Developing renewable thermo-hydrothermic bioinorganic materials from bone wastes of slaughterhouses

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Abstract. Adding value of slaughterhouses products and wastes today become greater attention, especially bone wastes for renewable biomaterials, in supporting sustainable green industries. However, the high potency of developing the renewable bioinorganic materials from bone wastes needs a comprehensive need assessment. The need assessment was conducted through three steps: literature search metaanalysis study for defining the needs, collecting and analysis data, and making decision of the needs. Results of the study showed that (1) there were prospective and sustainable raw materials from slaughterhouses in Indonesia, especially bones, for developing phosphate based bioinorganic materials; (2) there were some needs of developing bioinorganic nanoparticles materials in M-Si-P-O, M-Al-P-O, and M-Al-Si-P-O systems (with M = main and/or transition metals) for artificial bones and teeth purposes; and (3) there were some needs of developing thermo-hydrochromic bioinorganic materials sensoric temperature and humidity for supporting artificial insemination as well as medicinal purposes. The last result of the study was supported by current finding on natural inorganic thermo-hydrochromic pigment.

1. Introduction

Renewable biomaterials today become higher scientifically, technologically, and economically important, since the trend of green chemical industry for sustainable development. Scientifically, wide spread inter as well as cross discipline researchers have been currently working on biomaterials with biomass resources, such as calcium phosphate (CaP) based biomaterials from animal bones. Scientifically, one of renewable inorganic biomaterials i.e CaP takes attractively into account because of excellent properties for bone damage healing in terms of their osteoinductivity, osteoconductivity and biodegradability [1]. Calcium phosphate can properly induce the growth of bone through stimulating the recruitment of immature cells to develop into preosteoblast [1]. The osteoinduction is an important process in healing of fractural damage of bone [2]. The osteoconduction measures the grow of bone along the surface or internal pore of the implant after implanting bioactive materials into a bone environment [1], where the osteoconductivity can be characterized from SEM images and biopsy analysis tomographically [3]. Biodegradability of CaP biomaterials can be explained in terms of dispersing material into particles and dissolving material into ion [1]. Dispersing CaP into particle implies that the implanted CaP dispers into tiny particles then those are transferred by osteoclasts [4], meanwhile dissolving into ion means that the implanted CaP dissolves and releases Ca$^{2+}$ and HPO$_4^{2-}$, which are then absorbed by the cells for repairing bone damage or farcture and formatting of new bones [5]. Technologically, renewable bioinorganic materials become prominent artificial bone technology, for
instance CaP biomaterial obtained from natural raw materials was applied for producing bioceramics in orthopedic and dental reparation technology [6]. Economically, renewable biomaterials prepared from biomasses have green industrial values for sustainable development because of their natural abundant and cheaper resources, their potential bioenergy or biofuel feedstocks and their probability in adding beneficial values, thus the integration of biopower potential and biomaterials will lead to a new manufacturing paradigm [7].

On the other hand, the development and advancement of renewable biomaterials depend on the sustainable supply of biomasses, especially for production of bioinorganic materials in large scale for fulfilling market demand. For instance, in developing phosphate based bioinorganic materials, particularly renewable calcium phosphate (CaP) based bioinorganic materials, bone wastes as a by-product of slaughthouses and as a raw material for supplying enough hydroxyapatite(HA) become today’s attractive attention because of their potential contribution of national growth [8]. Furthermore, renewable CaP based biomaterials produced from animal bones of the by-product of slaughterhouses have potential candidate for smart biomaterials fulfilling the need of advanced technologies, for instance the bioceramic based biosensors when it is integrated with nanotechnology and thermochromic and or hydrochromic materials. Thus, adding value of slaughterhouses products and wastes today become greater attention, especially bone wastes for renewable biomaterials, in supporting sustainable green industries. However, the high potency of developing the renewable bioinorganic materials from bone wastes needs a comprehensive need assessment.

2. Methods
This study was a comprehensive need assessment. The need assignment was conducted through three steps: metaanalysis study for defining the needs, collecting and analysis data, and making decision of the needs. In the first step, meta-analysis study using literature search essay by adopting Wilson and Kelly method [9]. In the second step, the secondary data were collected through reviewing focused articles of international journals and by using secondary data published legally by government offices or agencies such as Statistic Centre Office or Badan Pusat Statistik (BPS) and data were analyzed to making decision by using Ishikawa cause-effect analysis [10]. The study was focused on bones materials as by-product of slaughterhouses that prospective raw material for developing phosphate based bioinorganic materials, bioinorganic nanoparticles, and hydro-thermochromic bioinorganic materials.

