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SUSTAINABLE FACTORS INFLUENCING THE ACCURACY OF EDIBLE BIRD'S NEST (EBN) PRODUCTION ESTIMATION IN SWIFTLET RANCHING

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Abstract:

In Malaysia's swiftlet ranching, accurate estimation of edible bird's nest (EBN) production is crucial for both economic planning and sustainable management. However, obtaining precise yield estimation remains difficult due to the complex interactions between biological, environmental, structural, and management factors. This paper pinpoints and examines the main factors that have an impact on the precision of EBN production estimates in Malaysia. The research groups these factors into six areas: (1) environmental conditions, (2) swiftlet population behavior, (3) structural design, (4) management practices, (5) data systems, and (6) external policy factors. The paper combines results from previous research, industry reports, and field observations to create a conceptual framework that connects these areas to estimate accuracy. The analysis highlights that precision in environmental monitoring, consistency in management practices, and

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standardized data collection are key to making production predictions more reliable. This study contributes to the literature on technology-enabled agriculture and sustainable rural enterprise management by proposing a framework that predicts how environmental, population, structural, management, data quality, and policy factors influence the accuracy of edible bird's nest (EBN) production estimation. These insights are important for improving yield forecasting, enhancing market transparency, and supporting more informed decision-making among industry players and policymakers.

Keyword:

Edible Bird's Nest, EBN Sustainability, Swiftlet Ranching, Yield Estimation.

Introduction

The edible bird's nest (EBN) industry has emerged as a significant contributor to Malaysia's rural economy and export market. Derived from the salivary secretion of the Aerodramus fuciphagus swiftlet species, EBN is highly valued for its nutritional and medicinal properties, particularly in East Asian markets. Over the past two decades, Malaysia has witnessed rapid growth in swiftlet ranching, with thousands of birdhouses established across Peninsular Malaysia, especially in Kelantan, Terengganu, Johor, and Perak (Maimun, 2024).

Despite the industry's economic promise, accurate estimation of EBN production remains a persistent challenge. Variations in environmental conditions, swiftlet behavior, building structures, and management practices lead to inconsistent yields between farms and across production cycles (Zulkefle et al., 2024). Furthermore, the absence of standardized monitoring systems and inconsistent data recording practices make it difficult for producers and policymakers to predict production trends accurately.

Previous research on the EBN industry in Malaysia primarily focuses on its economic potential, quality standards, and environmental sustainability. Studies by Alpandi et al. (2022) and Connolly (2016) highlight that the production of EBN is deeply influenced by microclimatic conditions within swiftlet houses. These environmental variables directly affect swiftlet comfort and nesting behavior, which in turn determine yield levels. Other works, such as Ruhaidah (2008), emphasize the role of management and maintenance practices in determining production consistency. Swiftlet houses with well-regulated temperature, humidity, and

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hygiene tend to record more stable yields compared to those with irregular maintenance routines. Furthermore, Zulkefle et al. (2024) and Maimun (2024) note that external factors such as government regulation, trade policies, and market demand also indirectly affect estimation accuracy. For instance, licensing and compliance with biosecurity standards enhance record-keeping and improve data reliability.

While technological adoption in the EBN sector is still developing, precision monitoring systems such as humidity sensors, temperature loggers, and acoustic devices are increasingly recognized as tools to improve data quality and yield predictability. This review suggests that accurate estimation of EBN production is not dependent on a single factor but rather on the combined influence of multiple, interacting dimensions.

Understanding the factors that contribute to accurate estimation is crucial for improving productivity, ensuring sustainability, and maintaining the quality of Malaysian EBN. This study aims to synthesize the existing evidence to identify and analyze the key factors influencing estimation accuracy, leading to a conceptual framework that can guide future empirical and policy-oriented research.

Materials and Methods

This study adopts a review paper research design, specifically employing a systematic literature review (SLR) approach to identify, evaluate, and synthesize the factors influencing the accuracy of edible bird's nest (EBN) production estimation in Malaysia. The research is guided by key questions focusing on the main factors affecting estimation accuracy, how these factors are measured and reported, and the existing gaps for future research and policy development. A comprehensive search was conducted across multiple academic databases including Scopus, Web of Science, and Google Scholar, using keywords such as "edible bird's nest," "swiftlet ranching," "yield estimation," "production accuracy," and "Malaysia." The search was limited to English-language publications from 2000 to 2024 to ensure relevance and currency.

