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Full Length Research Article

Shelf-Life Evaluation of House Cricket (*Acheta domesticus*) Meal as an Alternative Protein Source in Nigeria

[1*]Omogunloye-Adeoye O. A., [2]Adesetan T. O., and [3]Lawal O. A.

[1]Department of Pure and Applied Zoology, Federal University of Agriculture, Nigeria

[2]Department of Microbiology, Olabisi Onabanjo University, Nigeria

[3]Department of Zoology and Environmental Biology, Olabisi Onabanjo University, Nigeria

Corresponding Author: omogunloye-adeoyeoa@funaab.edu.ng

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Abstract

Protein malnutrition remains a significant challenge in many Nigerian households. House crickets, are a rich nutritional alternative protein source. This study aimed to assess the shelf life of house cricket meals under varying temperature and storage conditions, employing a modified logistic mathematical model. Adult and nymph house crickets were procured from Olabisi Onabanjo University, Ago-Iwoye, Nigeria. Samples underwent different drying processes, analyzed for microbial load and shelf life across various storage periods. Modified logistic model was used for shelf-life calculation. Periodic samplings revealed distinct microbial counts for the samples at different intervals. Sun-dried samples showed an average microbial load (2430.0 CFU/g), increasing slightly (2442.5 CFU/g) after thirty days. Oven-dried samples exhibited lower initial counts, ranging (272.5 CFU/g -287.5 CFU/g), with a slight increase observed after ninety days. Growth rates varied between adult and nymph samples, with adults showing rates of (0.400 CFU/g, 0.086 CFU/g, and 0.055 CFU/g), compared to nymph (0.525 CFU/g, 0.079 CFU/g, and 0.064 CFU/g). The maximum shelf life determined was 117 days at 80°C. House cricket meals demonstrate promising shelf life under controlled temperature conditions, suggesting potential for long-term storage and distribution. Further research is warranted to optimize processing methods and explore broader applications of house crickets as a sustainable protein source in Nigeria.

Keywords: House cricket, Shelf life, Alternative protein, Modified mathematical model

INTRODUCTION

The swift increase in global food demand is outpacing agricultural production, necessitating innovative, cost-effective, environmentally friendly, and sustainable solutions to address the global need for protein derived from animal sources (FAO, 2003; Tilman *et al*., 2011). Insects have had a vital impact on the development of nutritional patterns among populations in Latin America, Asia, Europe and Africa. Globally, over 1900 insect species have been consumed by humans (Bodenheimer, 1951; van Huis *et al*., 2013; Jongema, 2017). Edible insects including crickets have been documented as a good source of quality protein, fats and minerals and have been widely consumed in Nigeria (Alamu *et al*., 2013). House crickets (*Acheta domesticus*) are one of the most often consumed species among the growing demand for edible insects as a sustainable protein source in recent years. They are an abundant protein source, with crude protein making up 51% of their composition (Omogunloye-Adeoye *et al*., unpublished data). They also contain a significant amount of fat, providing energy and essential fatty and amino acids for various bodily functions (Oibiokpa *et al*., 2018). However, there are safety concerns related to cricket consumption, as some people may have allergic reactions to insects, often due to cross-reactivity with shellfish allergens (Gadea *et al*., 2021). Despite these concerns, crickets are now accepted as a food source in Western lands, offering convenience and sustenance through crafted products like protein powders and bars (Imathiu, 2020; EU Regulation 2023/5). These creatures are no longer shunned, as they provide a helping hand in nourishing bodies.

As stated by EFSA Scientific Committee (2015) and EFSA NDA Panel (2021), the potential dangers to human and animal health that are linked with the eating of edible insects (Testa *et al*., 2017) are contingent not only on the type of insects and the substrates on which they are grown, but also on the methods that are used to cultivate, harvest, and prepare the insects. According to Imathiu (2020) and Baiano (2020), people in developing nations are very worried about the safety of consuming insects as food because it forms part of their diet. This draws from the understanding that insects are vectors of disease-causing organisms which can harm both humans and animals (Kooh *et al*., 2019). In a study, house crickets' samplings revealed microbial counts of 2430 CFU/g and 590 CFU/g for adult and nymph which was below acceptable limits. The samples were free from disease-causing microbes (Omogunloye-Adeoye *et al*., 2024). In addition, the safety of edible insects is primarily determined by the procedures used in their rearing and processing; the processing method equally determine the shelf life.

