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Analysis of the Effect of Clothing Color Spectrum on the Absorption and Reflection Coefficient of Solar Radiation

Abel Indra Kusumah [1], Bagus Dwi Rahardiansyah [2], Pika [3], Caca Aulia [4*], Marzhal Qeianu Rafly [5]

[1] Physics Study Program, Faculty of Mathematics and Natural Sciences, University of Education Indonesia, Indonesia. Email abelindraa28@gmail.com

[2] Physics Study Program, Faculty of Mathematics and Natural Sciences, University of Education Indonesia, Indonesia. Email bagusdwi190406@gmail.com

[3] Physics Study Program, Faculty of Mathematics and Natural Sciences, University of Education Indonesia, Indonesia. Email pika@upi.edu

[4] Physics Study Program, Faculty of Mathematics and Natural Sciences, University of Education Indonesia, Indonesia. Email realme7756@gmail.com

[5] Physics Study Program, Faculty of Mathematics and Natural Sciences, University of Education Indonesia, Indonesia. Email marzhalqr6@gmail.com

***Corresponding Author Email realme7756@gmail.com**

Abstract. Clothing plays an important role in maintaining body comfort, especially in extreme weather conditions, but people often prefer clothes based on trends rather than thermal effectiveness. This study aims to examine the influence of clothing color on the increase in fabric surface temperature in various environmental conditions. The research method was carried out through experiments using different colored fabrics indoors and outdoors, as well as descriptive surveys to understand people's preferences and habits. The results of the experiment showed that dark-colored clothes absorbed heat more than light-colored clothes, while the survey revealed that most respondents still chose dark clothes for aesthetic reasons. This study contributes to a scientific understanding of the effect of clothing color on thermal comfort and underscores the need for public education to balance comfort with clothing style. This research is expected to be a guide in choosing clothes that suit thermal and aesthetic needs.

Keywords: clothing color, thermal comfort, heat absorption, color effect, clothing trends.

INTRODUCTION

Clothing is one of the products that affects the condition of our body in certain circumstances or activities and also plays an important role in maintaining body comfort, especially in extreme weather conditions. In hot climates, clothing serves to protect the body from exposure to sunlight or various other impacts, while in cold climates, the thermal insulation properties of clothing are important to keep the body warm. Clothing acts as a barrier that inhibits evaporation and reduces body heat loss by reducing air circulation near the skin. One factor that affects body comfort is body temperature, which can be affected by various external factors, including clothing color. (Pascoe, 1994)

Scientifically, color has a significant role in influencing the interaction of an object with light and heat, directly impacting various daily activities—detection of heat radiation emitted by the human body. Light-colored clothes, such as white or red, tend to reflect most of the light that falls on them, while dark-colored clothes, such as black, absorb more light and heat energy. This process is known as absorbance and reflection of light. When clothes absorb more light, they convert that energy into heat, ultimately increasing the temperature on the surface of the clothes that come into contact with our bodies. (Muda, 2017) (Monteith, 2013)

In comparison, black clothes feel hotter in the sun than white clothes because black absorbs almost all visible wavelengths of light and converts them into heat. In contrast, white reflects most of the light, absorbing only a small amount of heat. This principle also applies when drying clothes. Dark-colored clothes tend to dry faster because they absorb more solar energy and emit heat more efficiently. Meanwhile, bright colors reflect more energy, making them less effective as heat absorbers and transmitters. (Holmér, 1995)

This phenomenon can be explained through blackbody radiation, which explains the relationship between color and the ability to absorb and emit heat. The colors we see ourselves result from the interaction of light, the properties of objects, and the human eye's ability. White light, like sunlight, is made up of different wavelengths. When it hits an object, part of the light is absorbed, and part of it is reflected. The color we see is the reflected light. For example, a red object looks like this because it only reflects red light, while other wavelengths are absorbed. (Healy, 1998)

