SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879

Evaluation of Optimal Flatbed Heating Temperature for Uromastyx aegyptia in Tropical Captivity

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ARTICLE INFO

Article history:
Received 6 September 2025
Received in revised form 6 October 2025
Accepted 26 October 2025
Available online 28 October 2025

Keywords:
Uromastyx aegyptia; Thermoregulation; Flatbed heating system; Basking posture

ABSTRACT

Uromastyx aegyptia, a desert-dwelling reptile, requires stable basking temperatures between 50 °C and 55 °C for effective thermoregulation, yet maintaining such conditions in Malaysia's high-humidity tropical climate presents a significant challenge. This study evaluates the optimal setup temperature for a heated flatbed system designed to replicate desert substrate conditions. The plate was tested at 80 °C, 100 °C, and 120 °C. Thermal imaging and behavioral monitoring determined comfort based on basking posture, color change, and weekly body weight. Eight Dhabs, comprising four individuals in the control group and four in the hot flatbed group, were observed over a four-week period. At the 80 °C plate setting, the surface temperature stabilized between 52 °C and 55 °C, closely matching the species' natural basking range. Lizards exhibited relaxed postures, lighter coloration, and weight gain which indicating effective thermoregulation. The system provides a potentially reliable and welfare-focused solution for heating under tropical captivity conditions.

1. Introduction

The reptiles are ectothermic organisms that rely on external heat sources to regulate their internal body temperature and sustain essential physiological functions such as digestion, locomotion, and immune performance [1]. Among these, Uromastyx aegyptia, commonly known as the Egyptian spiny-tailed lizard or "Dhab," is a desert-dwelling species native to North Africa and the Middle East [2]. In its natural environment, this reptile thrives under extreme desert conditions where basking substrate temperatures typically range between 50 °C and 55 °C [3-4]. These high temperatures are critical for maintaining optimal enzymatic activity, metabolic balance, and reproductive health [4]. Replicating such conditions within tropical captivity poses significant engineering and environmental challenges. Malaysia's high ambient humidity (80–90 %) and moderate air temperatures, averaging around 25.9 °C, hinder the maintenance of dry, localized heat

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https://doi.org/10.37934/arfmts.135.1.139147

zones suitable for desert-adapted reptiles [5-6]. Conventional heating methods such as infrared lamps often produce uneven temperature gradients with localized hot spots, disrupting reptile thermoregulation and increasing the risk of overheating or skin burns [7][8]. Furthermore, radiant heating sources can interfere with natural photoperiods and circadian rhythms, contributing to stress and behavioral anomalies [7].

Inadequate thermoregulation in captive reptiles has been linked to metabolic suppression, poor digestion, and reduced immunity, ultimately leading to chronic health issues and shortened lifespan [9,7,10]. To address this, recent studies have emphasized the role of conduction-based heating systems such as flatbed surface heaters in achieving more uniform temperature distribution, improving thermal stability, and reducing energy waste [11-12]. Such systems mimic natural substrate heating by transferring heat through direct contact, providing reptiles with consistent and controllable basking surfaces [13].

Behavioral thermoregulation in reptiles can be effectively assessed through non-invasive indicators such as basking posture, limb extension, and color change [14-16]. Flattened postures, for example, increase conductive heat absorption, while lighter coloration during basking indicates thermal satisfaction and homeostasis [15]. These visual and behavioral cues have been widely recognized as reliable measures of reptile comfort and thermoregulatory efficiency [17-18]. Despite the established benefits of conduction-based systems, limited empirical data exists on the performance of engineered heating solutions under tropical conditions. The high humidity and fluctuating ambient temperatures in regions such as Malaysia can affect the heat-transfer rate and stability of basking surfaces, necessitating a system specifically adapted to these environments [8].

