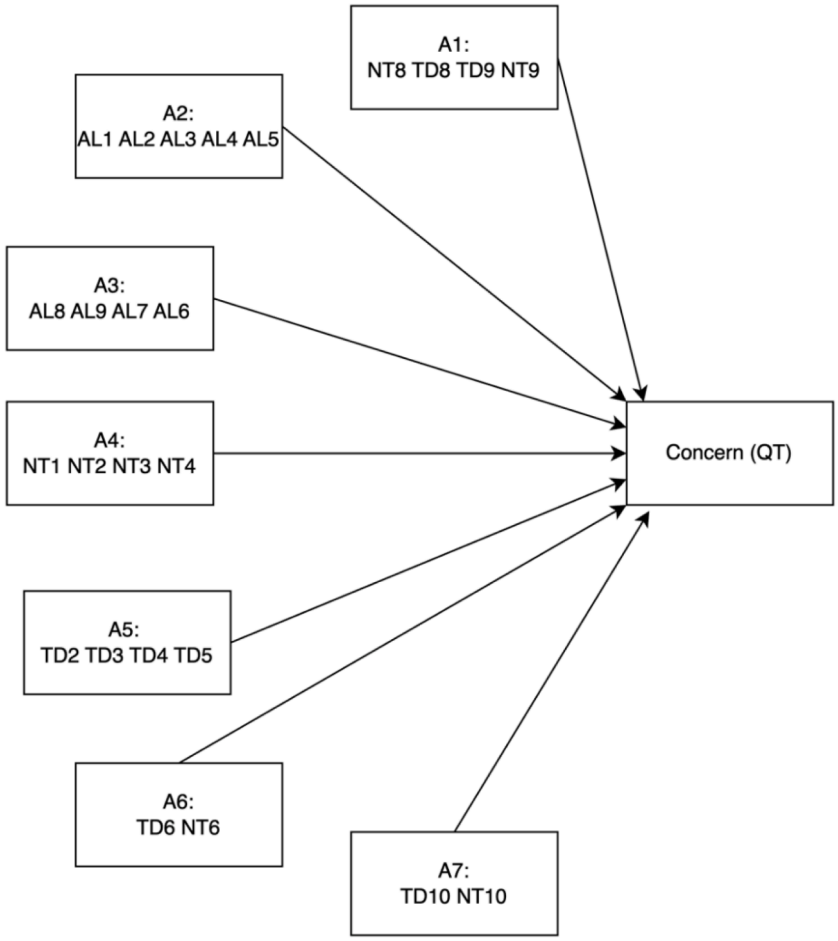

Fig. 10. Adjusted research model after EFA analysis.

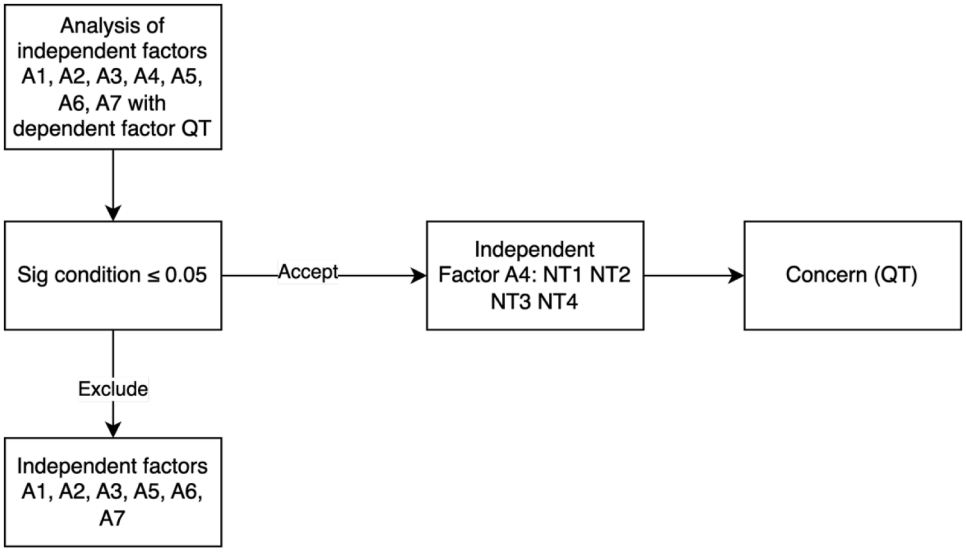

Fig. 11. The impact of independent factors on dependent factor (Concern QT) through linear regression analysis.

educational measures, as well as improvements in policy and hygiene practices, to minimize the risk of contamination and enhance food safety quality (Tuglo et al., 2021a). Therefore, this information is significant not only in shaping the policies and intervention strategies of schools and public health agencies but also in supporting the development of specific educational programs aimed at improving awareness and behaviors related to food safety and hygiene among students (Eley et al., 2022). It also provides evidence to promote change at snack bars and improve the overall environment around schools, thereby reducing the negative impact on student health.