3. Results and discussion
Slaughterhouses produced not only meat as a main product but also fat and bone as by-products, in year 2019, Indonesia has 1331 slaughterhouses spread up into 34 provinces in which about 40% of them located on Java Island, Sumatera 19.98%, Sulawesi 14.95%, Bali and Nusa Tenggara 10.52%, Kalimantan 8.72% and Maluku and Papua 7.21% [8], thus the slaughterhouses contributed also our national growth. Our slaughterhouses dominantly slaughtered dominantly ruminent animals, for instants beef, goat and swines. Proportion of meat, fat and bone produced from the animal slaughterhouses was studied using 662 beef animals (bulls, steers, and heifers) and results showed the carcass proportions (g/kg) were for bulls 727±41.4 (meat): 85± 27.4 (fat): 188± 21.2 (bone); for steers 679 ±13.3 (meat): 123±31.8 (fat): 197±20.2 (bone); for heifers 722±39.3 (meat): 93±34.1 (fat): 185± 13.5 (bone), respectively [11]. Those proportion of carcass showed that around 18-20% of the animals consist of bone as by-product. The bones composed by organic matter about 30% and inorganic compounds about 70%, that is mainly hydroxyapatite (HA) [12]. Thus we can have concluded that our slaughterhouses can provide HA as a prospective raw material for producing calcium phosphate biomaterials prospectively.

HA, a mineral part of animal bone, can be isolated and purified through physical as well as chemical processes. The isolation methods of HA from animal bone can be used single as well as mix-methods namely acid hydrolysis, alkaline hydrolysis, thermal decomposition and subcritical water process [12-14]. Each method has its own advantages and disadvantages, thus mixing of two or three methods would produce higher purity and desirable structure of the resulted HA because different isolation method has
different impact on physicochemical properties of HA obtained, for instant, its Ca/P molar ratio and surface morphology depend on treatment conditions.

HA naturally has physical, chemical, and biological properties. Physically, HA has mechanical properties, namely the bending, compressive, tensile strength, Young’s modulus of dense, and Vicker’s hardness values of HA ceramics lie in the range of 38–250, 120–150, and 38–300 MPa, 35 – 120 GPa, and 3–7 Gpa respectively [15-17]

Inorganic nanoparticles today become great attentions especially for advancement of biotechnology and pharmaceuticals because of their biocompatible and bioactive properties. The bioactive and biocompatible properties of inorganic nanoparticles are related to their self-assembled structure abilities as reviewed by Nie et al., who concluded that the potential applications rely on their ability to control interactions between the electronic, magnetic, and optical properties of the nanoparticles [18]. Insteads, inorganic nanoparticles manufactures for biomedical purposes have better safe properties in term of toxicological properties [19], as well as environmental, health and safety perspectives [20] and showing efficient cellular delivery [21]. Moreover, some inorganic nanoparticles are also chiral in origin, thus they have optical properties that are useful for bioapplications such as thermochromic and hydrothermochromic properties [22]. The last properties show a change of color because of changing their temperature and/or humidity.

Our current study on inorganic nanoparticles naturally prepared from biomasses such as biosilica particles from high siliconeous teropical plants and biophosphate nanoparticles from animal bones of slaughterhouses wastes. Nowadays, the advancements of synthesis or preparation methods as well as characterization techniques enables us to produce new bioinorganic nanoparticles for bioapplications by combining nanophosphate and nanobioslica nanoparticles in systems of M-Si-P-O, M-Al-P-O, and M-Al-Si-P-O where M metals are main and/or transition metals. The nanobiomaterials become prominent for artificial bones and teeth purposes as well as other bioaplications. On the other hand, our current finding on natural thermochromic nanopigmen can be usefull in consideration for enriching properties of those M-Si-P-O, M-Al-P=O, and M-Al-Si-P-O systems of inorganic nanoparticles for related bioaplications such as color self-controlling humidity of vaccine, viruses or microorganisms ampulles in order to solve the problems of lacking properties of our current glass ampulles that should be controlled through cooling or freezing by using liquid nitrogen. Thus, further researches and developments needed on that area become probably new potential direction in supporting science and technology of viruses caused deseases such as corona viruses and other dangerous viruses in the future.

4. Conclusion

It can be concluded that (1) there were prospective and sustainable raw materials from slaughterhouses in Indonesia, especially bones, for developing phosphate based bioinorganic materials; (2) there were some needs of developing bioinorganic nanoparticles materials in M-Si-P-O, M-Al-P-O, and M-Al-Si-P-O systems (with M = main and/or transition metals) for artificial bones and teeth purposes; and (3) there were some needs of developing thermo-hydrochromic bioinorganic materials sensoric temperature and humidity for supporting artificial insemination as well as medicinal purposes. The last result of the study was supported by current finding on natural inorganic thermo-hydrochromic pigment.

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