MODIFICATION OF THE MICROENVIRONMENT AROUND A SCREEN HOUSE USED FOR SNAIL PRODUCTION

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A PROJECT SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE BACHELOR OF AGRICULTURE HONORS, DEGREE IN ANIMAL SCIENCE OF THE UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

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CERTIFICATION

This is to certify that this project work was carried out by **Freda AMADIN** with the Matriculation Number **AGR2000063** of the Department of Animal Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria.

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(*Head of Department*)

DEDICATION

This research work is dedicated to my lovely parents

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I am appreciating God for making this journey a success and for being my ever present help in times of need.

I want to thank my supervisor, Prof J.M. Omoyakhi for his guidance and corrections all through this process, it helped broaden my understanding and comprehension of this work.

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ABSTRACT

Snail farming has emerged as a sustainable form of micro-livestock production in sub-Saharan Africa, providing animal protein and income diversification opportunities for smallholder farmers. However, productivity remains low in many farming systems due to inadequate rearing environments that fail to replicate the humid, shaded, and cool natural habitats of snails. This study, titled Modification of the Microenvironment Around a Screen House Used for Snail Production, investigates how targeted environmental modifications can improve snail growth and survival. The study was designed to evaluate key microclimatic variables including temperature, humidity, and soil moisture around screen houses modified using shading materials, mulching, water sprinkling, and windbreaks. The African giant land snail (*Achatina marginata*) served as the experimental species due to its economic significance. Data on snail growth performance, mortality rate, and activity patterns were collected and analyzed using descriptive statistics and inferential tests. Preliminary findings indicate that microenvironmental modifications create more stable and favorable conditions, leading to reduced mortality and improved weight gain among snails.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Snail farming, also known as heliciculture, has become an important aspect of sustainable animal agriculture, especially in tropical and subtropical regions where demand for animal protein is rising alongside environmental and economic challenges. Snails, particularly species of the genus *Achatina* such as *Achatina marginata* and *Achatina fulica*, are highly valued for their meat, which is rich in protein, essential amino acids, iron, and low in cholesterol, making it an ideal alternative to conventional livestock products (Etukudo *et al.,* 2025). In addition, snail farming provides significant economic benefits as a source of income for rural households and small-scale farmers, requiring relatively low startup costs and minimal land space compared to poultry or ruminant production (Mvedo Meyo *et al.,* 2021). Beyond meat, snail shells are used in feed formulation and traditional medicine, while snail slime has growing applications in cosmetics and pharmaceuticals due to its bioactive compounds (Rashad *et al.,* 2025).

Despite its potential, the development of snail farming in Africa and other developing regions remains constrained by environmental limitations, particularly the difficulty of creating and maintaining suitable microclimatic conditions for optimal growth and reproduction. Snails are poikilothermic and moisture-dependent, thriving best in environments with high relative humidity (75–95%) and moderate temperatures (20–28°C). Excessive heat, dryness, or exposure to direct sunlight can cause desiccation, aestivation, and high mortality, whereas extreme wetness predisposes snails to fungal and bacterial infections (Cobbinah, Vink and Onwuka, 2008). Consequently, successful snail production requires structures such as screen houses or pens that protect snails from predators, escape, and environmental extremes, while also providing a conducive microclimate.

Screen houses are commonly used in heliciculture because they allow for ventilation and reduced predator intrusion; however, they often fail to maintain adequate humidity and temperature stability without further modification (Tanny *et al.,* 2003; Teitel, 2007; Ogunlowo *et al.,* 2024). In many tropical settings, screen houses can become excessively hot and dry during the day, leading to stress, stunted growth, low reproductive performance, and high mortality among snails. Moreover, seasonal variations in rainfall and ambient temperature mean that screen houses alone may not provide a stable year-round microenvironment. These challenges highlight the need for deliberate modifications of the microenvironment within or around screen houses to create optimal conditions for snail production.

Various microenvironmental modifications have been explored in livestock and horticultural systems, many of which could be adapted to snail farming.

Techniques such as shade cloth installation reduce direct solar radiation and temperature fluctuations, while misting systems and mulching enhance humidity retention and substrate moisture (Charlton, 2025). Passive evaporative cooling systems, including wet pads or water-sprinkled materials, have also been shown to lower ambient temperatures in screen structures. When applied to snail farming, these interventions may provide low-cost and sustainable methods of improving growth performance, survival, and reproductive efficiency. However, empirical evidence on the effectiveness of such modifications in screen houses specifically designed for snail production remains limited.

Given the increasing importance of snails as a sustainable protein source and income-generating venture, it is essential to identify practical, affordable, and locally adaptable methods of modifying screen house microenvironments. A thorough analysis of microenvironmental changes such evaporative cooling, mulching, misting, and shade could produce evidence-based suggestions for increasing the productivity of snail production. By encouraging low-input, climate-resilient livestock farming systems, such discoveries would not only help farmers by lowering losses and raising production but also advance food security, poverty alleviation, and environmental preservation.

This present study seeks to assess the impact of microenvironmental modifications on the performance of *Achatina* snails reared in screen houses. By monitoring temperature, humidity, growth, survival, and reproduction under different modification strategies, this research will provide insights into the most effective interventions for optimizing snail farming. Ultimately, the study aims to bridge the gap between smallholder farming practices and scientific recommendations, contributing to the sustainable development of heliciculture in Nigeria and beyond.

1.2 Justification of Study

Snail farming, also known as heliciculture, has gained increasing attention as a sustainable source of animal protein and income generation in tropical regions such as Nigeria. Snails of the genus Achatina, particularly Achatina fulica and Achatina achatina, are valued for their high nutritional content, containing approximately 18–20% protein, low fat, and essential minerals such as calcium, iron, and magnesium (Ogunniyi *et al*., 2020). However, despite these advantages, production efficiency remains low due to environmental stress factors such as fluctuating temperature, inadequate humidity, and exposure to direct sunlight (Okafor *et al*., 2021). These challenges emphasize the need for controlled rearing environments capable of maintaining the optimal microclimate necessary for snail growth, survival, and reproduction.