3.4. Assessing air quality and the presence of Coliform and E.Coli microorganisms in street dust samples

The collection and analysis of data from measurement points at high schools and universities have revealed significant fluctuations in the concentrations of fine particulate matter, specifically PM2.5, PM1.0, and PM10, as well as the presence of Coliform and E.Coli bacteria in the air (Domingo et al., 2021). PM2.5 refers to particulate matter with a diameter of 2.5 micrometers or smaller, PM1.0 refers to particles with a diameter of 1.0 micrometer or smaller, and PM10 includes particles with a diameter of 10 micrometers or smaller. These particles can penetrate deep into the lungs and even enter the bloodstream, posing various health risks.

Over a four-week observation period, the analytical results for PM2.5, PM1.0, and PM10 concentrations are depicted in Fig. 12. The second week recorded the highest PM2.5 concentrations at locations C and D, with levels of 24 and 38 μg/m^3, respectively, while the third week saw lower concentrations at A and B, with 32 and 20 μg/m^3, respectively. Subsequently, the first and fourth weeks exhibited the lowest PM2.5 concentrations. This variability in PM2.5 distribution over the weeks and across different locations is attributed to weather conditions and daily traffic volume (Pérez et al., 2006). Despite these fluctuations, all recorded levels were below the permissible limit set by QCVN 05:2013/BTNMT, which is a 24-hour average threshold of 50 μg/m^3.

Regarding $PM_{1.0}$, the analysis showed that the second week also witnessed the highest concentrations at C and D, with 31 and 51 μg/m^3, respectively. The third week had lower PM1.0 concentrations at A and B, with 43 μg/m^3 and 24 μg/m^3, respectively, followed by the first and fourth weeks, which had the lowest $PM_{1.0}$ concentrations. Furthermore, Fig. 12 indicates that the second week had the highest PM_{10} concentrations at C and D, with 31 μg/m^3 and 51 μg/m^3, respectively. The third week had lower PM_{10} concentrations at A and B, with 32 μg/m^3 and 20 μg/m^3, respectively, followed by the first and fourth weeks, which had the lowest PM_{10} concentrations.

Lastly, the analysis of street dust-air samples also revealed contamination with *Coliform* and *E.Coli* bacteria, with the results clearly reflected in Fig. 13. Both schools A and B were contaminated in the first and third weeks, with the second week showing contamination only at school D, and the fourth week having the highest contamination at school C with *Coliform* counts reaching 3×10^3 CFU/g dust. Specifically for *E.Coli*, schools A and B recorded the highest contamination levels in the first week with counts of 2×10^3 CFU/g dust. In the second week, only schools C and D were contaminated with bacterial counts of approximately 1×10^3 CFU/g dust, with schools A and B being contaminated in the third week, and no schools were contaminated in the fourth week.

These findings not only document significant bacterial contamination but also reflect the relationship between the variance in fine particulate matter concentrations and factors such as weather, traffic volume, and the dispersion of dust in the air. The study revealed that 95 (72%) of the food samples were contaminated with bacteria considered pathogenic according to Vietnamese national standards. Specifically, *E. coli* (51.5%) and *Coliforms* are regarded as indicators of potential health risks in the local context. The reference to the study by (Bereda et al., 2016), which isolated *E. coli* (51.5%), *S. aureus* (64.4%), and *Salmonella* spp. (19.7%) in food samples, is provided to draw a comparison and highlight the presence of similar pathogenic bacteria in street food, even though S. aureus and Salmonella spp. were not specifically tested in our study.

Bacteria and fungi can persist in biological waste and remain viable in the air for extended periods (Fowoyo & Igbokwe, 2014). Another study indicated that pathogenic *Escherichia coli* (*E.Coli*), commonly found in poultry feces, can be transmitted through airborne particles generated during foraging by birds (Nguyen et al., 2021). The prevalence of pathogenic bacteria such as E. coli, S. aureus, and *Salmonella* in street food, along with the long-term viability of microorganisms in dusty air, poses a significant risk to public health (Andrade et al., 2023). When street food is prepared and sold under unsanitary conditions, the risk of exposing consumers to these pathogens increases, potentially leading to infectious diseases and food poisoning. This not only affects individual health but also places a strain on the healthcare system and results in socio-economic losses due to treatment costs and loss of labor (Scharff, 2020). Furthermore, the dispersion of fine dust in the air, exacerbated by traffic volume and weather conditions (Pérez et al., 2006), also increases the risk of environmental microorganisms contaminating food. These microorganisms originate not only from soil and plants but also from poultry feces, which can be dispersed through the air and contaminate food.

