J Ther Eng, Vol. 7, Supp 14, pp. 2093–2106, December 2021

Journal of Thermal Engineering
Web page info: https://jten.yildiz.edu.tr
DOI: 10.14744/jten.2021.xxxx

Review Article

Factors affecting on human thermal comfort inside the kitchen area of railway pantry car - a review

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ARTICLE INFO

Article history
Received: 13 February 2021
Accepted: 11 June 2021

Keywords:
Indoor thermal environment, Environmental ergonomics, Pantry car, Thermal sensation, Railway

ABSTRACT

Railway transportation plays a significant contribution to carrying passengers in India. In which during the journey, pantry cars are involved to serves the food to all onboard passengers. The kitchen atmosphere of the pantry car gets very hot and humid during cooking which could affect occupants' thermal comfort. Therefore, the current research article describes a review of the factors affecting human thermal comfort inside the kitchen of the railway pantry car. The factors influencing of human thermal comfort inside pantry car kitchens are classified into two categories viz; environmental factors that include "air temperature, mean radiant temperature, relative humidity, air velocity" and personal or individual factors including "metabolic rate and clothing insulation". All these factors need to be considered in order to achieve the optimum level of thermal comfort inside the kitchen environment of the pantry car. With the assistance of all these factors, we can estimate the thermal comfort indices such as; SET "standard effective temperature," PMV "predicted mean vote," PPD "predicted the percentage of dissatisfied," thereby recognizing the acceptable thermal sensation range for occupants' (chefs) in the pantry car kitchens during the work period. These kinds of parametric studies can cover a wide group of all pantry car chefs in evaluating thermal comfort. Furthermore, there is a need to apply all the consequences of this research to increase the chef's thermal comfort inside the pantry car kitchen while working.

Cite this article as: Shanmukh S A, Ramakrishna K, Govinda R B. Factors affecting on human thermal comfort inside the kitchen area of railway pantry car - a review. J Ther Eng 2021;7(Supp 14):2093–2106.

INTRODUCTION

According to the standard of the "ISO-7730", thermal comfort is a "condition of mind, which expresses satisfaction with the thermal environment" [1, 2]. Thermal comfort is related to the perception of a subject living in any thermal environment, which is related to many of factors; therefore, it is a bit complicated to guess and define correctly [3]. Because in the same thermal environment, the perception rate of workers is varied due to the different acclimatization of the body. It means in the similar thermal atmosphere the comfort condition differs not the same

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This paper was recommended for publication in revised form by Regional Editor Younes Menni

Published by Yıldız Technical University Press, İstanbul, Turkey

for occupants. As per the ASHRAE "American Society of Heating, Refrigerating and Air-Conditioning Engineers" in psychometric charts, the comfort zone depends on the satisfaction of occupants in any "thermal environment," it must be at least 80% [3-4]. Thermal comfort factors depend on the "heat exchange between the human body and the ambient environment" in any working condition [3].

Several thermal comfort studies have directed that six major parameters affect "human thermal comfort," in which the factors have been classified into two categories such as environmental and individual or personal [5-10]. Similarly, "psychological parameters, such as individual expectations, also affect thermal comfort" [11]. The environmental factors have been segregated into four measurable parameters such as "air temperature", "mean radiant temperature", "relative humidity", and "air velocity". However, personal or individual factors have separated into two components like "metabolic rate" and "clothing insulation" [12-19]. For estimation of thermal comfort inside the kitchen of a railway pantry car, all these factors need to be considered, as all the factors change from time to time because it depends on the occupant's perception rate. Therefore, it is a very challenging task to maintain the satisfaction rate of every occupant inside a closed indoor environment such as a kitchen of a railway pantry car. Because every human being is different from each other, while thermal comfort refers specifically to a set of optimal parameters of any group of people who feel "cold or hot" thermal sensation in any environment [20].