The amount of time that a food can remain appealing to consumers while retaining its nutritious value, wonderful taste, and attractive look is termed shelf life (Fu & Labuza, 1993). From a producer's standpoint, it marks the point beyond which sale of the product becomes economically imprudent due to diminishing quality and potential safety risks (Manso, 2000). The shelf life of food products can be assessed and then forecasted based on key modes of deterioration (Fu & Labuza, 1993).

Mathematical equations that describe the relationship between food, packaging, and environmental variables make up shelf-life models. These models are based on different degradation factors (i.e., critical factors) and are essential in predicting the shelf life of food, in designing the packages, and providing useful insights about the foods under abnormal circumstances along the supply chain. Most of the efforts in terms of mathematical modelling have focused on microbiological safety and spoilage (Blackburn, 2000).

Once a food product has reached its shelf life, it is considered unsuitable for consumption due to potential issues with safety, taste, and nutrition. The goal of shelf-life research is to determine the maximum duration a food can be stored without any noticeable quality loss. Various factors can affect food quality, including its raw materials, composition, water activity, acidity, pH, redox potential, and oxygen availability (intrinsic factors), as well as environmental conditions like sunlight, temperature, humidity, packaging damage, distribution, and retail locations (extrinsic factors) (Mossel *et al*., 1995). One way to increase the time a product lasts on store shelves is to use direct measures, such as storing it in a controlled atmosphere and monitoring it for indicators of spoilage. Shelf life can be assessed using a combination of sensory, physicochemical, chemical, and microbiological parameters to monitor changes in product quality and safety during storage (Kim *et al*., 2016; Marzoli *et al*., 2023).

Food quality relies on activities of microbes, which are linked to factors like water activity, pH, storage conditions, temperature, and humidity. Predictive microbiology models predict fluctuations in microbial populations from harvesting to production, providing a consistent evaluation of relevant parameters. These models are validated for specific environmental circumstances, making them effective for quantitative risk assessment (Manso, 2000). Although drying is a popular preservation technique, differing heat treatments can influence general shelf life, nutritional quality, and microbiological stability. Predictive microbiology is a reliable tool for estimating bacteria's course in foods and shelf life, especially when microbiological factors cause spoilage or unacceptability. Mathematical modelling, a science-based discipline, has extended beyond research to industrial applications, providing added value (McMeekin *et al*., 2002; Peleg, 2006; Brul *et al*., 2007; McMeekin, 2007).

Sun-dried samples may also be prone to product deterioration due to moisture reabsorption at night (Deng *et al.,* 2017). Dried *Acheta domesticus* powder has also been reported to exhibit moisture adsorption, with moisture content and water activity influencing its storage stability and predicted shelf life (Kamau *et al*., 2018). Despite, the existence of numerous preservation methods, a comprehensive assessment of the impact of heat treatment on house cricket preservation is necessary. With this background, we sought to investigate the effect of heat treatments on shelf life and microbial stability of house cricket using modified logistic mathematical models.

Material and Methods

Experimental design

The study evaluated the effect of three drying treatments: sun drying at ambient temperature (31-33°C), oven drying at 70°C, and oven drying at 80°C, on the shelf life of adult and nymph house crickets (*Acheta*

domesticus). Each drying treatment was applied separately to adult and nymph crickets, giving six treatment groups. For each treatment, two subsamples were taken for microbial analysis at each sampling interval, and the values obtained were averaged.

Following drying, the cricket samples were milled into flour and stored for up to 90 days. Samples were analysed for microbial load at predetermined storage intervals. Sun-dried samples were analysed on days 0, 10, 20, and 30, while oven-dried samples were analysed on days 0, 20, 40, 60, and 90.

Total viable counts (TVC) were determined at each sampling interval and expressed as colony-forming units per gram (CFU/g). The microbial load data were used to assess changes in microbial load during storage and to estimate the shelf life of the samples using microbial growth modelling. Linear regression was also used to examine the relationship between microbial load and storage duration.

