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Research article

Effect of Polycarbonate Sheet Color on Andrographolide Content in *Andrographis paniculata* (Burm.f.) Nees

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Abstract

The quality of dried *Andrographis paniculata* (Burm.f.) Nees (Fa-Talai-Jorn) is important to determine its effectiveness in traditional medicine. The present study was aimed to investigate the effect of the color of polycarbonate sheet on andrographolide content. Four colors of polycarbonate sheets (clear, green, blue, and gray) were used as covers for household solar dryers. Drying experiments of *Andrographis paniculata* with an initial moisture content of 85% w.b. were conducted to achieve a final moisture content of 7% w.b. by using four household solar dryers with different colors of polycarbonate sheets and natural sun drying. The andrographolide contents of the dried *Andrographis paniculata* samples were evaluated using the HPLC technique. The results indicated that the color of polycarbonate sheet affected andrographolide content. The highest andrographolide content of 3.40% was obtained from the solar dryer covered with gray polycarbonate sheet.

Keywords: *Andrographis paniculata* (Burm.f.) Nees; andrographolide; polycarbonate sheet color; solar drying

1. Introduction

In recent years, the global population has been grappling with the COVID-19 crisis caused by the coronavirus 2019. This virus primarily affects the respiratory system. Currently, there is ongoing research and development of herbal medicines to treat the symptoms caused by viruses (Ye et al., 2023; Soltani et al., 2023; Wang et al., 2024). *Andrographis paniculata* is considered to be one of the popular herbs used to alleviate illness (Khanal et al., 2021; Srikanth & Sarma, 2021; Komaikul et al., 2023).

Andrographis paniculata (Burm.f.) Nees (Fa-Talai-Jorn) (Hossain et al. 2014) (Figure 1) is an herb from the family of Acanthaceae, originated from India and Sri Lanka. It is commonly found in Southeast Asia. Fa-Talai-Jorn grows at a height of 30-110 cm in the tropical zone. Fa-Talai-Jorn is classified as a medicine in traditional Thai medicine

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textbooks. The chemical agents found in Fa-Talai-Jorn are dehydroandrographolide, neoandrographolide and andrographolide, which have been used for symptomatic treatment of various diseases including sore throat, cold, fever, laryngitis, and several infectious diseases for a long time (Kalariya et al., 2021). Obtaining andrographolide depends on many factors such as growing conditions, harvesting ages, and drying methods (Saohin et al., 2007; Pholphana et al., 2013).

Figure 1. *Andrographis paniculata* (Burm.f.) Nees (Fa-Talai-Jorn)

Herbs have a moisture content as high as 80% w.b. Removal of the moisture from herbs is necessary to prevent microbial contamination and to allow for further processing. Drying is one of the most common techniques of preservation in medicinal herbs. It can be used to extend an herb's shelf life. In general, there are several methods of drying depending on the usage. Conventional drying method, such as natural sun drying, is an ancient method of drying and has been used for many years but the drying conditions are uncontrollable and there is a risk of product loss. Freeze drying is the process of removing water from a product at a low temperature, which has the advantage of retaining a lot of nutrients. However, it requires a longer processing time. The most popular drying method is hot air drying, which is a high-temperature dehydration process. It offers advantages such as extending shelf life, preserving quality, and improving product quality, but its effectiveness depends on various factors, such as drying temperature and pretreatment method (Inyang et al., 2017; Tummanichanont et al., 2017; Adeyeye et al., 2022).

Currently, there are several studies on the drying of *Andrographis paniculata*. Chokthaweepanich et al. (2023) studied the effects of harvesting age and drying conditions on the andrographolide content of *A. paniculata*. They focused on days after sowing (DAS) ranging from 90, 100, 115, to 127 days and drying temperature using a hot air oven at 50, 65, and 80°C, as well as natural sun drying. The results showed that the highest andrographolide contents were obtained at 127 DAS at 65°C, 127 DAS at 80°C, and 115