There are many thermal comfort indices available through which we can estimate the working thermal environmental conditions, whether it is thermal comfort or not. And before applying any thermal comfort index, it is necessary to know whether it applies to it or not, to predict "thermal comfort". In the current scenario, PMV "Predicted Mean Vote" and PPD "Predicted Percentage of Dissatisfied" index is very popular to predict the thermal comfort for both the indoor and outdoor environment [21, 22]. It was established by Fanger "based on the heat balance equation" concept [22]. For thermal comfort conditions, the value of PMV should be slightly cool to slightly warm thermal sensation, and PPD should be less than 10% [23, 24]. In a parametric calculation, all "four environmental factors" and "two personal factors" are required for the estimation of the "PMV and PPD index" [25]. Two international standard models of PMV, "ASHRAE Standard 55-2017 and EN-16798," are available, through which the complies of the data are identified. The CBE Thermal Comfort tool is very popular nowadays for calculating the PMV-PPD index [26, 27]. Another popular thermal comfort index is the SET "Standard effective temperature," an index based on rational physiology developed by ASHRAE. Prediction of this thermal comfort index also requires six factors, and the calculations of this are similar to the PMV index [28-29]. Thermal sensation range of SET in this index is "<17 cool", "17-30 comfortable", "30-34 warm", "34-37 hot", ">37 very hot" [20, 30-31]. Nowadays, there is a lot of software available for calculating this index, one of which is the CBE Thermal Comfort tool.

Lots of researchers have concentrated to increase thermal comfort inside the indoor working environment like the kitchen. To enhance the thermal comfort inside the closed indoor environment they utilized proper installation of the ventilation or air supply system [32-37]. In order to design the kitchen environment, all these factors need attention, which helps to the enhancement of thermal comfort. Because good thermal sensation does not just give a comfortable feeling, but it also helps in improving working conditions, working efficiency, and improving quality.

Numerous research articles are available on thermal comfort within the kitchen environment, some of which are on railways, but none have focused on reviewing factors affecting the kitchen environment; all have focused their analysis and method of assessing the thermal comfort.

Simone et al. [38] directed a study on commercial kitchens in the United States using PMV and PPD indices based on physical measurements. The consequence of this indicated that the most suitable thermal comfort index PMV is not directly applicable to kitchens due to high temperature and high metabolic rate. Similarly, the research by Rahmillah et al. [39] directed that PMV and PPD indices are more predictive due to higher indoor temperatures; therefore, it is not suitable for thermal estimation of household kitchens in Malaysia. Ravindra et al. [26] investigated thermal comfort research on home kitchens in Punjab, India, for which they used the PMV-PPD index and adaptive strategy. Wan et al. [40] compared two Chine commercial kitchens based on ventilation systems. The "PMV model" has been used to predict thermal comfort with numerical simulations in this study. Accordingly, a field study was carried out by Simone and Olson [41] in commercial kitchen environments based on physical measurement estimation. This study proposed a data collection process for the "evaluation of the thermal environment". Azizpour et al. [42] performed a thermal comfort study on the tropical climate in large-scale hospitals at the "University Kebangsaan Malaysia Medical Centre," Malaysia. In this study, both "objective" and "subjective" measurements are included for the evaluation of thermal comfort state, using the effective temperature (ET*) and the PMV index. Liu et al. [43] investigated indoor thermal comfort of the Chinese kitchen based on the new ventilation approach to enhancement of thermal comfort. In this research, "field measurement" and "questionnaire surveys" have been carried out to assess thermal conditions. Taha and Sulaiman [44] conducted a study in Malaysia on the elderly kitchen environment to identify the occupants' perception during the working period. On-site measurement has been done and compared the measured data with the recommended range of thermal comfort standards. Manshoor et al. [45] directed research to determine the best position of curtain angle for the increment of air velocity at the kitchen zone, which helps to improve the performance of the "ventilation system" and make a comfortable environment. Correspondingly, Konstantinov and Wagner [46] conducted a thermal comfort study in the cabin of the train for the comfort of passengers, using the "computational fluid dynamics-CFD" approach and equivalent temperature for prediction of thermal comfort. Again, a similar kind of thermal comfort experiment was conducted by Konstantinov and Wagner [47] on "double-decker train cabins with passengers". In this study also CFD analysis has been used for flow simulation. Kim [48] investigated human thermal comfort in passenger trains using the CFD approach with the incorporation of the PMV-PPD index. In this research, with and without passengers, distribution of air velocity and air temperature has been tested. Ismail and Abdul [49] investigated studies on indoor thermal comfort of "hybrid turbine ventilators." Field measurements have been performed and included two "thermal comfort indices" such as standard effective temperature and operative temperature. Zhang et al. [50] conducted a thermal comfort study on a "hot and humid" building environment in China. Environmental and personal parameters have been taken in this study for the assessment of the thermal environment. While the SET index was included for parametric estimation. A review paper by Chun et al. [51] suggested PMV and SET index for indoor thermal comfort of transitional spaces. Objective and subjective measurement techniques are described for the appraisal of the thermal atmosphere. Similarly, Yang et al. [52] directed to assess the thermal comfort condition inside the "well-controlled climate chamber" they have used PMV and SET index. In this study also, both environmental and personal factors were considered for the prediction of the index.