Sample collection and preparation

Fresh samples of mature adults and nymph house crickets were harvested from the stock maintained in the animal house of Olabisi Onabanjo University, Ago-Iwoye. Adult and nymph crickets were kept separately in a freezer for 30 minutes and subsequently blanched in boiling water at 100°C for 10 minutes. They were then rinsed with clean water, drained and subjected to drying. The crickets were separately dried using sun drying at ambient temperature (31-33°C), oven drying at 70°C and oven drying at 80°C. The processing procedure was adapted from Schluter *et al*. (2017), with modification in the drying conditions, using sun drying at ambient temperature, oven drying at 70°C and 80°C.

Microbial analysis (ISO 4833-1:2013; Oxoid, 2017)

Microbial enumeration was performed using a modified United States Pharmacopeia (USP) <61> and ISO 4833-1 protocol for fatty matrices. The drying temperatures of 70°C and 80°C were selected based on established processing conditions reported in the literature (Bawa *et al*., 2020; EFSA, 2024; Siddiqui *et al*., 2024) and to minimise excessive thermal exposure that could adversely affect the nutritional quality of the cricket flour. The sun-dried samples were dried at ambient temperatures (31-33°C), while the oven-dried samples were dried at 70°C and 80°C, respectively, for three days.

To make 10^{-1} dilution, 1 g of the heat-treated sample was added to 9 ml of sterile diluents, 4% tween 20, 1 ml was put in a sterile petri dish in quadruplet portions, then overlaid with 19 ml of warm sterile molten agar (Oxoid, 2017). It was allowed to set, invert and incubate at 37°C and observed after 72 hours. Following incubation, visible colonies were counted and microbial load was expressed as colony-forming units per gram (CFU/g). Four plates were prepared from the 10^{-1} dilution at each sampling point, and the colony counts obtained were averaged for subsequent analysis. Microbial analysis was conducted on days 0, 10, 20 and 30 for sun-dried samples and on days 0, 20, 40, 60 and 90 for samples dried at 70°C and 80°C.

No further biochemical or molecular identification of individual bacterial isolates was performed, as the study focused on total viable bacterial load and its changes during storage.

It is therefore possible that kinetic modelling of changes in total viable bacterial counts during storage can be used for describe

microbial deterioration and support shelf-life prediction.

Shelf-life calculation

Statistical tools are crucial in the food industry for demonstrating a science-based shelf life, ensuring safety, and maintaining the original sensorial characteristics of food. Gibson *et al*. (1987) introduced sigmoidal functions, such as modified logistic and modified Gompertz, and are widely used to fit microbial growth data due to their four-phase structure (Valero *et al*., 2012). Microbial growth kinetics were determined using a two-step modeling approach. Simple linear regression (y = mx + c) was applied to isolate the maximum growth phase over the 90-day storage period. The resulting regression slope (m) was utilized to quantify the relative growth rate (B) at the inflection point. The modified logistic mathematical model was used for the determination of shelf life and stated as:

$$\text{Log } X_t = A + (C/(1 + e^{B(t-M)})$$

X_t = Number of cells at the upper asymptote
A = Lower asymptotic value as time t decreases to zero
C = Difference between the upper and the lower asymptotic value
M = Time at which the maximum growth rate is maximum (the shelf life of the product)
B = The relative growth rate at M determined from the slope of the graph

