The Analysis of Thermal Comfort in Kitchen

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Abstract

Human also has a thermoreceptor which is a non-specialized sensory receptor that has relative changes in temperature. Thermal comfort is a very important element for human body. Kitchen as an important part of a home is often forgotten. Cooking in the kitchen is a routine activity which is done from the morning until the evening; begin with preparing breakfast, lunch and dinner. The problem in this study was the occurrence of heat when cooking in the kitchen without air conditioning in tropical countries. This research analyzes thermal comfort while doing cooking activities in conventional kitchen with gas stoves in tropical dry season. Two residential kitchens are observed by measuring the temperature and humidity as well as analyze other possible factors. Psychometric chart is used to assess the comfort zone in the kitchen. This research is using Predicted Mean Vote (PMV) Index and Predicted Percentage Dissatisfied (PPD) Index. By using online psychometric chart, the sensation is in warm condition with the range value of PMV between 1.73 up to 2.36 and PPD 63% until 90%. However, 71% respondents perceived morning kitchen thermal as comfortable.

Keywords— Thermal comfort, PPD index, PMV index, psychometric chart.

1. Introduction

Thermal comfort has a significant influence towards human body. It is a heat balance between human and environment occupied. Human also has a thermoreceptor which is a non-specialized sensory receptor that has relative changes in temperature. This sensory acts to convey information to the brain in which the brain will give order to maintain human body’s temperature stable at 37 ± 0.5 °C under different climatic conditions. It is necessary so that the organs can perform its functions well. Some factors affect human thermal comfort are clothing worn, climate condition, and physical activity [1].

Kitchen is an important part of a home that is often forgotten. It is one of the few rooms that must exist in the residence. It is not just a place to prepare food, but it also can be used for recreation, family communication or even working for certain job. People are too focused on

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areas such as private rooms, a family room, and even bathroom. However, kitchen is part of the largest contributors to discomfort, because it often causes odor when cooking and increase the heat surrounding the room. Cooking is a routine activity which is done from the morning until the evening; begin with preparing breakfast, lunch until dinner.

Relatively few studies on thermal comfort in kitchen than that in house or outdoor environment in general. Many of the available studies regarding house have focused mainly on country which has four seasons [2][3][4]. However, the studies actually does not cover residential kitchen. Only scholars [5][6] analyzes conventional kitchen in Taiwan, while another scholar [7] studies commercial kitchen in United States. Scholar [5] states that the highest average concentrations of Carbon monoxide (CO) in residential kitchens in Taiwan during the period of cooking with gas stoves (24 hours on average) varied from 0.1 to 13.9 ppm. While research [8] concluded that the use of LPG stoves produce CO emissions of about 5.83 ppm which is smaller than charcoal-fueled stoves or kerosene. There are many problems in kitchen such as discussed by [9] regarding older people problems in kitchen and its design solution and proper clothing worn in institutional and restaurant kitchen [10].

Even though the cooking process of residential and commercial kitchen are similar, but at some points, they are so different such as in exhaust airflow rate and installation height. Residential kitchen is intermittent operation and no replacement air requirement for ventilation. Moreover, it used to be more conservative. A residence also has a much lower background ventilation rate, so escaping contaminant is more persistent. This situation presents a different challenge because it is not possible to overcome problems by simply increasing the ventilation rate at the cooking process. Most residential kitchens are ventilated by wall-mounted, conventional range hoods so that it depends almost entirely on buoyancy capture [11]. Moreover, very limited research carried out in non air-conditioned spaces.

This research analyzes thermal comfort while doing cooking activities in conventional kitchen with gas stoves in tropical season by considering air temperature, humidity and clothing.

2. Literature Review
Thermal comfort is a psychological concept that relies on the preferred physiological state (uncomfortable through comfortable). While British Standard BS EN ISO 7730 specify it as ‘that condition of mind which expresses satisfaction with the thermal environment.’

The most widely used indicator of thermal comfort is air temperature because every body can easily measure it. However, if it is lonely used, it will be not capable to measure thermal comfort. Some of environmental factors should be considered are radiant temperature, relative humidity and air velocity while the personal factors are activity and clothing [2].

In term of activity, the work rate has influence toward heat produced by human body. In addition, the effect of metabolic rate on thermal comfort is very critical. Metabolic equivalent (MET) can be used to measure physical activity in which expressing energy expenditure. While clothing worn also give influence toward thermal comfort due to clothing insulation which is measured in Clo units (Icl). One clo is the amount of thermal resistance which is significant to maintain thermal comfort for subject’ activities in a normally ventilated room (air movement 20 ft/min or 10 cm/sec) with temperature of 70°F (21.1°C) and RH<50%. It is necessary to understand how the fabric contributes toward thermal comfort or discomfort [1].

Predicted Percentage Dissatisfied (PPD) index can be used to quantify thermal comfort at specific environment. While the average thermal sensation which is measured by using ASHRAE thermal sensation scale usually called the Predicted Mean Vote (PMV). The value
ranges from +3 (hot), +2 (warm), +1 (slightly warm), 0 (neutral), -1 (slightly cool), -2 (cool), and -3 (cold).

Research relates to residential thermal comfort had been done in Belgium [4], Nigeria [2], Singapore [12], and Malaysia [13]. Scholar [6] and [12] study the effect of ventilation in indoor environment. None research done in Indonesia yet especially related with kitchen thermal comfort.

3. Research Method
The study is conducted in two kitchens located in Sleman, Yogyakarta. The type of kitchen studied is residential kitchen with the dimension of Kitchen A is 3 x 3 meters as shown in Figure 1 while Figure 2 visualizes Kitchen B with the dimension of 4x6 meters.

