Assessment of factors influencing customer thermal comfort in Universiti Malaysia Sabah cafeterias

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ABSTRACT In Malaysia's hot and humid tropical climate, maintaining acceptable thermal comfort in naturally ventilated foodservice environments remains challenging. This study assessed environmental, individual, and physiological factors influencing customer thermal comfort in five faculty cafeterias (A–E) at Universiti Malaysia Sabah (UMS). Environmental parameters, including air temperature, relative humidity, and air velocity, were measured using a 5-in-1 Environmental Meter during peak dining hours (10:00 a.m.–2:00 p.m.) between September and October 2024, while customer perceptions were obtained through structured questionnaires (N = 187). Measured air temperatures ranged from 29.8 to 33.9 °C, relative humidity from 58.4% to 79.9%, and air velocity from 0.0 to 2.6 m/s, with several values exceeding adaptive comfort ranges recommended by ANSI/ASHRAE Standard 55 for naturally ventilated buildings in tropical climates. Overall thermal comfort levels across all cafeterias were moderate. Cafeteria A recorded the highest comfort level (mean = 3.22 ± 0.93), likely due to better shading, surrounding vegetation, and improved airflow, whereas Cafeteria E exhibited the lowest comfort level (mean = 2.42 ± 0.78), associated with limited ventilation and minimal natural shading. Cafeterias B, C, and D demonstrated moderate comfort levels, with mean scores ranging from 2.50 to 2.72, indicating partial thermal adaptation among customers. Correlation analysis revealed a significant positive correlation between air temperature and perceived discomfort ($r = 0.61$, $p < 0.05$), while air velocity showed a significant negative correlation with discomfort ($r = -0.47$, $p < 0.05$). Environmental factors, particularly hot weather and insufficient airflow, were the strongest determinants of discomfort, whereas physiological factors such as gender showed minimal influence. The findings highlight the importance of improving ventilation strategies, shading, and landscape integration to enhance thermal comfort in naturally ventilated university cafeterias located in tropical climates.

KEYWORDS: Thermal comfort assessment; University cafeteria; Air temperature and humidity; Natural ventilation strategies; Sabah climate
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INTRODUCTION

Malaysia's tropical climate, characterized by consistently high temperatures and humidity, presents significant challenges in achieving thermal comfort within foodservice environments, such as cafeterias, canteens, and restaurants. According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), thermal comfort refers to the state of mind that expresses satisfaction with the thermal environment. This condition is determined by several environmental parameters—air temperature, relative humidity, air velocity, and mean radiant temperature—as well as personal and physiological factors.

In open-air and naturally ventilated foodservice premises, high humidity often limits the body's ability to dissipate heat through sweat evaporation, while heat from cooking equipment and high occupant density further elevate localized temperatures. Previous research in tropical climates has shown that moderate air movement can significantly improve perceived comfort, and that Malaysians generally adapt to a neutral thermal range between 24 °C and 30 °C (Taib *et al.*, 2022). However, such adaptive tolerance may be exceeded during peak operating periods. Nag and Dutta (2022) also observed that kitchen staff in hot and humid workplaces experience substantial discomfort during peak cooking periods due to fluctuating microclimates and high metabolic heat loads. Similar patterns have been observed in customer dining areas. Ismail *et al*. (2025) conducted a multi-zone investigation in a Malaysian hypermarket and reported that cafeteria zones recorded very high dissatisfaction levels, with a Predicted Percentage of Dissatisfied (PPD ≈ 93%), compared to adjacent retail areas (≈ 12%), primarily due to inadequate ventilation and heat accumulation. These findings demonstrate the sensitivity of foodservice environments to environmental variations and emphasize the importance of effective ventilation and airflow management in such settings.

Beyond environmental influences, individual and physiological characteristics also affect thermal perception. Clothing insulation, metabolic rate, age, and health status can shape how individuals experience thermal environments. Zhang *et al*. (2022) found that younger and more physically active individuals generally tolerate higher temperatures, while older or health-sensitive groups are more susceptible to heat stress. Understanding these differences is important for inclusive and occupant-centred thermal comfort strategies. Despite extensive research on thermal comfort in office buildings, classrooms, and residential environments, empirical evidence focusing on customer thermal comfort in university cafeterias—particularly those relying on natural ventilation without air-conditioning—remains limited. Moreover, few studies integrate objective environmental measurements with subjective comfort perceptions in such settings, limiting direct comparison with standards such as ANSI/ASHRAE Standard 55. University cafeterias are central to daily campus life and operate under fluctuating occupancy levels and climatic conditions, reflecting broader design challenges in tropical foodservice environments. Therefore, this study aims to assess the level of thermal comfort among customers and to identify the environmental, individual, and physiological factors influencing comfort perception in cafeterias at Universiti Malaysia Sabah.