Results and Discussion

The study evaluates the microbial parameters of adult and nymph house crickets at various processing and storage temperatures to assess their shelf life and microbial safety. This study examines three heat treatment protocols: sun drying (31-33°C), oven drying at 70°C, and oven drying at 80°C on the shelf life of adult and nymph house crickets. Adult house crickets showed significant variation in shelf life across treatments, ranging from 9 days (sun-dried) to 117 days (oven-dried at 80°C). Nymph house crickets demonstrated similar patterns, with shelf life increasing from 10 days (sun-dried) to 93 days (oven-dried at 80°C). Oven-dried house crickets at 70°C exhibited significantly lower microbial loads compared to sun-dried samples. This temperature appears to offer a balance between reducing microbial load and preserving the nutritional integrity of the crickets (van Huis *et al.*, 2021). Oven-drying at 80°C resulted in significantly longer shelf life compared to sun-dried samples. Adult house crickets consistently showed longer shelf life than nymphs across all treatments. These findings align with logistic growth behavior observed in perishable protein products (Labuza & Fu, 1993; Kreyenschmidt *et al.*, 2010). While 80°C is more effective at microbial reduction, the higher temperature may cause nutrient degradation, particularly protein denaturation and lipid oxidation (Rumpold & Schlüter, 2013). These results confirm the effectiveness of thermal treatment in enhancing the microbial stability of house cricket powders.

The upper asymptotic value of 10^5 CFU/g was consistent across both developmental stages. Growth rates varied by treatment and stage: adult house crickets showed rates of 0.400, 0.086, and 0.055, while nymphs demonstrated rates of 0.525, 0.079, and 0.064, as detailed in Table 1.

Interestingly, despite having a higher initial microbial load, adult house crickets exhibited a longer shelf-life at 80°C compared to nymphs. This difference may be attributed to variations in moisture

retention, fat content, or exoskeletal properties between life stages. Moisture content serves as an index of water activity (Olutiola *et al*., 1991), and is an important indicator of product stability and susceptibility to microbial spoilage (Uriah & Izuagbe 1990).

Table 1: Microbial Growth Kinetic Parameters and Estimated Shelf Life of Adult and Nymph House Crickets under Different Drying Treatments

Parameters	Adults			Nymphs		
	31-33°C	**70°C**	**80°C**	**31-33°C**	**70°C**	**80°C**
Lower Asymptotic value (CFU/g)	2430.0	272.5	287.5	590.0	287.5	272.5
Upper Asymptotic value (CFU/g)	10^5	10^5	10^5	10^5	10^5	10^5
Microbial growth rate	0.400	0.086	0.055	0.525	0.079	0.064
Shelf life (days)	9	69	117	10	74	93