The above literature cleared that thermal comfort is necessary for the built environment like a kitchen of railway pantry car. The thermal working environment of the railway pantry car is similar to the commercial kitchen environment, except for the moving nature of the train. The existing condition railway pantry car kitchen is depicted in Figure 1. Therefore, the main objective of this study was to review the major thermal comfort factors inside the kitchen environment of the railway pantry car.

INDOOR THERMAL COMFORT FACTORS THAT AFFECT INSIDE THE PANTRY CAR

According to the literature, the assessment of thermal comfort of the "occupants" inside a "hot and humid" built environment like the kitchen of a railway pantry car is related to "environmental factors" and "personal factors" that affect the worker's body and organs which they perceive while working [5, 27]. All these factors are the major contributing factors that need to be considered in order to achieve the "thermal satisfaction of workers" over the period of work.

(a)

(b)

Figure 1. The existing condition of kitchen of the railway pantry car (a) and (b) http://www.iieta.org/pdf-viewer/9117.

The environmental factors are correspondingly related to these parameters, such as; "air temperature", "mean radiant temperature (assessing with globe temperature)", "relative humidity", and "air velocity". Similarly, personal or individual factors are related to these parameters like; "clothing insulation", and "metabolic rate/activity level" [27]. Environmental and individual factors of human thermal comfort are demonstrating in Figure 2.

Other factors that affect human organism related to thermal comfort these are; age, gender, weight, health, drinking, working conditions, season, climate others too [3, 53-59]. These factors have a significant effect on the occupants while during working time inside the kitchen of the railway pantry car. This would be a considerable factor for achieving thermal comfort and improving the indoor built environment. All these factors are strongly related to the comfort zone of living in any work environment and should be compared with the recommended standard value of "thermal comfort", which can be both measurable and individual factors outside the recommended range.

As per the previous research directed inside the commercial kitchen environment, heating and cooking appliances such as; electric heater, pressure cooker, stove, oven,

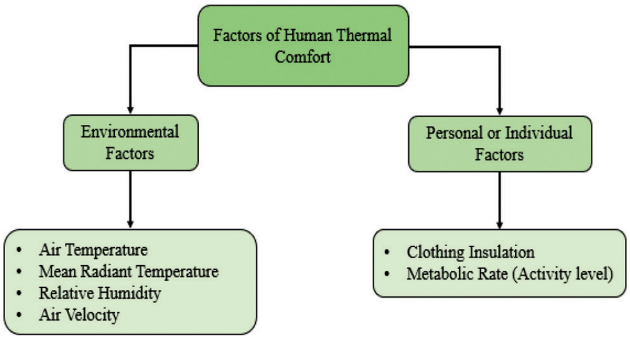

Figure 2. Environmental and individual factors for predicting thermal comfort inside pantry car kitchens.

kettle others too, create heat and moisture inside the kitchen at the time of meal preparation period [60, 61]. Due to this, the inner environment of the kitchen, like a pantry car, becomes too "hot and humid". There are several studies that describe the various factors of thermal comfort that affect the "indoor and outdoor" thermal environment based on the condition and scenario.