ADAPTIVE THERMAL COMFORT THEORY

Thermal comfort is defined as the condition of mind that expresses satisfaction with the thermal environment and is influenced by both environmental and human-related factors (ASHRAE, 2010). According to the adaptive comfort framework outlined in ANSI/ASHRAE Standard 55**,** occupants in naturally ventilated buildings—particularly in tropical climates—demonstrate behavioral and physiological adaptation that allows tolerance of higher indoor temperatures when adequate air movement is present (ASHRAE, 2010; Taib *et al*., 2022). In foodservice environments such as cafeterias, thermal comfort is primarily governed by air temperature, relative humidity, and air velocity, as these parameters directly affect heat exchange through convection and evaporation (Nag & Dutta, 2022). While individual and physiological factors such as clothing insulation, metabolic rate, age, and health status contribute to variations in thermal perception, studies have shown that environmental conditions exert a stronger influence on perceived comfort in semi-outdoor dining spaces (Zhang *et al*., 2022; Ismail *et al*., 2025). Therefore, integrating objective environmental measurements with subjective comfort assessments provides a robust theoretical basis for evaluating thermal comfort in naturally ventilated university cafeterias.

METHODOLOGY

Study Location and Participants

This study was conducted in five faculty cafeterias located within the main campus of Universiti Malaysia Sabah (UMS). Each cafeteria shares similar design characteristics—open dining areas without air-conditioning—to ensure comparability of thermal conditions. Proportional stratified random sampling was employed to ensure that respondents were representative of the total customer population at each cafeteria. Based on the Krejcie & Morgan (1970) sample size determination table, a total of 187 respondents were selected from an estimated population of 700 cafeteria users.

Data Collection

Two methods were used to collect data: (1) Environmental measurements and (2) Customer perception surveys.

Environment Measurements

Environmental parameters were collected using a 5-in-1 Environmental Meter (EN-300 model) to record air temperature, relative humidity, and air velocity. Measurements were taken during peak operating hours between 10:00 a.m. and 2:00 p.m., when customer activity was highest. Data collection was carried out over two months (September–October 2024) to capture variations in thermal conditions under typical weather patterns. Measurements were recorded near seated customers to reflect the actual conditions experienced during dining.

Customer Perception Survey

Immediately after the physical readings were taken, respondents at the same seating locations were invited to complete a structured questionnaire. The survey included three sections measuring perceived comfort based on environmental, individual, and physiological factors. Responses were rated using a five-point Likert scale ranging from *strongly disagree (1)* to *strongly agree (5)*. The questionnaire was developed based on prior studies by Liping & Hien (2007), Tariq (2014), and Omrani *et al*. (2017).

Data Analysis

The collected data were analysed using IBM SPSS Statistics version 26.0. Descriptive statistics—mean, standard deviation, frequency, and percentage—were used to summarize the comfort level across cafeterias. The Spearman's rank correlation test was performed to determine the relationship between measured environmental parameters and perceived comfort. Results were interpreted based on correlation strength and significance values ($p < 0.05$). The analysis framework followed the descriptive–correlational design commonly applied in environmental comfort studies (Holcomb, 2017).

RESULTS AND DISCUSSION

Demographic Information

A total of 187 complete questionnaires were collected, representing a 100% response rate. The respondent profile was dominated by young, healthy students, which provides important context for interpreting the thermal comfort findings as shown in Table 1. The dominance of respondents aged 18–22 years is consistent with the typical population of university cafeterias and may partly explain the overall moderate comfort levels reported, despite measured environmental conditions frequently exceeding adaptive comfort thresholds. Previous studies have shown that younger individuals tend to exhibit higher tolerance to warm environments and are more adaptable to thermal variations in tropical climates (Zhang *et al*., 2022; Taib *et al*., 2022).