Therefore, this paper focuses on developing a hot flatbed heating system for Dhab, designed to replicate the thermal conditions of its original desert habitat under tropical captivity. The comfort level of Uromastyx aegyptia will be evaluated through weight variation and basking posture during utilization of the flatbed system. Additionally, color-change observation will be used to confirm that the Dhab receives sufficient heat and exhibits behavioral signs of thermal comfort.

2. Methodology

2.1 Fabrication of hot flatbed system

In the material and tool preparation phase, a custom mold was fabricated using polyfoam. A release layer consisting of a plastic wrapper and cellophane tape was applied to facilitate easy demolding after curing. Subsequently, the cement mixture was prepared and poured into the mold to form the structural base of the heat flatbed system, as illustrated in Figure 1.

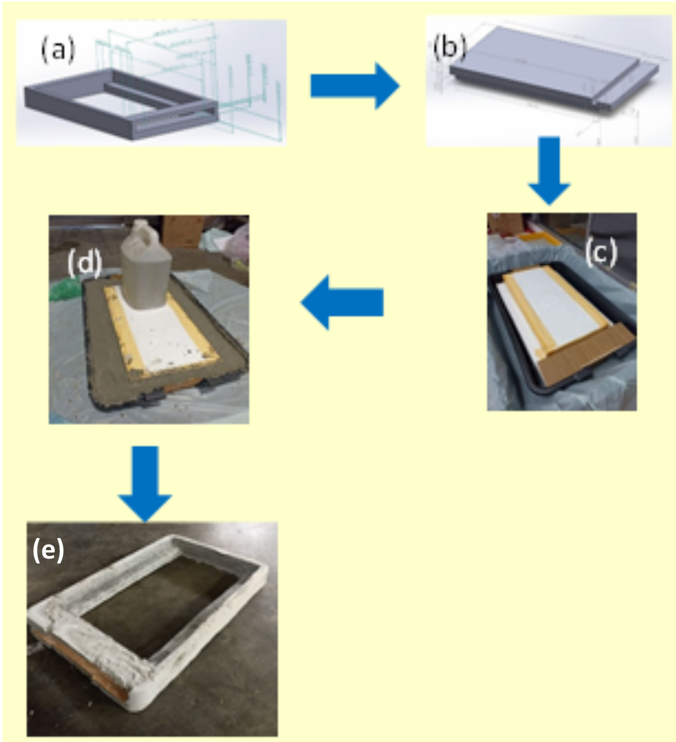


Fig. 1. Process flow of hot flatbed system fabrication. (a) Isometric view of hot flatbed casing; (b) Isometric view of cement mold; (c) Setup of cement moulding; (d) Poured cement; (e) Completed sturdy concrete of hot flatbed structure.

2.2 Hot flatbed system analysis

The study then proceeded to the data collection and verification phase, during which several key thermal parameters were evaluated. The heat plate was operated at three temperature settings: 80 °C, 100 °C, and 120 °C. The suitability of each setting was assessed by determining whether the surface temperature of the hot flatbed system remained within the optimal basking range for Uromastyx aegyptia (50 °C–59 °C) [2,3]. To ensure consistency in temperature measurement, a thermal imaging system was mounted on a fixed stand positioned 1.0 m horizontally and 1.2 m vertically from the center of the hot flatbed system platform. This setup provided a constant angle and resolution for all captured thermal data, as illustrated in Figure 2. The first heating trial was conducted by setting the Uringo Electric Dish Warmer to 80 °C, with a total operating duration of four hours. Thermal images of the hot flatbed system surface were captured at one-hour intervals (Hour 1, Hour 2, Hour 3, and Hour 4) using a Fluke Ti27 Infrared Camera. The same procedure was repeated for the remaining temperature settings (100 °C and 120 °C), each maintaining a four-hour heating period with thermal data recorded at identical one-hour intervals.