Wei et al. [62] investigated a study on "thermal comfort in commercial kitchen environments" in China, in which they found that the dominant contributing factor is the outdoor temperature. When the outside "temperature is low", there is a lot of change in the "inside temperature". Similarly, in the United States, Simone and Olesen [63] researched commercial kitchen environments in which air temperature and metabolic rate were found to be very high, Because of which the PMV index was not applicable for predicting thermal comfort. Logeswari and Mrunalini [64] conducted a heat stress study on large kitchen workers in the hostel environment in India; the results of this study found the body temperature of the workers to be very high, which was higher than the "World Health Organization" recommended limit. Similarly, in India, Ramesh and Manikandan [65] studied the hotel kitchen environment, focusing on solar radiation to improve thermal comfort. Ogulata [66] demonstrated that clothing value, climatic condition, and physical activity are key parameters that influence human thermal comfort. Heinonen [67] investigated thermal comfort studies in Finnish commercial kitchen environments, in which they found that the supply air temperature or airflow has a significant effect on indoor temperature. Thus, Lin et al. [68] directed the seasonal impact on the outdoor "thermal comfort" parameters; in this study, a strong correlation was found between thermal perception with "air temperature" and "mean radiant temperature". However, there was no significant relation to airflow and humidity. Consequently, Karjalainen [69] states that there is a gender difference in an indoor environment based on thermal perception; the sensitivity is higher in women than male subjects. Similarly, in a laboratory study based on the perception rate of "thermal comfort," there is a slight significant difference found between genders [70]. However, Fanger [71] stated in his research that he did not find any "significant differences between genders" in climate chamber research. There is a significant difference in "air temperature," "mean radiant temperature," and "air velocity" at thermal comfort, although there is no significant difference in terms of "humidity," as indicated in the study [72]. While Liu et al. [73] directed that weighted factors affect the "adaptive thermal comfort of occupants". Few studies have mentioned in his research, drinking consumption "impact on thermal comfort" of the workers, Baker and Standeven [74] demonstrated experimental research on behavioral factors such as the effect of drinking on "human thermal comfort". Haldi and Robinson [75] also discussed the hot drinking consumption "influence on the thermal comfort" of workers. Similarly, drinking beverages are significantly impacting human thermal comfort during work hours, reported by Mustapa et al. [76], which would equally affect the work environment in the pantry car.

Heart rate is a very important parameter of physiological factors, which demonstrates the thermal perception of an individual living in any environment how comfortable he is with the present environment. Which may be considered for evaluation of kitchen environments such as pantry cars, as reviewed by several researchers.

Such as Liu et al. [77] evaluated the physiological parameters like heart rate effect on the three categories of thermal comfort to improve the indoor work environment for occupants. Same way Liu et al. [78] mentioned in his research using mean skin temperature with heart rate variables to predict the perception of the workers for assessment of thermal comfort. However, changes in heart rate are much greater with a high metabolic rate in a warm environment, greatly affecting the thermal satisfaction of the occupant [79]. Further, Xiong et al. [80] designated that physiological parameters (e.g., skin temperature, heart rate) have a very significant consequence on the prediction of comfort temperature, which will greatly affect thermal comfort. The author of this study found thermal comfort and acceptability in up-step value (22°C-37°C). This can be an influential contributing factor for estimating the thermal comfort of cooks inside the kitchens of railway pantry cars. Similarly, Zhu et al. [81] experimented research on "thermal comfort based on the heart rate variability" under the different types of environmental scenarios. A study conducted by Matsuzuki et al. [61] on the commercial kitchen environment to identify the effect it's on occupants during the work period. In that, they used the heart rate variable for the estimation of thermal strain. Similarly, working hours, duration of time, time-shifting, and others too affect heat stains in the kitchen environment that the author has demonstrated [60].

However, some of the researchers have described in their studies the effect of ventilation systems such as exhaust hoods, air channel supply on indoor thermal comfort [82-84]. A proper installation position is essential for keeping an excellent indoor environment in agreement with ventilation systems that provide a suitable environment for the people living there, increasing their performance to work, which helps maintain thermal comfort. Through subjective evaluation, Kitagawa et al. [85] have investigated a study to identify the "effect of humidity and air movement on thermal comfort under the radiant cooling method." In a review by Cheng et al. [86], two different types of ventilation systems are mentioned, such as (i) "mixing ventilation" and (ii) "displacement ventilation," showing the effects on thermal comfort and performance of the system. As per Lin et al. [87], displacement ventilation is better for the thermal environment because of its results; they have proposed this to the building environment. Similarly Novoselac and Srebric [88] reviewed the research and gave a statement about the ventilation system; they suggested displacement ventilation is better for performance. Accordingly, Shan et al. [89] conducted a study on the comparison between "mixing ventilation and displacement ventilation" in a classroom-based on the air supply. The result of this directed "mixing ventilation leads to higher overall draft sensation during displacement ventilation" in cold feel sensation. Cho et al. [90] tested four different types of "ventilation systems," and they proposed a "new ventilation system" installation for enhancement of thermal comfort. All the researchers have put forward their rationale for a favorable air supply, showing that the "displacement ventilation system" is more appropriate for the indoor built environment. Which will control the thermal comfort factors like "air temperature" and "air velocity" inside the pantry car.