Although the gender distribution was uneven, with female respondents forming the majority, gender was found to have minimal influence on perceived thermal comfort. This finding aligns with Parkinson *et al.* (2021), who reported that gender-based differences in thermal perception diminish when clothing insulation, activity level, and environmental conditions are comparable. Similarly, Nag and Dutta (2022) emphasized that in naturally ventilated foodservice environments, environmental parameters such as air temperature and airflow exert a stronger influence on comfort perception than physiological attributes such as gender. The majority of respondents reported good health status, suggesting that most participants possessed normal thermal tolerance. However, the presence of respondents with reported health conditions, although limited, is noteworthy. Lan *et al*. (2020) highlighted that individuals with health-related sensitivities often experience higher thermal dissatisfaction under warm conditions, reinforcing the importance of inclusive thermal design strategies in public dining spaces. This supports the need to consider vulnerable user groups when improving thermal environments in university cafeterias. In terms of occupation, the predominance of student respondents reflects the exclusion of staff dining areas, which are typically air-conditioned and were intentionally omitted from this study. This methodological decision is consistent with Ismail *et al*. (2025), who emphasized that comparisons between air-conditioned and naturally ventilated spaces should be avoided due to fundamentally different thermal expectations and adaptation mechanisms. The distribution of respondents across Cafeterias A–E further ensures that comfort perceptions captured in this study reflect diverse environmental settings within the campus.

Table 1. Demographic characteristics of respondents (N = 187)

Variable	Category	n (%)
Gender	Male	55 (29.4)
	Female	132 (70.6)
Age group (years)	18–22	158 (84.5)
	23–27	26 (13.9)
	≥ 28	3 (1.6)
Occupation	Student	159 (85.0)
	University staff	2 (1.1)
Health status	No reported illness	179 (95.7)
	Reported illness	8 (4.3)
Cafeteria visited	Cafeteria A	53 (28.3)
	Cafeteria B	53 (28.3)
	Cafeteria C	27 (14.4)
	Cafeteria D	27 (14.4)
	Cafeteria E	27 (14.4)

Overall, while demographic characteristics provide important contextual understanding of the respondent population, the findings reaffirm that environmental factors—particularly air temperature and air velocity—remain the dominant determinants of customer thermal comfort in naturally ventilated cafeteria environments. This conclusion is consistent with prior studies conducted in tropical foodservice contexts (Nag & Dutta, 2022; Roslan *et al*., 2024) and supports the study's emphasis on environmental design interventions rather than demographic segmentation.

Environmental Measurements and Overall Comfort Levels

The analysis of environmental conditions across the five cafeterias revealed varying levels of customer thermal comfort. In addition to perceived comfort scores, objective environmental measurements were recorded to enhance reproducibility and facilitate comparison with adaptive comfort standards. Table 2 presents the mean perception scores for temperature, humidity, and air velocity, together with the overall comfort level for each cafeteria. During the study period (September–October 2024), measured environmental conditions across the cafeterias ranged from

29.8 to 33.9 °C for air temperature, 58.4% to 79.9% for relative humidity, and 0.0 to 2.6 m/s for air velocity. Several values exceeded the adaptive comfort ranges recommended for naturally ventilated buildings in tropical climates under ANSI/ASHRAE Standard 55 (2023)

Table 2: Customer comfort level towards the environment in the cafeteria.

No.	Cafeteria	Type of Measurement	Measured Value (Range)	Mean ± SD	Overall Mean ± SD	Comfort level (Interpretation)
1	CAFÉ A	Temperature	29.8 – 31.2 °C	3.14 ± 0.99	3.22 ± 0.93	Moderate (Comfortable)
		Humidity	60.0 – 75.0 %	3.26 ± 0.98		
		Air velocity	0.0 – 2.6 m/s	3.00 ± 0.92		
2	CAFÉ B	Temperature	32.0 – 33.9 °C	2.81 ± 0.92	2.72 ± 0.74	Moderate (Comfortable)
		Humidity	58.4 – 71.2 %	2.85 ± 0.66		
		Air velocity	0.2 – 1.5 m/s	2.56 ± 0.75		
3	CAFÉ C	Temperature	30.5 – 32.5 °C	2.33 ± 0.73	2.69 ± 0.71	Moderate (Comfortable)
		Humidity	73.8 – 79.9 %	2.77 ± 0.70		
		Air velocity	0.0 – 0.8 m/s	2.96 ± 0.71		
4	CAFÉ D	Temperature	31.0 – 33.0 °C	2.32 ± 0.73	2.50 ± 0.76	Moderate (Comfortable)
		Humidity	65.0 – 78.0 %	2.64 ± 0.76		
		Air velocity	0.3 – 1.2 m/s	2.54 ± 0.77		
5	CAFÉ E	Temperature	30.8 – 32.8 °C	2.28 ± 0.86	2.42 ± 0.78	Moderate (Comfortable)
		Humidity	62.0 – 76.0 %	2.43 ± 0.80		
		Air velocity	0.4 – 1.4 m/s	2.58 ± 0.84		

Note.
1. Interpretation of mean scores: 1.00–2.33 = low (uncomfortable); 2.34–3.66 = moderate (comfortable); 3.67–5.00 = high (very comfortable).
2. Measured values were recorded during peak hours (10:00–14:00).