These findings suggest a deeper insight into the relationship between air quality and public health (Bellizzi et al., 2021), while emphasizing the importance of continuous monitoring of air quality and microorganisms as an essential part of public health protection measures .

3.5. Evaluating the contamination of food types in the areas in front of school entrances

Based on the collected and analyzed samples, it is evident that the contamination levels of *Coliform* and *E.Coli* in street food at school entrances pose significant concerns regarding food hygiene and safety, as clearly presented in Fig. 14. Bread samples from secondary schools showed alarmingly high levels of *Coliform* contamination, with counts reaching up to approximately 6.4×10^6 CFU/g, ranging from 1×10^6 to 6.4×10^6 CFU/g bacteria. Similarly, rice paper salad samples from university gate areas also recorded the presence of this bacterium, with counts ranging from 1×10^6 to 3.5×10^6 CFU/g. The distribution of E. Coli is notably concerning, especially in bread from high schools, with a

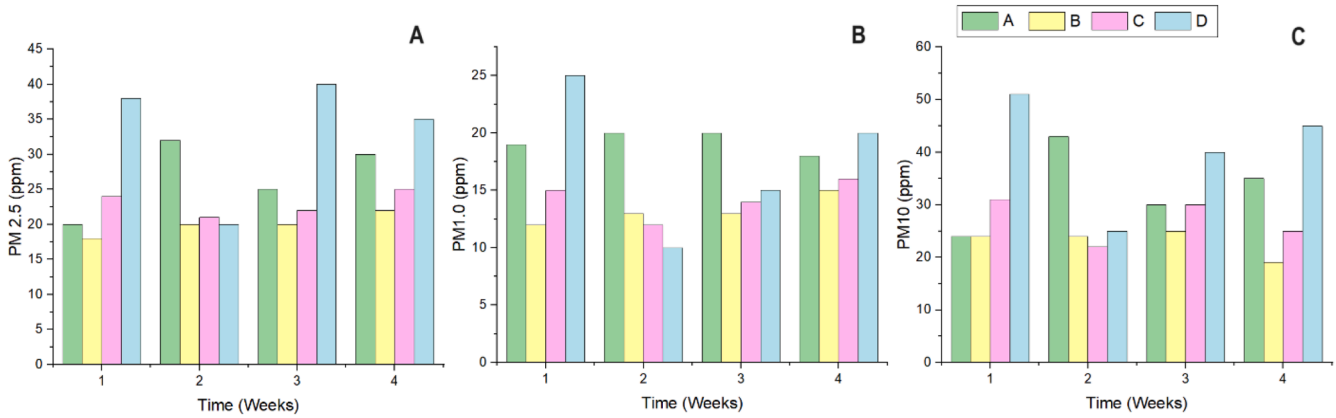

Fig. 12. Particulate Matter Concentrations ($PM_{2.5}$, $PM_{1.0}$, and PM_{10}) at Sampling Sites Over a 4-Week Period.

