A pilot study on thermal comfort in Indian Railway pantry car chefs

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Abstract. An Indian railway pantry car kitchen is a typical kitchen, where involves various kinds of thermal environment factors. Till now, the research related to pantry car kitchen is rarely reported. Therefore, this pilot study explores the thermal environmental factors and its impact on the chef’s comfort in two different pantry car kitchen (Non-AC and AC) using a subjective and physical measurement technique. The thermal comfort level was quantified by Predicted Mean Vote (PMV) Index and Predicted Percentage Dissatisfied (PPD) Index. The thermal sensation of non-air-conditioned pantry cars was hot with PMV and PPD values are 2.93 and 99% respectively. Whereas, air-conditioned pantry cars was a warm thermal sensation with PMV and PPD values are 2.17 and 84% respectively. Moreover, most of the chef (86%) are perceived thermal discomfort in both pantry car kitchens. The result concluded that both types of pantry car kitchens are having thermal sensation effect of hot and warm. A further detail study is necessary and a possible design intervention may require to enhance thermal comfort of chefs.

1. Introduction

Indian Railways has the world’s second and the largest rail network in Asia, under one organization, conveys 2 crores travellers and carrying 20 lakh tonnes daily [1, 2]. With 63,974 kilometres of route lengths, Indian Railway has a network of more than 12,000 passenger trains (Express/Mails, Superfast Express/Mail, Yuva Express, Sampark Kranti Express, Kavi Guru Express, Vivek Express, Rajya Rani Express, Sub-urban trains, Jan Sadharan Express, Shatabdi Express, Rajdhani Express, Humsafar Express, AC Express, Duronto Express, Tejas Express etc.) running across nation every day [1, 2, 3, 4]. Catering is one of the key features of the Indian railways, serving its on-board passengers with the relishing food to quench their hunger during the travel [5]. On-board catering needs to be multi-varied as India being multi-cultural country across it dimensions [5]. Indian Railways serves the food need of almost every passenger belonging to different states through it existing 11,237 catering stalls and have 338 pairs of pantry cars in its fleet. In a one-pantry car coach, consist of five cooking chefs and 40 to 50 waiters and 2-pantry car staffs [3, 5]. Pantry car, contributing as major catering service, which is an integral part of every long and medium distance train, serves the food requirement of travellers on-board [6]. Pantry cars use common cooking equipment like heater, ovens, kettle, deep fryers, soup warmer etc.; these equipment while meal preparation leads to fumes, humidity and heat generation [5, 7]. Due to this the inner environment becomes severely hot and humid [7]. The existing hot and humid condition in pantry car leads to excessive perspiration and makes the workers working conditions tougher and not favorable for human working [8]. These uncomfortable working conditions adversely affect the worker’s physical and mental health. They frequently suffer from headache and other thermal hazards [8, 9]. Any researcher has not yet focused on evaluating the status of the indoor thermal environment in pantry cars. While some research has been done on the commercial kitchen thermal environment.

Rahmillah et al. [10] research conducted on the analysis of thermal comfort in kitchen. In this paper comparison between two kitchens upon the basis of various, environmental factors viz. humidity, temperature to ascertain thermal comfort. The result in this article indicates that online psychometric charts are indicated using the range value of PMV, from 1.73 to 2.36 and the PPD 63% to 90% sensation is in hot condition. However, 71% of respondents felt comfortable at the kitchen thermal in the morning. Wei et al. [11] studies on thermal comfort under non-uniform thermal environment condition in
domestic kitchen. This paper result shows that when the outdoor air temperature is low, there is a large temperature variation in the kitchen, particularly close the side of the outer window. Simone and Olesen [12] studies on thermal environment evaluation in commercial kitchens: procedure of data collection. This research investigated the cause and effect of discomfort while cooking due to the airflow variations in the kitchen. The results of the test show that only the cooking area presented dissatisfaction with relatively thermal conditions. In reality, 50% of employees have assessed dissatisfaction in both cooking and food preparation areas. Similar kind of study conducted by Simone et al., [13] on thermal comfort in commercial kitchens (RP-1469): procedure and physical measurements (Part 1). This research article describes the data collection technique established on the physical measurement and subjective responses. Studies have shown that the predicted mean vote/percentage people dissatisfied (PMV/PPD) index is not suitable for entirely thermal environments in the commercial kitchen. Again next research conducted by Simone and Olesen [14] on thermal environment evaluation in commercial kitchens of United States. In the commercial kitchen, more than 100 kitchen environments were tested in summer and winter in the United States using an established method and procedure to evaluate indoor thermal comfort. The result is indicated in this article, PMV/ PPD Index is not appropriate for application in commercial kitchen. This is mainly due to the combination of high air temperature and high activity level.