Fig 1. Kitchen A

Fig 2. Kitchen B
The tools used in the study are Multienvirometer to measure temperature (°C) and humidity (%RH), Graph thermal comfort ASHRAE-55, Psychometric Chart and camera. Method that is used in this study are observation and survey. The data of temperature and humidity were taken during cooking time for four days in dry season with six times measurement in every morning (5.30 - 7 AM), afternoon (11 AM - 12.30 PM) and evening (4 - 5.30 PM). In addition, survey to twenty women was conducted to find the preferences of comfort material for clothing worn while cooking activity conducted.

4. Results and Discussion

Factors affecting thermal comfort

The temperature and relative humidity varies greatly throughout the day. Based on Ministry of Health of Republic Indonesia No 1405/MENKES/SK/XI/2002 concerning the requirements of the work environment, comfort temperature is between 18–28°C. Other literature stated that thermal comfort for tropic can be divided into: cool comfortable (20.5°C–22.8°C); optimal comfortable (22.8°C–25.8°C); and warm comfortable (25.8°C–27.1°C). That’s why, the kitchen temperature while cooking in the morning and evening is categorized as warm comfortable (Figure 3).

Fig 3. Graph of Temperature and Humidity in Kitchen A and B

The kitchen temperature during morning and day tend to be higher in kitchen A than that in B. It may due to the use of ceiling in kitchen A in which it could trap more heat remain in the kitchen than the roof tile did in kitchen B. In addition, the position of kitchen A got more sunlight than kitchen B which was located in the middle of the house. The temperature during afternoon in kitchen B was lower than A. It is probably due to the influence of air insulation coming inside from the left door and ventilation at the top of the cooking area. Whereas the temperature of kitchen A slightly decreases. Moreover, there is no ventilation inside the kitchen A which makes the heat remain in the kitchen.

According to SNI 03-6572-2001: the natural ventilation provided should consists of permanent opening, window, door or others that can be opened, with the number of ventilation openings not less than 5% against the floor area. Based on calculation, the ventilation for kitchen B should around 1.2 m². It considered to be fulfilled because there is
1.2 m² ventilation in the top of cooking area (0.4 x 1 m) and 2 m² from the left door (1 x 2 m). In addition, it is also completed by five big windows in directly opposite the kitchen. Whereas an opening needed in kitchen A is as much as 0.45 m² (which comes from 0.05 x (3x3m)). It is not enough since the recent door is covered by a heavy gorden. Applying natural ventilation also had been applied in Singapore, as a result, comfortable indoor environment can be provided [12].

Recommended humidity for tropic area is between 40-60% along the year, but it should be 55-60% for meeting room in which many people involved. The average of humidity in this study is 71.53% (the detail can be seen in Figure 3) which considers as comfort since research in Malaysia which is also a humid tropic nation stated that the mean relative humidity corresponding to the optimum comfort temperature was close to 73% [13].

Activities will also influence thermal conduction. Based on Table MET for various of activities, cooking activity has MET value of 1.6 to 2.0. People with this activity has metabolic heat generation around 90-115 W/m² [14]. Thermal insulation in clothing is an important parameter of thermal comfort [15]. Based on a survey to twenty women; 87.5% prefer wearing cotton for clothing while cooking, whereas 12.5% choose jersey material because of familiarity. Cotton fabric is a textile with a soft and porous character that makes the skin easier to 'breathe'. It is made from cotton plant so that it is very comfortable to wear as well as become the most widely used in the clothing industry [16].

The influence of clothing and operative temperature in the morning can be seen in Figure 4. The clothes that are used: the maximum limit of 1.4 clo, standard: 1 clo and the bottom limit is around 0.75 clo. According to the graph, the condition of the kitchen is not including into comfortable because it is over the line limit. But the relative humidity is recognized as 50% while the air velocity is 0.15 m/second. The cooking activities varies from 1.6 to 2.0 MET while the operative temperature is 27.075°C and to be comfort at that area, it is necessary to wear clothing which less than 0.1 clo.
Fig 4. The Effect of Clothing and Operative Temperature in the Morning

**Psychrometric Chart**

Online psychrometric chart is used to get PMV, PPD, and comfort zone area. The input data of operative temperature, humidity, metabolic rate, and clothing are determined based on the research results. The comfort zone can be seen in the blue area, whereas the operative temperature is symbolized by red circle point. The complete results for comfort zone in the morning, afternoon, and evening can be seen in Figure 5.

(a)  

(b)  

(c)
Fig 5. Psychometric Chart in the Morning (a), Afternoon (b), and Evening (c)
Based on the calculation of online psychometric chart, the value of PMV lies in the range of 1.73 up to 2.36 which means in warm sensation. While the PPD range from 63 until 90%. Even though 63% people feel dissatisfied with the thermal comfort in the morning, but based on the survey conducted, most women prefer to cook in the morning (71%) because of comfortable weather. While only 29% want to cook in the evening, and none choose afternoon to do cooking activity. Scholar [7] also states that PMV/PPD may not suitable for commercial kitchen which has characteristic of high activity level and hot temperature. Moreover, research by [3] showed that people live in tropical countries such as Ghana may have higher perceived heat tolerance. Eventhough the standard is between 26-28\(^0\)C (at summer), but the interviewees accept higher temperature as comfort.

5. Conclusion and Recommendation

According to the discussion in the previous, the sensation of thermal comfort in residential kitchen is in warm condition with the range value of PMV between 1.73 up to 2.36 and PPD 63% until 90%. However, 71% respondents perceived morning kitchen thermal as comfortable.

Recommendation
Future studies should be practiced in countries that has four seasons.

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