Potential of bovine bone as biogenic hydroxyapatite for dental implants

Riza Muharni[1], Gunawarman Gunawarman[2], Yuli Yetri[3], Oknovia Susanti[2]
[1]Mahasiswi S3 Teknik Mesin Faculty of Engineering, Department of Mechanical Engineering, Universitas Andalas / Department of Mechanical Engineering, Universitas Muhammadiyah Sumatera Barat, Indonesia
[2]Faculty of Engineering, Department of Mechanical Engineering, Universitas Andalas, Indonesia
[3]Department of Mechanical Engineering, Politeknik Negeri Padang, Indonesia

*Email: gunawarman@eng.unand.ac.id; rizamuharni12@gmail.com; gunawarman@eng.unand.ac.id; yuliyetri@pnp.ac.id; oknovia.s.@eng.unand.ac.id

Abstract

Purpose: Bovine bone is one of the sources that can be utilized for natural (biogenic) hydroxyapatite material because of its similarity in physical and chemical properties to human bone and tooth enamel. Bovine bone is used as a substitute for bone grafts and dental restorations. The purpose of this study was to determine the potential of bovine bone to produce high-quality biogenic hydroxyapatite that is suitable for use as a dental implant coating.

Results: The results showed that bovine bone produced biogenic hydroxyapatite with high crystallinity, rich in calcium phosphate, faster processing time, cheaper costs and environmentally friendly.

Keywords: bovine bone; dental implant; hydroxyapatite biogenic

1. Introduction

Bone is a complicated type of tissue in the body that helps keep the body strong and protects important organs. Consequently, impairment of bone tissue can result in a diminished quality of life. To address this issue, many efforts have been made in the field of using biological materials for implants (Indra et al., 2022; Afifah & Cahyaningrum, 2020). Biomaterials are currently under development as materials for the restoration of bone tissue, with the expectation that they will facilitate cellular proliferation that sustains the life cycle of the substituted tissue. Biomaterials can be classified into two categories: natural and synthetic. Natural biomaterials include things like collagen, elastin, and chitin. Synthetic biomaterials are made from materials such as metals, polymers, ceramics, and composites. Artificial biomaterials are frequently employed in various medical applications (Yetri, Ikhsan, Indra, et al., 2024).

Ceramics, specifically bioceramics, are the most frequently utilized biomaterials for the fabrication of artificial bone. Bioceramics are very friendly to the body, don't react badly with chemicals, resist wear very well, and are made up of materials that are similar to the minerals found in strong tissues in the human body, like bones and teeth. One specific type of bioceramic that has been subjected to extensive research is hydroxyapatite (HA) (Yetri, Ikhsan, Affi, et al., 2024).

Hydroxyapatite is a biomaterial widely employed to promote the natural growth of living tissues and to restore damaged body parts, owing to its calcium phosphate composition, which exhibits a relatively low bioresorption rate, low solubility, and remarkable stability (Muharni et al., 2023; Muharni, 2024; Muharni & Dewi, 2021). Hydroxyapatite can be made by mixing materials that provide calcium and phosphate. There exist both synthetic and natural forms of hydroxyapatite. Biogenic hydroxyapatite comes from the bones of mammals like pigs, camels, goats, and cows, and it is taken out from these bones (Sogabe et al., 2023; Cañon-Davila et al., 2023).

Bovine bone represents a promising source of natural (biogenic) hydroxyapatite material due to its composition, which consists of 93% hydroxyapatite and 7% β-Tri Calcium Phosphate (β-TCP), a component of calcium phosphate compounds recognized for its potential applications in tissue engineering and as a foundational material for synthesizing hydroxyapatite (w. kho et al, n.d.; Kumar & Mohanty, 2022; Firdaus Hussin et al., 2022). A review of various studies that successfully yield biogenic hydroxyapatite from bovine bone is presented in Table 1 below:

Table 1. Several studies using bovine bone as hydroxyapatite material

No	Judul	Hasil	Referensi
1.	Extraction of natural hydroxyapatite for biomedical applications - Areview	Produces high crystalline HA	Mohamed et al, 2022 (Firdaus Hussin et al., 2022)
2.	Three common preparation methods of hydroxyapatite	Produce HA with high crystallinity	Guoqing Ma, 2019 (Ma, 2019)
3.	Facile syntesis of hydroxyapatite from bovine bone and gelatin / chitosan-hydroxyapatite scaffold for potensial tissue engineering application	HAp is produced from higher temperatures 850 °C.	Nguyen et al, 2022 (Anh et al., 2022)
4.	Synthesis and characterization hydroxyapatite from bovine bone for production of dental implants	Temperature 750 °C for 6 hours to produce HA powder	Jamiu et al, 2019 (Odusote et al., 2019)
5.	Synthesis and characteristics of Hydroxyapatite from bovine bone (Bos taurus) using calcination technique	crystallization 95 % and group OH^-, PO_4^{3-}, CO_3^{2-}	Fifi Afifah et al, 2020 (Afifah & Cahyaningrum, 2020)
6.	Characteristics of hydroxyapatite from bovine bone waste using thermal mechanical method	Calsium Ca 37,418 % , fosfor 23,185 % , Ca / P 1,61	Ikhsan et al, 2018 (Yetri, 2018)
7.	Preparation of natural hydroxyapatite from bovine femur bone using calsination at varios temperatures	HAP was produced at a temperature of 700 °C.	W.Kho et al, 2015 (w. kho et al, n.d.)
8.	Synthesis and characterizations of hydroxyapatite from bovine bone using alkaline hydrolysis method	Hydroxyapatite carbonate with an average crystal size of 10 - 12 nm.	Nuning et al, 2018 (Aisah et al., 2018)

9.	Study of the coalescence phenomena in biogenic nano-hydroxyapatite produced by controlled calcination processes at low temperature	Hydroxyapatite size 75 µm	D. Canon et al, 2023 (Cañon-Davila et al., 2023)
10.	Synthesis of organic derived hydroxyapatite scaffold from pig bone waste for tissue engineering applications.	Pure HA crystals with rod-like morphology 38-52 nm long & 7-13 nm wide	Ofudje et al, 2018 (Ofudje et al., 2018)

2. Methods

The methodological approach employed in this study will be a qualitative method, which is illustrated in Figure 1 as follows:

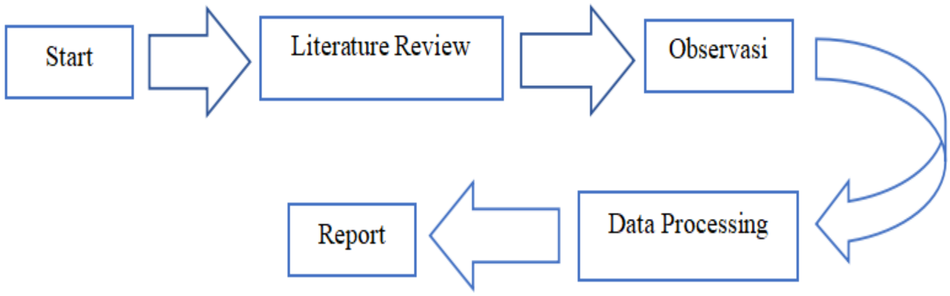

Figure 1. Research Flow Chart

Figure 1 above shows a research flowchart. This study began with a search for relevant literature through journals and the internet, followed by initial observations to identify the research problem. This was followed by problem formulation, data processing, and report preparation.

3. Results

Bovine bone has 70% inorganic minerals, 20% organic material, and 10% water (Dinda et al., 2020). The majority of the inorganic elements are present in hydroxyapatite, which includes calcium carbonate (CaCO3), a key component of human bones and teeth, and can serve as a raw material for the production of hydroxyapatite (HA) in tissue engineering (George et al., 2020)(Hassanen et al, 2016). The organic constituents of bovine bone comprise chemical reaction elements and apatite compounds, specifically Ca, P, O, H, along with inorganic substances such as Na and Mg (Rincón-López et al., 2018)(Arokiasamy et al., 2022). The composition and mechanical characteristics of both bovine and human bones are illustrated in Table 2 and Table 3 below:

Table 2. Composition of bovine bones and human bones (Arokiasamy et al., 2022)(Khalil et al., 2017)(Obada et al., 2023)

No	Composition	Percentage (%)	
		Bovine Bones	Human Bones
1.	Organic	30	25
2.	inorganic	60	70
3.	Water	10	5

Table 3. Mechanical properties of bovine bones and human bones (Hassanen et al, 2016)

No	Mechanical properties	Bovine Bones	Human Bones
1.	Tensile strength limit (MPa)	113 ± 2,1	124 ± 1,1
2.	Compressive strength limit (MPa)	147 ± 1,1	170 ± 4,3
3.	Shear strength limit (MPa)	91 ± 1,6	54 ± 0,6
4.	Tensile modules elasticity (GPa)	8,7	0
5.	Compressive modulus of elasticity (GPa)	25	17,6
6.	Torsion modulus of elasticity (GPa)	16,8	3,2
7.	% maximum elongation	0,88 ± 0,02	1,41
8.	% maximum compression	1,7 ± 0,02	1,85 ± 0,04