This mechanism is closely related to the physiological function of the human eye, especially in the retina, which has two types of light-receiving cells: rod cells and cone cells. Cone cells are responsible for color perception and are divided into three types based on sensitivity to specific wavelengths: red, green, and blue. When light of a certain wavelength reaches the retina, these cone cells send signals to the brain to be interpreted as color. For example, the green color is visible because the wavelength of light reflected by an object is 500–560 nm, which corresponds to the sensitivity of green cone cells. The study of these interactions not only explains everyday visual experiences but also underlies a wide range of applications in optical science, design, and visual technology (Sanchez, 2011)

RESEARCH METHODS

The quality of a study depends on the quality of data collection. This research is carried out in a quantitative way using an experimental method to collect data using scientific methods to find primary data that is numerical. To get perfect results, a qualitative method is added through questionnaires distributed online to collect data. The method applied in this questionnaire uses a descriptive survey approach, where data is collected through direct questions to respondents to understand their characteristics, preferences, and habits. (Sekaran, 2016) (Rustamana, 2024) (Pujiastuti, 2010)

Tools and materials are very much needed in this research to support the data collection; the tools and materials used are:

- Digital thermometer
- Stopwatch
- Mobile
- Laptop
- Incandescent lamp (5 Watts)
- The fabric is white, red, green, black. (veil)

We conducted this research in Bandung, Bojongloa Kidul Leuwi Panjang District. This research was conducted outdoors and indoors to get different results and compare the two. Outdoor research is divided into two situations, namely, when the fabric is exposed to direct sunlight and blocked by shadows. The ambient temperature at the time of the study ranged from 26o C (Cloudy) and 30o C (Sunny). The research was carried out indoors by heating the fabric under a 5-watt incandescent lamp with a lamp temperature of 70° C and a room temperature of 25° C. In order to add data from the experiment, we added data collection by means of a descriptive survey using several repoolents to fill it out online and answer several questions to be subsequently analyzed to describe general trends.

DISCUSSION

Experiment Data

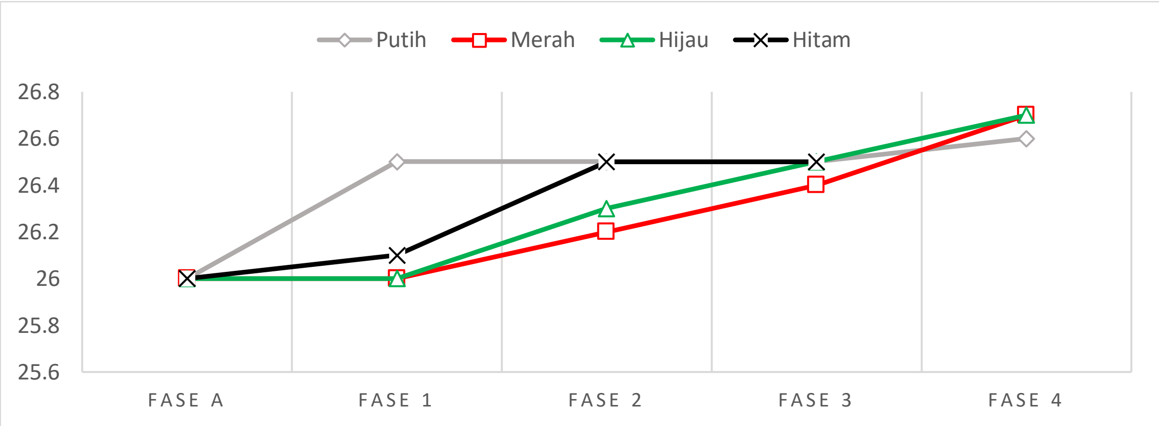
Indoor

Results of observation of the fabric's surface temperature (Table 1.) with cotton material in a closed room using a 5-watt incandescent lamp with an initial temperature of 26o C.

Table 1 Changes in fabric surface temperature with color variation after outdoor heating.