Studies selected for inclusion were required to focus on Malaysian swiftlet ranching or relevant comparable contexts, specifically addressing environmental, biological, structural, managerial, data quality, or policy factors related to EBN production estimation. Articles lacking empirical data, purely review-based without new synthesis, or unrelated to production factors were excluded. The initial screening of titles and abstracts identified 78 articles; after a careful full-text review, 35 studies met the inclusion criteria for data extraction.

Data extraction was conducted systematically, capturing study aims, methodologies, key findings, and contextual factors impacting estimation accuracy. Extracted information was organized into six thematic categories aligned with the conceptual framework presented: environmental, population, structural, management, data quality, and policy-related factors. Narrative synthesis was employed to integrate qualitative and quantitative findings, identifying common patterns, conflicts, and research gaps. To enhance rigor, selected studies were critically appraised using a tailored checklist assessing study design, sample size, data validity, and relevance. While lower-quality studies were included for comprehensive coverage, their limitations were duly noted. Finally, the review acknowledges that publication bias, language restrictions, and data availability may limit the findings and should be considered when interpreting the synthesized evidence.

Journal of Tourism, Hospitality and Environment Management
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Result

The results of this systematic literature review reveal six key dimensions that influence the accuracy of edible bird's nest (EBN) production estimation in Malaysia. These dimensions include environmental conditions, swiftlet population dynamic and behavioral indicator, structural characteristics, management practices, data quality, and policy factors. The findings highlight how these interconnected factors collectively impact yield predictability. A detailed synthesis of the evidence within each dimension is presented below.

Environmental and Microclimatic Factors

The internal microclimate of a swiftlet house is a major determinant of nesting success and production stability. Optimal ranges of temperature (28–31°C) and relative humidity (85–95%) are essential for swiftlet comfort and nest adhesion (Zulkefle et al., 2024). Light intensity should remain below 5 lux, while sound levels between 60–75 decibels are ideal for attracting swiftlets without causing stress. Accurate and continuous monitoring of these parameters ensures the reliability of input data for estimation. Environmental instability or irregular measurement contributes to errors in yield prediction. Therefore, precision environmental monitoring—through automated sensors or periodic manual recording—enhances both productivity and data accuracy.

Swiftlet Population Dynamic and Behavioral Indicator

Production estimation also depends on accurate assessment of the swiftlet population dynamic and behavioral characteristics. Parameters such as the number of breeding pairs, nest occupancy rate, chick survival, and colony stability directly influence the number of nests harvested. Uncontrolled migration, noise disturbance, or predator presence can cause population fluctuations, leading to unpredictable yields. Incorporating reliable population data into estimation models reduces uncertainty and improves the precision of yield forecasting (Alpandi et al., 2022).

Structural and Architectural Characteristics

The design and material of a swiftlet house influence both the internal environment and the nesting behavior of swiftlets. Larger houses with multiple levels provide more nesting surfaces and airflow, while building materials such as concrete help maintain thermal stability (Connolly, 2016). Ventilation design, window placement, and house orientation relative to wind direction and sunlight are equally important. Proper documentation of structural dimensions, materials, and orientation facilitates more accurate comparisons between houses, thereby improving the reliability of production estimation across different sites. Crucially, Ya'acob et al. (2022) identified that the dominant factor driving inefficiency in Malaysian swiftlet ranching was scale inefficiency. This suggests that many swiftlet houses operate at a sub-optimal size, failing to benefit from economies of scale and resulting in lower-than-expected yield. The persistent finding that many ranches are 'too small' implies that structural design and capacity planning are foundational to reliable EBN estimation. If the physical structure limits the maximum possible EBN output, any estimation model that ignores this scale constraint will inevitably generate inaccurate forecasts.

