ENHANCING THE QUALITY AND VALUE OF RAW CLEANED EDIBLE BIRD NESTS THROUGH CLEANING, DRYING AND ENZYMATIC PROCESSING

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2024

IB 2024 6

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Edible bird's nest (EBN) is renowned for its high nutritional value and medicinal properties. Malaysia exported 105 tons of raw cleaned (RC) EBN to China in 2022, indicating its significance in the market. However, the EBN industry faces challenges related to quality discrepancies arising from diverse processing methods and drying techniques, compounded by reliance on skilled labor, hindering efficient product recovery and market competitiveness. This study aims to address these challenges by focusing on enhancing the quality and value of RC EBN products. Research objectives include investigating quality differences among RC EBN products, assessing changes post-primary processing, and exploring solutions to reduce reliance on skilled labor. Structural and chemical analyses reveal distinct characteristics among RC EBN products, emphasizing variations in antioxidant activity and total sialic acid content. Three primary processing methods were studied, including two commonly used industry methods (semi-dry and wet methods) and a newly proposed method (semi-wet method) requiring fewer skills. After cleaning, RC EBNs showed significant reductions in nitrite and nitrate content, while no reduction was observed in

antioxidant activity, total sialic acid, total glycoprotein, or total polysaccharide content. The semi-wet cleaning method demonstrated significantly higher antioxidant activity, and total sialic acid content compared to the semi-dry method, with equivalent chemical properties to the wet method but with consistent product recovery. Additionally, the study investigated three distinct drying methods: continuous cold air drying, continuous hot air drying, and intermittent hot air drying. Shaping or compacting fragment EBNs prior to cold air drying was recommended to enhance product quality. Enzymatic hydrolysis offered an alternative approach for processing heavy feather RUC EBN and wastage EBN, yielding valuable EBN hydrolysates. Integration of heat treatment with enzymatic hydrolysis resulted in a remarkable 96% recovery rate, providing promising avenues for waste utilization and product enhancement. Overall, this multifaceted approach aims to address critical challenges in the EBN industry, offering comprehensive insights and innovative solutions to enhance product quality, value, and market competitiveness. Moreover, the study highlights the potential transformation of EBN residue into EBN hydrolysate as a nutraceutical, offering reduced dependency on skilled labor and mitigated product costs.

Keywords: Drying, edible bird's nest, enzymatic hydrolysis, hydrolysate, primary processing

SDG: GOAL 3: Good Health and Well- Being, and GOAL 12: Responsible Consumption and Production

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENINGKATAN KUALITI DAN NILAI SARANG BURUNG WALIT YANG TELAH DIBERSIHKAN (RC EBN) MELALUI PROSES PEMBERSIHAN, PENGERINGAN, DAN PEMPROSESAN ENZIMATIK

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Sarang burung walit (EBN) terkenal dengan nilai nutrisi yang tinggi dan sifat perubatan yang penting. Malaysia telah mengeksport 105 tan sarang burung walit mentah yang telah dibersihkan (RC) ke China pada tahun 2022, menunjukkan kepentingannya dalam pasaran. Namun, industri EBN menghadapi cabaran berkaitan dengan ketidaksempurnaan kualiti yang timbul daripada pelbagai kaedah pemprosesan dan teknik pengeringan, yang diperkuatkan oleh kebergantungan kepada pekerja mahir, yang menghalang pemulihan produk yang cekap dan kebolehan bersaing dalam pasaran. Kajian ini bertujuan untuk menangani cabaran ini dengan memberi tumpuan kepada meningkatkan kualiti dan nilai produk RC EBN. Objektif penyelidikan termasuk menyiasat perbezaan kualiti di antara produk RC EBN, menilai perubahan selepas pemprosesan asas, dan meneroka penyelesaian untuk mengurangkan kebergantungan kepada pekerja mahir. Analisis struktur dan kimia mendedahkan ciri-ciri yang berbeza di antara produk RC EBN, dengan menekankan variasi dalam aktiviti antioksidan dan kandungan asid sialik total. Tiga kaedah