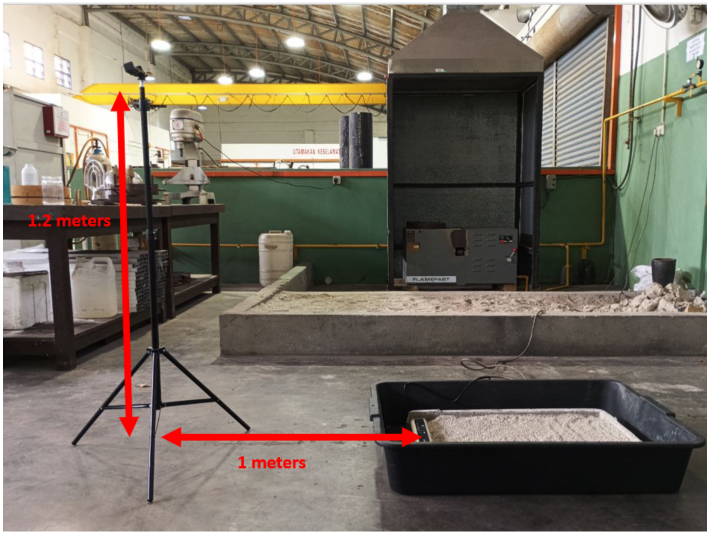


Fig. 2. Experiment setup for temperature measurement

2.3 Health Outcomes of the Uromastyx Aegyptia

This experimental study was conducted to examine the physiological and behavioral responses of Dhab to a custom-developed conductive heating system. The investigation was carried out over a one-month period to capture both short-term behavioral adaptations and longer-term physiological changes under varying environmental conditions. The experiment took place at Dhabsinai Farm, Malaysia. Ethical approval was obtained from the USM Institutional Animal Care and Use Committee (USM IACUC) with Approval ID: USM/IACUC/2025/(153)(1381)), and a research permit was granted by the Department of Wildlife and National Parks (Reference No.: JPHLTN.600-6/1/4 JLD3 (86))

A total of eight healthy adult Uromastyx aegyptia were randomly selected and divided into two groups (Control and Hot Flatbed), each consisting of four individuals (n = 4 per group). This sample size aligns with previous studies on reptilian morphology and behavior, which indicate that groups of 4–8 individuals provide statistically valid and biologically meaningful results [19]. Surface temperatures were measured using a Fluke Ti27 Infrared Camera, while basking posture and skin-color changes were continuously monitored using a Tapo C210 CCTV system. Each specimen was individually identified using a color-coded tail marker for ease of observation and data recording, with assigned colors listed in Table 1. The study primarily focused on assessing the Dhabs’ behavioral interest toward the heating system, supported by weekly weight-gain data to evaluate its applicability for long-term welfare studies.

Table 1
Name Coded for Dhab Specimen

Group	Color Code	Specimen ID
Control Group	Merah	DS001
	Biru	DS002
	Putih	DS003
	Hijau	DS004
Hot Flatbed Group	Merah	DS005
	Biru	DS006
	Putih	DS007
	Hijau	DS008

The Control group was placed in standard enclosures without additional heating, representing baseline husbandry conditions. The Hot Flatbed group was placed in modified enclosures equipped with the hot flatbed heating system, which comprised a flat heating plate embedded beneath a shallow sand layer designed to maintain a stable surface temperature of approximately 50-60 °C. The hot flatbed system enclosure was also fitted with a Tapo C210 CCTV camera positioned adjacent to the habitat, allowing continuous video recording for detailed behavioral analysis and thermal interaction assessment. Behavioral observations were conducted daily between 8:00 AM and 12:00 PM. All lizards were fed once daily at 10:00 AM with a plant-based diet consisting of leafy greens, edible flowers, and selected vegetables. This dietary regimen followed standard recommendations for herbivorous reptiles, ensuring balanced nutrition to support digestive efficiency and metabolic stability [20].