Journal of Tourism, Hospitality and Environment Management
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Management and Hygiene Practices

Management consistency significantly affects yield predictability. Swiftlet ranchers who maintain strict hygiene routines, control pests, and manage harvest cycles efficiently tend to achieve stable yields. Excessive harvesting can disrupt breeding cycles, while poor sanitation encourages fungal growth and reduces nest quality (Ruhaidah, 2008). Regular inspection, cleaning, and timing of harvests must be standardized and recorded to support data integrity. Management factors thus form a critical component of accurate estimation by ensuring that biological and environmental conditions are optimized. In addition, the majority of ranches are unable to fully utilize their available inputs (Ya'acob et al., 2022). This low efficiency often stems from inconsistent management, which directly correlates with unreliable record-keeping and poor data quality. To address this, the authors advocate for the development and strict adherence to Standard Operating Procedures (SOPs) for ranching practices. Furthermore, they stress the importance of implementing reliable data sharing mechanisms from highly efficient ranches to create accurate benchmarks, which would significantly improve the foundation for precise production estimation across the entire industry (Ya'acob et al., 2022).

Data Quality and Monitoring Techniques

The accuracy of EBN production estimation depends heavily on the quality of data collected. Inconsistent measurement intervals, missing data, or human recording errors can distort yield predictions. To minimize such errors, ranchers should adopt standardized data-collection templates and employ simple technological tools such as IoT sensors and cloud-based logs. Consistency in data format, measurement frequency, and variable definitions improves comparability between farms and across time. Moreover, training ranchers in basic data literacy enhances both record accuracy and decision-making capacity.

Policy and External Factors

Government regulation and institutional support play an indirect but significant role in estimation accuracy. Licensing systems, environmental standards, and trade regulations encourage better documentation of production volumes. Stable climatic conditions and biosecurity enforcement reduce disruptions in swiftlet breeding cycles, ensuring consistent yield data (Maimun, 2024). Critically, for the industry's sustained growth and competitive reliability and consequently, for accurate estimation policy must focus on human capital. Research emphasizes that sufficient knowledge and experience among ranchers are paramount (Ya'acob et al., 2021). Therefore, government initiatives must extend beyond mere regulation to include policy level training and data sharing initiatives. These programs are essential to standardize management practices across the nation, directly reducing variability and improving the predictive accuracy of EBN estimates, which ultimately supports export competitiveness and resource planning.

Discussion

The findings from the systematic literature review highlight six interconnected dimensions that influence the accuracy of EBN production estimation in Malaysia: environmental, biological, structural, managerial, data quality, and policy factors. The conceptual framework integrates these dimensions to provide a holistic understanding of how they collectively impact yield predictability and estimation reliability. It illustrates how environmental, biological, structural,

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managerial, data quality, and policy factors interact to shape estimation reliability. This integrated model provides a comprehensive understanding of the multifaceted influences on production accuracy. It also serves as a foundation for guiding future research and practical interventions in swiftlet ranching.

Table 1: Conceptual Framework of Factors Influencing Accurate Estimation of EBN Production in Malaysia

Dimension	Key Variables	Influence on Estimation Accuracy
Environmental (M)	Temperature, humidity, light, sound	Determines comfort and nest-building behavior
Population (P)	Swiftlet count, occupancy rate, survival	Defines biological yield potential
Structural (S)	Size, ventilation, material	Regulates internal microclimate
Management (H)	Harvest cycle, hygiene, feeding	Ensures production consistency
Data (D)	Measurement reliability, frequency, completeness	Improves model precision and comparability
Policy (E)	Licensing, climate stability, regulation	Provides institutional framework for standardization

This synthesis confirms that accurate estimation of EBN production is multidimensional. It is not merely a matter of measuring output but of ensuring the quality of input data and management practices. Environmental monitoring and population tracking are central to estimation accuracy, but they must be complemented by systematic data management and policy support.

The adoption of precision farming techniques such as environmental sensors, digital record systems, and standardized data protocols can significantly enhance estimation reliability. Furthermore, inter-agency collaboration between local governments, research institutions, and industry associations can facilitate data sharing and capacity building among small-scale ranchers.

Conclusion

Accurate estimation of edible bird's nest production in Malaysian swiftlet ranching depends on a complex interplay of environmental, biological, structural, managerial, data, and policy-related factors. Improved accuracy can only be achieved through holistic management that integrates precise environmental monitoring, consistent management practices, reliable data collection, and institutional support. By adopting evidence-based monitoring and reporting practices, Malaysia's EBN industry can enhance its productivity, sustainability, and international competitiveness. Future research should focus on developing standardized data systems and empirical validation of the conceptual framework proposed in this paper.

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Journal of Tourism, Hospitality and Environment Management
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