CFU/g: Colony forming unit/gram

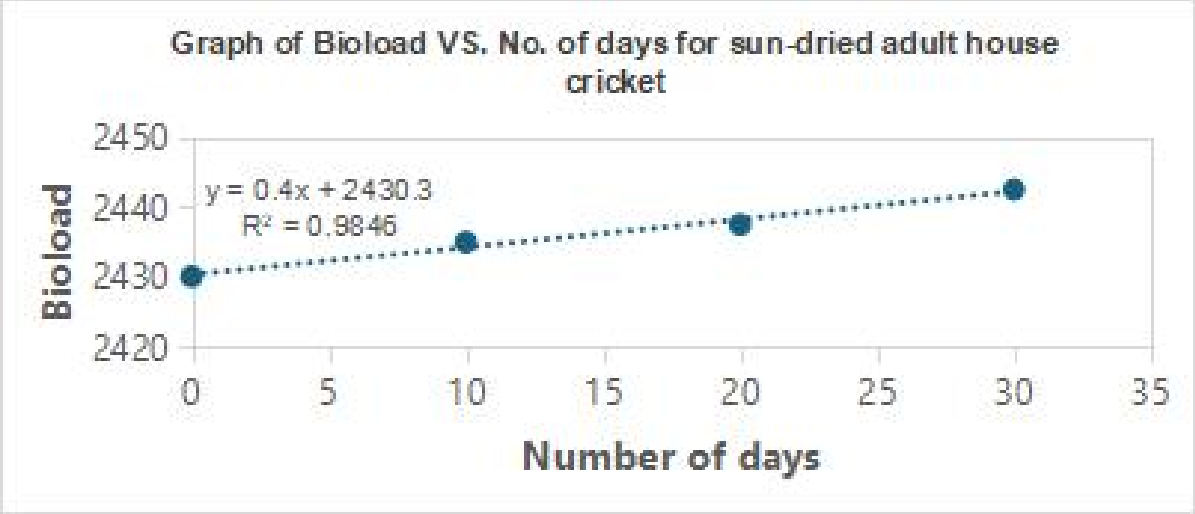


Figure 1: Graph of bioload vs. No. of days for sun-dried adult house cricket

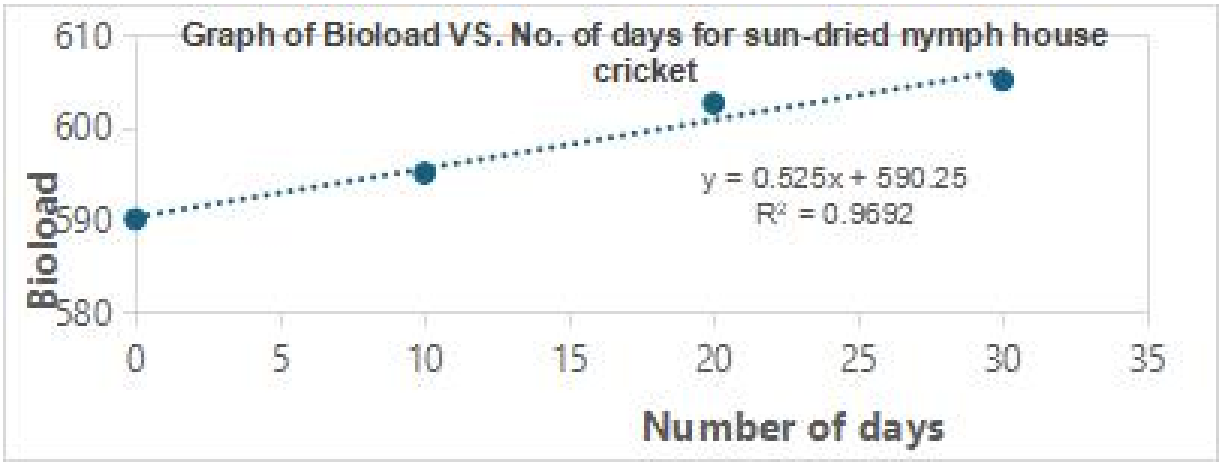


Figure 2: Graph of bioload vs. No. of days for sun-dried nymph house cricket

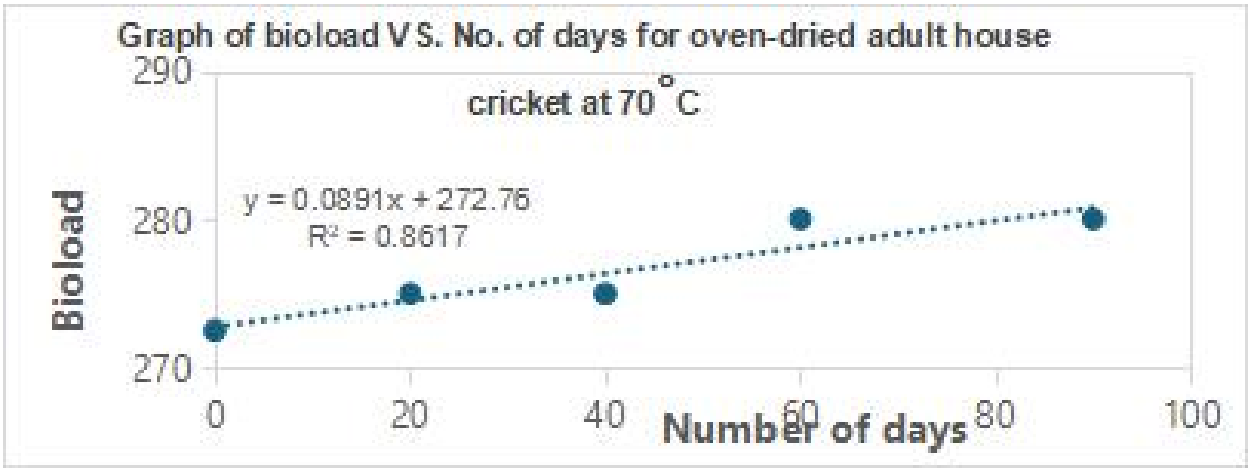


Figure 3: Graph of bioload vs. No. of days for oven-dried adult house cricket (70°C)