DAS at 80°C. Saohin et el. (2007) also studied the effects of drying temperature and residual moisture content on the total lactone contents of Fa-Tha-Li (*Andrographis paniculata (Burm.f.*) Nees.) for capsule preparation. The fresh Fa-Tha-Li leaves were dried at 40, 50 and 60ºC until the residual moisture content dropped to below 10% v/w. The results revealed that there were no significant differences in the amount of total lactones in Fa-Tha-Li leaves dried at 40, 50 and 60°C. However, drying at 60ºC took the shortest time to reach the residual moisture content of less than 10%v/w. Tummanichanont et al. (2018) studied the effect of harvesting age ranging from 80-90 days and 110-150 days after seeding, and drying method including drying in a cabinet dryer (CAD) at 45°C, a heat pump dryer (HPD) at 30°C, and a freeze dryer (FD), on the changes in bioactive compounds. The study found that the andrographolide content was higher when using the freeze dryer compared to other methods. Gulati et al. (2020) studied the effects of different drying including natural sun drying, microwave-assisted drying, oven drying, hot air drying, and shade drying on andrographolide content. It was found that the shade drying method was the most suitable for removing moisture content and preserving andrographolide content.

Therefore, drying methods affect the andrographolide content, and several studies found that drying methods that avoided solar radiation resulted in the highest amount of andrographolide. Thus, the purpose of this work was to investigate the amount of andrographolide in *Andrographis paniculata* that had been dried inside a household solar dryer with variation of the color of the polycarbonate sheet cover. The andrographolide content was determined using high-performance liquid chromatography technique (HPLC).

2. Materials and Methods

2.1 Characteristics of the dryer

The solar dryers used in this study was the Household Solar Dryer type (HSD). The size of solar dryers was 1.0 m in width, 1.2 m in length, and 0.45 m in height. The dryers consisted of various components including a cover made of polycarbonate sheet with 6 mm in thickness and bent into a parabolic shape and a metal floor made of a black metal plate. There were two air inlets situated at the frontside of the solar dryer. One 12V DC fan powered by a 6 W solar panel, placed at the backside of the dryer, acted like an air outlet. One tray made of food-grade plastic (0.9 m × 1.0 m) was placed inside the dryer (Figure 2a). In this study, four colors of polycarbonate sheets were utilized: clear, blue, green, and gray (Figure 2b), each with varying transmittance levels.

2.2 Materials

Andrographis paniculata (Fa-Talai-Jorn) used in this study were collected from Kampansan district, Nakhon Pathom province, Thailand. They were chopped into fine pieces and a weight 5 kg of *A. Paniculata* were used for each dryer. The samples were spread evenly on the tray inside the dryer to a thickness of 10 cm. The initial moisture content was about 85% w.b.

2.3 Experimental set up

The experiment was conducted at the Department of Physics, Faculty of Sciences, Silpakorn University, Nakhon Pathom, Thailand (13.82°N, 100.1°E) during 18-20 May 2023. The drying test was started at 8:00 and stopped at 18:00. During the drying process,

(a)

(b)

