

CHAPTER I

INTRODUCTION

1.1 Background

Chicken and duck eggshell waste constitutes a significant type of household and livestock by-product that is abundantly available in Indonesia. According to data from the Indonesian Central Bureau of Statistics (Badan Pusat Statistik, BPS), the production of laying hen eggs reached 6.34 million tons in 2024. Meanwhile, based on projections from the National Food Agency (Neraca Pangan NFA) as of April 22, 2025, egg production is expected to increase by 2.78% to 6.52 million tons, with national consumption demand reaching 6.22 million tons. The substantial production volume indicates that the amount of eggshell waste generated is considerably high; however, it remains largely underutilized. In fact, eggshells possess significant potential to be utilized as a raw material for the synthesis of advanced materials such as hydroxyapatite (HAp).

Hydroxyapatite (HAp) is a ceramic material widely utilized in the biomedical field due to its ability to support the regeneration of hard tissue such as bone and teeth. It is commonly applied in bone tissue reconstruction, soft tissue engineering, and the treatment of periodontal defects (damage to the supporting structures of teeth) (Mozartha, 2015). The primary mineral components in the structure of bones and teeth consist of calcium phosphate (CaP) salts (Mozartha, 2015). HAp is frequently employed in biomedical applications because of its biocompatibility, bioactivity, and strong affinity for biopolymers (A. Setiawan et al., 2017). Furthermore, HAp exhibits a wide range of biomedical applications as composite material with notable strength, toughness, and durability, making it suitable for load-bearing applications such as bone implants, prosthetics, and dental restorations (Mondal et al., 2023).

One of the calcium sources for hydroxyapatite (HAp) is derived from eggshells. Chicken eggshells exhibit a purity of approximately 98.43%, while duck eggshells have a purity of about 75.12%. In addition, previous studies have reported the synthesis of HAp using various precursor materials. (Tekege et al., 2023). There are several sources of hydroxyapatite (HAp), including

mammalian bones (such as cattle, camels, and horses), aquatic marine sources (such as fish bones and fish scales), shell-based sources (such as clams, mussels, eggshells, and marine shells), and limestone (Mohd Pu'ad et al., 2019). Hydroxyapatite derived from duck eggshells contains a high amount of calcium carbonate (CaCO_3), making it a potential source of hydroxyapatite for bone tissue regeneration. (Tekege et al., 2023). Based on the aforementioned sources of HAp, chicken eggshells exhibit the greatest potential as a source of hydroxyapatite due to their high calcium carbonate (CaCO_3) purity, reaching approximately 98.43% (Tekege et al., 2023).

One of the HAp sources derived from eggshells has been investigated by Sabir 2022, who reported that duck eggshells exhibit an HAp purity of 91.87% using a thermal synthesis method at 950°C (Sabir et al., 2022). In contrast, Kalbarczyk et al. (2022) found that chicken eggshells yielded an HAp purity of 78% when treated at temperatures ranging from $400\text{--}600^\circ\text{C}$ (Kalbarczyk et al., 2022).

Studies on the effect of heat treatment on the morphology of HAp samples have been widely reported. HAp synthesized at 950°C and observed at $2500\times$ magnification using SEM exhibited agglomerated (cluster-like) morphology with closely spaced particles, along with a stable and well-ordered crystalline phase (Dewantara & Irfa'i, 2025). According to Yanti 2020, the effect of calcination time at 900°C for 120 and 180 minutes showed that at 120 minutes, the HAp morphology appeared granular and nearly spherical, whereas at 180 minutes, the morphology formed irregular agglomerates (Yanti & Gandi, 2020).

To enhance its physical performance and broaden its applications, HAp needs to be processed into ceramic materials. In several studies, polyvinyl alcohol (PVA) has been used in the fabrication of HAp-based ceramics. For instance, the addition of 5% PVA to HAp mixtures has been shown to increase the compressive strength of the ceramic by up to 30% (Głąb et al., 2021). However, excessive PVA concentration may lead to excessive pore formation and a reduction in mechanical strength; therefore, the PVA content must be carefully optimized (Głąb et al., 2021). Meanwhile, Sankar Rajan 2022,

reported that combining HAp with a PVA matrix modified with polyethylene glycol (PEG) can produce a bio-membrane with a stable porous structure, exhibiting very high cell viability (up to 99%) at low concentrations and low cytotoxicity levels (<7%). In this context, PVA plays a crucial role as a polymer matrix for HAp dispersion (Sankar Rajan et al., 2022). According to wijanarko 2023, hydroxyapatite is an inorganic material with a crystalline system composed of calcium and phosphorus, commonly referred to as calcium phosphate (Wijanarko & Irfa'i, 2023). However, previous studies have not comprehensively examined and characterized hydroxyapatite materials derived from both duck and chicken eggshells. Therefore, this study aims to compare the physical characteristics of hydroxyapatite derived from duck and chicken eggshells when composited with PVA.

Accordingly, this research focuses on the fabrication of hydroxyapatite ceramics from duck and chicken eggshells with PVA incorporation at varying temperatures (800°C, 900°C, dan 1000°C). The resulting ceramics will be characterized using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and hardness testing to evaluate their physical properties.

1.2 Problem Formulation

1. How is the synthesis process of hydroxyapatite derived from chicken and duck eggshells carried out?
2. How does temperature variation affect the morphology and purity of the resulting hydroxyapatite?
3. What are the physical and mechanical characteristics of hydroxyapatite ceramics mixed with PVA derived from chicken and duck eggshells?

1.3 Research Objectives

1. To determine the synthesis process of hydroxyapatite derived from chicken and duck eggshells.
2. To investigate the effect of temperature variation on the purity and morphology of the formed hydroxyapatite.
3. To analyze the physical and mechanical characteristics of hydroxyapatite ceramics derived from chicken and duck eggshells with PVA incorporation.

1.4 Research Benefits

1. This study provides an alternative approach for utilizing hydroxyapatite derived from readily available inorganic materials as a bone substitute material.
2. This research can serve as a reference for further studies on hydroxyapatite synthesis and development.
3. This study contributes to reducing environmental problems caused by chicken and duck eggshell waste.
4. This research is expected to become a reference for future studies in the field of biomaterials and bone substitute applications.

1.5 Hypothesis

1. An increase in calcination temperature will result in higher purity of hydroxyapatite due to the more complete removal of impurity compounds.
2. An increase in calcination temperature will enhance the mechanical strength of the resulting ceramic material.

1.6 Research Limitations

1. The hydroxyapatite source is limited to chicken and duck eggshells only.
2. The temperature variations used are limited to 800°C, 900°C, and 1000°C.
3. The addition of PVA is fixed at 10% of the total mass.
4. Sample characterization is conducted using XRD, FTIR, SEM, and Hardness testing.