pemprosesan asas telah dikaji, termasuk dua kaedah industri yang biasa digunakan (kaedah separa kering dan basah) dan kaedah yang baru dicadangkan (kaedah separa basah) yang memerlukan kemahiran yang lebih sedikit. Selepas pembersihan, RC EBN menunjukkan pengurangan yang signifikan dalam kandungan nitrit dan nitrat, sementara tidak ada pengurangan yang diperhatikan dalam aktiviti antioksidan, kandungan asid sialik, kandungan glikoprotein, atau kandungan polisakarida. Kaedah pembersihan separa basah menunjukkan aktiviti antioksidan yang lebih tinggi dan kandungan asid sialik yang lebih tinggi berbanding dengan kaedah separa kering, dengan sifat kimia yang setara dengan kaedah basah tetapi dengan pemulihan produk yang konsisten. Selain itu, kajian ini mengkaji tiga kaedah pengeringan yang berbeza: pengeringan udara sejuk berterusan, pengeringan udara panas berterusan, dan pengeringan udara panas secara berperingkat. Membentuk atau memampatkan pecahan EBN sebelum pengeringan udara sejuk disyorkan untuk meningkatkan kualiti produk. Hidrolisis enzimatik menawarkan pendekatan alternatif untuk pemprosesan EBN RUC bulu "banyak" dan EBN "buang", menghasilkan hidrolisat EBN yang berharga. Penyatuan rawatan haba dengan hidrolisis enzimatik menghasilkan kadar pemulihan yang luar biasa tinggi, memberikan jalan yang menjanjikan untuk penggunaan sisa dan penambahbaikan produk. Secara keseluruhan, pendekatan yang berbagai ini bertujuan untuk menangani cabaran penting dalam industri EBN, menawarkan pandangan menyeluruh dan penyelesaian inovatif untuk meningkatkan kualiti produk, nilai, dan kebolehan bersaing dalam pasaran. Selain itu, kajian ini menyorot potensi transformasi sisa EBN menjadi hidrolisat EBN sebagai nutraseutikal, menawarkan kebergantungan yang berkurang kepada pekerja mahir dan kos produk yang dikurangkan.

Kata Kunci: *Pengeringan, sarang burung walit, hidrolisis enzimatik, hidrolisat, pemprosesan utama*

SDG: MATLAMAT 3: Kesihatan yang Baik dan Kesejahteraan, dan MATLAMAT 12: Penggunaan dan Pengeluaran Bertanggungjawab

ACKNOWLEDGEMENTS

First and foremost, I want to express my gratitude to God for His grace and mercy, which enabled me to successfully complete my thesis.

I extend my heartfelt appreciation to my supervisor, Prof Dr. Lai Oi Ming, whose unwavering guidance, mentorship, and constructive feedback have profoundly shaped the trajectory of my research. Your expertise and dedication have been invaluable, and I consider myself truly fortunate to have had you as my mentor. I am equally grateful to the members of the supervisor committee, Prof Dr. Tan Chin Ping, Prof Dr. Wong Shew Fung and Prof. Madya Dr.Yaya Rukayadi, for generously providing me with access to their laboratory and research facilities. Their insightful comments and suggestions have significantly elevated the quality of my research, and I am deeply appreciative of their contributions.

I am indebted to the edible bird's nest processors for their generous funding through the National Industry-UPM Edible Birdnest Processing Research Group Scheme made this research endeavor possible. Their support not only facilitated my academic pursuits but also underscored the vital synergy between academia and industry. My sincere appreciation also goes to the Department of Veterinary Service, Malaysia, for their steadfast support throughout my academic journey.

To my beloved parents and sibling, your unwavering love and unwavering support have been the bedrock of my strength. Your encouragement and unwavering belief in me have been a constant motivation during the highs and lows of my PhD journey. I am genuinely blessed to have you by my side.

In closing, this significant achievement would not have materialized without the contributions, guidance, and support of the many individuals and entities who have been part of this journey. Each of you has played a pivotal role in shaping my academic and personal growth, and for that, I extend my heartfelt and sincere gratitude.

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Date: 13 June 2024

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LIST OF ABBREVIATIONS

AA	Amino acid
ABTS	2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)
CAIQ	Chinese Academy of Inspection and Quarantine
CCP	Critical control point
CFU	Colony forming unit
DPPH	2,2-diphenyl-1-picrylhydrazyl
EBN	Edible bird's nest
GMP	Good manufacturing practice
HACCP	Hazard analysis critical control point
MC	Moisture content
MS	Malaysia Standard
RC	Raw cleaned
RSM	Response surface methodology
RUC	Raw uncleaned
SA	Sialic acid
SE	Standard error
SEM	Scanning electron microscope
SEM- EDX	Scanning electron microscopy-energy dispersive X-ray analysis
SME	Small and medium-sized enterprises
SOP	Standard operating procedure
UV	Ultraviolet
TAC	Total aerobic count
TCM	Traditional Chinese medicine
TPC	Total plate count