4. Discussion

Jamiu et al. In 2019 (Odusote et al., 2019), it was said that bovine bone is a natural and cost-effective source of hydroxyapatite because it is similar to human teeth, bonds well with bone tissue, and is safe for the body. Nguyen et al. in 2022 (Anh et al., 2022) suggest that HA made from bovine bone is cheaper and better for the environment. W. Kho et al. in 2015 (w. kho et al, n.d.) mention that HA from bovine bone has a lot of organic minerals. On the other hand, Mohamed et al. in 2022 (Firdaus Hussin et al., 2022) claim that HA from bovine bone is clean, has a high level of crystallinity, is rich in calcium phosphate, and is less expensive to make. Fifi et al. in 2020 (Afifah & Cahyaningrum, 2020) state that HA from bovine bone has a crystallinity of 95%, which means the higher the crystallinity, the more stable the HA is in the body and the stronger it is mechanically.

5. Conclusion

Bovine bones possess the capability to generate biogenic hydroxyapatite, which exhibits high crystallinity, is abundant in calcium phosphate, has a quicker processing time, is more cost-effective, is devoid of contamination, and is environmentally sustainable.

6. References

Afifah, F., & Cahyaningrum, S. E. (2020). SINTESIS DAN KARAKTERISASI HIDROKSIAPATIT DARI TULANG SAPI (Bos taurus) MENGGUNAKAN TEKNIK KALSINASI SYNTHESIS AND CHARACTERIZATION OF HYDROXYAPATITE FROM

COW BONES (Bos Taurus) USING CALCINATION TECHNIQUES. *Unesa Journal of Chemistry*. https://doi.org/10.26740/ujc.v9n3.p189-196

Aisah, N., Harahap, M. E., Budianto, D., Wibowo, M., Effendi, M. D., Setiawan, J., Roseno, S., & Gustiono, D. (2018). Synthesis and Characterizations of Hydroxyapatite from Bovine Bone Using Alkaline Hydrolysis Method. *Insist*, *3*(1), 124. https://doi.org/10.23960/ins.v3i1.124

Anh, N. T. H., Trinh, T. P., Tan, L. Van, Tho, N. T. M., & Van Cuong, N. (2022). Facile synthesis of hydroxyapatite from bovine bone and gelatin/chitosan-hydroxyapatite scaffold for potential tissue engineering application. *Vietnam Journal of Chemistry*, *60*(2), 198–205. https://doi.org/10.1002/vjch.202100126

Arokiasamy, P., Al Bakri Abdullah, M. M., Abd Rahim, S. Z., Luhar, S., Sandu, A. V., Jamil, N. H., & Nabiałek, M. (2022). Synthesis methods of hydroxyapatite from natural sources: A review. In *Ceramics International*. https://doi.org/10.1016/j.ceramint.2022.03.064

Cañon-Davila, D. F., Castillo-Paz, A. M., Londoño-Restrepo, S. M., Pfeiffer, H., Ramirez-Bon, R., & Rodriguez-Garcia, M. E. (2023). Study of the coalescence phenomena in biogenic nano-hydroxyapatite produced by controlled calcination processes at low temperature. *Ceramics International*. https://doi.org/10.1016/j.ceramint.2023.02.119

Dinda, S., Bhagavatam, A., Alrehaili, H., & Dinda, G. P. (2020). Mechanochemical synthesis of nanocrystalline hydroxyapatite from Ca(H2 PO4)2 .H2 O, CaO, Ca(OH)2, and P2 O5 mixtures. *Nanomaterials*. https://doi.org/10.3390/nano10112232

Firdaus Hussin, M. S., Abdullah, H. Z., Idris, M. I., & Abdul Wahap, M. A. (2022). Extraction of natural hydroxyapatite for biomedical applications—A review. *Heliyon*, *8*(8), e10356. https://doi.org/10.1016/j.heliyon.2022.e10356

George, S., Mehta, D., & Saharan, V. K. (2020). Application of hydroxyapatite and its modified forms as adsorbents for water defluoridation: An insight into process synthesis. *Reviews in Chemical Engineering*. https://doi.org/10.1515/revce-2017-0101

Hassanen et al. (2016). *Preparation and synthesis of hydroxyapatite bio-ceramic from bovine bone by thermal heat treatment* (Issue May).