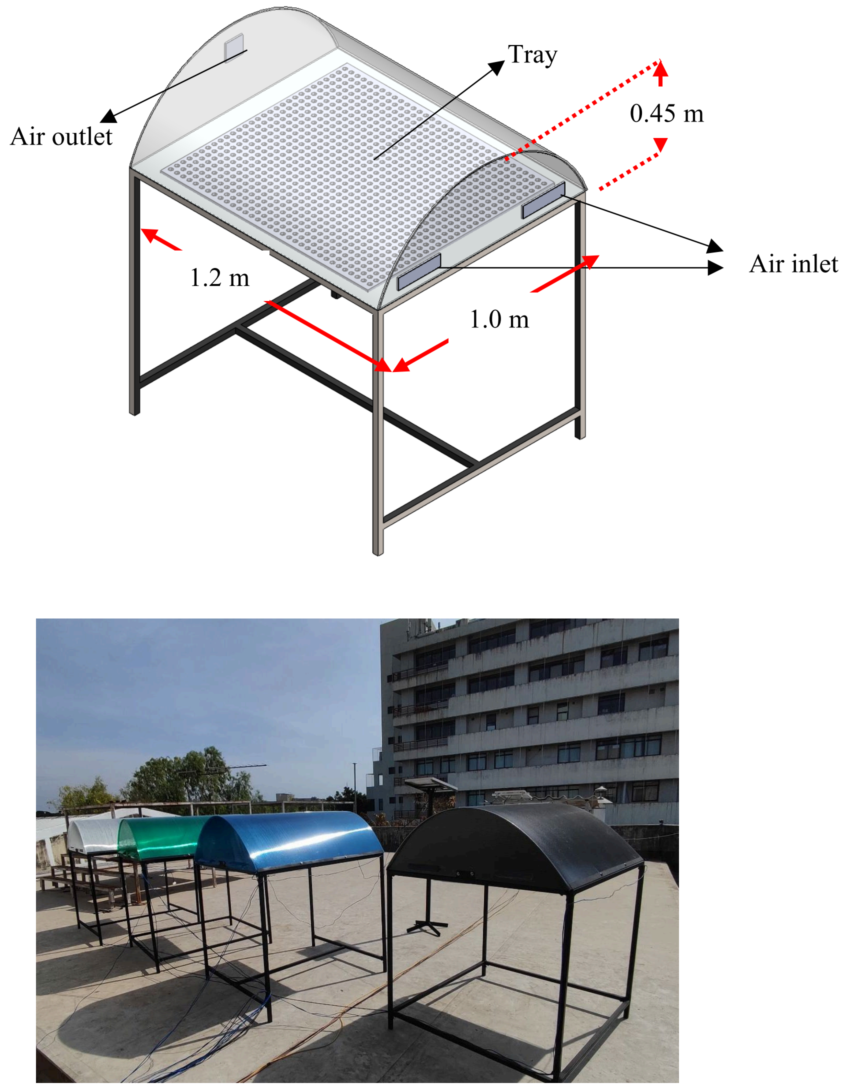

Figure 2. (a) Illustration of household solar dryer (b) household solar dryer with different color of polycarbonate sheet cover

the *Andrographis paniculata* samples were weighed every 2 h at intervals until the end of the drying process which means the equilibrium mass of the sample was reached. The dried samples were placed in an oven at 103ºC to obtain the solid mass of the samples (m_s) in order to determine the moisture content of the products. Data collected during the experiment included solar intensity, air temperature, and relative humidity both inside and outside the solar dryers, and the mass of the samples was measured and collected by different equipment (Table 1).

Table 1. Equipment used in the experiment

Parameter	Equipment	Model	Uncertainties
Solar intensity	Pyranometer	Kipp&Zonen, CMP11	± 10 W/m²
Air temperature	Thermocouple	Type K	± 0.1°C
Relative humidity	Humidity sensor	E+E Elektronik, EE23	± 0.5%
Data	Data logger	Yokogawa, DC100	
Mass of sample	Balance	OHAUS, Adventurer Pro.AV212	± 0.02 g

The moisture content in *Andrographis paniculata* samples was evaluated on a wet basis (w.b.). The moisture content was calculated every 2 h, and expressed as % according to the following equation (Hii et al., 2012):

$$\mathrm{M} = \frac{\mathrm{m_w}}{\mathrm{m_w} + \mathrm{m_s}} \times 100\% \tag{1}$$

where M is moisture content (%, w.b.), $\mathrm{m_w}$ is the mass of water in the product (kg) and $\mathrm{m_s}$ is solid mass of the product (kg).

2.4 Determination of andrographolide content

After the drying process, the *Andrographis paniculata* samples from four solar dryers and natural sun drying were ground and sifted into a similar powder. The method for quantifying andrographolide content in *Andrographis paniculata* extract by high-performance liquid chromatography (HPLC) (Waters Alliance 2695 HPLC Separation module) technique was modified from Sharma et al. (2018). A Luna ® 5 µm C18 (2) 100 Å LC column (4.6 x 150 mm) was used in this study. A sample of the dried *Andrographis paniculata* powder (20 mg) was extracted with 10 mL of methanol solvent using the sonication assisted method and 20 min extraction duration. After extraction, the solvent from each sample was distilled off and the residue was completely dried. The residue was dried to a constant weight. The extracted material was then subjected to HPLC analysis for quantification of andrographolide. UV detection was employed at 225 nm, isocratic elution was used at a flow rate of 0.7 ml/min, and the injection volume was set to 10 µL.