A pantry car chef faced all the environmental factors described above and occupant perception rates are more tolerant than other vehicle and building environments because the facility of indoor working of the pantry car is completely different from other vehicles. There is a lot of change in indoor and outdoor environmental conditions due to its moving nature, whereas in the case of a building, it does not [5]. Therefore, it is a little challenging to determine correctly instead of building. As the pantry car plays a vital role in the journey of the railway to provide food to the passengers, which increases the responsibilities of the workers working inside the pantry car to provide fresh and pure food to the passengers. Consequently, their thermal perception must be good in the kitchen environment to work comfortably there.

ENVIRONMENTAL FACTORS THAT EFFECT ON INDOOR THERMAL COMFORT INSIDE THE PANTRY CAR

Air Temperature

Air temperature is a vital environmental factor that directly impacts "human thermal comfort." It is described as the mean temperature of the air near the body, corresponding to place and period [3]. Inside the pantry car's kitchen, the air temperature depends on the seasons and climatic zone during the working period. While in the pantry car has "air conditioning" and exhaust hood to control the "air temperature," which avoids weather changes.

Various studies illustrated the recommended range of the comfort air temperature for the summer and winter seasons. The "National Building Code" of India recommended the comfort temperature range for the occupant's during the season; "summer (23-26°C)" and "winter (21-23°C)" [91]. The standard comfort range of air temperature according to ASHRAE is for the "summer season 24.5-27.0°C", and the "winter season 19.5-22.5°C" [27]. These comfort temperatures have been determined based on the national and international standard data set, which is not validated or suitable for every context [27]. Therefore, numerous researchers have used an adaptive strategy to achieve the optimum temperature for occupants as per the working environment [92-93].

Deb and Ramachandraiah [94] proposed a comfort (neutral) temperature (31.93°C) for railway waiting hall passengers during the summer season based on a subjective survey. Correspondingly, Ye et al. [95] suggested a comfort temperature (23.3°C) for Chinese railway passengers. While comfort temperature for the airconditioned (24.4°C) and non-airconditioned (28.4°C), school buildings in Malaysia [1]. In the kitchen environment, to achieve the optimum temperature of household workers at Punjab in the Indian context, Ravindra et al. [26] have used an adaptive strategy for a better work environment.

The previous study guide to the measurement of air temperature inside the kitchen of the pantry car environment should be "1 ft (0.3 m) near the workstation and 43 in. (1.1 m) above the workstation floor" as per the recommended by ASHRAE standard [5]. The chest and facial area are a significant body part that is affected due to temperature variation inside the commercial kitchen environment [35, 38]. Hence the temperature difference of medium and standing activity level of work condition inside the kitchen like pantry car should be recorded as per the recommendation.

Mean Radiant Temperature

Mean radiant temperature (MRT) also plays a very significant contribution to "predicting the thermal comfort of occupants", which is described as a "uniform temperature in an imaginary atmosphere," where the radiant heat was emanating from the "human body equal to the heat transfer" from the actual atmosphere [96]. It is pretty difficult to estimate and is not measured directly. There are many methods or techniques to determine this, which has been shown by many researchers. It can be determined by globe temperature, which has been described in several studies. It depends on the "diameter of the globe", generally taking the diameter of the globe to 0.15 meters (5.9 in) [96]. The recommended formula of the "MRT" using with globe temperature has been incorporated below [5, 27].

$$t_{mr} = \left[\left(t_g + 273 \right)^4 + \frac{1.1 \times 10^8 v_a^{\ 0.6}}{\varepsilon D^{0.4}} \times \left(t_g - t_a \right) \right]^{1/4} - 273 \quad (1)$$

Where, mean radiant temperature- tmr, Air temperature- ta, Globe temperature- tg, Velocity of air- va, Globe diameter- D, Emissivity of the globe surface- ε.

The measuring distance and height of the MRT are assumed to be similar to the "air temperature" in commercial kitchen environments [5, 38, 41]. Air movement has an essential impact on the variation of "MRT and air temperature". The comfortable range of MRT for official occupants 18°C-27°C, which varies on the person's clothing and activity level. Some researchers have used MRT to equal the mean dry-bulb air temperature in the buildings, kitchen environments, and others when calculating thermal comfort indices because of the difficulty in predicting MRT [97-99]. This will be considered keeping in mind the above-described conditions of MRT for the estimation of thermal comfort indices of occupants while working in the pantry car.