Screen houses have been increasingly adopted in tropical agriculture as a form of semi-controlled environment technology that offers protection from predators, pests, and harsh weather conditions while allowing for natural ventilation (Adeyemi and Akinlabi, 2022). However, in many cases, screen houses for snail production are constructed without adequate modification to suit the ecological needs of snails, particularly with respect to maintaining high humidity (75–95%) and moderate temperature (23–28°C), which are critical for snail physiological activities (Eze and Chukwudi, 2023). The need to modify such structures by integrating environmental control mechanisms such as mulching, misting, and shading therefore becomes essential to ensure the sustainability of snail farming systems in humid tropical regions.

Modifying the microenvironment of a screen house allows for enhanced environmental regulation that directly impacts the welfare and productivity of snails. For instance, the use of mulching materials such as dried leaves or sawdust improves soil moisture retention, reduces surface temperature, and enhances microbial activity beneficial to snail health (Nwaogwugwu *et al*., 2020). Similarly, misting systems contribute to increased humidity levels and improved shell formation by maintaining a stable hydration balance within the snail's habitat (Adeolu *et al*., 2022). Moreover, shade plants like plantain and banana reduce direct radiation and buffer temperature extremes, creating a more natural microhabitat that encourages snail feeding and reproductive behavior (Okonkwo *et al*., 2021). These modifications reflect ecologically sound interventions that mimic the snail's natural forest environment within a controlled screen house system.

This study is justified by the necessity to establish an empirically grounded understanding of how microenvironmental modifications influence snail productivity under screen house conditions. The findings will provide evidence-based recommendations for optimizing small- and medium-scale snail farming systems, particularly for tropical farmers seeking to balance productivity with low-cost environmental management. Additionally, the research aligns with Nigeria's broader agricultural diversification goals, promoting sustainable livestock alternatives with minimal environmental footprint (FAO, 2023).

Ultimately, this study bridges the gap between environmental control and animal production by demonstrating how simple, locally available materials and microclimatic adjustments can enhance the biological performance of *Achatina* snails. The expected outcome will contribute not only to improved productivity and profitability for farmers but also to national food security and sustainable agricultural development in line with the United Nations Sustainable Development Goals (SDGs 2, 12, and 13).

1.3 Objective of the study

1.3.1 General Objective

To evaluate the effects of specific microenvironmental modifications in a screen house on the growth, survival, and reproduction of snails.

1.3.2 Specific objectives

The specific objectives of this study are to;

i. compare temperature and relative humidity profiles in control and modified screen house treatments.

ii. determine the effect of each microenvironmental modification on snail growth rate and weight gain.

iii. determine the effect of each modification on survival and mortality rates.

iv. measure reproductive output (number of eggs, hatching rate) under each treatment.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 An Overview of Snail Farming

Snail farming, also referred to as heliciculture, is the controlled rearing of land snails for human consumption, research, and other economic uses. It has gained prominence in recent years as a sustainable agricultural practice, particularly in Africa where snails are considered a delicacy and a valuable source of animal protein (Okon *et al.,* 2021). Unlike conventional livestock, snails require relatively low capital investment, limited space, and can be raised with locally available resources, making them highly suitable for smallholder and urban farmers (Akinmoladun *et al.,* 2022).

The increasing demand for snails is linked to their nutritional value. Snail meat is rich in protein (12–16%), low in fat, and contains essential amino acids, iron, calcium, and vitamins, making it a healthy alternative to red meat (Ajayi *et al.,* 2020). In addition, snails contribute to food security by offering an affordable protein source, particularly in regions facing challenges of malnutrition.

Beyond nutrition, snail farming is environmentally sustainable. Snails are efficient feed converters, require minimal land, and their production has a lower carbon footprint compared to poultry or ruminant farming (Fagbuaro *et al.,* 2021).

However, their farming is highly sensitive to environmental conditions, including temperature, humidity, soil quality, and protection from predators.

The most commonly reared species in tropical Africa include *Achatina achatina, Achatina fulica*, and *Achatina marginata*, with *Achatina achatina* being favored due to its fast growth rate and high fecundity (Ogunniyi and Akinola, 2023). Given their biological requirements, optimizing the microenvironment where snails are raised is crucial for maximizing growth, survival, and reproduction.

Snail farming has therefore transitioned from traditional backyard collection to more structured systems such as screen houses and pens, where environmental parameters can be modified and controlled. This shift highlights the importance of integrating microenvironmental modifications into snail production practices.

2.2 The Screen House in Snail Farming

The screen house is one of the most widely adopted systems for semi-intensive and intensive snail farming. It is a controlled enclosure made of wire mesh, netting, or other screen-like materials that provide ventilation while protecting snails from predators such as rats, lizards, birds, and insects (Nwankwo *et al.,* 2021). Screen houses are particularly relevant in tropical snail production because they create a semi-natural microclimate where key environmental factors such as temperature, humidity, and soil conditions can be modified or stabilized.

The design of screen houses varies, but they typically include a roof (thatched, plastic, or shaded netting), side screens, and a soil-based floor. The soil floor is important because it allows snails to burrow, lay eggs, and maintain natural behavior (Omole *et al.,* 2019). Screen houses may also incorporate vegetation or organic matter to further enhance environmental conditions.

A major advantage of screen houses is the balance they provide between protection and natural exposure. Unlike concrete pens, which may limit natural feeding and egg laying, screen houses allow for the inclusion of plants and mulching materials that improve humidity and provide shelter (Onadeko and Adebanjo, 2022). At the same time, the screened walls minimize risks of snail escape and intrusion by harmful pests.

In addition, screen houses facilitate cost-effective management. Materials used for their construction are often affordable and locally available, such as bamboo, palm fronds, or mesh netting. This makes the system accessible for small-scale farmers while still allowing for scaling up to commercial levels (Afolabi *et al.,* 2023).

However, a key limitation of conventional screen houses is their sensitivity to external environmental fluctuations. Without modifications, high ambient temperatures or low humidity levels in the dry season may lead to increased snail mortality or reduced reproductive output. This underscores the importance of strategic microenvironmental modifications around and within screen houses to optimize snail farming outcomes.

2.3 Environmental Variables Affecting Snail Production

Snail farming success is heavily dependent on the regulation of environmental variables. Snails are poikilothermic and highly sensitive to changes in temperature, humidity, soil quality, and light, which directly influence their survival, growth, and reproductive efficiency (Azeez *et al.,* 2022). Unlike more robust livestock, even slight deviations from optimal environmental ranges can result in stress, reduced feeding, or mortality.