3. Results and Discussion

3.1 Transmission of polycarbonate sheet

Polycarbonate sheets exhibit distinct characteristics in terms of absorbance and transmittance. The transmission parameter (T) indicates a polycarbonate sheet's behavior with respect to solar radiation (Serrano & Moreno, 2020). Polycarbonate sheets can transmit light like glass because each polycarbonate sheet offers ultraviolet (UV) protection in the range of 100-400 nm. They also have special coatings that reflect UV radiation outward and help filter sunlight. However, natural light can still pass through. In this study, four colors of polycarbonate sheet cover were tested the light transmission value using UV-visible spectrophotometers (AquaMate 8000, Thermo Scientific) for the wavelength in range of 250-950 nm.

From Figure 3, the results show that the clear polycarbonate sheet stands out for its ability to transmit solar radiation across a wide range of spectrum, from visible light to infrared, allowing approximately 65% of light transmission. This feature makes it ideal for applications requiring natural lighting and heat retention. The green polycarbonate sheet is designed to transmit solar radiation within the range of 500 to 570 nm. This targeted transmittance range makes it suitable for environments where this specific light spectrum is advantageous. The blue polycarbonate sheet is engineered to transmit light falling within the 450 to 495 nm range. This characteristic makes it a preferred choice for applications that benefit from this light spectrum, such as those found in plant growth facilities or aesthetic lighting installations. The gray polycarbonate sheet allows solar radiation across a broad spectrum, spanning from visible light to thermal radiation.

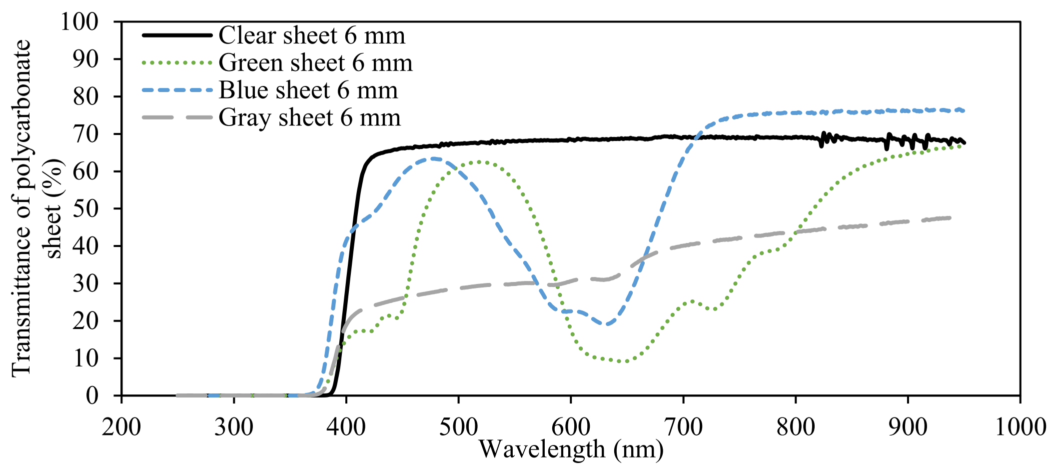

Figure 3. The transmittance of polycarbonate sheets at different color

3.2 Drying experiment

The chopped *Andrographis paniculata* used in the experiment amounted to 5 kg at full capacity for each solar dryer. The drying experiment was carried out from May 18 to May 20, 2023. The solar intensity variation during the drying experiment showed that over a period of 3 drying days, the solar intensity followed a bell curve pattern occurring between 8:00 a.m. to 6:00 p.m. (Figure 4). The highest solar intensity during the day was approximately 950 W/m^2 at noon. The solar intensity then continuously decreased until the end of each day.

The variation of air temperature inside the solar dryers covered with different colors of polycarbonate sheet (clear, green, blue, and gray) compared to ambient temperature, is presented in Figure 5. The change in air temperature pattern was influenced by the solar intensity. Due to the components of the solar dryer absorbing shortwave radiation from the sun and emitting longwave radiation (infrared radiation), it was important to prevent infrared radiation from escaping into the ambient environment. This was achieved by using a polycarbonate sheet cover. Thus, the air temperatures inside the solar dryers were higher than ambient temperature with average air temperatures of 58.2, 53.7, 53.7, 51.9, and 36.9°C for the clear, green, blue, gray, and ambient conditions, respectively. This result corresponds to the transmittance value of polycarbonate sheet color.