Physiological monitoring focused on weekly body-weight assessment to evaluate potential health and growth variations. Each Dhab's body weight was measured every Friday at 5:00 PM using an AGT-S2 digital weighing scale set to gram precision. Weight data were analyzed to determine the percentage change over time using Equation (1):

$$POD = \left(\frac{W_{W_0} - W_{W_i}}{W_{W_0}}\right) \times 100 \quad (1)$$

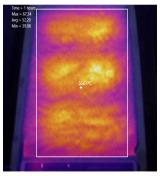
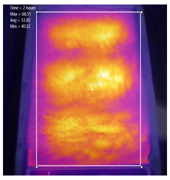
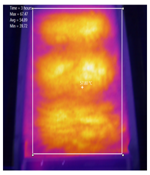
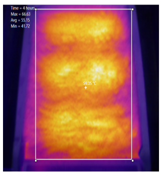
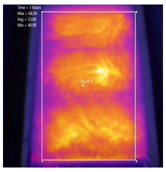
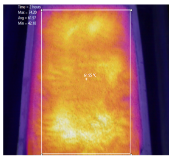
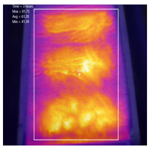
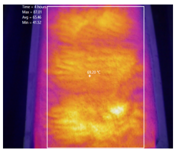
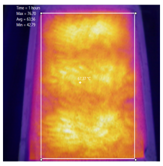
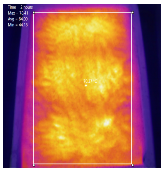
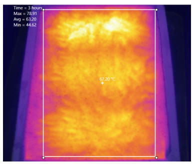
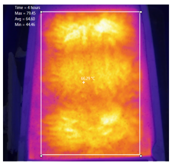
where the percentage of difference of Dhab weight, *POD*, weight of Dhab for previous week, W_{w_0} and weight of Dhab for current week, W_{w_i}. This metric served as an indicator of overall health status, growth progress, and the physiological impact of the hot flatbed heating environment.

3. Results

3.1 Optimization hot flatbed system temperature

Table 2 presents the average surface temperature distribution recorded across the hot flatbed system under three heating conditions: 80 °C, 100 °C, and 120 °C. When the hot flatbed system was operated at 80 °C, the mean surface temperature ranged between 52.20 °C and 55.15 °C, which falls within the optimal basking range for Uromastyx aegyptia (50 °C–55 °C). This range corresponds to the natural substrate temperature typically observed in the species' desert habitat and has been identified as essential for maintaining enzymatic activity, metabolic efficiency, and reproductive function [14].

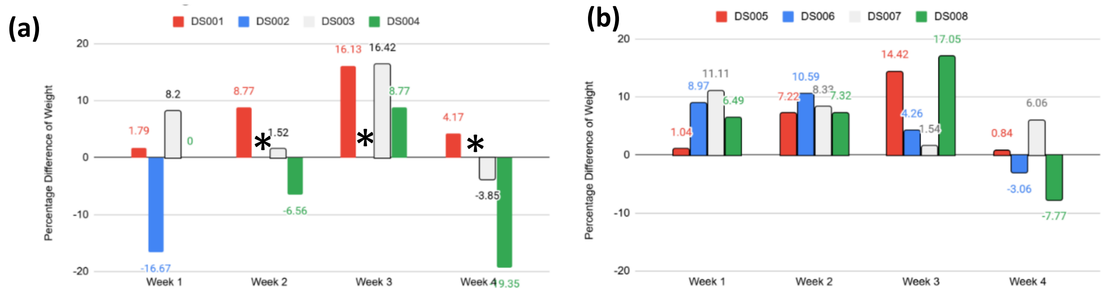
Table 2
Temperature distribution of hot flatbed system