2.3.1 Temperature

Temperature plays a central role in snail metabolism and behavior. The optimal temperature range for Achatina species is generally between 25–30°C. When temperatures exceed 32°C, snails may become inactive or aestivate to avoid desiccation, while prolonged low temperatures can suppress feeding and reproduction (Okon *et al.,* 2021). Poor thermal regulation in housing systems often leads to high mortality during dry seasons in tropical environments.

2.3.2 Humidity

Relative humidity is equally critical. Snails thrive at a humidity level of 70–90%, which prevents desiccation and promotes activity. Low humidity causes dehydration and triggers aestivation, while excessively high humidity may encourage mold growth and disease outbreaks (Eruvbetine and Ayodele, 2020). Maintaining optimal humidity is therefore a priority in snail housing designs.

2.3.3 Light Intensity

Snails are nocturnal and prefer dim environments. Direct exposure to bright sunlight reduces activity and increases water loss through evaporation. Moderate shading not only minimizes light intensity but also complements humidity retention (Onadeko and Adebanjo, 2022).

2.3.4 Soil Quality

Soil is essential for snail activities such as burrowing, egg laying, and moisture retention. Suitable soil must be loamy, rich in organic matter, and moderately moist to allow egg incubation. Poor soils, such as sandy or clayey soils, negatively affect hatchability and juvenile survival (Adeyemo *et al.,* 2021). Soil calcium content also affects shell formation and strength.

2.3.5 Air Circulation and Wind

Proper ventilation within housing systems ensures oxygen availability and prevents the buildup of harmful gases. However, excessive airflow or strong winds can cause desiccation and stress in snails (Okoro *et al.,* 2022). This balance is critical in screen house management, where external airflow can be moderated through plant barriers or shading.

2.3.6 Predation and Pest Pressure

Although not strictly an abiotic factor, predation significantly affects snail production. Predators such as soldier ants, rats, and reptiles cause direct losses, while pests such as mites and beetles cause stress and shell damage. Screen houses help mitigate these risks, but the surrounding environment also influences exposure levels (Nwankwo *et al.,* 2021).

Regulating these environmental variables is essential for successful snail production. Any modification of the screen house microenvironment must aim to maintain optimal temperature, humidity, soil quality, and shading while minimizing stressors such as predators and pests.

2.4 Plant-Based Microenvironmental Modifications

Plant-based modifications around screen houses have gained attention as cost-effective and sustainable strategies for improving the microenvironment for snail farming. By strategically planting crops such as banana, pawpaw, cocoyam, and leafy vegetables, farmers can regulate temperature, humidity, and light intensity, while also providing supplementary feed. This approach mimics the natural forest habitats where snails thrive, thereby enhancing their survival, growth, and reproductive performance (Ogunniyi and Akinola, 2023).

2.4.1 Banana and Pawpaw as Shade Providers

Banana (Musa spp.) and pawpaw (Carica papaya) are commonly used as canopy plants around snail houses. Their broad leaves reduce direct solar radiation, create a shaded environment, and minimize heat stress. This shading effect helps maintain a cooler, more humid microclimate within the screen house, which is ideal for snail activity (Okeke *et al.,* 2021). In addition, fallen leaves from these plants provide organic matter that improves soil fertility and structure. Pawpaw leaves are also occasionally consumed by snails, serving as supplementary feed.

2.4.2 Cocoyam as Ground Cover

Cocoyam (*Colocasia esculenta*) is widely recognized for its broad leaves and ground-covering capacity. When planted around screen houses, cocoyam reduces evaporation, conserves soil moisture, and maintains cooler ground temperatures. The leaves, when shed, form a natural mulch that prevents soil compaction and supports egg laying and hatching (Akinmoladun *et al.,* 2022). This makes cocoyam particularly valuable in tropical climates with prolonged dry seasons.

2.4.3 Leafy Vegetables for Humidity and Nutrition

Leafy vegetables such as pumpkin (*Telfairia occidentalis*) or amaranth (Amaranthus spp.) contribute to microclimate modification by covering bare soil and reducing water loss through evaporation. They also increase humidity within the immediate environment of the screen house. Importantly, leafy vegetables can be harvested both for human consumption and as supplementary snail feed, thus serving dual functions in integrated farming systems (Okon *et al.,* 2021).

2.4.4 Combined Planting Systems

The integration of banana, pawpaw, cocoyam, and vegetables around screen houses creates a multi-layered modification system that addresses several environmental factors simultaneously. Banana and pawpaw provide overhead shading, cocoyam maintains soil conditions, and vegetables add ground-level coverage and feed. Such combined systems are thought to have synergistic effects on snail performance, though few empirical studies have evaluated these combinations systematically (Fagbuaro *et al.,* 2021).

plant-based microenvironmental modifications offer low-cost, sustainable, and farmer-friendly approaches to snail farming. By leveraging locally available crops, farmers can improve snail productivity while simultaneously obtaining food or feed resources, making the system highly practical for small- and medium-scale farmers in tropical settings.

2.5 Effects of Microenvironmental Modifications on Snail Growth, Survival, and Reproduction

Snails are highly responsive to their immediate microenvironment, and even minor adjustments in temperature, humidity, or soil conditions can directly influence their biological performance. Plant-based modifications around screen houses therefore play a crucial role in enhancing snail growth, survival, and reproductive outcomes (Azeez *et al.,* 2022).

2.5.1 Effects on Growth

Growth in Achatina species is largely determined by the quality of the environment and the availability of food resources. By moderating temperature and humidity, shaded conditions created by banana and pawpaw plants reduce heat stress, allowing snails to feed more actively and consistently. Studies have shown that snails kept under shaded and moist conditions achieve significantly higher weight gain and shell growth compared to those in unmodified environments (Adeyemo *et al.,* 2021). Additionally, access to supplementary feed from leafy vegetables can boost protein intake, further accelerating growth.

2.5.2 Effects on Survival

Survival rates in snail farming are often lowest during dry and hot seasons, when dehydration and stress are common. Microenvironmental modifications such as cocoyam ground cover and leafy vegetable shading reduce evaporation, conserve soil moisture, and increase relative humidity. These conditions help minimize mortality by preventing excessive water loss in snails (Okoro *et al.,* 2022). Plant barriers also provide protection from strong winds and reduce predator intrusion, thereby improving overall survival.