From above researches, we can find there are various studies available related to thermal comfort, affecting factors for human thermal comfort of hotel, restaurant and commercial kitchen workers in developed countries. Nevertheless, literature pertaining to these issues in developing countries especially in India is nil. Literature related to thermal comfort of railway pantry car workers is almost negligible. Hence, this paper explore a pilot study of thermal environment conditions in Indian Railway pantry cars of two different trains. The purpose of this study was to analyze thermal comfort in Indian Railway pantry cars. Therefore, the objective of this study was to understand the thermal environment and its impact on occupant’s thermal comfort in non-air-conditioned and air-conditioned of pantry cars.

2. Methods

2.1. Data collection, physical & subjective measurements
A study was carried out in the North Eastern Region in India. Only fifteen day period was permitted to collect data, due to safety and security reasons. Therefore, study period was chosen in the first half of March 2017, which usually a dry weather climate condition in north-eastern region India. Direct observations and questionnaire survey was carried out in this study to analyse thermal comfort in both types of pantry cars.

The study entails field measurements of environmental variables: air-temperature (°C), humidity (%RH), and wind-speed (m/s), using handheld anemometer (Kestrel 3000 Pocket Wind Meter) in pantry car food cooking areas during their working hours. A globe temperature was measured with 6 inch black-globe thermometer in the centre of cooking place, is an estimate of the mean radiant temperature. Mean radiant temperature ($t_{mrt}$) was calculated from globe temperature ($t_g$), air temperature ($t_a$), and air velocity ($v_a$) using equation (1) as per the estimation Mishra and Ramgopal [15].

$$t_{mrt} = \left( (t_g + 273)^4 + \frac{1.1 \times 10^8 t_a^{0.6} \times (t_g - t_a)}{t^{0.4} D^{0.6}} \right)^{1/4} - 273$$

Here $\varepsilon$ is the emissivity of the globe surface (taken as 0.95) and D is the globe diameter. The operative temperature calculated based on the average value of the mean radiant temperature, air temperature and wind velocity using equation 2 [16].
Where, $t_{mr}$ = mean radiant temperature, $t_a$ = air temperature and $v$ = air velocity

Physical data measured as per the Simone and Olesen [14] air temperature, globe temperature, humidity, and wind velocity measured at 0.1 m and 1.7 m close to the workstation and 1.1 m above the floor at the workstation. These measurements were observed during morning (breakfast 7:00 am), Day (lunch 11:30 am) and night (dinner 6:30 pm).

In order to evaluate the thermal comfort of an indoor space in kitchen activities, subjective evaluation is important. The ASHRAE 7-point Thermal Sensation Scale (Figure 1) was used to evaluate the thermal conditions of pantry car chef for subjective evaluation. To measure the thermal comfort in a particular environment, the Predicted Percent Dissatisfied (PPD) index has been used. Predicted mean vote (PMV) index is defined using the ASHRAE thermal sensation scale to measure the average thermal sensation. The following values are from neutral (0) to cold (-3) to hot (+3): (i) ± 1: slightly warm (+) or cold (-); (ii) ± 2: hot (+) or cold (-); (iii) ± 3: hot (+) or cold (-); (iv) 0: Neutral (neither cold nor hot) [10, 17].

Tools used in the study were Graph thermal comfort ASHRAE-55, Psychometric chart. For documentation, still photography had been used.

![Figure 1. ASHRAE 7 points thermal sensation scale.](image)

2.2. Subject characteristics of pantry cars

The survey has been conducted on nine pantry car chefs. In which the air-conditioned (A.C) pantry car (Rajdhani Express) has been negotiated with 4 chefs and 5 chefs from non-air-conditioned (Non-A.C.) pantry car (Avad Assam Express). The demographic data of the subjects were collected using interview method. The Subject characteristics of air-conditioned and non-air-conditioned pantry car chefs are explained as follows, with data being presented as mean (SD) and percentages.