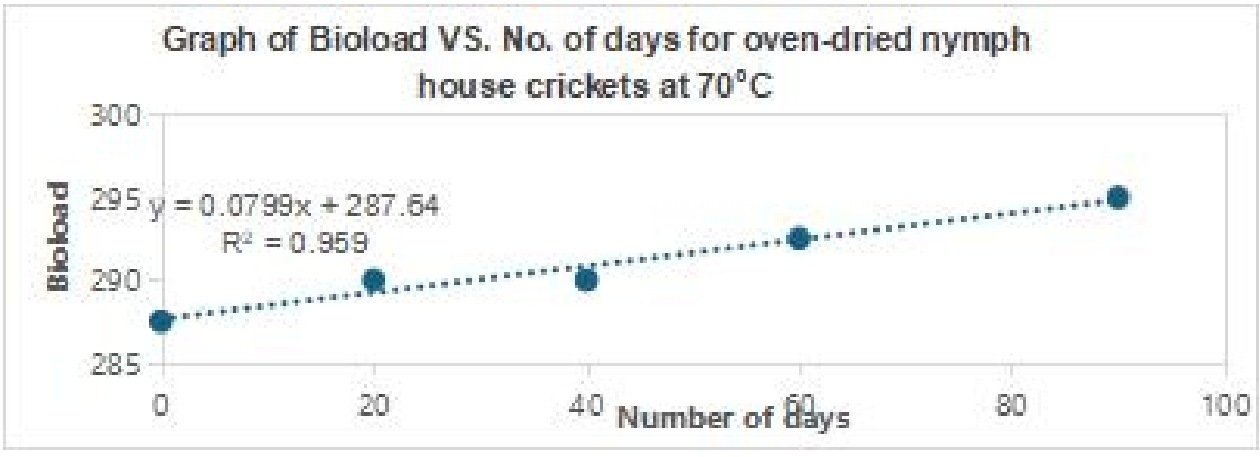


Figure 4: Graph of bioload vs. No. of days for oven-dried nymph house cricket (70°c)

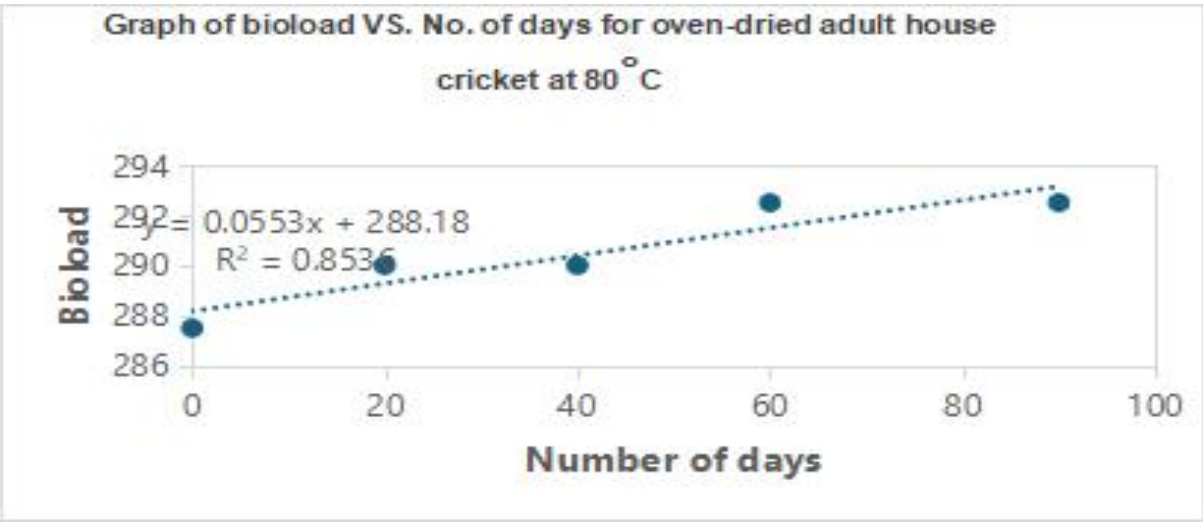


Figure 5: Graph of bioload vs. No. of days for oven-dried adult house cricket (80°C)