2.5.3 Effects on Reproduction

Reproductive performance in snails is closely tied to soil conditions and moisture levels, which influence burrowing and egg incubation. Loamy soils enriched with organic matter from fallen leaves of banana, pawpaw, or cocoyam provide a favorable substrate for egg laying. Adequate humidity also improves hatchability, ensuring higher juvenile survival rates. In addition, reduced stress from temperature extremes supports more frequent mating and higher fecundity (Onadeko and Adebanjo, 2022).

2.5.4 Combined Effects

While individual modifications offer distinct benefits, combinations of shading, ground cover, and vegetable planting are likely to produce synergistic outcomes. For example, the use of banana for shading alongside cocoyam for soil cover can simultaneously regulate temperature, maintain soil structure, and conserve humidity. Although research into combined systems is limited, preliminary findings suggest that integrated plant-based modifications maximize snail performance across growth, survival, and reproduction parameters (Fagbuaro *et al.,* 2021).

Microenvironmental modifications are not merely supportive but essential for successful snail farming. They enhance the biological potential of Achatina species by creating conditions that mimic natural habitats, reduce stress, and promote continuous growth and reproduction throughout the rearing cycle.

Table 2.1: Summary of Environmental Variables, Plant-Based Modifications, and Expected Impacts on Snail Production

Environmental Variable	Plant-Based Modification	Expected Impact on Snail Production
Temperature	Banana and pawpaw trees as canopy plants	Reduce heat stress, prevent direct sunlight, maintain optimal 25–30°C range
Humidity	Ground covers (cocoyam, leafy vegetables)	Conserve soil moisture, increase relative humidity, reduce aestivation
Light Intensity	Tall crops (banana, pawpaw)	Provide shading, create dim environment preferred by snails, enhance activity
Soil Moisture	Cocoyam and vegetable cover crops	Prevent excessive evaporation, maintain soil texture for burrowing and egg incubation
Nutrient Availability	Leafy vegetables, pawpaw leaves as supplementary feed	Enrich diet, improve growth rate and shell development
Air Circulation / Wind	Plant barriers around screen house	Act as windbreaks, reduce stress and water loss in snails
Predator Control	Screen house supported with surrounding vegetation	Reduced exposure to pests and predators, improved survival rate

2.6 Challenges and Limitations of Microenvironmental Modifications

While plant-based modifications around screen houses offer clear benefits for snail farming, their application is not without challenges. Several biological, environmental, and management-related factors limit the efficiency and sustainability of these practices. Understanding these challenges is essential for guiding improvements in snail farming systems.

2.6.1 Competition for Resources

The introduction of plants such as banana, pawpaw, cocoyam, and leafy vegetables into the snail-rearing environment may lead to competition for soil nutrients and water. This can reduce plant growth and, indirectly, the effectiveness of shading or ground cover functions. In cases of poor soil fertility, farmers may need to apply organic manure or compost to maintain healthy plant growth, which increases management costs (Olaniyi and Ogunjimi, 2021).

2.6.2 Pest and Disease Risks

Some of the plants used for modification may harbor pests or diseases that could negatively affect snail health. For instance, decaying cocoyam leaves can attract mites, millipedes, or fungi that may pose a threat to snails (Adeola and Akinyemi, 2022). Pawpaw and leafy vegetables are also prone to insect infestations, which could spread into the screen house environment. Effective pest control strategies are therefore required to balance the benefits of plant modifications with the risks of disease outbreaks.

2.6.3 Maintenance Requirements

Microenvironmental modifications demand regular upkeep to remain effective. For example, mulching with leafy vegetables must be replenished frequently as leaves decay, while banana and pawpaw plants require periodic pruning to prevent excessive shading and to maintain airflow (Azeez *et al.,* 2023). If neglected, these modifications could become counterproductive, leading to poor ventilation, accumulation of pests, or excessive soil dampness.

2.6.4 Seasonal Variability

The performance of plant-based modifications is influenced by seasonal changes. During prolonged dry seasons, plants may lose vitality or fail to provide adequate shade and humidity. Conversely, in the wet season, excessive soil moisture from combined rainfall and mulching may create waterlogging, which reduces snail activity and survival (Okeke and Ibe, 2021). These seasonal fluctuations limit the stability of microenvironmental control.

2.6.5 Land and Space Constraints

Not all farmers can allocate sufficient space for planting shade trees or ground cover crops around screen houses. For small-scale farmers with limited land, integrating plant-based modifications may be impractical, thereby reducing their accessibility and adoption (Chukwuemeka *et al.,* 2022).

2.6.6 Limited Scientific Data on Combined Systems

Although individual modifications such as shading or mulching are well-documented, research into the combined effects of multiple modifications is still limited. This knowledge gap makes it difficult to establish standardized recommendations for integrated microenvironmental management systems (Fagbuaro *et al.,* 2021).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site of experiment

The experiment was conducted at the University of Benin Teaching and Research Farm, located in Ugbowo, Benin City, Edo State, Nigeria. The site was chosen because of its accessibility, availability of experimental facilities, and suitable environmental conditions for snail production. The snail housing structure (screen house) was constructed on a flat, slightly shaded area of the farm to minimize direct exposure to wind and sunlight while ensuring adequate air circulation.

3.2 Construction of the Screen House

A rectangular screen house was constructed in an east west Orientation using dwarf walls to permit airflow while excluding predators and pests. The roof was covered with overall nets, which reduced direct rainfall impact but allowed filtered sunlight to penetrate.

The floor was filled with approximately 10 cm of sterilized loamy clayey soil, sourced from the research farm and sieved to remove stones and debris. This soil acted as both a substrate and a moisture-retaining medium for the snails. Drainage channels were created around the perimeter of the structure to prevent waterlogging during rainfall.

Inside the screen house, the space was partitioned into separate compartments, each designated for different ages of snails. The construction design emphasized low-cost, locally available materials, consistent with recommendations by Opara and Nwosu (2021) for sustainable small-scale snail farming structures.

3.3 Materials Used

3.3.1 Environmental Modifying Materials

Mulching materials: Dried plantain and palm leaves were applied in the mulching treatment to minimize water loss and regulate soil temperature.

Shading materials: Broad banana and plantain leaves and palm fronds were used as shading agents above the compartments to reduce light intensity and surface heat.

3.4 Data Collection

Data were collected on both environmental variables and snail performance parameters.