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Swiftlets construct their nests using secretions from salivary glands beneath their tongues. These nests can serve as shelter for canaries, facilitating breeding and roosting. Across the globe, there exist more than twenty-four species of insectivorous, echolocation swiftlets (Hamzah et al., 2013). Nevertheless, the production of commercially valuable edible bird's nests (EBN) is attributed to only two species of swiftlets at present. These species belong to the *Collocalia* genus within the *Apodidae* family, specifically white nest swiftlets (*Aerodramus fuciphagus*) and black nest swiftlets (*Aerodramus maximus*). During the reproductive phase, unique sublingual glands located beneath the tongue of the swiftlet secrete mucin glycoproteins into saliva. These mucin glycoproteins are intricately bound together to form palm-sized white nests in the shape of a half-bowl (Shim & Lee, 2018). When these nests are freshly formed, the cement-like substance (comprising glutinous secretions and mucin glycoproteins) is viscous and soft. However, it gradually dries and solidifies upon exposure to air (Lim & Cranbrook, 2002). Processors and traders show a preference for EBNs from *A. fuciphagus* because they primarily consist of hardened nest-like cement with minimal feather and impurity content (Seow et al., 2016). In contrast, EBNs from other sources tend to contain more feathers and impurities. It is worth noting that EBN mainly originates from Southeast Asia.

For ages, within the Chinese community, EBN has held a renowned status due to its nutritional and medicinal attributes, serving as a significant ethnomedicinal

commodity. The origins of EBN consumption trace back to the Tang Dynasty (618-907 AD), during which it was regarded as the pinnacle of delicacies and presented to the Chinese emperor's court. Subsequently, the medicinal properties of EBN have been extensively documented, leading to its recognition as one of the principal supplements during the late Ming Dynasty (1405-1433 AD) and the early Qing Dynasty (1644-1911 AD) (Chye et al., 2017). From traditional Chinese medicine (TCM) perspective, EBN is thought to yield nourishing benefits that encompass fortifying the immune system, addressing malnutrition, boosting metabolic functions, augmenting skin radiance, alleviating asthma, facilitating expectoration, mitigating coughs, supporting children's nourishment, enhancing libido, bolstering kidney performance, aiding recovery from illnesses and surgical interventions, and refining concentration (Tong et al., 2020).

Modern science and technology have substantiated the advantageous attributes of EBN, revealing its nutritional worth and pharmacological capabilities (Albishtue et al., 2019; Careena et al., 2018; Chua et al., 2013; Guo et al., 2006; Haghani et al., 2016; Hou et al., 2015; Hou et al., 2017; Hu et al., 2016; Hwang et al., 2020; Khalid et al., 2019; Kong et al., 1987; Ma & Liu, 2012; Mahaq et al., 2020; Marcone, 2005; Matsukawa et al., 2011; Ramachandran et al., 2018; Roh et al., 2011; Xie et al., 2018; Vimala et al., 2012; Yew et al., 2018; Yida et al., 2015; Zeng & Lai, 2019; Zainal Abidin et al., 2011). These include: (i) Supporting overall health and fortifying the immune system; (ii) promoting cell growth; (iii) safeguarding against joint degeneration and providing chondro-protection against osteoarthritis; (iv) demonstrating anti-inflammatory properties; (v) serving as an anti-influenza and antiviral agent; (vi) enhancing antioxidant capacity with antioxidative effects; (vii)

contributing to skin whitening, anti-aging, anti-inflammatory, and wound healing; (viii) promoting corneal wound healing and eye care; (ix) influencing learning and memory functions in multi-generational mice; (x) enhancing stem cell proliferation; (xi) providing neuroprotection in Alzheimer's or Parkinson's Disease; (xii) exhibiting anti-obesity effects; (xiii) Mitigating the detrimental effects of lead acetate (LA) toxicity in the uterus. (xiv) preventing cardio-metabolic and diabetic diseases; (xv) Offering anti-hypertensive effects. In light of these findings, EBN has unequivocally demonstrated its worth as both a nutritional resource and a therapeutic agent.

1.2 Problem Statement

Despite the escalating demand for edible bird's nest (EBN) products, a notable discrepancy persists in the quality of commercially available raw cleaned (RC) EBN products. This variability arises from the diverse primary processing methods and drying techniques adopted by industry players, leading to inconsistencies in the physical and chemical attributes of RC EBN. Moreover, the industry's reliance on skilled labor in primary processing presents operational challenges and impedes efficient product recovery. Addressing these challenges is imperative to enhance the overall quality, safety, and market competitiveness of RC EBN products.