It	Color	Early phases	Phase 1	Phase 2	Phase 3	Phase 4
1	White	26o C	26.5o C	26.5o C	26.5o C	26.6o C
2	Red	26o C	26o C	26.2o C	26.4o C	26.7o C
3	Green	26o C	26o C	26.3o C	26.5o C	26.7o C
4	Black	26o C	26.1o C	26.5o C	26.5o C	26.7o C

Graph 1. Graph of the surface temperature of the fabric after outdoor heating.



In (Table 1) it can be seen that after drying the fabric and placing it in the room and stored under an incandescent lamp, the surface temperature of the fabric still increases due to the 5 Watt incandescent lamp but it is not significant because the temperature increase that occurs ranges from 0.1 to 0.5o C. The initial temperature in the room used as the research site is 25^{o} C and the initial temperature of the fabric is 26^{o} C. This temperature research was carried out for 40 minutes, which was divided into four phases 10 minutes per phase. It can be seen in phase one *(16.00-16.10)* (Graph 1) that the surface temperature of the fabric that first experiences an increase in temperature is white and black. In the second phase *(16.10-16.20)* (Graph 1), black, green, and red began to experience an increase in temperature; in white, the temperature was fixed. In phase three *(16.20-16.30)* (Graph 1.1.), the colors green and red experienced an increase in temperature while the white and black colors had constant temperatures. In the fourth phase (*16.30-16.40)* (Graph 1.), all colors experienced an increase in temperature. The temperature increase is not noticeable because the 5-watt lamp is not hot enough to heat the fabric's surface temperature.

Outdoor

The results of observation of the fabric's surface temperature (Tables 2 and 3) outdoors by direct and indirect drying (covered with shadow) in the sun are shown. The air temperature when the observation is in progress is 30° C.

Table 2. Changes in the surface temperature of the fabric with color variations with outdoor heating and exposure to direct sunlight.

It	Color	Early phases	Phase 1	Phase 2	Phase 3	Phase 4
1	White	29.1o C	49.9o C	46.2o C	36.9o C	35.9o C
2	Red	30.4o C	58.0o C	53.7o C	37.6o C	37.9o C
3	Green	30.3o C	62.3o C	55.7o C	38.0o C	38.5o C
4	Black	29.0o C	62.7o C	59.7o C	39.5o C	38.9o C

Graph 2. Graph of the surface temperature of the fabric with outdoor heating and exposure to direct sunlight.