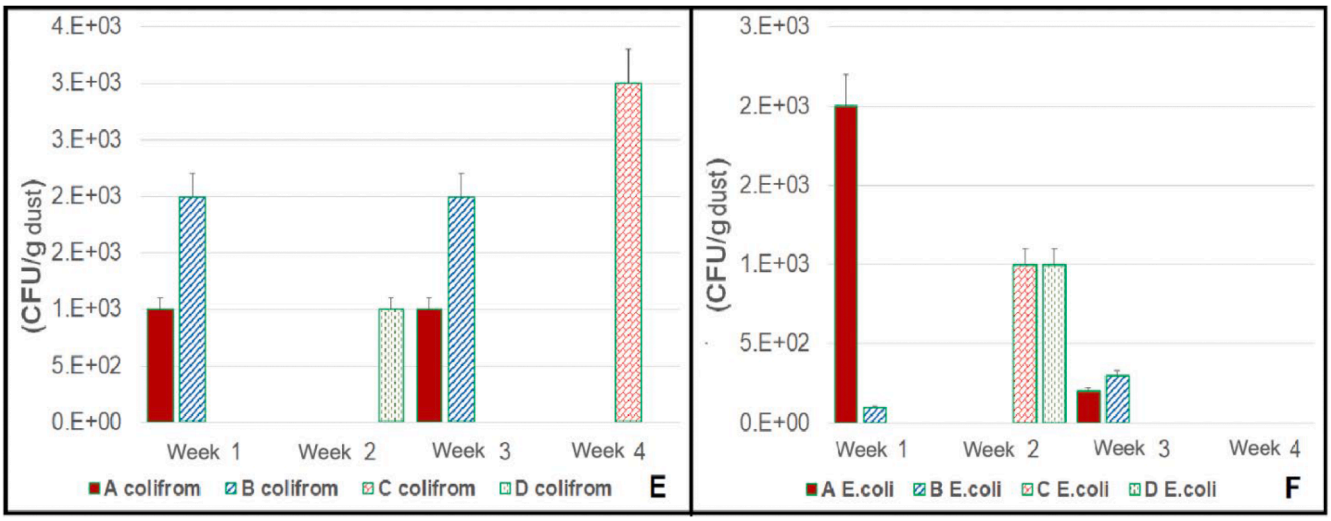

Fig. 13. Results of the analysis for street dust - air samples (E) Coliform count (F) E.coli count.

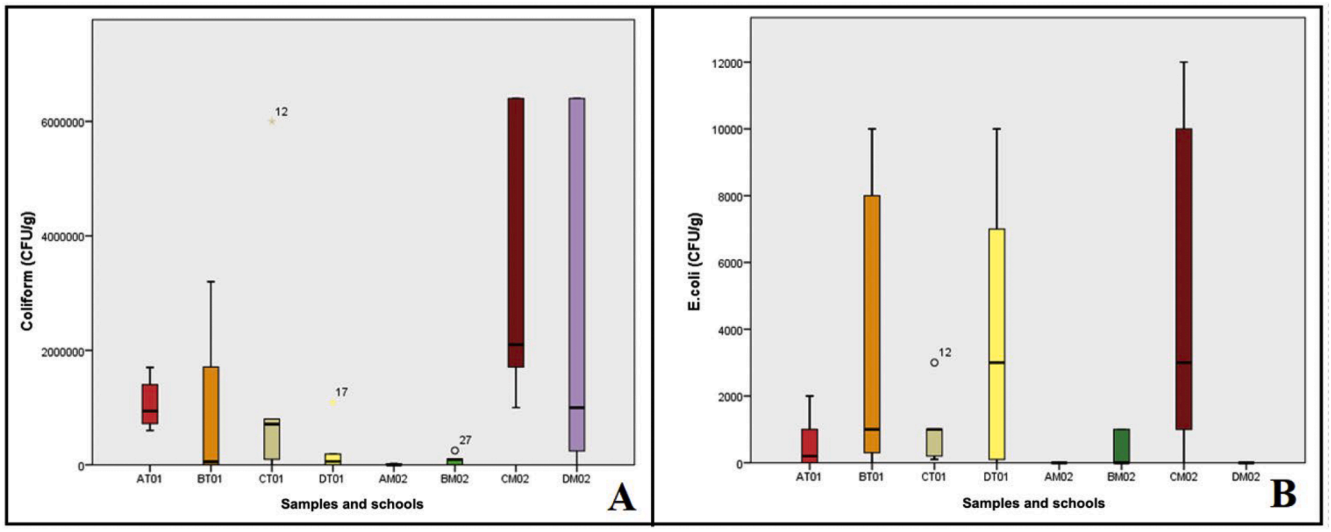

Fig. 14. Results of the analysis for rice paper and mixed bread samples (A) Coliform count (B) E.coli count.