In Malaysia, where RC EBNs exported to China undergo primary processing, the importance of this stage within the EBN industry is underscored. However, limited literature on EBN cleaning techniques divulges the intricacies of the process, and research investigating the yield and quality variations resulting from contemporary cleaning methods is lacking. The persistent scarcity of skilled labor in EBN primary processing further exacerbates these challenges, prompting the exploration of cost-

effective and quality-focused solutions. Given the intrinsic link between revenue generation and product recovery rates in primary processing plants, it is vital to explore alternative cleaning methods to produce RC EBNs of superior quality and substantial yield while reducing reliance on skilled labor. Additionally, the choice of drying technique significantly impacts the quality of RC EBN. Therefore, a comprehensive drying study is essential to identify optimal drying methods that preserve EBN quality while minimizing processing time and costs.

Moreover, the optimization of EBN processing through enzymatic hydrolysis to produce EBN hydrolysate presents a novel opportunity to enhance product yield, quality, and value. However, the lack of standardized protocols and optimal conditions for enzymatic hydrolysis hinders the efficient production of high-quality EBN hydrolysate from low- grade RC EBN. Addressing these multifaceted challenges is essential for the EBN industry to meet consumer demands for premium, safe, and nutritionally rich EBN products while maximizing production efficiency, quality and minimizing waste generation.

1.3 Research Questions

This study aims to answer the following questions:

I. What are the quality differences of different RC EBN products?

II. What are the changes in the bird's nest after primary processing, especially the nutritional value?

III. What are the solutions to reduce primary processing's reliance on skilled labor?

IV. What is the better drying method to maintain EBN quality?

V. In addition to primary processing methods, what can be done to recover EBN from residues of EBN and clean heavy feather RUC EBN?

VI. What can be done to increase the product value of low-grade RC EBN?

1.4 Research Objectives

The primary objective of this study is to enhance the quality and product value of raw cleaned (RC) edible bird nest (EBN) through a multi-faceted approach involving cleaning, drying, and enzymatic processing. The following five main objectives outline the systematic progression of the research. The initial step involves investigating the structural and chemical properties of current RC products in the market. This foundational objective aims to establish a baseline understanding that informs potential enhancements in EBN quality. Building upon the structural and chemical analysis, the study shifts to investigating the physiochemical changes of EBNs before and after primary processing. This objective specifically explores both current and a novel cleaning method, emphasizing the implementation of the new method that requires less skilled labor and ensures higher and consistent product recoveries. Transitioning to the drying phase, the study delves into the changes in EBN resulting from different drying approaches. This objective focuses on identifying methods that yield the highest quality EBN product following the cleaning process. Subsequently, the research investigates enzymatic hydrolysis as an alternative method for cleaning heavy feather raw uncleaned (RUC) EBN and recovering EBN from residue after primary processing. The emphasis is on assessing the potential of enzymatic hydrolysis to improve efficiency and economic viability in the EBN cleaning process. The study concludes with the development of a biotechnological process method, combining heat treatment and enzymatic hydrolysis. This final

objective aims to increase the value of low-grade RC EBN while simultaneously addressing concerns related to efficiency and economic viability. Through this sequential progression of objectives, the study aims to provide a comprehensive understanding and practical solutions for enhancing the overall quality and value of RC EBN (Figure 1).

The five main objectives of this study were:

I. to investigate the structural and chemical properties of different types of raw cleaned edible bird's nest in the Market.,

II. to investigate the impact of primary processing on cup- shaped raw uncleaned edible bird's nest with current cleaning methods, and to develop a new cleaning method for primary processing that requires less skilled labor and yields higher and more consistent product recoveries,

III. to investigate the impact of different drying approaches on edible bird's nest,

IV. to investigate enzymatic hydrolysis as an alternative method for cleaning heavy feather raw uncleaned (RUC) EBN and recovering EBN from residues remaining after primary processing,

V. to develop a biotechnology process method combining heat treatment and enzymatic hydrolysis to increase the value of low-grade RC EBN

1.5 Significance of Study

This study has the potential to provide comprehensive insights into key aspects of the EBN market. It aims to address several critical inquiries, including the qualitative distinctions among RC EBN products, the qualitative modifications in EBN post-primary processing, and the impact of different primary processing methods on product quality. These findings can serve as valuable guidelines for optimizing the process flow in RC EBN factories, ensuring consistency and quality in production.

Moreover, the research focuses on addressing current challenges within primary processing, such as reducing reliance on skilled labor, increasing the yield rate of the end product, and enhancing the value of lower-grade RC EBN. By tackling these issues head-on, the study aims to derive viable solutions that can drive efficiency and profitability in the EBN sector.