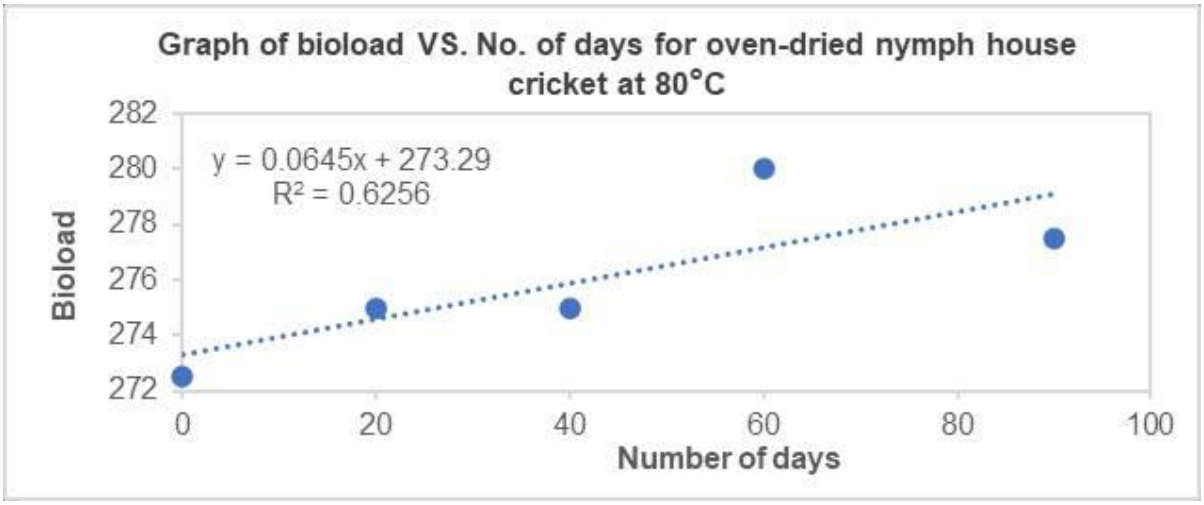


Figure 6: Graph of bioload vs. No. of days for oven-dried nymph house cricket (80°C)

The sun-dried samples showed distinct microbial biomass patterns. On day 0, adult house crickets had 2430.0 CFU/g, while nymphs showed 590 CFU/g. By day 10, these values increased to 2435.0 CFU/g for adults and 595.0 CFU/g for nymphs. Further increases were observed on day 20, reaching 2437.5 CFU/g for adults and 602.0 CFU/g for nymphs. By day 30, the final measurements were 2442.5 CFU/g for adults and 605.0 CFU/g for nymphs. The oven-dried samples at 70°C and 80°C demonstrated different initial patterns. On day 0, adults showed 272.5 CFU/g at 70°C and 287.5 CFU/g at 80°C, while nymphs measured 287.5 CFU/g at 70°C and 272.5 CFU/g at 80°C. After 90 days, adult samples maintained stable counts of 280.0 CFU/g at 70°C and 292.5 CFU/g at 80°C. Similarly, nymph samples showed final measurements of 295.0 CFU/g at 70°C and 277.5 CFU/g at 80°C, as detailed in Table 2.

Table 2: Temperature conditions and mean biological loads of periodic sampling of adult and nymph house crickets (CFU/g)

Number of days	Bioload of adult house crickets at varying temperature (°C)			Bioload of nymph house crickets at varying temperature (°C)		
	31-33°C	70°C	80°C	31-33°C	70°C	80°C
0	2430.0	272.5	287.5	590.0	287.5	272.5
10	2435.0	N/A	N/A	595.0	N/A	N/A
20	2437.5	275.5	290.0	602.0	290.0	275.0
30	2442.5	N/A	N/A	605.0	N/A	N/A
40	N/A	275.5	290.0	N/A	290.0	280.0
60	N/A	280.0	292.5	N/A	292.5	280.0
90	N/A	280.0	292.5	N/A	295.0	277.5