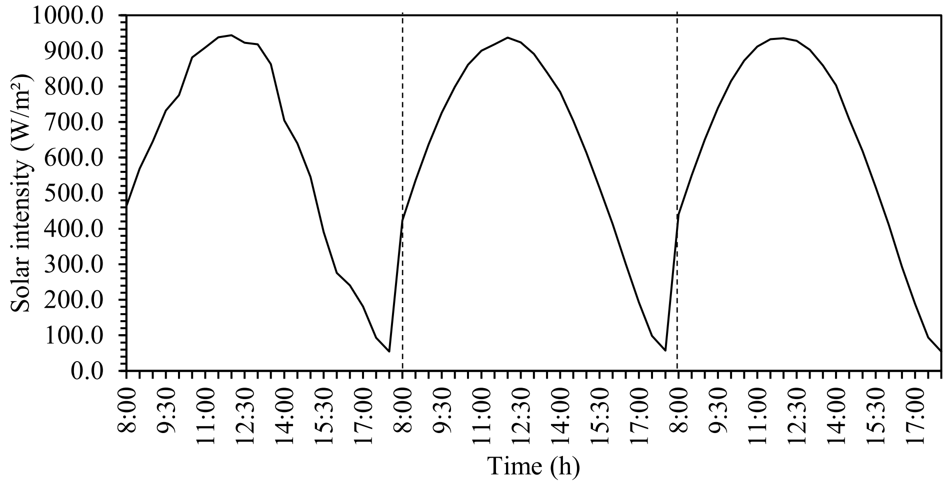

Figure 4. Variations of solar intensity during drying experiment (18-20 May 2023)

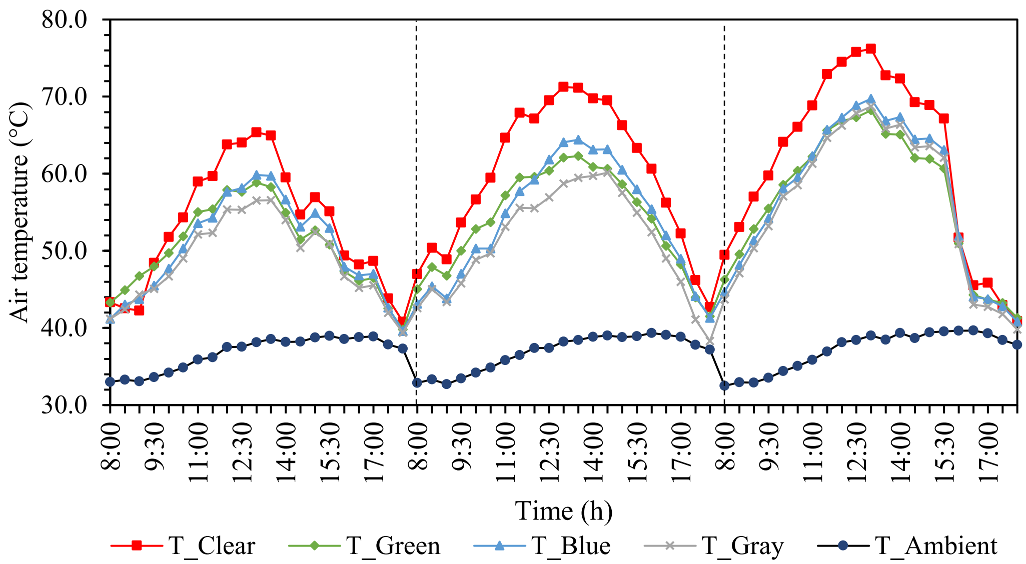

Figure 5. Variations of air temperature during drying experiment (18-20 May 2023)

The variation of air relative humidity during the drying period is presented in Figure 6. It was found that the patterns of air relative humidity changed according to the air temperature; the air relative humidity increased as air temperature decreased and decreased as air temperature increased. This was due to the difference of air temperature between the inside of solar dryer and ambient conditions that affected the convective mass transfer. The average air relative humidities of different polycarbonate sheet colors were 15.7%, 20.5%, 19.6%, 21.4%, and 65.9% for the clear, green, blue, gray, and ambient conditions, respectively.