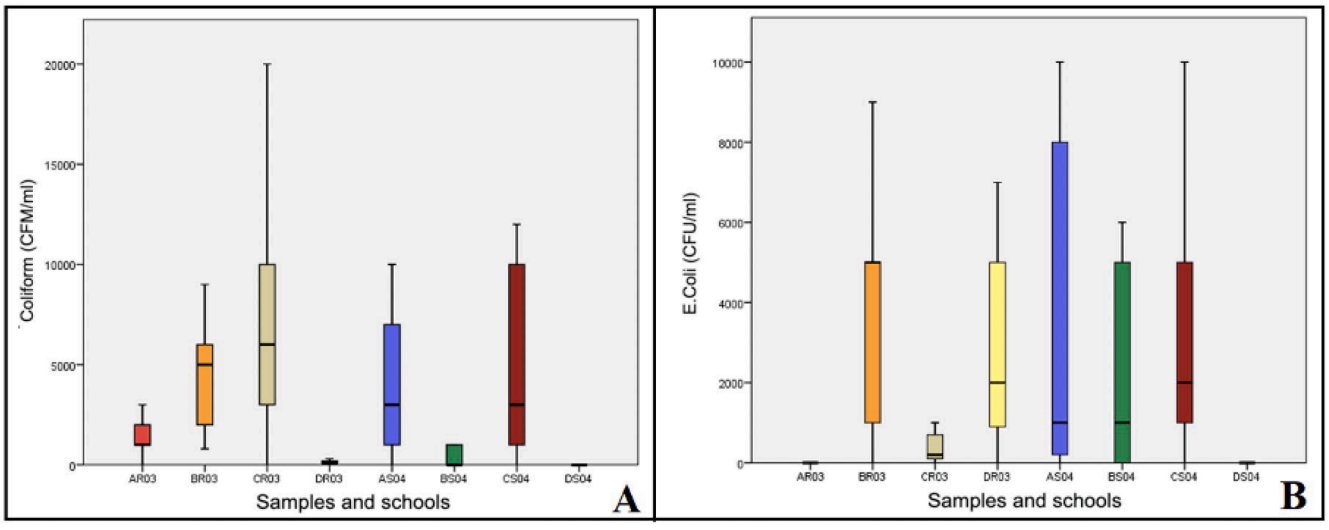

Fig. 15. Results of the analysis for kumquat tea and soy milk samples (A) Coliform count (B) E.coli count.

count of 12×10^3 CFU/g. Both university and high school areas were contaminated with bacterial counts close to 10×10^3 (CFU/g), while the remaining samples had lower bacterial counts or were not contaminated.

Expanding the scope of the study to beverages, contamination also emerged as a significant concern, as clearly reflected in Fig. 15. Samples of kumquat tea and soy milk from various educational institutions showed *Coliform* contamination ranging from 0 to 2×10^4 CFU/ml. Soy milk from high school was contaminated with a count of 12×10^3 (CFU/ml), followed by soy milk from university with a bacterial count of 10×10^3 (CFU/ml), and kumquat tea from the university with a bacterial count of 6×10^3 (CFU/ml), ranging from 800 to 6×10^3 (CFU/ml), with the remaining samples showing lower levels of contamination. Although the contamination levels in kumquat tea and soy milk were lower compared to bread and rice paper salad, the presence of these two types of bacteria still warrants serious attention.

The contamination levels in beverages were compared with the Vietnamese national standard QCVN 6-2:2010/BYT, which sets the maximum permissible limit for *Coliforms* at 10 CFU/ml and does not allow any presence of *E. coli*. Other food items were compared with the regulation 46/2007/QĐ-BYT by the Ministry of Health of Vietnam, which also sets similar limits for *Coliform* and *E. coli*. The results indicate that many samples exceeded these safety thresholds. For example, soy milk from high schools showed *Coliform* counts up to 12×10^3 CFU/ml, significantly above the permissible limit, indicating severe contamination. Similarly, bread and rice paper salad samples showed high levels of *E. coli* and *Coliforms*, well beyond the acceptable safety limits, highlighting significant food safety concerns. These comparisons emphasize the urgent need for stricter regulatory oversight and improved hygiene practices among street food vendors to protect consumer health.

These findings not only align with previous research on but also emphasize that animal-derived ingredients in food are a key factor leading to a high risk of *E.Coli* contamination, as pointed out by (Ge et al., 2013).This result further reinforces the evidence that street food, especially pre-processed products, often contains large amounts of microorganisms exceeding safe thresholds, posing a danger to consumer health (Kamboj et al., 2020). While existing research indicates that to minimize costs, merchants often resort to using groundwater instead of treated or purified water, a practice fraught with substantial bacterial contamination, further investigations also reveal that the preservation and selling practices employed at the surveyed establishments are significantly deficient. These inadequate measures directly compromise consumer health, as evidenced by the elevated presence of *E. coli* and *Coliform* bacteria (Anh et al., 2021). This situation underscores the urgent need for enhanced regulatory oversight and improved sanitation protocols to safeguard public health, particularly in food handling and distribution sectors (Sepadi & Nkosi, 2023).

An essential and practical solution to address these concerns is the education of food vendors (Madaki & Bavorova, 2019; Singh et al., 2016). Educating street food vendors on proper hygiene practices, safe food handling, and the importance of using clean water can significantly reduce the risk of bacterial contamination. These findings highlight that street food vendors in Ho Chi Minh City generally engage in poor food handling practices and most operate under unsanitary conditions (Samapundo et al., 2016).Training programs and workshops organized by health authorities can provide vendors with the necessary knowledge and skills to maintain food safety standards. Moreover, regular monitoring and support from local health departments can ensure adherence to these practices, ultimately leading to safer street food consumption (Okojie & Isah, 2019). By featuring this aspect more prominently, we highlight a proactive approach that not only addresses immediate health risks but also fosters long-term improvements in public health and food safety. This educational initiative can serve as a foundation for building a more sustainable and health-conscious street food industry.