Temperature settings	1 Hours	2 hours	3 hours	4 hours
80 °C	 Max = 67.34 °C Avg = 52.20 °C Min = 39.08 °C	 Max = 68.51 °C Avg = 53.85 °C Min = 40.52 °C	 Max = 67.47 °C Avg = 54.89 °C Min = 39.72 °C	 Max = 66.63 °C Avg = 55.15 °C Min = 41.72 °C
100 °C	 Max = 68.54 °C Avg = 53.80 °C Min = 40.98 °C	 Max = 74.20 °C Avg = 61.97 °C Min = 42.18 °C	 Max = 81.75 °C Avg = 61.20 °C Min = 41.39 °C	 Max = 87.01 °C Avg = 65.46 °C Min = 41.52 °C
120 °C	 Max = 76.70 °C Avg = 63.56 °C Min = 42.79 °C	 Max = 78.41 °C Avg = 64.00 °C Min = 44.18 °C	 Max = 78.91 °C Avg = 63.20 °C Min = 44.62 °C	 Max = 79.45 °C Avg = 64.60 °C Min = 44.46 °C

In contrast, higher settings of 100 °C and 120 °C resulted in surface temperatures exceeding 63 °C, surpassing the recommended thermal comfort zone for desert reptiles. Exposure to such high surface temperatures can induce heat stress, tissue damage, or behavioural distress, as reported in similar reptilian studies where excessive basking temperatures disrupted physiological equilibrium and induced avoidance behaviours [17]. These elevated settings also demonstrated steeper thermal gradients and localized hot spots, reducing uniformity and increasing energy loss. Therefore, the 80 °C setting is identified as the optimal operational parameter for the hot flatbed system, providing a biologically compatible, energy-efficient, and thermally stable basking surface for Uromastyx aegyptia. This temperature range ensures safe and consistent heat exposure, replicating natural basking conditions and supporting proper thermoregulation without risking overheating which is a principle consistent with recent ecological findings emphasizing the link between controlled temperature exposure and reptile health under changing environmental conditions [9].

3.2 Body Weight Variation and Health Assessment of Uromastyx aegyptia

Figure 3 illustrates the weekly percentage weight variation of Uromastyx aegyptia maintained in the control enclosure (without heating) and the hot flatbed -equipped enclosure. In the control group, body weight changes were irregular and generally negative, with significant reductions observed in DS002 (–16.67%) and DS004 (–8.85%). The mortality of specimen DS002 by week 2 further indicates that the absence of a stable heating source impaired metabolic balance and physiological stability, consistent with previous findings that inadequate thermoregulation in reptiles leads to suppressed metabolism, reduced immunity, and higher mortality risk [7,9].



*Note: DS002 is dead

Fig 3. Graph of Difference of Dhab's Weight in (a) Controlled tank (No heater) and Graph of Difference of Dhab weight in Tank with (b) Hot Flatbed group

Conversely, specimens in the Hot Flatbed group (DS005–DS008) demonstrated positive and consistent weight progression during the same period. Notably, DS007 and DS008 exhibited weight gains of 14.42% and 17.05%, respectively, suggesting enhanced digestion, nutrient absorption, and thermal homeostasis facilitated by the conductive heating environment. These results align with Domínguez–Guerrero *et al* [17], who reported that reptiles exposed to stable substrate temperatures within their thermal preference range exhibit improved physiological performance and behavioral stability.

Figure 4 illustrates the distinct variation in dorsal skin coloration of Uromastyx aegyptia housed within the hot flatbed enclosure, offering valuable insight into the species' thermoregulatory behavior. In Figure 4(a), the lizards exhibit a duller and darker dorsal pigmentation during the morning hours, reflecting lower body temperatures following nocturnal cooling. This darker coloration enhances heat absorption by improving radiant and conductive heat uptake from the substrate and surrounding environment [18,19]. In contrast, Figure 4(b) shows a noticeable shift to a lighter, brighter coloration in the afternoon, indicating a behavioral and physiological response as body temperature approaches the species' optimal thermal range.