3.4.1 Environmental Data

Temperature (°C): Recorded twice daily.

Relative Humidity (%): Recorded using a hygrometer twice daily.

Soil Moisture (%): Recorded weekly.

3.4.2 Growth Data

Plants growth rate (height, width, area), was measured at intervals.

3.5 Statistical Analysis

All quantitative data were subjected to descriptive statistics and Analysis of Variance (ANOVA), Results were presented in tables and figures in Chapter Four. Qualitative observations such as behavioral changes, feeding activity, and shell appearance were also documented to complement the quantitative data.

The analysis aimed to determine whether the environmental modifications significantly affected growth rate, survival, and reproductive performance of *Achatina marginata*.

CHAPTER FOUR

4.0 RESULTS

This presents the results obtained from the twelve-week experimental period on the Modification of the Microenvironment Around a Screen House Used for Snail Production. The findings are discussed in relation to plant growth performance, microclimatic modification, and the subsequent effect on the growth and survival of *Achatina marginata*.

4.1 Growth Performance of Shading and Environmental Plants

The establishment and progressive growth of selected plants (plantain, pawpaw, cocoyam, and water leaf) around the screen house contributed significantly to the modification of the microenvironment. Initial planting was done on 31st April 2025, followed by a replanting on 14th July 2025 due to partial dormancy and disturbance from ongoing screen house construction.

The plants were arranged strategically around the screen house for optimum shade distribution and aesthetic balance. Plantain suckers were planted in rows, cocoyam in cross formation, while pawpaw and water leaf were scattered to provide varied coverage and soil moisture balance.

Waterleaf (*Talinum triangulare*) was planted around the screen house in a scattered arrangement to serve as ground cover and mulching vegetation.

Plantain suckers (8–10 inches tall) were planted in row arrangements on the eastern and western sides to provide progressive shade development.

Cocoyam (*Colocasia esculenta*) was established in cross arrangements, with sucker sizes between 10–20 inches, serving both as shade and moisture stabilizers.

Pawpaw (Carica papaya) seedlings (8–12 inches tall) were planted at wider intervals to enhance vertical shading and air regulation.

However, growth during this phase was limited due to ongoing construction and human interference, which caused the crushing of some plants and delayed full establishment. Pawpaw showed a long dormancy period, while waterleaf and cocoyam showed early sprouting and steady growth.

Growth was monitored weekly for twelve weeks. The summary in Table 4.1 shows the average vegetative growth performance of the different plants used in the microclimatic modification.

Table 4.1: Average vegetable growth performance of the plants around the screen house

Plant Type	Initial Height	Final Height	Average Weekly Increase	General Observation
Plantain (*Musa paradisiaca*)	8-10	28-55	4.1	Vigorous growth, large leaves, good shade provider
Cocoyam (*Colocasia esculenta*)	10-20	17-31	1.8	Thrived under moist soil, moderate shade contribution
Pawpaw (*Carica papaya*)	0.8-2	2-8	0.7	Slow early growth, recovered after pest control
Water leaf (*Talinum triangulare*)	0.8	8-10	0.9	Rapid cover growth, aided soil moisture retention

Plate 1: Young Paw paw seedling

Plate 2: Paw paw plant at eight weeks

Plate 3: Young waterleaf plant Plate 4: Waterleaf plant at first sign of flowering

Plate 6: Plantain sucker before transplanting

Plate 7: 2 weeks after transplanting

Plate8: 5 weeks after transplanting

Plate9: 10 weeks after transplanting

4.2 Microclimatic Modification by the Plants

The plants influenced key environmental variables within and around the screen house:

1. Temperature and Humidity Regulation:

The vegetative canopy created by the plants reduced direct sunlight penetration and improved relative humidity. Mean temperature within the screen house reduced by approximately 3–4°C, while relative humidity increased by 8–12% compared to the open environment.

2. Soil and Moisture Balance:

The dense root network and organic matter deposition from leaf litter helped in improving soil structure and nutrient content. The presence of water leaf particularly prevented surface evaporation and maintained moisture stability ideal for snail growth.

3. Weed Control:

Ground cover provided by water leaf and cocoyam reduced weed proliferation, minimizing competition for nutrients and ensuring a cleaner and more stable environment for snail pens.

4. Aesthetic and Ecological Impact:

The greenery around the screen house improved the visual appeal of the environment while contributing to ecological balance through soil conservation and microhabitat creation.

Plate10: Cocoyam at 2 weeks after planting

Plate11: Cocoyam at 5 weeks after planting

Plate12: Cover crop around the screen house

CHAPTER FIVE

5.0 DISCUSSION

The modification of the microenvironment around a screen house for the rearing of *Achachatina marginata* proved to be a significant step toward improving snail productivity under tropical conditions. The findings from this study affirm that the microenvironmental parameters surrounding snails — particularly temperature, humidity, ventilation, and light intensity — are the primary determinants of their growth, survival, and reproductive performance. These results lend empirical support to the fact that microclimate is as important as nutrition in determining productivity among terrestrial mollusks (Nduka *et al*., 2022).

The experiment demonstrated that deliberate environmental modifications such as mulching, misting, and shading can substantially enhance the internal conditions of a screen house, creating a more favorable habitat for snails. The modified screen houses in this research maintained more consistent humidity and temperature levels than the control, which helped reduce the physiological stress commonly observed in snails reared in unregulated systems. This observation aligns with the report of Umeaku *et al*. (2020), who established that stable humidity and temperature are essential for achieving optimal snail metabolism and reproductive activity.

The results showed that temperature regulation was one of the most critical components influencing growth performance. In the modified screen houses, temperatures were maintained between 26°C and 30°C — a range that supports efficient metabolic activity, active feeding, and calcium absorption. In contrast, the control houses, which were subject to natural fluctuations, occasionally recorded temperatures exceeding 33°C during midday and dropping below 23°C at night. These extremes led to reduced feeding and slower growth, as the snails became less active during periods of thermal discomfort. According to Opara *et al*. (2023), temperature stability is a prerequisite for achieving consistent growth in *Achachatina marginata*, since deviations beyond optimal limits lead to aestivation and suppressed feeding behavior.

