

Journal home page: <http://ajarcde-safe-network.org> ISSN 2581-0405

Synthesis of Hydroxyapatite from Chicken Bones Using The High Temperature Method

R B Setiawan¹, F Z Mumtaz², L Suprianti³ and R M Kusuma⁴

¹ Chemical Engineering, Faculty of Science and Technology, UPN "Veteran" Jawa Timur, Surabaya, Indonesia

² Chemical Engineering, Faculty of Science and Technology, UPN "Veteran" Jawa Timur, Surabaya, Indonesia

³ Chemical Engineering, Faculty of Science and Technology, UPN "Veteran" Jawa Timur, Surabaya, Indonesia

⁴ Agrotechnology, Faculty of Agriculture, UPN "Veteran" Jawa Timur, Surabaya, Indonesia

ARTICLE INFO

Article History:

Received: 20 December 2025

Final Revision: 07 January 2026

Accepted: 09 January 2026

Online Publication: 11 January 2026

KEYWORDS

Hydroxyapatite, Chicken Bone, High Temperature

CORRESPONDING AUTHOR

*E-mail: liliksuprianti.tk@upnjatim.ac.id

ABSTRACT

This study investigates the synthesis of hydroxyapatite (HAp) from chicken bone waste, which is abundantly available due to high poultry production, using a high-temperature method. The objective of this study was to determine the effect of variations in sintering temperature (300, 400, 500, and 600°C) and sintering time (3, 4, 5, 6, and 7 hours) on the yield and Ca/P ratio of the HAp produced. The prepared chicken bone powder was first calcined at 900°C for 3 hours before sintering. The results showed that the optimal conditions were 600°C for 7 hours, characterized by a change in the sample's colour to white and a yield of 69%. XRF analysis confirmed the formation of HAp with a Ca/P ratio of 1.69. It was concluded that a sintering temperature of 600°C for 7 hours is optimal for producing pure HAp from chicken bone waste.

Contribution to Sustainable Development Goals (SDGs):

SDG 3: Good Health and Well-being

SDG 9: Industry, Innovation and Infrastructure

SDG 12: Responsible Consumption and Production

1. INTRODUCTION

1.1. Research Background

Chickens, as the most widely farmed poultry in the world, play an important role in meat production. In Indonesia, broiler chicken production reached 3,765,573.09 tons in 2022 and 3,997,652.7 tons in 2023, indicating a significant increase in demand. It is known that approximately 22.49% to 30.27% of the total weight of chickens consists of bones, producing a large amount of bone waste that is often not optimally utilized [1]. On the other hand, chicken bones consist of collagen (33.3%), phosphate (57.35%), and calcium carbonate (3.85%), which can be used as raw materials for the production of hydroxyapatite [2].

Hydroxyapatite, with the chemical formula $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$, is a calcium phosphate compound with a structure similar to human bones and teeth. This compound is an important component in various biomedical applications, especially in the production of bone and dental implants [3]. Various hydroxyapatite synthesis techniques have been developed in several studies, each with its own advantages and disadvantages. These synthesis methods include precipitation, high-temperature, wet, dry, and hydrothermal methods [4].

The synthesis of hydroxyapatite from chicken bones using the wet method yielded optimal results at 800°C for 6 hours. The wet method produces hydroxyapatite with crystallinity reaching 86.90%, a particle diameter of 27.43 nm, and a purity of 80.38% [5]. However, this synthesis process is quite complex and expensive because it requires strict control of various parameters, such as pH, temperature, reaction concentration, and stirring



This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License

Published under licence by SAFE-Network

concentration [6]. The synthesis of hydroxyapatite from tuna bones at high temperatures yielded optimal results at 700°C for 5 hours, with a yield of 65.61±2.21%, containing OH⁻, CO₃²⁻, and PO₄ groups, and appearing white. However, at a higher sintering temperature, namely 1,200°C for 5 hours, the HAp compound decomposed into tricalcium phosphate (TCP) [4].