According to Table 2, Cafeteria A recorded the highest overall comfort score (3.22 ± 0.93), indicating a moderate level of comfort among customers. This finding is attributed to favourable microclimatic conditions, including surrounding vegetation and proximity to a lake, which likely contributed to localised cooling and improved airflow. Similar cooling effects associated with greenery and water features have been reported by Cao *et al*. (2022) and Castelo *et al*. (2024).

Cafeteria B ranked second (2.72 ± 0.74) and also reflected moderate comfort. Respondents reported slightly higher dissatisfaction with air temperature and air movement compared to Cafeteria A, likely due to limited shading and vegetation. This observation is consistent with Azmeer *et al*. (2024), who emphasised the role of sustainable landscaping in mitigating heat accumulation in tropical public spaces.

Cafeterias C and D recorded moderate comfort levels (2.69 ± 0.71 and 2.50 ± 0.75, respectively). Although customers were generally comfortable, the lower scores suggest thermal strain associated with high humidity and inadequate air circulation. Amaripadath *et al*. (2023) reported that elevated humidity reduces sweat evaporation efficiency, intensifying discomfort, while Roslan *et al.* (2024) observed that operative temperatures exceeding 30 °C combined with low air velocity (<0.2 m/s) resulted in “warm–hot” thermal sensation levels in Malaysian cafeterias.

Cafeteria E recorded the lowest comfort score (2.42 ± 0.78), indicating noticeable discomfort. This cafeteria is primarily surrounded by built structures and lacks natural shading, restricting airflow and promoting heat accumulation. This finding supports Chindapol (2019), who reported increased discomfort in naturally ventilated restaurants with poor ventilation design and limited vegetation.

Overall, comfort scores across all cafeterias ranged from 2.42 to 3.22, falling within the moderate comfort category. This indicates that while customers were not fully uncomfortable, environmental conditions were generally suboptimal for achieving high thermal satisfaction.

Correlation Between Measured and Perceived Comfort

Spearman's correlation analysis revealed a significant positive correlation between air temperature and perceived discomfort ($r = 0.61$, $p < 0.05$), confirming that higher air temperatures substantially increased customer discomfort. Air velocity showed a moderate negative correlation with discomfort ($r = -0.47$, $p < 0.05$), indicating that increased airflow improved thermal comfort. Relative humidity exhibited a weak and non-significant correlation with discomfort. This may be attributed to the semi-open design of the cafeterias, which allowed partial dissipation of humidity despite high ambient moisture levels. These findings demonstrate consistency between objective environmental measurements and subjective comfort perceptions, reinforcing the reliability of the mixed-method approach adopted in this study.

Determinants of Factors Influencing Thermal Comfort in Cafeterias

To further understand the determinants of comfort, the factors were grouped into environmental, individual, and physiological categories, as shown in Table 3. Among these, the most influential factor was environmental, with hot weather showing the strongest effect (mean = 4.04 ± 0.912). The least influential was physiological, specifically gender, which had the lowest mean (mean = 2.02 ± 1.039).

Table 3. Factors influencing thermal comfort in cafeterias. N = 187

Factor Type	Statement	Mean ± SD	Interpretation
Environmental	Hot weather makes me uncomfortable in the cafeteria	4.04 ± 0.912	High – strongly agree
	I feel sticky, which makes me uncomfortable in the cafeteria	3.69 ± 1.064	High – strongly agree
	I feel thirsty and my skin becomes dry, making me uncomfortable	3.22 ± 1.027	Moderate – agree
	Less wind makes me feel hot in the cafeteria	3.91 ± 0.971	High – strongly agree
	The lack of fans in the cafeteria makes me feel hot	3.83 ± 0.999	High – strongly agree
Individual	My clothing makes me hot	2.78 ± 1.094	Moderate – agree
	My thick clothes make me uncomfortable	2.77 ± 1.213	Moderate – agree
	I take off my jacket when I feel hot in the cafeteria	3.86 ± 1.065	High – strongly agree
	My current activity (sitting/standing/walking) makes me hot	2.11 ± 1.023	Low – disagree
	My current activity affects my comfort in the cafeteria	2.32 ± 1.132	Low – disagree
Physiological	My age affects my comfort in the cafeteria	2.08 ± 1.033	Low – disagree
	My gender affects my comfort in the cafeteria	2.02 ± 1.039	Low – disagree
	My health status affects my comfort in the cafeteria	2.37 ± 1.199	Moderate – agree