Relative Humidity

As per the "ASHRAE standard 55", the explanation of relative humidity (RH) is "the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature" [100]. There are various studies that suggested the acceptable limit of the RH percentage based on the condition and scenario. Such as air-conditioned building environments, the permissible limit of RH percentage should generally be between 30 to 60% [101, 102]. However, the percentage of indoor RH has been directed more than 30% to reduce the drying nasal passage for occupants, when less than 30% will increase the dry sensation, which directly affects the worker's health and efficiency [103]. When the RH percentage increases more than the acceptable limit, the "heat loss by evaporation will be much greater". According to the "ASHRAE 55 standard", the acceptable limit of RH has been illustrated in Table 1 [27].

If the temperature is within the "comfort range: 19–23°C", then RH has a lower impact on the comfort, for which the RH is in the 40–70% range [104]. In an indoor environment such as a pantry car kitchen, workers' high and sedentary activity level does not much affect the RH percentage. Whereas in a ventilated environment, the higher RH percentage gives workers a warm sensation during work when the wind velocity is low [104]. According to ASHRAE 55 standard [4], during the summer and winter seasons, an acceptable limit based on the operative temperature is illustrated in Table 2. Inside the pantry car kitchen environment, the RH data should be measure as per Simone et al. [38], such as suggested "1 ft (0.3 m) near the workstation and 43 in. (1.1 m) above the workstation floor," which has validated and tested based on the international standard.

Table 1. Acceptable limit of RH percentage [27]

RH percentage range	Sensation
30% to 60%	Comfortable
40% to 60%	Optimum
50%	Ideal

Table 2. Acceptable limit based on the operative temperature [4, 104]

Season	Operative temperature ranges
"Summer (clothing insulation = 0.5 clo)"	
RH 30%	24.5–28°C
RH 60%	23–25.5°C
"Winter (clothing insulation = 1.0 clo)"	
RH 30%	20.5–25.5°C
RH 60%	20–24°C

Air Velocity

According to the statement by Simion et al. [3], air velocity is the "mean or average speed of the air to which the body is exposed, concerning the location and time". The human body, specifically the neck, head, and legs, is a very sensitive part that greatly senses the flow of air movement, and these depend entirely on the perception rate of the workers. In the kitchen of the railway pantry car, many workers feel the movement of the air differently, as shown in the previous study [27]. Therefore, it is essential to control air movement and its direction to sustain a "comfortable indoor environment". As per Chandel and Aggarwal [104], several circumstances of air velocity for the thermal comfort of workers are illustrated in Table 3.

Indoor air velocities also affect the thermal comfort of people within spaces. The greater the air velocity, the greater the heat exchange between people in a space and the air around them [105]. Nicol [105] also suggested that the indoor comfort temperature can be increased by 3°C or 4°C per a 1m/s increase of air velocity.

The acceptable limit of air velocity in the indoor built environment for the summer season is (<0.25m/s), and for the winter season is (<0.15m/s) [27]. Manshoor et al. [106] experimented on the commercial kitchen environment and found that air velocity (0.05m/s) is most appropriate to prevent heat. Another similar type of study was directed

Table 3. Acceptable limit based on the air velocity [104]

Specific individual living assessment	Ranges of air velocity
Grievances about stagnant air	0 to 0.5m/s
Usually favorable "manufactures of air outlet devices, e.g., base performance on 50 fpm air velocity in the occupied zone"	0.5 to 2.5m/s
"Awareness of air motion, but can be comfortable (e.g. some retail shops and stores) when the temperature of moving air is above room air temperature"	2.5 to 5m/s
"Constant awareness of air motion, but can be acceptable (e.g. some factories) if air supply is intermittent and above room air temperature"	5 to 10m/s
"Increasingly draft conditions with complaints about (wind) in disrupting a task, activity and so forth"	10m/s

by Manshoor et al. [107] in the commercial kitchen environment in Malaysia. The analysis of this suggested that if the supply of air increases, the temperature will decrease in the cooking zone. They recommended "0.28m/s-air velocity" for thermal comfort because "high air velocity" is not applicable for commercial kitchens. While as per Chen et al. [108], the discharge rate (14 m3• min-1) is capable to remove fume outdoors in the commercial kitchen environment. The result already states that increasing the volume of the exhaust hood will reduce the dissatisfaction rate of the occupants. Few researchers suggested the natural ventilation or air supply system and solar chimney for improving the thermal environment in hot and humid regions [109-111]. Accordingly, some researchers guided the optimization modeling such as "heating and cooling" systems for better thermal comfort conditions, which helps to save energy consumption [112-116].