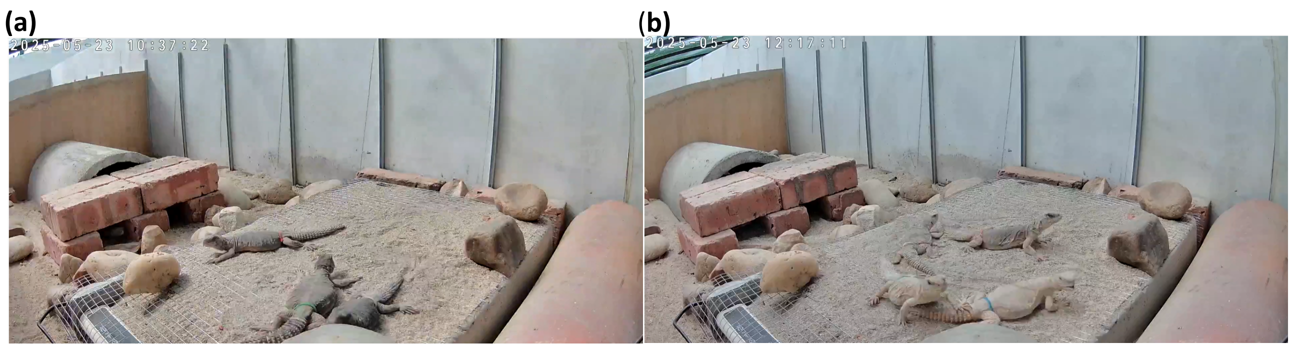


Fig 4. Dull colour of body skin in morning session (a); (b)Light colour of body skin in afternoon session

In this study, effective thermoregulation was characterized by a combination of defined behavioral and physiological indicators, including a flattened basking posture, progressive lightening of dorsal skin color, and consistent weekly weight gain. These parameters suggest stable metabolic performance and positive energy balance, representing improved physiological health under controlled thermal conditions. Previous studies on Uromastyx and other desert reptiles have similarly linked color modulation, posture adjustment, and weight stability with successful thermal regulation and metabolic efficiency [17,19,21]. Although internal body temperature, feeding rate, and hormone levels were not directly measured, the behavioral indicators observed through continuous CCTV monitoring provide consistent, non-invasive evidence of thermoregulatory effectiveness.

4. Conclusions

This study developed and tested a hot flatbed system to simulate natural basking conditions for Uromastyx aegyptia in tropical captivity. The results showed that setting the hot flatbed system at 80 °C produced a stable surface temperature between 52 °C and 55 °C, closely matching the species' natural basking range.

Lizards in the hot flatbed group exhibited healthy weight gain, normal coloration changes, and active basking behavior, indicating effective thermoregulation and improved physiological health. Notably, individuals DS007 and DS008 showed weight increases of 14.42% and 17.05%, respectively, reflecting the system's positive impact on growth performance. In contrast, control specimens without heating displayed weight loss and signs of stress.

The hot flatbed system operates based on the principle of conductive heat transfer, allowing direct and efficient thermal exchange between the substrate and the reptile's body, thereby supporting natural thermodynamic processes critical for reptilian physiology.

Overall, the system provides a safe, efficient, and biologically suitable heating method for desert reptiles kept in humid tropical environments, offering a potentially reliable and welfare-focused solution that enhances thermal comfort compared to conventional UV-based heating methods. However, limitations of this study include the small sample size, absence of internal body-temperature data, and limited humidity control. Future work should focus on integrating humidity regulation and automated thermal control to further improve the system's precision and long-term applicability for reptile welfare management.

Acknowledgement
This research was not funded by a grant. The authors gratefully acknowledge Dhabsinai Farm, Malaysia, for providing the research site and technical assistance throughout the experimental work. Ethical approval for this study was granted by the Universiti Sains Malaysia Animal Ethics Committee (Approval ID: USM/IACUC/2025/ (153) (1381)), and research permission was obtained from the Department of Wildlife and National Parks (PERHILITAN) (Reference No.: JPHLTN.600-6/1/4 JLD3 (86)).

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