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Fabrication and Characterization of Ready-Use Artificial Skull

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Abstract:

Background: At present, medical care in Thailand is far advanced in all specialties. With this, we have to import large amount of high-cost medical equipment from other countries. However, there are many animal and plant products which can be modified and used for medical care.

Objective: This research aims to add value to Thailand's agricultural products, including rice starch, rubber, and animal bones in Thailand by transforming these products into medical devices, namely artificial skull for the Thai people.

Materials and method: By using green technology, which is to use chemicals that are not toxic to the environment and humans to prepare pure medical cow bone implants in the human body. Heating to remove contaminants and crushing, casting, and sintering. Increasing toughness by coating with rice starch and additives. Artificial skull prototype fabricated based on fresh cow bone in Thailand was made.

Result: Artificial skull was made which consists of 75% by weight cow bone powder and binder which is composed of 80% by weight rice starch and 20% by weight filler, representing 25% for forming. Biocompatibility with the living body and highly responsive to the growth of human bone tissue. The samples had a maximum degree of swelling in the water of 23% after 2 hours becoming stable.

Conclusion: This simple green technology was friendly to the environment and human. This method could make value-added agricultural products for medical material. For this reason, trade deficit to the country could be decreased.

Keywords: Artificial skull, Hydroxyapatite, Cow bone, Plastic skull.

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Introduction

Currently, Thailand still has to import medical equipment worth about one hundred thousand million baht per year from abroad. Exports, on the other hand, amount to about ten thousand million baht. The research team aims to add value to Thailand's agricultural products, including rice starch, rubber, and animal bones. They will be processed into medical devices, especially artificial skulls for the Thai people. This is the development of agricultural products, and we will manage the knowledge from research to expand the results to the community by bringing it to the production and export industries.[1-3]

Hydroxyapatite (HA) is generally a compound of calcium phosphate. It can be synthesized by chemical methods such as co-precipitation[4,5], sol-gel synthesis[6,7], hydrothermal[8], and thermal deposition.[9] The problem with these methods is that the reactant cost to produce hydroxyapatite is high. In addition, the yield is low. Therefore, the increasing demand for HA has led to the processing of HA from natural sources such as edible animal bones, eggshells, and cockle shells[6,10] as attractive alternatives in the future.[11] If researchers want to use HA powder for medicinal purposes, the powder must be shaped to be convenient and easy to use, depending on the research objective. The molding must be mixed with binder to obtain the desired shape. Pharmaceutical grade rice starch, such as Era-Tab[12], was used as a tablet ingredient, as was medical grade PVA, a water-soluble polymer.[13]

The research project is to produce a dense and porous prefabricated artificial skull from cow bones mixed with rice starch and PVA. This will be used to repair broken and damaged human skulls after accidents or serious diseases in Thailand. The precursor from Thai cow bones, a material of natural origin, is physically and chemically processed, so that it is pure without organic substances. It is then introduced into the synthesis process and processed into a fine powder that is formed into a human skull prosthesis, aiming for commercial expansion. Therefore, there is joint research funding with academic departments of universities to urgently advance concrete results. This research will start with laboratory trials. Then, further trials are conducted with human subjects from various disciplines, such as general surgery, neurosurgery, orthopedics, etc.[14]

Materials and method

Materials

The cow bone was prepared according to the American Society for Testing and Materials (ASTM) designation F1581-99, 2016.[15] The concentration of trace elements had to be as follows: Arsenic < 3 ppm, cadmium < 5 ppm, mercury < 5 ppm, lead < 30 ppm and total heavy metals < 50 ppm. Then the bovine bone particles were crushed by high-speed grinding for 3 hours. Era-Tab was supplied by Erawan Research and Laboratory, Thailand. PVA was purchased from Sigma-Aldrich, USA.