Further research is needed to optimize the synthesis process of hydroxyapatite from chicken bones using high-temperature combustion techniques. This study aims to produce high-purity hydroxyapatite suitable for biomedical applications. This approach is expected not only to contribute significantly to the field of biomedical materials but also to offer an efficient and sustainable solution for the utilization of chicken bone waste.

1.2. Literature Review

Hydroxyapatite is one type of bioceramic material. Bioceramics are ceramic-based biomaterials specifically designed and synthesized for skeletal repair and reconstruction, and can be used as implants, catalysts, or metal adsorbents. Hydroxyapatite is bioactive, which supports the growth of new bone tissue [7][8]. This characteristic suggests that hydroxyapatite can bind to hard tissues and trigger specific biological responses [9]. One material that can be synthesized into hydroxyapatite is Chicken bone. Chemically, chicken bone composition contains salts, mainly calcium phosphate and calcium carbonate [10].

Table 1. Composition of chicken bones

Composition		Mass (%)
Hydroxyapatite		69%
Matrix organic	Collagen	21%
	Other Substances	1%
Water		9%

Chicken bone consists of two phases: the organic phase, which is mainly type I collagen at 22%, and the inorganic phase, which is mainly hydroxyapatite (HAP) crystals at 69%. In addition, chicken bones also contain 9% water [3]. The calcium and phosphate content of chicken bone makes it an ideal raw material for producing hydroxyapatite. Hydroxyapatite can be synthesized using three methods: wet methods, including sol-gel and hydrothermal methods, and dry methods. Other is the dry method and high-temperature method

1.2.1. Wet Method

The wet method of hydroxyapatite synthesis consists of two types, namely sol-gel and hydrothermal:

1. Sol Gel

In the synthesis of hydroxyapatite, wet methods such as sol-gel and wet deposition can be used. The sol-gel method can produce nanophases of hydroxyapatite by increasing crystallinity and yielding homogeneous layers, and it is pure and effective for the synthesis of hydroxyapatite at the nanoscale. This method is carried out at low temperatures, is easy to implement, is affordable, and can be applied under various conditions [11].

2. Hydrothermal

The hydrothermal method involves crystal formation by utilizing high pressure and reaction temperatures above the boiling point

of water. This method can also be used for mineral extraction, the synthesis of geological materials, and crystal growth. This research chose the hydrothermal method because of its advantages in controlling particle size and shape, the high reactivity of the resulting powder, and its ability to form powder directly from solution [12].

1.2.2. Dry Methods

The dry method does not use solvents, unlike the wet method. Process parameters do not greatly influence the characteristics of powders synthesized by dry methods. Therefore, most dry methods do not require precisely controlled conditions, making them suitable for mass production of powders. Several researchers have adapted familiar dry methods, including solid synthesis and mechanochemical processes, for the preparation of HAp particles [13]:

1. Solid-states synthesizers

The solid-state method is a cost-effective and straightforward approach commonly used for the mass production of hydroxyapatite (HAp) powder. It typically involves milling calcium- and phosphate-containing precursors, followed by high-temperature calcination, which yields a well-crystallized structure. However, limited ion diffusion in the solid phase often leads to phase heterogeneity, irregular particle shapes, and relatively large grain sizes. Although modifications such as molten salt synthesis and PEG-assisted reactions have been explored to improve particle morphology and reduce aggregation, solid-state methods still offer limited control over particle size and structure. Consequently, despite their industrial practicality, solid-state routes are less suitable for applications requiring precise control, such as biomimetic synthesis and biomedical uses of Hap [13].

2. Mechanochemical

The mechanochemical method is a dry synthesis technique in which mechanical energy from milling induces chemical reactions between solid precursors, enabling the formation of well-defined and often nanosized materials. This method enhances thermodynamic and kinetic reactions through pressure and deformation, offering better control over microstructure compared to conventional solid-state processes [13]

1.2.3. High-Temperature Methods

In high-temperature methods, chemical compounds in materials are broken down without or with little air or oxygen. This process involves heating the material to high temperatures below its melting point without additional reagents, thereby changing the compound's structure to the desired concentration [14].