Interpretation of mean scores: 1.00–1.80 = very low (strongly disagree), 1.81–2.60 = low (disagree), 2.61–3.40 = moderate (agree), 3.41–4.20 = high (strongly agree), 4.21–5.00 = very high (extremely agree).

Environmental Factors

Environmental conditions exerted the strongest influence on customer comfort, with high mean agreement scores across all related items. The statement *"Hot weather makes me uncomfortable in the cafeteria"* recorded the highest mean value (4.04 ± 0.91), followed by *"Less wind makes me feel hot in the cafeteria"* (3.91 ± 0.97). These findings reaffirm that air temperature and airflow are the primary determinants of comfort in tropical environments. ANSI/ASHRAE Standard 55-2023 identifies these two parameters as critical in maintaining thermal balance, while Arsad *et al*. (2023) emphasized that

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even minor reductions in air velocity can lead to noticeable discomfort in humid climates. Humidity, although significant, was rated slightly lower than temperature. This is likely because the open-air cafeteria design allowed for some natural ventilation, reducing humidity's impact—a finding consistent with Roslan *et al*. (2024).

Individual Factors

Individual adaptation behaviours showed a moderate influence on comfort (overall mean = 2.77 ± 1.10). The statement *"I take off my jacket when I feel hot in the cafeteria"* received the highest score (3.86 ± 1.07), suggesting that behavioural responses such as clothing adjustment were common coping strategies. These findings correspond with Azmeer *et al*. (2024), who observed that light, breathable clothing and self-regulated behaviour are effective ways to maintain comfort in tropical settings. The lowest individual factor score related to activity level (*mean = 2.11 ± 1.02*) suggests that sedentary activities, such as sitting or eating, had little effect on comfort. This aligns with the metabolic rate assumptions in ANSI/ASHRAE Standard 55 (2023), where sedentary conditions (~1.0 met) minimally influence thermal stress.

Physiological Factors

Overall, physiological factors were the least influential. The statement *"My gender affects my comfort"* recorded the lowest mean (2.02 ± 1.04), indicating negligible gender-based differences in perceived comfort. Parkinson *et al*. (2021) similarly reported that gender differences in thermal preference diminish when environmental and clothing factors are controlled. However, *"My health status affects my comfort"* achieved a slightly higher mean (2.37 ± 1.20), suggesting that individuals with certain health conditions may experience greater discomfort. Lan *et al*. (2020) found that people with reduced heat tolerance or chronic conditions reported higher dissatisfaction under warm conditions, supporting the need for inclusive design considerations in public dining spaces.

The findings highlight that environmental parameters, especially air temperature and air velocity, remain the dominant determinants of comfort in tropical cafeteria environments. Individual behavioural adaptation, such as clothing adjustment, contributes moderately to comfort maintenance, while physiological attributes—though least influential overall—should not be ignored, particularly for health-sensitive groups. Overall, the study supports previous research in tropical foodservice contexts (Nag & Dutta, 2022; Ismail *et al*., 2025) and provides localized evidence from Sabah, Malaysia. The results underscore the necessity for improved natural ventilation, shading strategies, and design interventions such as ceiling fans or open ridge vents to enhance comfort and customer satisfaction in university cafeterias.

Proposed Adaptive Thermal Comfort Framework for natural ventilated university cafeterias

Figure 1 presents the adaptive thermal comfort framework applied in this study to explain thermal comfort perception in naturally ventilated university cafeterias. Consistent with the adaptive comfort theory outlined in ANSI/ASHRAE Standard 55, the framework conceptualises thermal comfort as the outcome of interactions between environmental conditions and human adaptive responses within a tropical context.

At the first level, environmental factors—specifically air temperature, relative humidity, and air velocity—are identified as the dominant determinants of thermal comfort in naturally ventilated cafeteria environments. These parameters directly influence heat exchange mechanisms, including convection and evaporation, and form the primary physical conditions experienced by cafeteria users. In tropical settings, elevated air temperatures and humidity can intensify thermal discomfort, while increased air movement has the potential to mitigate heat stress and improve comfort perception.