Indra, A., Putra, A. B., Handra, N., Fahmi, H., Nurzal, Asfarizal, Perdana, M., Anrinal, Subardi, A., Affi, J., & Gunawarman. (2022). Behavior of sintered body properties of hydroxyapatite ceramics: effect of uniaxial pressure on green body fabrication. *Materials Today Sustainability*. https://doi.org/10.1016/j.mtsust.2021.100100

Khalil, Reswati, Ferawati, Kurnia, Y. F., & Agustin, F. (2017). Studies on physical characteristics, mineral composition and nutritive value of bone meal and bone char produced from inedible cow bones. *Pakistan Journal of Nutrition*. https://doi.org/10.3923/pjn.2017.426.434

Kumar, R., & Mohanty, S. (2022). Hydroxyapatite: A Versatile Bioceramic for Tissue Engineering Application. In *Journal of Inorganic and Organometallic Polymers and Materials*. https://doi.org/10.1007/s10904-022-02454-2

Ma, G. (2019). *Three common preparation methods of hydroxyapatite Three common preparation methods of hydroxyapatite*. https://doi.org/10.1088/1757-899X/688/3/033057

Muharni, R. (2024). *A Description of Natural Extract Methods From Bovine Bone For Dental Implan* (pp. 30–35). WoFDiC.

Muharni, R., Berli, A. U., Dewi, A. S., Yetri, Y., & Earnestly, F. (2023). *Potensi Hidroksiapatit Nano pada Dental Implan*. *8*(2), 4–9.

Muharni, R., & Dewi, A. S. (2021). *Perilaku Korosi Paduan Titanium Ti6Al4V ELI Dilapisi Biokeramik pada Cairan Modifikasi Air Ludah Buatan pada Temperatur yang Berfluktuasi*. *6*(2), 4–8.

Obada, D. O., Osseni, S. A., Sina, H., Oyedeji, A. N., Salami, K. A., Okafor, E., Csaki, S., Abolade, S. A., Akande, A., Dauda, M., Kuburi, L. S., Dalhatou, S., Abifarin, J. K., Bada, A. A., & Dauda, E. T. (2023). Hydroxyapatite materials-synthesis routes, mechanical behavior, theoretical insights, and artificial intelligence models: a review. *Journal of the Australian Ceramic Society*. https://doi.org/10.1007/s41779-023-00854-2

Odusote, J. K., Danyuo, Y., Baruwa, A. D., & Azeez, A. A. (2019). Synthesis and characterization of hydroxyapatite from bovine bone for production of dental implants. *Journal of Applied Biomaterials and Functional Materials*, *17*(2). https://doi.org/10.1177/2280800019836829

Ofudje, E. A., Rajendran, A., Adeogun, A. I., Idowu, M. A., Kareem, S. O., & Pattanayak, D. K. (2018). Synthesis of organic derived hydroxyapatite scaffold from pig bone waste for tissue engineering applications. *Advanced Powder Technology*. https://doi.org/10.1016/j.apt.2017.09.008

Rincón-López, J. A., Hermann-Muñoz, J. A., Giraldo-Betancur, A. L., De Vizcaya-Ruiz, A., Alvarado-Orozco, J. M., & Muñoz-Saldaña, J. (2018). Synthesis, characterization and in vitro study of synthetic and bovine-derived hydroxyapatite ceramics: A comparison. *Materials*, *9*(3). https://doi.org/10.3390/ma11030333

Sogabe, T., Shoji, Y., Miyashita, N., Farrell, D. J., Shiba, K., Hong, H., & Okada, Y. (2023). *Obtention and characterization of nano bio-hydroxyapatite particles by combined hydrothermal alkaline and ultrasonic wet milling methods*. *1*(April), 0–2.

w. kho et al, 2015. (n.d.). *Preparation of natural hydroxyapatite from bovine femur bones using calcination at various temperatur* (pp. 2–19).

Yetri, Y. (2018). *Karekteristik Hidroksiapatit (HA) Dari Limbah Tulang Sapi dengan Metode Mekanik-Termal Characteristics of Hydroxyapatite (HA) by Mechanical-Thermal Method of bovine bone*. *13*(April), 43–53.

Yetri, Y., Ikhsan, I., Affi, J., Gunawarman, G., & Asmara, Y. P. (2024). The Potential of Hydroxyapatite-Alumina Composites for Artificial Bone Implant. *International Journal of Thin Film Science and Technology*, *13*(2), 87–93. https://doi.org/10.18576/ijtfst/130201

Yetri, Y., Ikhsan, Indra, A., Affi, J., & Gunawarman. (2024). Extraction of hydroxyapatite from bovine bones: The manufacturing development and its behavior properties towards acrylic resin/hydroxyapatite/alumina composites. *Materials Chemistry and Physics*, *319*(March), 129244. https://doi.org/10.1016/j.matchemphys.2024.129244