Additionally, the study includes an in-depth examination of drying techniques used in EBN processing. The choice of drying method significantly influences the quality of RC EBN products, and identifying optimal drying techniques is crucial for maintaining product integrity and minimizing processing costs. The outcomes of this research are expected to be highly beneficial for stakeholders in the EBN industry. By enhancing our understanding of RC EBN products and their processing, the study offers actionable recommendations for improving primary processing techniques, including both conventional methods and innovative biotechnological approaches. These recommendations have the potential to significantly elevate the production of high-grade EBN products and extract valuable EBN from residues. Importantly, the adoption of these innovative methods also promises to reduce reliance on specialized labor, thereby increasing operational efficiency and profitability for industry stakeholders. Overall, by addressing these critical challenges and incorporating insights from the drying study, the research aims to empower individuals within the primary processing sector to produce superior quality EBN products and achieve greater returns on their investments.

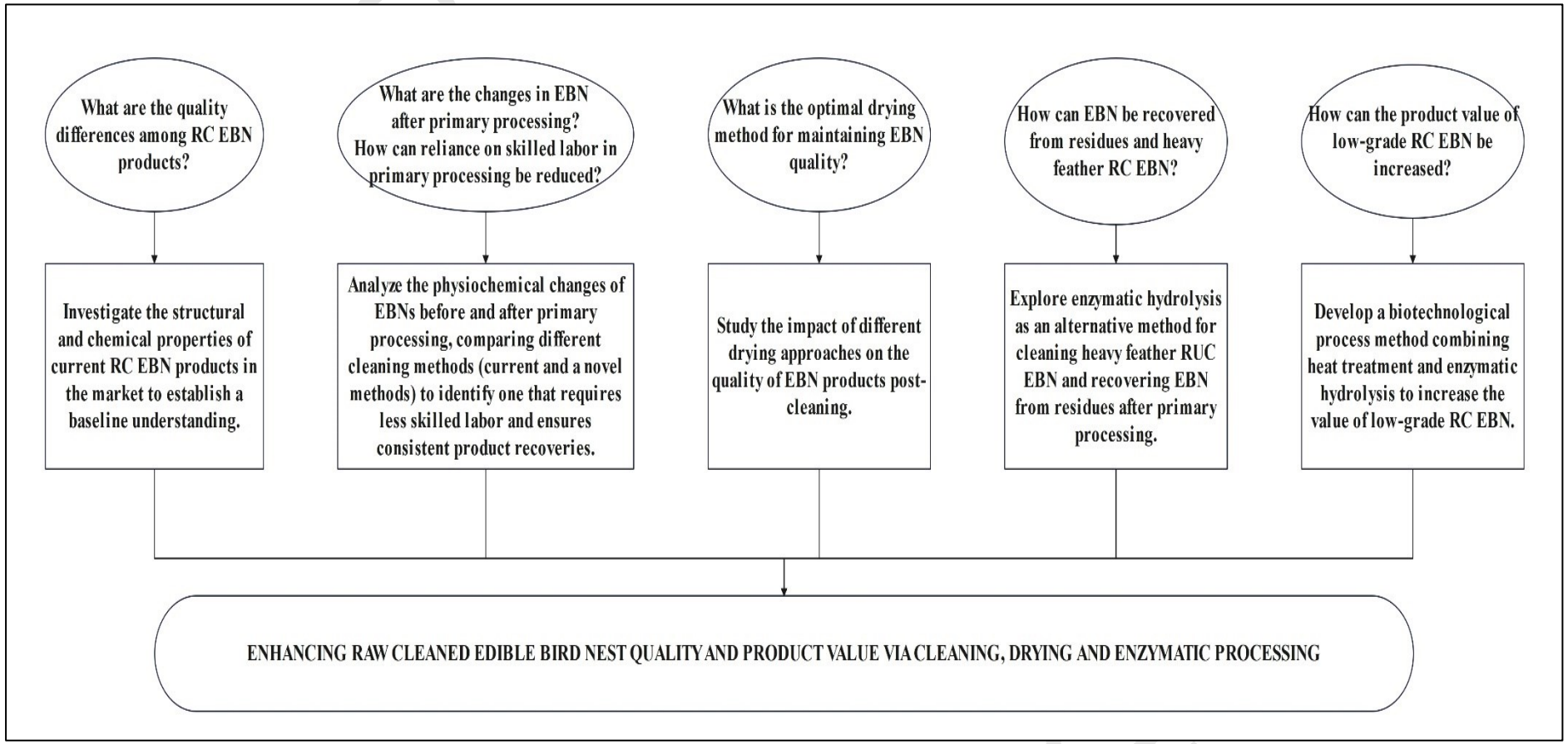

Figure 1 : Flowchart of research process

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