Specimen preparation

Calcined cow bones were prepared, dried, and wet ground using 95% ethanol as a suspension medium. Grinding through a ball mill with a grinding pot and grinding ball (pot mill) for 70 hours, drying at 80°C, then filtering the powder through a 400 mesh sieve (size less than 37 microns) until obtained. The obtained powder is mixed with rice starch powder (Era-Tab) and a PVA binder. Then it is pressed into the mold for an artificial skull. Finally, it is dried at 150°C for 14 hours.

Characterization of samples

A scanning electron microscope (SEM-EDS, JEOL, JSM-IT800, Japan) was used to study the morphology of the cross section of the samples. The degree of swelling and volume expansion were determined as follows.[16] All quantitative data were analyzed with origin 8.0 (Origin Lab Corporation, USA) and presented as the mean ± standard deviation. Statistical comparisons were carried out using analysis of variance (ANOVA, Origin 8.0). A value of $p < 0.05$ was considered to be statistically significant.

Result and discussion

Figure 1 shows the prototype of the artificial bone, and Figure 2 shows the SEM (Scanning Electron Microscope) results of the cow bone surface after being calcined at 900°C to remove all organic matter and visible white spots less than 1 μm in size uniformly distributed on the surface of the cow bone. This was caused by the growth of new calcium phosphate crystals, and the chemical composition on the surface of cow bone was analyzed at spectrum No. 1 (Figure 3) by the EDS (Energy Dispersive Spectroscopy) technique. The main minerals were calcium (Ca) and phosphorus (P). Nitrogen as a component of protein was not found, indicating that there was no organic matter in the cow bone. The average value of Ca:P was 1.68 ± 0.34, which is close to the pure HA of 1.67 (Figure 4).

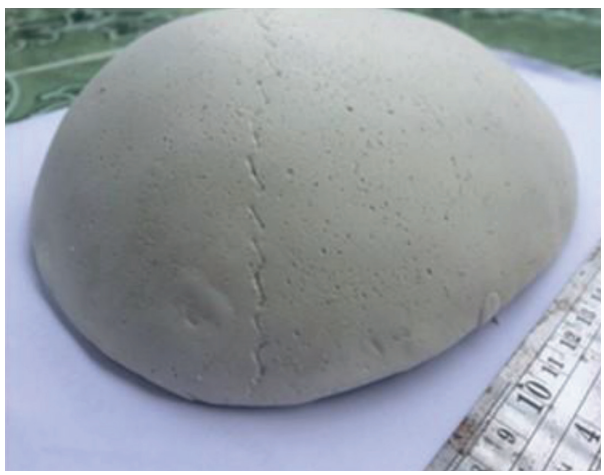

Figure 1 shows prototype of an artificial skull

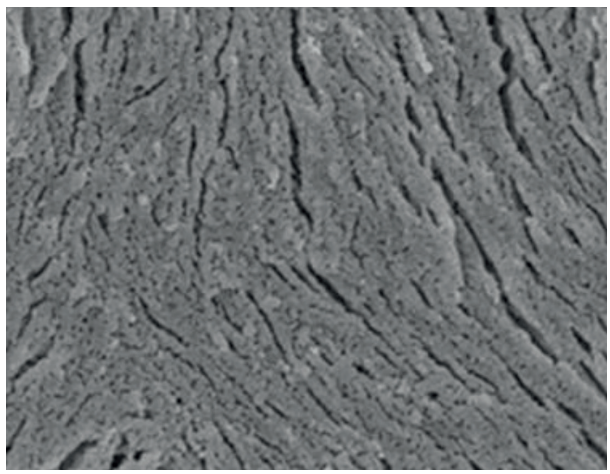

Figure 2 shows scanning electron microscope (SEM) of cow bone surface at 900^0C (3,000 x)