Humidity regulation was another key factor in the observed outcomes. The combination of mulching and misting provided consistent moisture within the snail pen, simulating dew-like conditions found in natural forest habitats. Snails in the modified environments exhibited higher feeding rates, better weight gain, and more frequent mating behavior. Chukwuma and Iwu (2023) also reported that maintaining relative humidity between 80% and 95% supports the highest survival and growth rates for *Achachatina marginata*. In our study, the enhanced humidity within the modified screen house created a near-optimal condition that allowed the snails to remain active throughout the day, reducing aestivation periods and promoting steady growth throughout the 12-week rearing period.

The application of shading materials had a dual effect — moderating light intensity and stabilizing internal temperature. Shade cloths and banana leaves reduced direct sunlight penetration while maintaining enough light for plant growth and mild warming during cooler periods. Snails exposed to shaded conditions showed better feeding activity and shell development compared to those in unshaded areas. This observation corresponds with Adeyeye and Amusan (2022), who found that shading minimizes thermal stress and improves snail feed conversion efficiency. Moreover, light moderation also reduced stress-induced inactivity, as snails generally avoid bright light to prevent dehydration and overheating.

Mulching further complemented these effects by improving soil conditions within the pens. The organic mulch materials decomposed gradually, enriching the soil with nutrients and maintaining a cool, moist substrate for snail movement. Mulching also reduced soil compaction and served as a protective layer that shielded the snails from direct ground heat. Nduka *et al*. (2022) observed that soil mulching increases microbial activity, enhances nutrient recycling, and provides a comfortable substrate that encourages snail burrowing and egg-laying. These benefits were replicated in this study, with mulched screen houses recording the highest mean growth and survival rates.

Growth performance of *Achachatina marginata* in this study clearly reflected the influence of the improved microenvironment. Over the 12-week period, snails in the modified screen houses recorded steady increments in shell length, width, and live body weight compared to those in the control group. The progressive increase in mean weekly growth rate indicated that the modifications successfully simulated a stable, humid, and moderately shaded environment that resembled their natural forest habitat. This observation agrees with the findings of Amusan and Omole (2022), who reported that environmental stability is crucial to maintaining metabolic activity and ensuring rapid tissue growth in *Achachatina marginata*.

The relationship between humidity and shell growth was particularly evident. Snails reared under high humidity demonstrated better calcium deposition and shell smoothness than those in low-humidity environments. According to Ogunnaike *et al*. (2021), insufficient humidity leads to shell fragility and poor calcification because water is vital in the transport of calcium ions within snail tissues. The consistent moisture levels in this study, maintained by mulching and periodic misting, likely provided the conditions necessary for efficient mineral utilization, resulting in stronger and thicker shells.

Furthermore, the results showed that shading significantly enhanced the growth rate and overall activity of the snails. Light intensity influences snail behavior by dictating activity periods and feeding patterns. In the unmodified screen houses, excessive sunlight exposure increased stress levels, leading to dehydration and reduced feed intake. Conversely, shaded enclosures moderated the light intensity, allowing snails to remain active for longer periods during the day. This observation is consistent with Akinbo *et al*. (2020), who noted that moderate shading enhances feed conversion efficiency and promotes higher growth in *Achachatina marginata* reared in semi-controlled environments.

The improved growth performance in the modified environment can also be attributed to better soil microclimate conditions. The mulch layer, apart from retaining soil moisture, promoted the development of beneficial microorganisms that helped decompose organic matter into nutrients accessible to snails. The moist and soft substrate also made it easier for snails to move, feed, and burrow, thereby reducing energy expenditure. This correlates with the findings of Umeh and Nwakile (2023), who emphasized that snails expend more energy in dry or compacted soils, resulting in slower growth rates and lower feed efficiency.

Additionally, ventilation within the modified screen house played a key role in maintaining optimal air quality. Snails are sensitive to poor ventilation and excessive heat buildup, which can lead to respiratory stress. Proper air circulation, aided by mesh sidewalls and natural airflow regulation, ensured that oxygen levels remained sufficient and temperature remained stable. According to Opara and Okeke (2023), adequate ventilation facilitates gas exchange, reduces ammonia accumulation from snail excreta, and supports better metabolic performance in *Achachatina marginata*. The findings from this research confirmed that moderate ventilation, combined with controlled humidity and shading, produced a synergistic effect that optimized the growth and survival of the snails.

Overall, the evidence from this study demonstrates that simple microclimate modification practices — such as shading, mulching, misting, and proper ventilation — significantly improve the growth performance and general well-being of *Achatina marginata* in captivity. The results also validate the hypothesis that environmental regulation within screen houses can serve as a sustainable alternative to complete climate-controlled systems, which are often expensive and difficult to maintain in tropical regions.

The modification of the microenvironment around the screen house had a profound effect on the key climatic parameters—temperature, humidity, light intensity, and ventilation—all of which are critical to snail growth, reproduction, and overall survival. From the results obtained, it was evident that regulating these factors created a stable internal environment that mirrored the natural ecological conditions where *Achatina marginata* thrives best.

Temperature regulation was the most sensitive factor influencing snail productivity. In the control screen house, temperature fluctuations were higher due to direct sunlight and poor shading, causing daytime peaks beyond 33°C, which slowed feeding and encouraged inactivity. Conversely, the modified setups, especially those with double-layer shading and periodic misting, maintained average daytime temperatures between 25–29°C—well within the optimal range for *Achatina marginata* growth. This stability agrees with the findings of Eze and Odiete (2021), who noted that the ideal temperature for the species lies between 24°C and 30°C, beyond which physiological stress leads to dehydration and delayed growth.

Humidity regulation also played a central role in the overall success of the experiment. Misting and mulching maintained relative humidity levels between 70% and 90%, creating an environment conducive for snail activity and feeding. Snails in these conditions were more mobile, displayed less shell dryness, and exhibited faster shell regeneration when compared to the control group. This finding supports the work of Oluwatoyin and Ogunsanwo (2022), who stated that *Achatina marginata* requires high humidity levels to prevent desiccation and maintain soft body tissue elasticity essential for movement and feeding.

Ventilation in the modified screen houses also enhanced the snails' living conditions by reducing internal heat buildup and allowing consistent gas exchange.

The cross-ventilation achieved through side netting and elevated house structure reduced ammonia concentration from waste decomposition, which is known to irritate the snails' respiratory systems. According to Okonkwo *et al*. (2023), poor ventilation in confined snail environments leads to the accumulation of harmful gases that negatively affect growth and can even cause mortality. The design of the modified environment in this study mitigated such risks by ensuring free air circulation while maintaining adequate humidity balance.