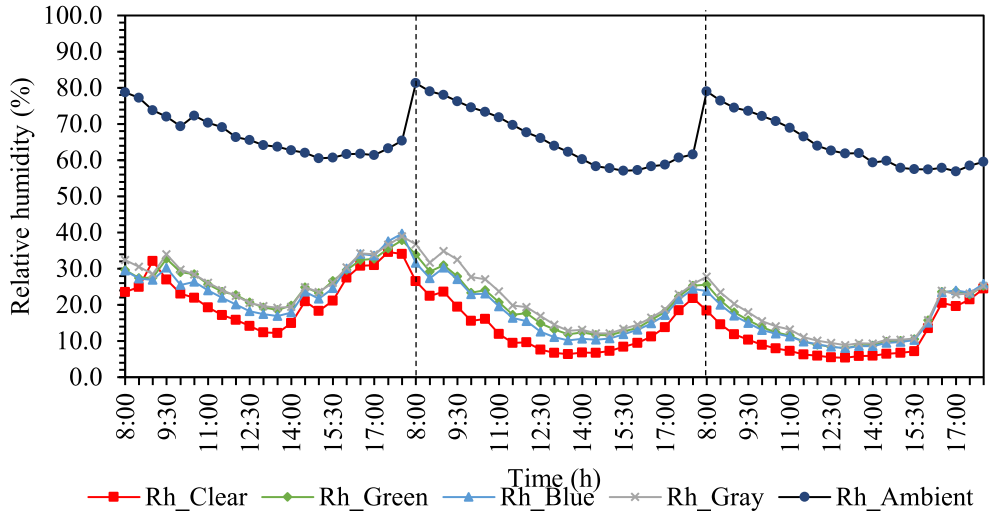

Figure 6. Variations of air relative humidity during drying experiment (18-20 May 2023)

The moisture content reduction of *Andrographis paniculata* dried inside the solar dryer compared to natural sun drying, is presented in Figure 7. As can be seen in the Figure, the moisture content was reduced from an initial moisture content of about 85% w.b. to a final moisture content of 7% w.b. in 3 days of drying. It was observed that the moisture content of *Andrographis paniculata* from each dryer decreased more slowly than the ambient conditions. This was likely due to the ambient condition sample receiving more solar intensity than the samples inside the solar dryers, which were covered by polycarbonate sheet. From Figure 7, it was found that the sample from the solar dryer covered by a gray polycarbonate sheet had the slowest drying time.

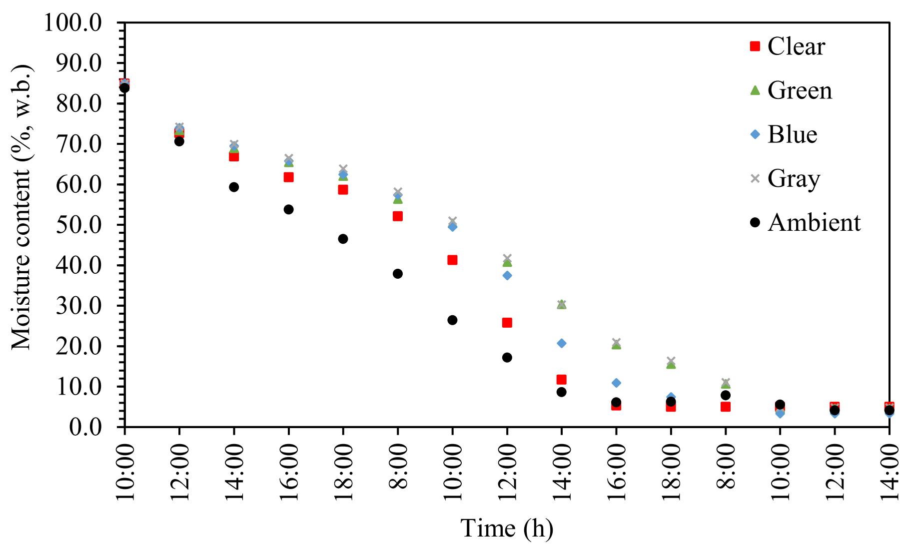

Figure 7. Variations of moisture content during drying experiment (18-20 May 2023)