3.6. Proposed solutions for enhancing youth awareness and strengthening regulatory measures for street food vendors

3.6.1. Solutions for youth

In the context of research on food hygiene, safety, and the impact of air pollution on street food, particularly in areas in front of school gates, solutions must be proposed to mitigate the effects of pollution and enhance the awareness of students. A crucial solution is the implementation of a multidimensional educational strategy (Sanlier et al., 2018). Schools and relevant agencies should organize engaging, age-appropriate, and understandable campaigns about food safety issues and the impact of pollution on street food, utilizing various communication channels such as social media, websites, and bulletin boards where most students spend their time (Prescott et al., 2019). Integrating environmental and health education into the curriculum, emphasizing the impact of air quality on food safety, is essential (Eley et al., 2022). Additionally, organizing workshops with experts and scientists to provide in-depth knowledge on the subject, including information on identifying, selecting safe food sources, and measures to prevent and address health issues related to contaminated food consumption, is vital (Organization, 1988). Through these solutions, students can equip themselves with the knowledge to recognize and respond to health issues, thereby taking control of their and the community's health, contributing to a healthy and sustainable school environment (Anna Shutaleva et al., 2021).

3.6.2. Solutions for street food vendors

Furthermore, the pivotal role of street vendors in this issue cannot be overlooked (Samapundo et al., 2015). A key point is that street food is one of the long-standing traditional cultural values of Vietnam, which must be cherished and preserved while also serving as a livelihood for the majority of the Vietnamese population, thus encouraging innovation while maintaining identity. To limit the impact of air pollution, street vendors are encouraged to use protective covers for food to avoid dust and dirt, select ingredients with clear origins, and use environmentally friendly packaging that meets standards (Alamri et al., 2021; Gallo et al., 2020). On the other hand, encouraging personal hygiene practices such as the use of sanitizers, masks, and gloves, as well as equipping work areas with trash bins, will contribute to reducing the risk of food contamination from insects and waste (Tuglo et al., 2021a). Moreover, blending the maintenance of traditional street vending's beauty not only creates a healthier environment for both vendors and consumers but also opens up economic development opportunities, creating sustainable livelihoods for the community, and contributing to the overall development of the national economy.

3.6.3. Solutions for governing bodies

From a management perspective, the collaboration between local authorities and schools in zoning areas for vending is essential and must be conducted sustainably and seriously (Madilo et al., 2023). Individuals wishing to sell should register their vending spots with the local authorities and adhere to existing regulations on food safety and hygiene, including signing a commitment and registering for a food safety and hygiene permit based on current regulations (Food Safety Law 2010, Circular 30/2012/TT-BYT). Additionally, schools could implement competitive bidding for cafeteria spaces (on alternate days) and allow students to vote for quality-assured dishes, thereby encouraging healthy competition and raising food hygiene standards at the vending locations (Dwumfour-Asare, 2015).

Furthermore, in the current business context where supply exceeds demand, enhancing quality and satisfaction emerges as an urgent issue, especially when over 70% of consumers express deep concerns about the risk of bacterial contamination from such food, potentially leading to a long-term decline in trust and changes in consumer behavior (Sanlier et al., 2018). This not only directly impacts the income and livelihood of street vendors but also poses a risk of social security-related issues. In

this situation, the responsibility and business ethics of vendors play a crucial role in ensuring food quality. Despite numerous inspections and penalties, violations of food safety and hygiene continue to worsen. Additionally, the specialized food safety inspection force is still limited, while the number of street food production facilities in the country is vast. Therefore, alongside the active involvement of regulatory bodies, the self-regulation and ethical standards of street vendors are critically important factors determining food quality. Only when producers adhere to business ethics will the issue of contaminated, unsafe food affecting consumer health be eradicated (Hutter, 2011).

Governing bodies play a critical role in ensuring the safety and hygiene of street food through the development and enforcement of comprehensive policies and regulations (Moges et al., 2024). Local authorities should collaborate closely with schools to create designated vending zones that are regularly monitored for compliance with food safety standards. This includes mandatory registration for all vendors, adherence to strict hygiene protocols, and routine inspections to ensure compliance. Authorities could also implement incentive programs for vendors who consistently meet safety standards, such as certification or public recognition, to encourage adherence to best practices. Moreover, regulatory bodies need to establish clear guidelines and provide training sessions for vendors on food safety and hygiene (Addo-Tham et al., 2020), emphasizing the importance of using clean water, proper food storage, and handling practices. These training sessions can be integrated into mandatory certification programs that vendors must complete to obtain or renew their permits.