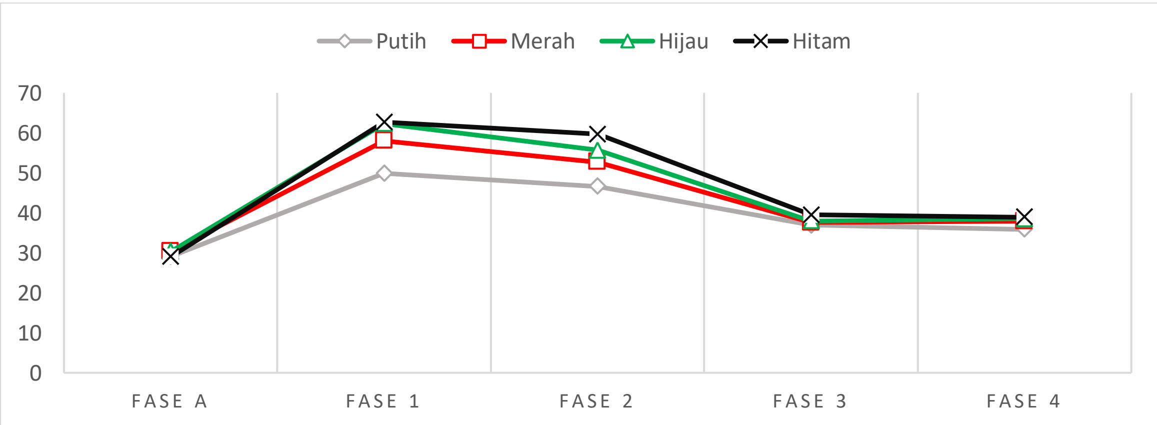
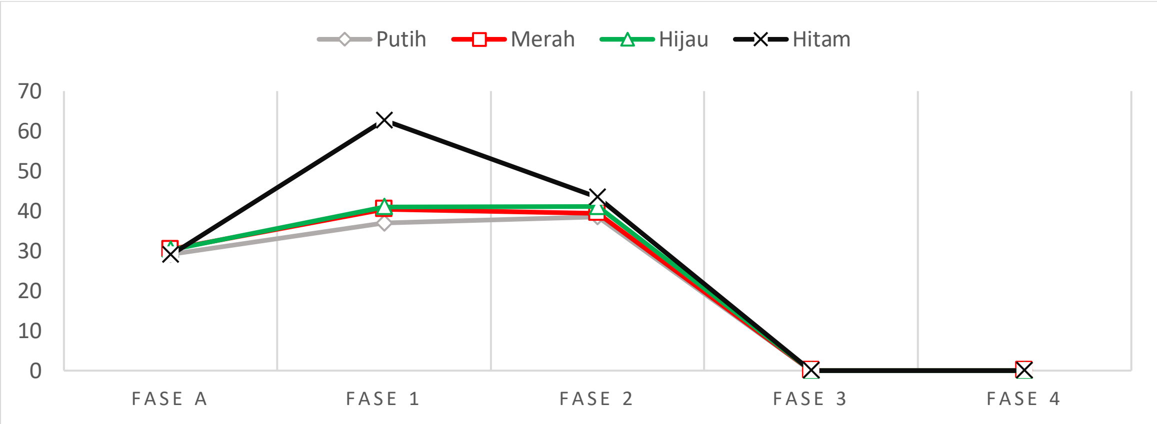


Table 3. Changes in the surface temperature of the fabric with outdoor heating but blocked by shadows.

It	Color	Early phases	Phase 1	Phase 2	Phase 3	Phase 4
1	White	29.1o C	36.9o C	38.5o C	-	-
2	Red	30.4o C	40.4o C	39.4o C	-	-
3	Green	30.3o C	41.0o C	41.1o C	-	-
4	Black	29.0o C	41.3o C	43.4o C	-	-

Graph 3. Graph of the surface temperature of the fabric with outdoor heating but blocked by shadows.



In (Tables 2 and 3) it can be seen that when the fabric is placed under the hot sun, the temperature of the clothes changes over time. Seen in phase one *(10.15-10.25)* (Charts 2 and 3.) It can be seen that all colors of fabric experience an increase in surface temperature, but green and black colors experience a very significant increase in temperature because black absorbs all wavelengths of sunlight and green colors have a wavelength (Table 4.) 500–560 nm will be hotter as well as the surface temperature because the wavelength is smaller when compared to red and white colors and if the fabric is covered with shadows, the surface temperature of the fabric will also rise but not significant and has a temperature difference of about 20o C. In the second phase *(10:25 a.m. to 10:35 a.m.)* (Figures 2 and 3), all colors experienced a decrease in temperature due to a decrease in ambient air temperature due to the sun blocked by clouds. However, black still had a high surface temperature, and at the same time, the temperature of the surface of the cloth covered with shadows increased in temperature compared to the previous phase due to the transfer of conduction heat, which resulted in a hot temperature dividing the heat into a lower temperature. In phase three (E Irawati, 2019)*(10:35 a.m. to 10:45 a.m.)* (Graphs 2 and 3) the surface temperature of the fabric decreased due to cloudy weather. In the fourth phase (*10.45-10.55 a.m.)* (Figures 2 and 3), all surfaces of the fabric experienced a decrease in temperature because clouds completely covered the sun.

Table 4. Color wavelength.