3.3 Andrographolide content

The results of variation in andrographolide content for each different cover color condition using the HPLC technique are presented in Figure 8. The highest percentage of andrographolide content was found for the experiment conducted under drying conditions with the gray polycarbonate sheet cover. This result may be related to the lowest transmittance values of gray cover color compared to other cover colors (Figure 3). Different transmittance values of polycarbonate sheet colors result in the amount of solar intensity absorbed by the products, leading to variations in the amount of heat absorption. Among the samples with 4 cover colors, the blue cover color had the lowest percentage of andrographolide content probably due to the blue cover transmitting a higher amount of the UVA solar radiation spectrum (up to 380 nm in wavelength). The gray cover had a low light transmission into the solar dryer, which was approximately 20%, resulting in a low amount of UV radiation transmission, thereby leading to the highest andrographolide content (Figure 8).

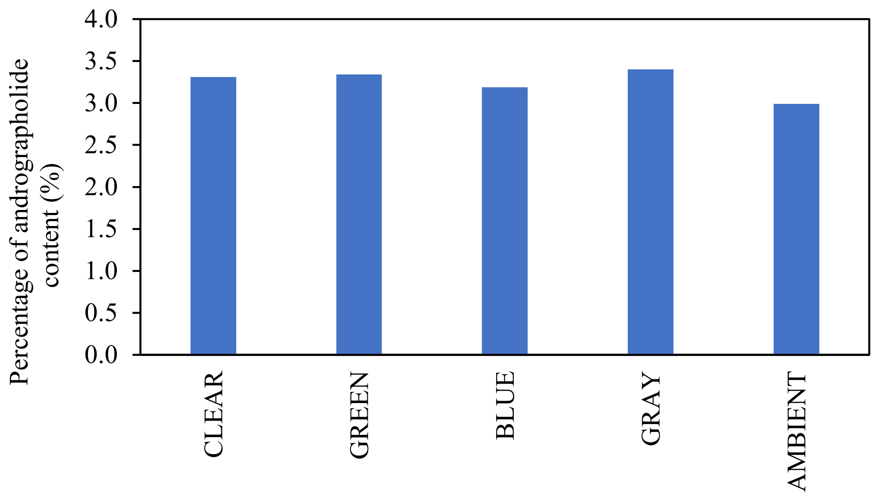

Figure 8. Andrographolide content at different colors of polycarbonate sheet cover

The results show that UV radiation affected the percentage of andrographolide content. This is likely because andrographolide, which is categorized as a diterpenoid lactone, is sensitive to photodegradation caused by exposure to solar radiation, especially UV radiation. Furthermore, the heat from infrared radiation (IR) affects the thermal degradation of the diterpenoid lactone in *Andrographis paniculata*, which can significantly alter their chemical structure and reduce their pharmacological properties (Saravanan et al., 2008).

4. Conclusions

In this study, the effect of polycarbonate sheet color on andrographolide content in *A. paniculata* was investigated. *Andrographis paniculata* was dried by using household solar dryers, which were covered with different polycarbonate sheet colors (clear, green, blue, and gray). The andrographolide content from the solar dryers was quantified using the

HPLC technique and compared to that of *A. paniculata* dried under natural sun drying. The results show that the maximum andrographolide content (3.4%) obtained was from *A. paniculata* dried in the solar dryer with the gray cover. This was due to the gray cover having the lowest transmittance value compared to the other colors and natural drying method. The results show that UV radiation and infrared radiation affected the percentage of andrographolide content. In the future, experiments should be carried out with variation of other variables, such as the thickness and type of polycarbonate sheet, etc. Other drying methods should also be compared with the household solar dryer.

5. Acknowledgements

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6. Conflicts of Interest

The authors declare that they have no conflicts of interest.

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