Keeping all these conditions in mind, ventilation can be designed for adequate movement of air in the kitchen environment of a railway pantry car. So that the laborers working there can get a good environment which will help in increasing "thermal comfort".

INDIVIDUAL FACTORS THAT EFFECT ON INDOOR THERMAL COMFORT INSIDE THE PANTRY CAR

Metabolic Rate (Activity Level)

In a thermal comfort study, metabolic rate or activity level is the vital individual factor through which to identify the working conditions or scenarios of occupants in both indoor and outdoor environments as to what kind of work they are performing. If the metabolic rate is high, the workers feel more heat, and the more sweat comes out of the workers' body, the thermal discomfort between workers is increased [3]. When the value of the metabolic rate decreases, the occupants feel a cold thermal sensation because the skin temperature decreased drastically, due to which the discomfort increases [3, 117]. It has a "significant effect" on the human body over thermal sensation, temperature interference, and workers' comfort [3, 118]. Table 4 demonstrated the various types of work activity and metabolic rates.

Table 4. Various types of work activity and metabolic rate [3]

Work Movement	Metabolic Rate, met (W/m^2)
"Sleeping"	0.7 (40)
"Reclining"	0.8 (45)
"Seated, quiet"	1.0 (60)
"Standing, relaxed"	1.2 (70)
"Light work"	1.6 (93)
"Medium work"	2.0 (117)
"Heavy work"	3.0 (175)

Few authors have considered the metabolic rate (2.0 met) for cooking activities in the kitchen environment due to standing and medium activity levels [5, 27]. The metabolic rate also significantly influences the "prediction of thermal comfort indices". Such as Simone et al. [38] have demonstrated in their research that the PMV index does not apply to the prediction of thermal comfort due to the high metabolic rate. Similarly, Rahmillah et al. [39] also state that the PMV method is not appropriate for estimating thermal comfort inside the kitchen atmosphere due to high metabolic rate and temperature. The metabolic rate can be measured either by "telling human subjects to perform certain activities or assumed" from recommended Table 4 [3, 119].

Clothing Insulation

Clothing comfort is "one of the most important attributes of textile materials" [120]. The basic "understanding of comfort aspects of textile materials would be extremely useful for fiber, yarn and fabric manufacturer, researcher, garment designer, processing industries, garment houses,

Table 5. Different types of garments clothing insulation values [135]

Cloth statement	*"Clo"*	Cloth statement	*"Clo"*
Underwear		Dresses and skirts	
"Bra"	"0.01"	"Skirt (thin)"	"0.14"
"Panties"	"0.03"	"Skirt (thick)"	"0.23"
"Men's briefs"	"0.04"	"Sleeveless, scoop neck (thin)"	"0.23"
"T-shirt"	"0.08"	"Sleeveless, scoop neck (thick), i.e., jumper"	"0.27"
"Half-slip"	"0.14"	"Short-sleeve shirtdress (thin)"	"0.29"
"Long underwear bottoms"	"0.15"	"Long-sleeve shirtdress (thin)"	"0.33"
"Full slip"	"0.16"	"Long-sleeve shirtdress (thick)"	"0.47"
"Long underwear top"	"0.20"		
Footwear		Sweaters	
"Ankle-length athletic socks or stockings"	"0.02"	"Sleeveless vest (thin)"	"0.13"
"Sandals/thongs or Shoes	"0.02"	"Sleeveless vest (thick)"	"0.22"
"Slippers (quilted, pile lined) or Calf-length socks"	"0.03"	"Long-sleeve (thin)"	"0.25"
"Knee socks (thick)"	"0.06"	"Long-sleeve (thick)"	"0.36"
"Boots"	"0.10"		
Shirts and blouses		Suit jackets and waist coasts	
"Sleeveless/scoop-neck blouse"	"0.12"	"Sleeveless vest (thin)"	"0.10"
"Short-sleeve knit sport shirt"	"0.17"	"Sleeveless vest (thick)"	"0.17"
"Short-sleeve dress shirt"	"0.19"	"Single-breasted (thin)"	"0.36"
"Long-sleeve dress shirt"	"0.25"	"Single-breasted (thick)"	"0.44"
"Long-sleeve flannel shirt"	"0.34"	"Double-breasted (thin)"	"0.42"
"Long-sleeve sweatshirt"	"0.34"	"Double-breasted (thick)"	"0.48"
Trousers and coveralls		Sleepwear and Robes	
"Short shorts"	"0.06"	"Sleeveless short gown (thin)"	"0.18"
"Walking shorts"	"0.08"	"Sleeveless long gown (thin)"	"0.20"
"Straight trousers (thin)"	"0.15"	"Short-sleeve hospital gown"	"0.31"
"Straight trousers (thick)"	"0.24"	"Short-sleeve short robe (thin)"	"0.34"
"Sweatpants"	"0.28"	"Short-sleeve pajamas (thin)"	"0.42"
"Overalls"	"0.30"	"Long-sleeve long gown (thick)"	"0.46"
"Coveralls"	"0.49"	"Long-sleeve short wrap robe (thick)"	"0.48"
		"Long-sleeve pajamas (thick)"	"0.57"
		"Long-sleeve long wrap robe (thick)"	"0.69"