1.3. Research Objective

This study aims to investigate the potential of hydroxyapatite produced from chicken bones via high-temperature calcination and sintering.

2. MATERIALS AND METHODS

The materials used were chicken thigh bones obtained from traditional markets in the Surabaya area. Aquadest and 95% acetone were purchased from a chemical store located at Jalan

Klampis Jaya, Surabaya. The tools used in the synthesis of hydroxyapatite are a furnace, an analytical balance, a mortar and pestle, a sieve, and an Erlenmeyer flask.

The initial process was to boil 500 grams of chicken bones in a saucepan with distilled water for 30 minutes, then wash and rinse them with distilled water. The cleaned bones were soaked in 95% acetone for 24 hours. After soaking, the bones were dried in the sun for 7 days. The dried bones were ground in a mortar and pestle, then sieved through a 100-mesh sieve to obtain a fine powder. The chicken bone powder was heated in a furnace at 900°C for 3 hours. After burning, the powder was weighed using an analytical balance and sintered at 300, 400, 500, and 600°C for 3, 4, 5, 6, and 7 hours, respectively. After sintering, the samples were cooled to room temperature (about 28°C) and weighed again to calculate the yield.

Characterization of hydroxyapatite from chicken bone was done by calculating the yield of hydroxyapatite powder color analysis, and XRF analysis. The yield of hydroxyapatite (HAp) from chicken bone is the ratio of the relative weight of HAp powder after the sintering process compared to the weight of HAp powder before the sintering process. The yield is calculated by comparing the final weight of the sample with its initial weight, then multiplying by 100%.

$$\text{Yield} = \left(\frac{\text{final sample weight}}{\text{initial sample weight}} \right) \times 100\% \quad (1)$$

The color of hydroxyapatite (HAp) from chicken bones was identified through visual observation [14]. X-Ray Fluorescence (XRF) analysis was conducted to determine the elemental composition of hydroxyapatite (HAp) in chicken bones, focusing on calcium (Ca) and phosphorus (P), the main elements that form HAp, and to calculate the Ca/P ratio.

3. RESULT AND DISCUSSION

In this report, we performed calcination and sintering processes to synthesize hydroxyapatite from chicken bone waste using a high-temperature method. First, calcination of chicken bones was used to produce inorganic calcium phosphate powder free of organic components. Secondly, sintering was performed to improve the crystallinity, phase purity, and structural stability of the hydroxyapatite formed. Figure 1 displays the color appearance of HA prepared from chicken bones at various sintering temperatures of 300, 400, 500 and 600°C with various sintering times of 3, 4, 5, 6 and 7 hours.

The colour observation shows that hydroxyapatite extracted from chicken bones becomes black after calcination and tends to become lighter as the sintering temperature increases. The black or dark grey colour observed after combustion is a strong indication of residual carbon (C). After combustion, the chicken bones turned black. However, after sintering at 300 and 400°C, the HAp colour became dark grey. After sintering at 500°C, the HAp became grey. This condition indicates that the powder still contains organic components and has not shown a high level of purity. The use of sintering temperatures below 600°C results in bone powder that remains grey [4]. Peak results are obtained at a sintering temperature of 600°C, at which HAp turns white. During calcination, the collagen-rich organic components undergo thermal decomposition. The pyrolysis process converts the organic matter into carbon, turning the entire sample black.

Sintering at higher temperatures causes the residual carbon black to undergo a combustion reaction (oxidation), converting solid carbon into CO₂ gas, so the color of HAp tends to be lighter when sintered at higher temperatures [15].