In addition to education and training, enforcing penalties for non-compliance is essential. Governing bodies should increase the frequency of inspections and impose stringent penalties for violations to deter unsafe practices. Public health campaigns can also be launched to raise awareness among consumers about the importance of food safety (Charlesworth et al., 2021), encouraging them to support vendors who comply with regulations. By focusing on policy development, enforcement, and education, governing bodies can create a safer food environment and protect public health more effectively. This approach ensures that street vendors are aware of and adhere to necessary regulations, ultimately reducing the risk of foodborne illnesses and improving the overall quality of street food.

4. Discussion

4.1. Theoretical implications

This study makes important theoretical contributions by examining the complex relationship between air pollution and street food safety, particularly in urban educational settings. It highlights how airborne pollutants can directly influence food safety by contributing to microbial contamination, while also exploring how students' awareness and behaviors toward these risks are shaped by their environment. This dual focus provides a deeper understanding of the interplay between environmental conditions and food safety in contexts where street food consumption is common. By integrating the Theory of Planned Behavior (TPB) (Ajzen, 2020) with empirical microbial analyses, the research underscores the importance of environmental factors in public health discussions. The application of TPB in this context highlights how attitudes, subjective norms, and perceived behavioral control collectively influence students' awareness and behaviors regarding street food safety (Ukenna & Ayodele, 2019).

One of the key theoretical advancements of this study is the identification and categorization of factors through Exploratory Factor Analysis (EFA). The analysis revealed seven distinct factors: perception of air pollution and its impact on food safety, cultural and practical preferences for street food, perceived impact of air quality on food choices, awareness of food contamination risks, concerns about food safety management, general concerns about air pollution, and health impacts of air pollution. These factors offer a nuanced understanding of how environmental concerns are integrated into everyday food consumption choices and safety perceptions (Khanna et al., 2022).

Furthermore, the study bridges the gap between environmental health risks and socio-cultural behaviors (Gu et al., 2019), demonstrating that air pollution does not merely affect respiratory health but also has a direct impact on food safety through the contamination of street food by dust particles. This intersectional approach provides a comprehensive framework for future research, encouraging the examination of other environmental pollutants and their broader implications on public health and consumer behaviors (Xu et al., 2021).

By elucidating these relationships, the study enhances the theoretical discourse on urban health, food safety, and environmental pollution. It calls for a more integrated approach in public health strategies, considering not only direct health impacts but also indirect effects mediated through everyday practices like street food consumption. This theoretical framework can be applied to other urban settings, fostering a global perspective on the management of air pollution and its multifaceted impact on public health.

4.2. Practical implications

The findings of this study have several practical implications that can significantly enhance public health strategies and food safety practices in urban environments, particularly around educational institutions.

First, the identification of high bacterial contamination levels, particularly *Coliform* and *E.Coli*, in street food samples highlights the urgent need for stringent food safety regulations. Local authorities should enforce regular inspections and implement stricter hygiene standards for street food vendors to ensure compliance with food safety guidelines (Andrade et al., 2023). By addressing the direct sources of contamination, such as the use of untreated water and poor sanitation practices, these measures can substantially reduce the risk of foodborne illnesses (Teferi, 2020).

Second, the study emphasizes the importance of educational campaigns aimed at both students and street food vendors. Schools and relevant agencies should organize engaging, age-appropriate campaigns to raise awareness about the impact of air pollution on food safety. These campaigns could utilize various communication channels such as social media, websites, and bulletin boards to reach a broad audience (Famakin et al., 2023). Additionally, integrating environmental and health education into the curriculum can equip students with the knowledge to recognize and respond to health risks associated with contaminated street food (Black et al., 2015).

Third, the role of street food vendors is crucial in ensuring food safety (Katagum et al., 2021). Training programs and workshops organized by health authorities can provide vendors with essential skills in proper hygiene practices, safe food handling, and the importance of using clean water. Encouraging the use of protective covers for food, selecting ingredients with clear origins, and using environmentally friendly packaging can further minimize contamination risks. Personal hygiene practices, such as using sanitizers, masks, and gloves, should be promoted among vendors to reduce the spread of bacteria.

Fourth, the collaboration between local authorities and schools in zoning areas for vending is essential (Onodugo et al., 2016). Designating specific areas for street food vendors and ensuring these areas meet hygiene standards can create a safer environment for food preparation and consumption. Implementing a registration system for vendors and requiring them to adhere to food safety regulations can enhance accountability and food quality.