The subjects of A.C. pantry car, age ranging from 29 to 35 years (mean ± 32 years; SD ± 2.9 years), and having working experiences of mean = 5.3 years with SD ± 1 years in their current jobs which is between 1 and 6 years. The subjects having mean and SD of weight and height 68.3 ± 2.4 kg and 173.7 ± 6.6 cm respectively. 50% of participants have a habit of smoking and all of them were having drinking habits. All of the subjects wore the pantry uniform with apron. The mean daily working time was 15 (SD ± 1) hours. The rest hour of subjects were reported as 8 hours with SD of 1 hour. The average break time of the subjects during continuous work was reported as 28 minutes with SD of 3 minutes.

The subjects of non-A.C pantry car, age ranging from 28 to 36 years (mean ± 32 years; SD ± 4 years), and has working experiences of mean = 4.4 years with SD ± 2 years in their current jobs which is between 2 and 6.4 years. The subjects having mean and SD of weight and height 69.4 ± 7.5 kg and 172.5 ± 3.5 cm respectively. 60% of participants possessed the smoking and drinking habits. Most of the subjects were habitual of wearing pantry uniform without apron (75%). The mean daily working time was 13.6 (SD ± 1) hours. The rest hour of subjects were reported as 8 with SD of 1 hour. The average break time of subjects during continuous work was reported as 15 minutes with SD of 4 minutes.
3. Results and discussion

3.1. Environment parameters measurement

The environmental parameters including relative humidity, air temperature, globe temperature and wind velocity were measured, according to ASHARE standard 55. In addition, metabolic rate and the level of clothing both air-conditioned and non-air-conditioned pantry car chefs were identified. The measured average value of operative temperature, mean radiant temperature, air-temperature, relative-humidity, wind-speed, metabolic rate and clothing-level was in non-air-conditioned pantry car 34 °C, 34 °C, 34 °C, 84 %, 0.18 m/s, 1.8 met and 0.49 Clo respectively. Similarly, operative temperature, mean radiant temperature, air-temperature, relative-humidity, wind-speed, metabolic rate and the level of clothing were the average value measured in air-conditioned pantry car at 29.65 °C, 29.4 °C, 29.9 °C, 84 %, 0.04 m/s, 1.8 met and 0.66 Clo respectively.

Therefore, in both types of pantry cars, it was found that the environmental parameters that are very important for thermal comfort were out of the ASHRAE thermal comfort range. As per previous studies for thermal comfort standard in indoor environment; The National Building Code of India specifies the use of two narrow ranges of temperature, for all climate and building types: summer (23-26 °C) and winter (21-23 °C) (BEE, 2005) [18]. The acceptable operative temperature range is based on the comfort zone diagrams in the ASHRAE standard 55-2004; In the summer season (insulation of clothing = 0.5 Clo), and relative humidity is 30% and operative temperature is 24.5-28 °C; While the relative humidity is 60% and the operative temperature is 23-25.5 °C, in the same winter season (the insulation of clothes = 1.0 clo), and the relative humidity is 30% and the operative temperature is 20.5-25.5 °C; Similarly, relative humidity and operative temperature respectively is 60% and 20-24 °C [19].

3.2. Thermal environment of pantry cars

Figure 2 and figure 3 shows, the temperature and humidity during daytime tends to be higher in non-air-conditioned pantry car as compared to that in air-conditioned pantry car. Air-conditioned pantry car is cooler due to presence of an air-conditioning facility as compared to non-air-conditioned pantry car. The temperature value 40°C for non-air-conditioned pantry car and 29.5°C for air-conditioned pantry car was found to be the maximum; during the daytime cooking. In both types of pantry car environments, the temperature range was found more than the comfortable limit. It is because of the impact of air separator, which flows from entryway, and ventilation of the cooking region. The percentage of relative humidity 88.25 % and 84.02 % were found higher than the ASHRAE comfortable range in daytime cooking; in both non-air-conditioned and air-conditioned pantry car coaches correspondingly. While preparing food in a non-air-conditioned pantry car, the pantry car window is closed and sometimes the door is also closed; because of which the inner environment becomes too humid. In air-conditioned pantry car, the cooling efficiency of the air-conditioner is reduced during cooking. Due to which the humidity inside the pantry car is increased.

Figure 2. Temperature profile in Non-air-conditioned and Air-conditioned pantry car.
Figure 3. Humidity profile in Non-air-conditioned and Air-conditioned pantry car.