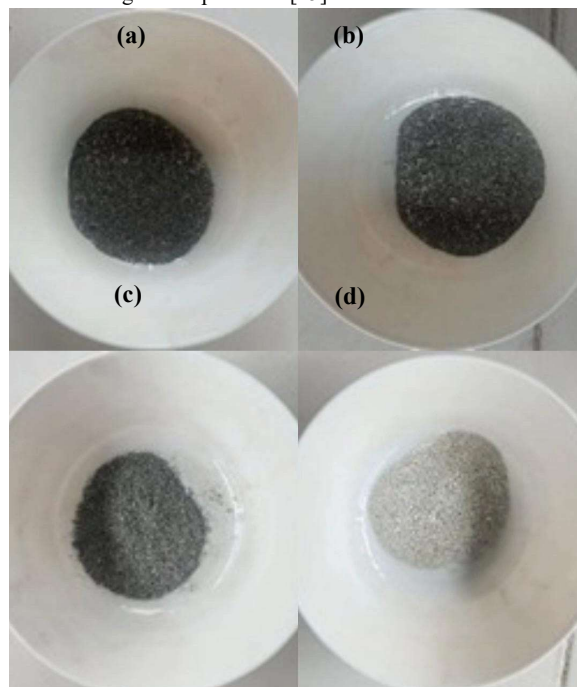


Fig. 1. Appearance of hydroxyapatite products from chicken bones at a sintering time of 7 hours with variations in sintering temperature (a). 300°C, (b). 400°C, (c). 500°C, (d). 600°C

In Figure 2, the variation in sintering temperature and time clearly influences the yield of HAp produced. The data show that increasing the sintering temperature decreases the yield of HAp. The lowest yield obtained was 69% at a sintering temperature variation of 600°C and a sintering time of 7 hours. The decrease in HAp yield at sintering temperatures between (600-800°C) ranged from 30-40%. Conversely, the highest yield of 80.70% was obtained at 300°C and 3 hours of sintering [4]. These results are consistent with previous research showing that sintering at higher temperatures and times results in carbon undergoing a combustion reaction (oxidation), converting solid carbon into CO₂ gas, thereby decreasing yield [15]. At 100.5°C and 365.6°C, there are organic inflexion points in bone powder that indicate the loss of water and material. At 365.6°C, an inflexion point marks the loss of collagen and other organic materials [4]. In the sintering process that occurs in the temperature range (200-300) °C, there is a slight loss of component mass which is a combination of water content and organic matter. The mass loss will be significant when sintering at (300-500)°C, due to the decomposition of organic materials such as collagen, fat, and protein associated with other components in the bone. At a sintering temperature of 600°C, only calcium phosphate compounds remain [4].

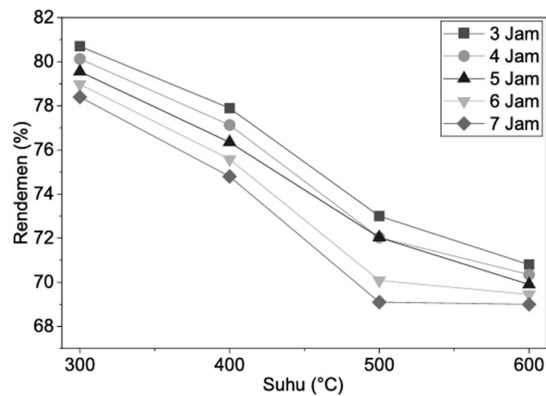


Fig. 2 Percent Yield Against Temperature at Variation of Sintering Time

Table 2 shows the main composition of chicken bone before calcination, as determined by XRF analysis of pure chicken bone samples: calcium (Ca) at 4.412%, phosphorus (P) at 1.107%, and the rest as Balance at 92.992%. The low Ca and P content values compared to the theoretical values in hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$) indicate that pure chicken bones are still dominated by organic materials, such as collagen, fat, and water, which are not detected as metal elements by XRF instruments [16]. In natural bone structure, about 30-35% of the total mass consists of organic material (mainly type I collagen), while the remaining 65-70% is inorganic material composed of apatite minerals [17]. The dominance of the Balance value of 93% confirms that most of the components of pure chicken bone have not undergone a deorganization process, so inorganic elements such as Ca and P are still trapped in the organic matrix. This condition also indicates that the calcination or sintering stage has not been carried out, so that the hydroxyapatite mineral has not been fully exposed from the organic bone tissue [18]. Thus, the XRF results for pure chicken bone indicate that the sample's composition remains dominated by organic matter. At the same time, the constituent elements of hydroxyapatite (Ca and P) are only present in small amounts. This is in accordance with the characteristics of natural bone before undergoing the refining or sintering process.