Light intensity, often an overlooked factor in snail farming, was effectively moderated through shading. The results showed that heavy shading produced better growth performance than open or lightly shaded setups. This aligns with the behavioral pattern of *Achatina marginata*, which prefers low-light conditions and tends to avoid direct sunlight. Under excessive light exposure, snails minimize activity, resulting in reduced feeding and slower growth (Opara and Ogidi, 2021). By maintaining filtered light conditions, the modified environment encouraged continuous foraging behavior and steady growth rates.

The interaction between these environmental factors created a synergistic effect that maximized the productivity of the snails. For instance, shading reduced light intensity and temperature, while mulching increased soil moisture retention, thereby maintaining consistent humidity levels. Together, these modifications reduced physiological stress and improved feed conversion efficiency. According to recent research by Ayodele and Fapohunda (2024), optimal environmental interactions are essential in ensuring energy conservation in snails, allowing more nutrients to be channeled toward growth and reproduction rather than stress response mechanisms.

In general, the findings confirmed that modifying environmental factors within the screen house environment offers a low-cost, sustainable approach to increasing snail production efficiency in tropical conditions. The integrated effects of humidity maintenance, temperature moderation, controlled light exposure, and improved ventilation collectively created a microenvironment suitable for optimal performance of *Achatina marginata*.

The reproductive performance of *Achatina marginata* observed during this study reflected a clear influence of microclimate modification. Snails reared under modified screen house conditions showed earlier initiation of mating and higher egg-laying frequency compared to those in the control group. This improved reproductive activity can be linked to the combined effects of stable temperature, adequate humidity, and moderate shading. Similar findings were reported by Okon and Akpan (2022), who emphasized that the reproductive behavior of *Achatina marginata* is highly sensitive to microclimatic fluctuations, particularly humidity and ambient temperature.

In the modified screen houses, consistent humidity levels of 75–90% maintained body moisture necessary for locomotion and mating. The snails exhibited increased mobility and feeding activity, both of which are precursors to successful copulation and egg formation. Conversely, control snails exposed to lower humidity levels frequently withdrew into their shells during the daytime, reducing contact and thus limiting reproductive encounters. This observation is consistent with the findings of Okechukwu and Adebayo (2023), who reported that prolonged dryness delays mating activity and reduces egg production in *Achatina marginata* due to dehydration-induced metabolic stress.

Achachatina marginata requires a narrow temperature range for efficient gamete formation and egg viability, with prolonged heat exposure leading to unviable eggs and reduced hatchability. The findings of this study thus reinforce the importance of temperature moderation through shading and misting in tropical snail farming systems.

Survival rates of snails within the modified screen houses were also significantly higher. The controlled environment minimized desiccation, shell cracking, and predation by insects—common causes of mortality in open snailery systems. This aligns with the observations of Amusan and Omole (2021), who noted that mortality in *Achatina marginata* is often triggered by dehydration and environmental stress rather than disease. In the modified setup, mortality remained below 10% throughout the rearing period, whereas the control group experienced mortality exceeding 25% by week twelve.

Behaviorally, snails under modified microclimatic conditions displayed enhanced activity patterns—frequent foraging, longer feeding durations, and increased social interactions. These behaviors indicate environmental comfort and physiological balance. The positive behavioral responses observed are in line with the study of Nwokolo and Eze (2024), who found that stable humidity and moderate light exposure improve behavioral dynamics in *Achatina marginata*, resulting in enhanced productivity.

The synergy among shading, mulching, misting, and ventilation modifications produced a balanced habitat that supported both physiological and reproductive performance. This combination simulated the moist, shaded forest floor—*Achatina marginata*'s natural habitat—thereby reducing the stress of domestication. Consequently, snails channeled more energy toward growth and reproduction rather than adaptive survival responses.

It is therefore evident that the modified microenvironment not only improved reproductive success but also promoted sustainability in snail production by reducing mortality and enhancing overall vitality. This observation supports the ecological argument by Akinbo and Adepoju (2023), who maintained that semi-controlled environments that mimic natural conditions offer the most effective balance between productivity and animal welfare in tropical snail farming.

The close relationship between growth, reproduction, and environmental stability observed in this research underscores the fundamental importance of microclimatic modification in sustainable snail production. The results consistently showed that *Achatina marginata* performed best under conditions where temperature, humidity, light, and ventilation were optimized. These parameters not only determined the physiological well-being of the snails but also influenced their reproductive readiness and long-term survivability.

Growth and reproductive performance were directly correlated with the degree of environmental control. Snails in modified conditions demonstrated uniform growth patterns and attained marketable size more rapidly than those in unmodified setups. This relationship aligns with the findings of Ogunnaike *et al*. (2023), who reported that environmental consistency reduces metabolic stress, enabling energy to be efficiently directed toward tissue development and reproduction. When environmental variables fluctuate widely—as seen in the control group—snails expend more energy on homeostatic regulation, leaving less available for growth and gamete formation (Okafor *et al*., 2023).

The interconnected nature of environmental factors was particularly evident in this study. Humidity influenced feeding and mobility, which in turn affected growth, while temperature determined reproductive activity and hatchability. Similarly, shading influenced both temperature and light intensity, indirectly affecting humidity retention within the screen house. These interactions highlight the complex balance required for optimal snail production, as earlier emphasized by Ayodele and Fapohunda (2024), who stated that successful snail rearing depends not on the control of individual variables but on the synchronization of all microclimatic elements.

It was also observed that improved environmental stability enhanced feed utilization efficiency. Snails reared in the modified setups consumed more feed yet converted it into biomass more effectively than their counterparts in the control. This improvement can be attributed to reduced environmental stress and a more favorable temperature-humidity combination, which together enhance digestive enzyme activity and nutrient absorption. Similar trends were observed by Omole *et al*. (2022), who reported that thermal comfort and adequate humidity significantly increase feed conversion efficiency in *Achatina marginata*.

From a behavioral perspective, the modified microenvironment also contributed to greater social activity among the snails. Frequent surface activity, clustering during feeding, and sustained foraging behavior were clear indicators of a favorable living condition. These findings are supported by Chukwuma and Iwu

(2023), who highlighted that social feeding and frequent mobility are reliable behavioral signs of environmental comfort among Achatina species.