Wavelength (nm)	Color
<380	Ultra Violet
380 – 435	Violet
435 – 480	Blue
480 – 490	Blue Hujauan
490 – 500	Bluish Green
500 – 560	Green
560 – 580	Yellowish Green
580 – 595	Yellow
595 – 650	Orange
650 – 780	Red
>780	Infrared

Questionnaire Data

We added questionnaires to augment and corroborate the experiment's results. The questionnaire results showed that the majority of respondents were women aged 15-25 who had their last high school education. Most of them live in areas with low or hot temperatures. This age group dominates because they are usually more active in responding and aware of modern trends and lifestyles than other age groups.

Many respondents prefer black because it is considered modern, elegant, and versatile for various occasions. However, when facing hot weather, they prefer bright or pastel colors. This option is considered more comfortable because it gives a cool impression and minimizes the feeling of heat due to the reflection of sunlight.

T-shirts are the most chosen type of clothing because of their simple, comfortable, and practical nature for daily activities. In addition, cotton is also a favorite because of its ability to absorb sweat, so it is perfect for the hot weather they often experience. While comfort remains an important factor for some respondents, the main reason for choosing clothes is the fashion aspect. This shows that they care very much about appearance and trends as a form of self-expression, especially at a young age who tend to want to look attractive.

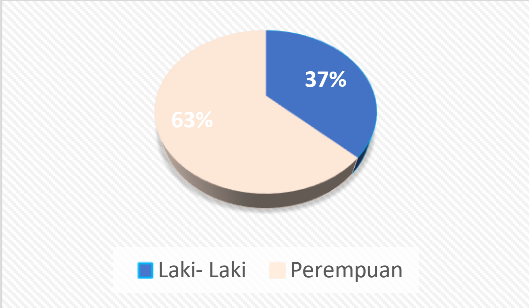
Overall, these results reflect that respondents have a preference for a simple and practical lifestyle but still consider the aesthetic aspects and suitability to their daily needs. The choices they make are heavily influenced by the environment in which they live and the trends that are developing.

Table 5 Questionnaire data results

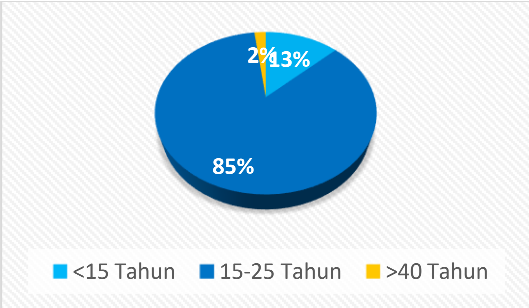
Gender	Age	Graduates	Location	Favorite Colors	Types of Clothing	Frequently Used Colors	Function of Clothing
Female 29	<15 Years 6 People	Elementary School 5 People	Highland (Cold) 17 people	Red 3 People	T-shirt 28 People	Dark 12 People	Comfort of 13 People
Male 17	15-25 Years 39 People	Junior High School 5 People	Lowland (Hot) 29 people	Blue 9 Person	Cotton 14 People	Sunny 17 People	Fashion 33 People
	>40 Years 1 Person	High School 30 People		Green 3 Person	Wool 4 Person	Pastel 17 People	
		College 6 People		Black 20 People			
				White 11 People			

Questionnaire Results

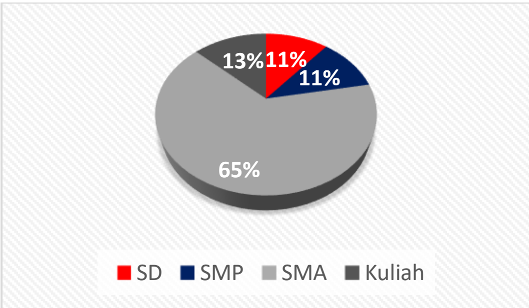
Gender: Female (63%) and male (37%).