N/A: Not available; CFU/g: Colony forming unit/ gram

The microbial load increased steadily over time for both sun-dried adult and nymph house crickets. A constant upper asymptotic value was observed, suggesting a microbiological threshold. As expected, microbial growth rates declined sharply with increased drying temperatures, reflecting the inhibitory effect of heat treatment on microbial proliferation. This finding is consistent with previous studies showing that higher drying temperatures can reduce microbial loads in edible insects (Megido *et al.*, 2018; Kröncke *et al.*, 2019). The higher microbial load observed in the sun-dried samples highlights the importance of adequate hygienic practices and effective microbial control during drying. Nyangena *et al*. (2020) reported that solar-drying alone had limited effectiveness in reducing microbial populations in *Acheta domesticus*, whereas pre-treatments such as boiling or toasting improved microbial safety. Higher drying temperatures were found to be more effective in reducing biomass retention, possibly due to reduced microbial spoilage, and were associated with reduced biomass retention in both adult and nymph house crickets over the 90-day storage period.

The findings demonstrate that higher drying temperatures prolonged shelf life by lowering moisture content and microbial activity. The highest shelf stability was recorded at 80°C, and lowest at sun-dried samples. Rapid degradation occurred in sun-dried samples due to residual moisture and microbiological proliferation. Adult house crickets demonstrated a prolonged shelf life compared to nymphs in all treatments, likely due to their more robust exoskeletons. These findings underscore the significance of optimizing drying conditions for edible insect preservation.

The comparative analysis clearly indicates that while sun-drying fails to preserve the dried house cricket samples, all oven-dried treatments provide excellent shelf life stability. For the sun-dried cohorts (Table 3), the steep linear trends and high correlation coefficients indicate that microbial proliferation began immediately, causing total product spoilage by day 9 to 10. In sharp contrast, all four oven-dried groups successfully suppressed microbial replication, maintaining bioload values well within safe, acceptable limits throughout the entire 90-day storage observation period.

For the oven-dried adults (70 °C and 80 °C) and the 70 °C nymphs, the flat slopes indicate a heavily restricted and controlled microbial baseline. For the 80 °C nymph treatment, this near-zero linear slope further confirms that the high-heat thermal processing completely disrupted normal microbial growth kinetics, inducing a state of biological latency. These outcomes demonstrate that controlled thermal oven-drying regardless of the specific temperature or life cycle stage is a highly effective and mandatory intervention for ensuring long-term microbiological safety and commercial shelf life.

Table 3: Summary of linear regression parameters of bioload changes in adult and nymph house crickets under different drying treatments during storage

Treatments	Intercept (b)	Slope (m)	Coefficient of Determination (R^2)	Correlation Coefficient (r)
Sun-dried Adult	2430.0	0.4000	0.9846	0.9923
Sun-dried Nymph	590.25	0.5250	0.9692	0.9845
Oven-dried Adult (70°C)	272.76	0.0891	0.8617	0.9283
Oven-dried Nymph (70°C)	287.64	0.0799	0.9590	0.9793
Oven-dried Adult (80°C)	288.18	0.0553	0.8536	0.9239
Oven-dried Nymph (80°C)	273.29	0.0645	0.6256	0.7910

Conclusion

In summary, the storage stability of house cricket powder relies on effective moisture control and temperature management. Prolonged storage increases risks of microbial contamination without proper intervention. Oven drying at 80°C is the most effective method to inhibit microbial growth, though it may impact texture and nutritional value. A recommended drying range of 70°C to 80°C is suggested. Sun drying offers limited shelf life of about 10 days, making it unsuitable for long-term storage. The findings emphasize the necessity of controlled heat processing for preservation, with future research needed on the effects of these temperatures on amino acids and heat-sensitive vitamins.

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Authors Contributions

Omogunloye-Adeoye, O.A.: Conceptualization, methodology, investigation, sample preparation, data collection, data analysis, and manuscript preparation. Adesetan, T.O.: Microbiological methodology, microbial analysis, interpretation of microbiological results, and critical review of the manuscript. Lawal, O.A.: Supervision, research guidance, interpretation of results, and critical review and revision of the manuscript. All authors read and approved the final version of the manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

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