Lastly, the study's findings advocate for enhanced regulatory oversight and improved sanitation protocols to safeguard public health (Nayak & Jespersen, 2022). Regular monitoring and support from local health departments can ensure adherence to best practices, ultimately leading to safer street food consumption. These measures, combined with community engagement and education, can create a sustainable and health-conscious street food industry, contributing to the overall

development of the national economy and public health.

In summary, this study provides actionable insights that can guide policymakers, health authorities, and educators in implementing effective strategies to mitigate the health risks associated with street food consumption in polluted urban areas. By addressing both the environmental and behavioral aspects of food safety, these practical measures can ensure a healthier future for urban communities

4.3. Limitations and future research

This study provides valuable insights into the impact of air pollution on street food safety, but it is not without limitations. These limitations offer opportunities for future research to expand on the findings and address the gaps identified.

One major limitation is the scope of food types evaluated. The study focused on a limited number of food items, specifically rice paper salad, banh mi (Vietnamese's bread), kumquat tea, and soy milk. While these items are popular and representative of street food consumed by students, a broader range of food types should be assessed in future studies to provide a more comprehensive understanding of contamination levels across different street food categories. Expanding the variety of food samples can help identify specific vulnerabilities and tailor safety interventions more effectively.

Another significant limitation is the range of pathogenic microorganisms evaluated (Khaneghah et al., 2020). This study primarily focused on *Coliform* and *E.Coli* due to their prevalence and health impact. However, other pathogens such as *Salmonella, Staphylococcus aureus*, and *Listeria monocytogenes* also pose significant health risks and should be included in future analyses. By broadening the scope of microbial testing, future research can offer a more detailed risk assessment and contribute to more robust public health strategies.

The sample size of the survey and empirical analysis also presents a limitation (Nguyen & Trung, 2022; Roelen & Taylor, 2020). Although the study collected data from multiple educational institutions, the sample size could be increased to enhance the statistical power and generalizability of the findings. Larger sample sizes would provide a more accurate representation of the student population's attitudes and behaviors, leading to more reliable conclusions and recommendations.

Moreover, the study was conducted within a specific geographic and cultural context in Ho Chi Minh City, Vietnam. Future research should consider conducting similar studies in different regions and countries to compare results and identify common patterns or unique challenges (Adam et al., 2024; Tuglo et al., 2021b). This cross-regional analysis can contribute to a global understanding of the interplay between air pollution, food safety, and public health.

Additionally, the study's design did not account for seasonal variations in air pollution levels (Fan et al., 2020) and their impact on food safety. Future research should incorporate longitudinal studies that monitor contamination levels and public health impacts across different seasons. This approach can help identify seasonal trends and inform more effective timing for interventions and public health campaigns.

Finally, while the study highlighted the importance of educational campaigns and regulatory measures, it did not evaluate the effectiveness of specific interventions (Young et al., 2020). Future research should include intervention studies that test the impact of various educational programs, regulatory changes, and technological solutions on reducing contamination levels and improving public awareness and behavior.

5. Conclusion

This study underscores the significant microbial risks posed by air pollution on street food safety, particularly through the transmission of microorganisms from street dust to food sold near school entrances. By integrating sociological surveys with empirical sampling, the research highlights the complex relationship between societal attitudes and environmental health risks. The Exploratory Factor Analysis (EFA) and regression analysis identified key factors influencing students' awareness and behavior, especially the perception of air pollution's impact on food safety and concerns about air quality. The findings reveal alarming levels of bacterial contamination, particularly Coliform and E.Coli, in street food samples, underscoring the urgent need for targeted public health strategies. These strategies should focus on enhancing food safety regulations, improving air quality, and raising public awareness about the risks associated with consuming street food in polluted areas. The study provides a crucial link between environmental pollution and foodborne microbial contamination, paving the way for interventions to reduce these risks and ensure safer urban environments. Enhanced regulatory oversight and improved sanitation protocols are essential to protect public health, especially in food handling and distribution. Further research is encouraged to explore additional measures and monitor the effectiveness of proposed solutions, highlighting the need to address environmental factors affecting food safety and to elevate public awareness of these critical health issues. Ensuring a healthier future for urban communities, particularly the younger population, requires comprehensive and sustained efforts to mitigate microbial risks associated with street food consumption.

Author agreement statement

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

CRediT authorship contribution statement

Thanh Tran: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Van Huu Dat:** Writing – original draft, Visualization, Validation, Methodology, Data curation. **Vu Nhat Phuong:** Writing – original draft, Validation, Software. **Tran Hoang Cam Tu:** Visualization, Validation. **Do Vinh Duong:** Writing – original draft, Visualization, Validation, Software. **Ho Huu Loc:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.mran.2024.100327.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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