users of the fabrics for specialty applications and all others related with textile and garment industries" [120]. Clothing helps workers to keep their body temperature balanced in the hazardous or hot and humid environment, which acts as a balancing medium of the environment and the skin of the workers [121]. Clothing insulation is the "thermal insulation provided by clothing" [4]. The unit of the clothing insulation is "Clo" and 1 "Clo" equal to the 0.155 $K \cdot m^2 \cdot W^{-1}$ [4, 120]. According to the ASHRAE standard thermal insulation from clothing is one of the most important input variables used to predict thermal comfort [122, 123]. Clothing insulation has "correlated with outdoor air temperature, indoor operative temperatures, relative humidity, and also by the presence of a dress code" in the thermal environment [124]. In the thermal environment, clothing adaptation has a "significant role in achieving thermal comfort and is apparently the most effective adjustment for occupants to adapt themselves" [125]. Zhao et al. [126] suggested that clothing insulation is the vital contributing factor to achieve optimum comfort states; the authors were found a great influence on energy consumption in the thermal environment. Simultaneously during the analysis, positive correlations were found between age and clothing insulation value.

It can be measured from “human subjects or mannequins, or an initial assumption is made using ASHRAE recommended standard” [119, 127]. The clothing values of different garments are demonstrated in Table 5 [27, 111]. As reported by Chandel and Aggarwal [104], people in India during the winter season normally wearing “sweater, jacket, inner thermal, socks, cap” compared to the 0.9 clo value “sweater, long sleeve shirt, heavy slacks” which recommended by ASHRAE. However, pantry car chef’s generally wearing clothes according to Indian style outfits while performing the cooking period inside the kitchen of the railway pantry car [128-134]. Present study clothing value can be estimated for the “summer” and “winter” season as per the recommended Table 5.

CONCLUSION

Railway pantry cars play a major contribution in serving meals to every onboard passenger, which is an integral part of every long and short distance trains. Current study describes factors affecting human thermal comfort inside the kitchen of an Indian railway pantry car.

As per the literature review in this study, six major factors of human thermal comfort have been determined which influence the thermal comfort inside the pantry car environment. These six factors are segregated into two different parts such as; (a) environmental factors “air temperature, mean radiant temperature, relative humidity, air velocity”, and (b) personal or individual factors “metabolic rate, clothing insulation”. All factors are difficult to record in the same period, and location due to every parameter has some specific limitations. The determination of thermal comfort inside the pantry car’s kitchen requires a combination of all factors at the same time. If certain parameters have been adjusted or modified, this will also affect other parameters on thermal comfort estimates. Based on study literature, the building indoor environment conditions are different from pantry cars due to which the effect of “temperature,” “humidity,” and “air velocity” is different in pantry car kitchens. However, clothing and metabolic rate also differ according to conditions.

The suggested thermal comfort factors described during the literature review will help to understand the effect on thermal comfort in the current state of railway pantry car kitchens, which will be encouraged to enhance the thermal comfort of the railway pantry car kitchen in further attention. Also, field experiments and computational fluid dynamics-CFD simulation approaches can be employed to perform the thermal comfort evaluation of pantry cars.

ACKNOWLEDGMENT

This review article is a part of doctoral thesis research work aimed at improving the thermal comfort of chefs working in pantry car kitchens on the Indian Railway.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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