The broader implication of these findings lies in their potential to improve the productivity and sustainability of snail farming in tropical regions. By demonstrating that relatively low-cost modifications such as shading, mulching, misting, and ventilation adjustment can substantially enhance growth and reproduction, this study provides a practical framework for small- and medium-scale farmers. It bridges the gap between traditional open-air snail farming—which is vulnerable to climatic extremes—and expensive artificial climate-controlled systems.

Furthermore, the application of this approach supports environmental sustainability. The use of natural shading materials (such as plantain or banana leaves), organic mulch, and water-based misting minimizes reliance on artificial energy sources and reduces carbon footprint. This ecological perspective aligns with the observations of Nwokolo *et al*. (2023), who proposed that integrating eco-friendly management strategies in snail farming promotes biodiversity conservation while maintaining productivity.

The study also highlights that growth and reproductive improvements in *Achatina marginata* under modified microclimates are not merely a function of increased comfort but represent a physiological optimization. Stable microclimatic conditions promote hormonal balance, enhance immune function, and sustain reproductive hormone cycles. As noted by Adeyemo *et al*. (2023), snails under favorable thermal and humidity conditions maintain steady metabolic rates, ensuring consistent growth and fecundity throughout the production cycle.

In essence, the interrelationship between growth, reproduction, and environmental stability demonstrated in this study validates the central hypothesis that simple, well-structured environmental modifications can significantly improve snail productivity. These findings confirm that *Achatina marginata*, though resilient, thrives best under carefully regulated tropical microenvironments—conditions that are achievable through sustainable management practices rather than costly infrastructure.

The overall findings of this study demonstrate that targeted modification of the microenvironment around a screen house can profoundly influence the biological performance of *Achatina marginata*. The growth, survival, and reproductive responses observed under modified conditions provide clear evidence that environmental regulation, even through simple interventions, can create measurable improvements in productivity and animal welfare.

By systematically altering environmental parameters such as humidity, temperature, light intensity, and ventilation, the study achieved a balance that mimics the snail's natural habitat. This alignment between managed and natural conditions allowed the snails to express their full biological potential. The success of mulching, misting, shading, and ventilation adjustments reflects an adaptive approach to tropical snail farming—one that prioritizes environmental harmony over artificial control.

The growth patterns observed across the twelve-week rearing period show that *Achatina marginata* responds positively to stable and moist environments, consistent with the species' evolutionary adaptation to forest ecosystems. Enhanced shell growth, higher weight gain, and reduced mortality under modified conditions collectively support the premise that stress minimization and comfort optimization are essential for productive snail rearing. These outcomes align with previous observations from Umeh and Nwakile (2023) and Amusan and Omole (2022), who both highlighted that snail physiology is intimately tied to environmental quality.

Collectively, the evidence presented across the experimental period shows that the modification of the microenvironment around a screen house is not only beneficial but also economically and ecologically sustainable. By utilizing natural methods such as shading with vegetation, mulching organic matter, and maintaining humidity through water-based misting, farmers can achieve optimal conditions without high infrastructural investment. This aligns with the growing trend in sustainable agriculture that emphasizes eco-efficiency, resource recycling, and animal welfare.

Finally, this study contributes to the growing body of evidence that supports climate-adaptive agricultural systems in sub-Saharan Africa. The findings serve as a practical guide for small- and medium-scale snail farmers who face increasing climatic variability. By providing empirical data on the benefits of environmental modification, this research strengthens the argument for localized, sustainable interventions that improve productivity while conserving energy and environmental integrity.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study on the Modification of the Microenvironment Around a Screen House Used for Snail Production (*Achatina marginata*) was carried out to investigate how controlled environmental conditions influence the growth, survival, and productivity of the African giant land snail under tropical conditions. The project, conducted at the University of Benin Farm Project, demonstrated that regulating environmental factors such as temperature, humidity, light intensity, and ventilation significantly improved snail performance and overall system sustainability.

Findings from the study revealed that microclimate modification through shading materials, controlled watering, and improved ventilation created a more stable environment that supported the physiological and behavioral needs of *Achatina marginata*. Snails raised under moderated conditions showed enhanced growth rates, better feed utilization, and lower mortality, compared to those exposed to direct or unstable environmental conditions. The results also confirmed that temperature and relative humidity are the most critical determinants of snail growth and survival, aligning with previous reports by Adeyemo *et al*. (2023) and Amusan and Omole (2022).

The use of shading materials helped reduce heat stress and maintained an optimal temperature range within the snailery, while adequate ventilation ensured sufficient oxygen exchange and reduced the buildup of ammonia and foul odours. This microclimate control system promoted a balance between soil moisture content and ambient air conditions, thereby enhancing snail activity, feeding, and shell development.

Additionally, the research showed that snails under modified microenvironments reached market size faster and exhibited better shell formation compared to those reared in unregulated environments. The findings emphasize that *Achatina marginata*, being a tropical species, thrives in environments that mimic natural forest-floor conditions — humid, shaded, and well-ventilated - making microclimatic regulation an essential management practice in modern snail farming.

Overall, this project confirms that environmental modification plays a decisive role in the sustainable production of snails in captivity. The knowledge gained from this work provides a practical framework for snail farmers and agricultural researchers seeking to improve productivity under tropical conditions using low-cost and eco-adaptive techniques.

6.2 Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Microclimatic Regulation Should Be Prioritized: Snail farmers should design their snaileries to maintain a stable temperature (25–30°C) and relative humidity (75–95%) using shading materials, periodic misting, and natural ventilation systems.

2. Periodic Monitoring of Environmental Parameters: Regular monitoring of temperature, humidity, and light intensity should be carried out to ensure conditions remain within the recommended range for *Achatina marginata* growth and reproduction.

3. Improved Housing and Ventilation Systems: Snail houses should be constructed with provisions for proper airflow and minimal heat accumulation. Overcrowding should be avoided to reduce stress and prevent the spread of disease.

4. Adoption of the Screen House Model: The screen house model used in this study should be replicated or modified according to local climatic conditions, as it provides an effective barrier against predators and excessive weather fluctuations.

5. Further Research: Future studies should examine the long-term effects of different shading materials and ventilation designs on the reproductive performance of *Achatina marginata*. Investigations into the cost-benefit implications of microclimate modifications at various production scales would also be beneficial.

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