The reason (of above figure 2 and figure 3) may be the temperature of the pantry kitchen is felt as warm during the morning, day, and night-time during cooking time. This fact was also agreed with following studies; National Building Code (NBC) of India indicates that in terms of a Tropical Summer List (TSI), the indoor comfort for air-conditioned environment should be from 25°C to 30°C with the ideal condition at 27.5°C in any case of their climatic area [20]. According to ASHRAE standards, 55 – 2004, the acceptable ranges of thermal environmental condition in summer seasons are 24.5–28°C (when relative humidity is 30%) and 23–25.5°C (when relative humidity is 60%) keeping clothing insulation at constant (0.5 Clo) [19]. Further study expressed that thermal comfort for tropical region can be partitioned into: cool comfortable (20.5°C –22.80°C); ideal comfortable (22.80°C –25.80°C); and warm comfortable (25.80°C –27.10°C) [10].

3.3. Psychometric chart evaluations
To achieve PMV, PDD index value and comfort region area, an online psychometric chart was used. From field survey, data such as the operative temperature, mean radiant temperature, air-temperature, relative humidity, wind-speed, metabolic rate, and clothing levels were demarcated on the research result. A comfort region is depicted by the blue area, whereas the actual existing position of the psychometric variables of both types of pantry cars is indicated through the red circle spot. There was a psychometric variable; dry bulb temperature ($t_{db}$) 34 °C, relative humidity (rh) 83 %, air humidity ratio (Wa) 28.7 gw/kgda, wet bulb temperature ($t_{wb}$) 31.5 °C, dew point temperature ($t_{dp}$) 30.9 °C, enthalpy (h) 73.5 kJ/kg and dry bulb temperature ($t_{db}$) 29.8 °C, relative humidity (rh) 82.9 %, air humidity ratio (Wa) 22.1 gw/kgda, wet bulb temperature ($t_{wb}$) 27.3 °C, dew point temperature ($t_{dp}$) 26.5 °C, enthalpy (h) 56.5 kJ/kg of non-air-conditioned and air-conditioned pantry cars respectively. In both types of pantry cars, the psychometric variables do not comply with ASHRAE standard 55-2017, which is out of the thermal comfort zone. Overall outcomes for a thermal comfort region in the non-air-conditioned pantry car and air-conditioned pantry car coaches are depicted in Figure 4 and Figure 5 individually.
As per the estimation of online psychometric chart, a thermal sensation of non-air-conditioned pantry cars was hot with PMV and PPD values being 2.93 and 99% respectively whereas for air-conditioned pantry cars thermal sensation was warm with PMV and PPD values were 2.17 and 84% respectively. However, based on the survey conducted, 86% respondents in both the pantry cars perceived the thermal discomfort during the cooking hours. Analysis revealed that the position of relative air temperature of the non-air-conditioned pantry car and air-conditioned pantry car coaches was found to be out of comfort zone of ASHRAE standard. Thus, it could be concluded that both types of pantry cars are having a hot and warm effect of thermal sensation. Therefore, as per the PMV/PPD index estimation working thermal environment condition at present inside both railway pantry cars is not suitable for the chefs. Simone
and Olesen [13] also state that PMV / PPD Index are not suitable for application in commercial kitchen. Often the measured index is outside the recommended range. This is mainly due to the combination of high air temperature and high activity level.

4. Conclusion
Indian Railway is one of the spacious rail networks among other countries. A pantry car is an important place that helps the Indian Railway catering system by serving food on every medium, and long distance trains for on-board passengers. This pilot study attempts to deem the present situation of the indoor thermal environment of air-conditioned and non-air-conditioned pantry cars coaches’ of Indian railway (IR) in the summer season. The analysis of the survey results is as follow:

- PMV and PPD index results depicts that both types of railway pantry car coaches have warm and hot thermal sensation. However, 86% of subject respondents in both types of pantry cars felt thermal discomfort.
- The values of environmental factors for example; relative humidity and air temperature in both pantry car coaches were found more than ASHRAE standard values during the cooking process. Especially graphical result shows that in a daytime cooking air temperature and relative humidity was very high.

Considering the overall actualities, it can be concluded that both types of pantry cars have a similar impact on thermal sensation. A further detailed study is fundamental to understand the factors responsible for causing the warm sensation.

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