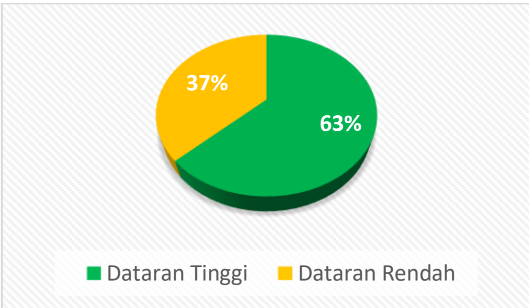
Age: (13%) <15 years old, (85%) 15-25 years old, (2%) >40 years old.



Graduates: High school (65%), junior high school (11%), elementary school (11%), and college (13%).



Location (Temperature): Low/hot (63%) and high/cold (37%)



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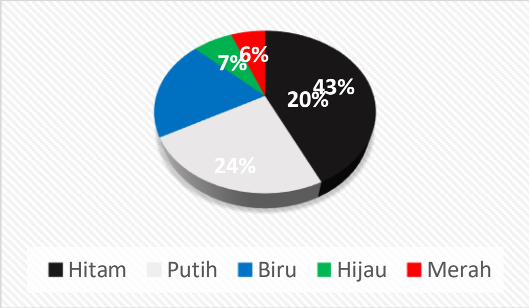
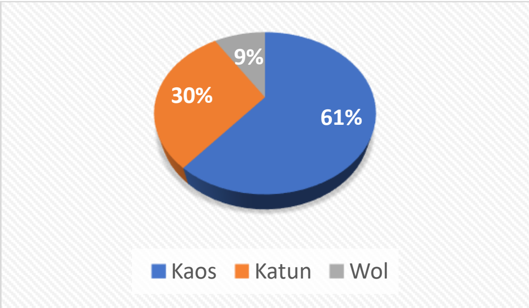
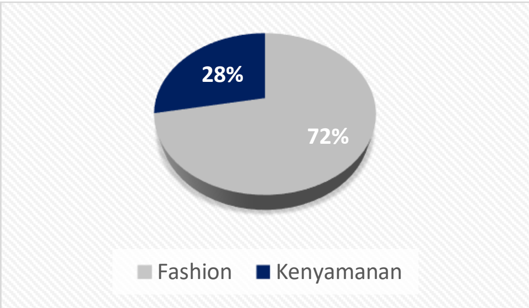
5.Favorite **Colors**: Black (43%), white (24%), blue (20%), green (7%), and red (6%).



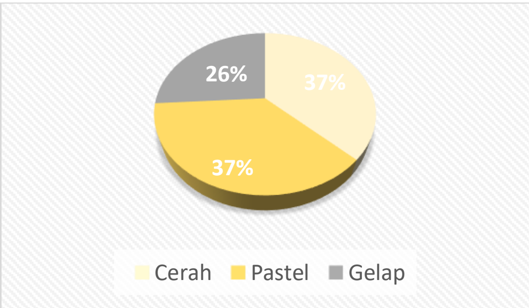
Clothing Type: T-shirt (61%), cotton (30%), wool (9%).



Clothing Function: Fashion (72%), comfort (28%).



Clothing Color in Hot Weather: Light (37%), Pastel (37%), Dark (26%).



Difference in Questionnaire and Experiment Results

The questionnaire reflects people's behaviors and preferences that are influenced by trends and lifestyles. Meanwhile, the experiment provides a scientific basis for determining the most optimal clothing based on thermal effectiveness. However, in reality, people's choices are often not in line with scientific results due to subjective factors such as aesthetics and social customs.

The experiment results showed that light-colored clothes had a lower temperature rise than dark-colored clothes. The survey results show that 26% of 46 respondents still choose dark-colored clothes for fashion reasons. This condition shows the need to educate the public on choosing the right clothes, especially in understanding the influence of color on comfort. This research is expected to be a guide for the public to be more comfortable in their daily clothes. With a better understanding, people can balance between their comfort and sense of style.

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that dark-colored clothes tend to cause a greater increase in temperature on the surface of the clothes compared to light-colored clothes. This is due to the difference in heat absorption ability between dark and light-colored clothes. Therefore, brightly colored clothes are recommended to be worn in hot weather conditions to reduce the increase in body temperature.

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