Table 2. Main Composition of Chicken Bone

No	Element	Percentage (%)
1	Ca	4.412
2	P	1.107
3	Sr	0.003
4	Zn	0.008
5	Fe	-
6	Cr	0.004
7	K	0.37
8	Cl	0.66
9	S	0.424
10	Bal	92.992

Table 3 shows the results of X-Ray Fluorescence (XRF) analysis on chicken bone samples that have gone through the

sintering process at 600°C for 7 hours, showing a significant increase in the content of calcium (Ca) and phosphorus (P) elements of 35.388% and 20.93%, respectively, while the Balance value decreased to 42.781%.

The increase in Ca and P content indicates that the heating process has removed most of the organic components, such as collagen and fat, leaving the main inorganic elements of bone more dominant [19]. The decrease in Balance value compared to the pure chicken bone sample (92.992%) signifies the decomposition of organic matter and an increase in the proportion of the remaining hydroxyapatite mineral.

Table 3. Composition of Hydroxyapatite from Chicken Bone with Sintering Temperature 600°C at 7 Hours

No	Element	Percentage (%)
1	Ca	35.388
2	P	20.93
3	Sr	0.016
4	Zn	0.037
5	Fe	0.029
6	Cr	0.008
7	K	0.363
8	Cl	0.121
9	S	0.323
10	Bal	42.781

The Ca/P ratio obtained from the XRF results was 1.69, close to the theoretical value of stoichiometric hydroxyapatite (1.67) [17]. This indicates that at 600°C, the hydroxyapatite crystal structure begins to form predominantly without significant decomposition into other phases such as β -tricalcium phosphate (β -TCP) [20]. This condition is consistent with literature reports stating that calcination at 600-700°C can produce hydroxyapatite with high crystallinity and good purity [16][18]. Thus, the increase in Ca and P content and the approach of the Ca/P ratio to the theoretical value indicate that the sintering process at 600°C for 7 hours has produced a purer, more stable hydroxyapatite material, with most organic components successfully degraded.

4. CONCLUSION

This study shows that chicken bone waste has potential as a raw material for producing hydroxyapatite via the high-temperature method. The synthesis process, which includes calcination and sintering, successfully removes organic matter from chicken bones and forms hydroxyapatite. Optimal conditions were 600°C and 7 hours, yielding 69%. The higher the sintering temperature and time, the lower the hydroxyapatite yield, while the purity increases. XRF analysis confirmed the formation of hydroxyapatite with a Ca/P ratio of 1.69. This study confirms that chicken bone waste can be a sustainable alternative for the production of hydroxyapatite in Indonesia.

REFERENCE

- [1] DataIndonesia.id. Kumpulan Data Pekerja Migran Indonesia pada 2024. <https://assets.dataindonesia.id/2025/01/22/1737537462393-88-PPT-Report-Kumpulan-Data-Pekerja-Migran-Indonesia-pada-2024.pdf>
- [2] Herdiana, O. (2023). Perencanaan Business Intelligence untuk Strategi Pengembangan Produk Unggulan Menggunakan Algoritma Support Vector Machine. *Jurnal Informatika*, 2(2), 28-34.
- [3] Purba, H., H. (2009). Inovasi Nilai Pelanggan dalam Perencanaan dan Pengembangan Produk; Aplikasi Strategi Samudra Biru dalam Meraih Keunggulan. *Graha Ilmu*.
- [4] Ulrich, K., and Eppinger. (2000). *Product Design and Product Development*. Singapore: McGrawhill.
- [5] Purba, H.H., and Aisyah, S. (2017). *Quality Improvement and Lean Six Sigma*. Yogyakarta: Expert.
- [6] Kim, W. C., dan Mauborgne, R. (2005). *Blue Ocean Strategy*. INSEAD Institute.