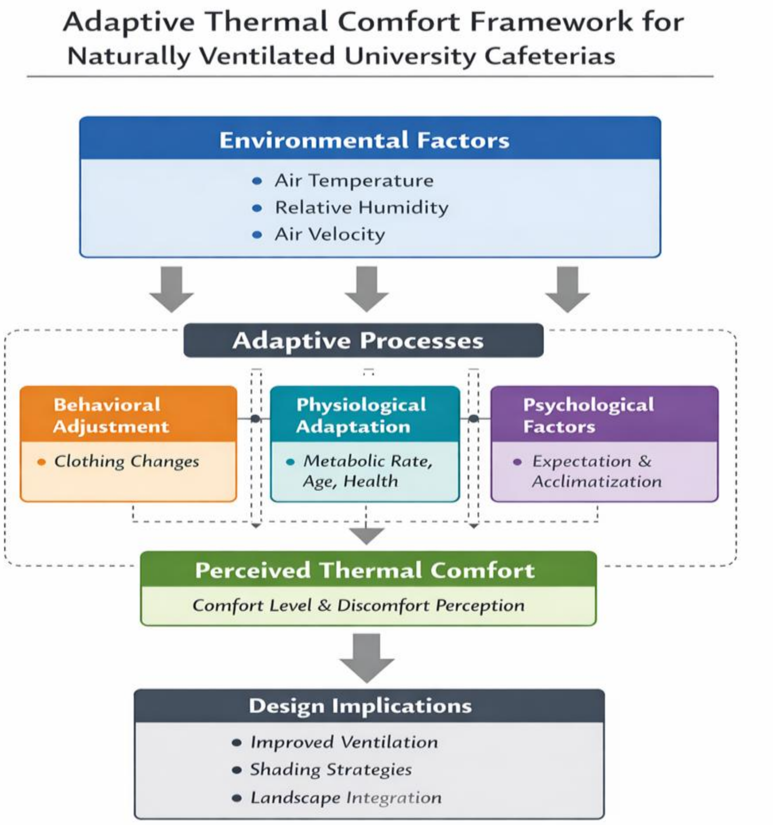

Figure 1. Adaptive Thermal Comfort Framework for natural ventilated university cafeterias

The second level represents adaptive processes that moderate the impact of environmental conditions on occupants. Behavioural adaptation includes actions such as adjusting clothing or altering posture in response to thermal sensations. Physiological tolerance reflects individual differences related to age and health status that may influence thermal sensitivity. Psychological expectation accounts for acclimatisation to warm and humid conditions, which shapes users' acceptance of higher indoor temperatures in naturally ventilated spaces. These adaptive mechanisms allow occupants to tolerate a wider range of thermal conditions compared to those prescribed by static comfort models.

At the third level, the interaction between environmental factors and adaptive processes results in perceived thermal comfort, expressed through overall comfort level and discomfort perception. This perceived comfort forms the basis of the subjective evaluations captured through the questionnaire survey in this study, complementing the objective environmental measurements.

Finally, the framework links perceived thermal comfort to design implications, highlighting the importance of environmental and architectural interventions aimed at improving comfort in naturally ventilated cafeterias. Strategies such as enhancing natural and mechanical ventilation, providing effective shading, and integrating landscape elements are emphasised as practical measures to reduce thermal discomfort in tropical campus dining environments. Overall, the framework provides a theoretical basis for integrating objective environmental measurements with subjective comfort perceptions and supports the study's focus on environmental design strategies as the most effective means of enhancing thermal comfort in naturally ventilated university cafeterias.

CONCLUSION

This study concludes that customer thermal comfort in Universiti Malaysia Sabah cafeterias remains moderate, with variation across locations primarily influenced by environmental surroundings and ventilation characteristics. Cafeteria A achieved the highest comfort level due to favourable natural features, while Cafeteria E recorded the lowest comfort as a result of dense built surroundings and restricted airflow. Environmental factors—particularly air temperature and air velocity—emerged as the dominant determinants of comfort, while individual behavioural adaptations contributed moderately. Physiological factors were least influential overall, although health status remained relevant for vulnerable groups. These findings highlight the need for integrated strategies focusing on improved natural ventilation, shading, and adaptive design interventions to enhance thermal comfort in naturally ventilated university cafeterias in tropical climates.

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