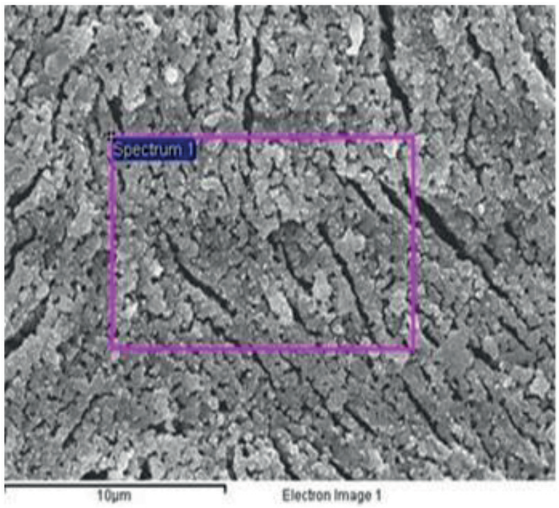

Figure 3 shows energy dispersive spectroscopy (EDS) of cow bone surface of spectrum 1

Element	Weight%	Atomic%	
C K	6.51	12.62	
N K	-	-	
O K	43.31	59.80	
P K	15.28	8.7	
Ca K	34.90	18.88	
Totals	100.00		**Ca/P = 1.68**

Figure 4 Chemical composition spectrum 1 by EDS technique

The sample of an artificial skull consists of 75 wt% cow bone powder, and 80 wt% rice starch and, 20 wt% filler, corresponding to 25 wt% of the binder for moulding.

The samples had a maximum degree of swelling in water of 23 ± 0.5%, which became constant after 2 hours (Figure 5).

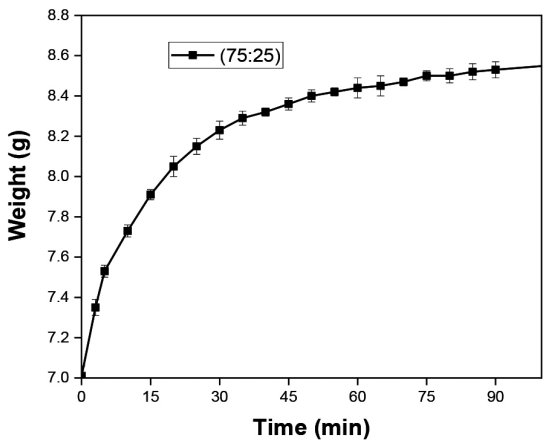

Figure 5 Weight increase of the samples

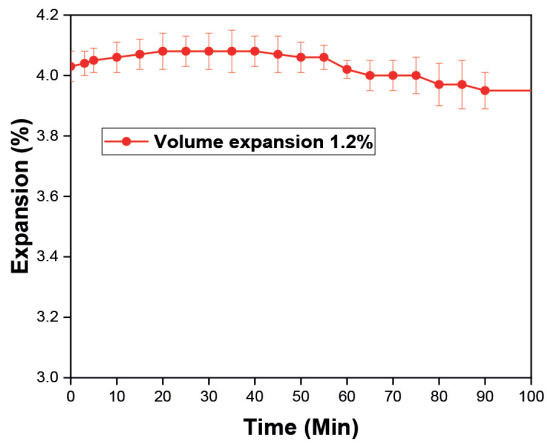

Figure 6 Volume expansion of the samples

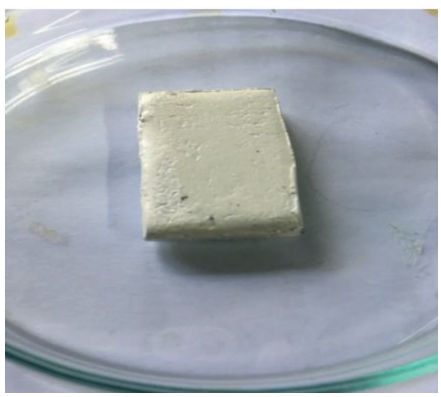

Figure 7 Artificial skull parts before immersion testing

Figure 8 Artificial skull parts after immersion testing

An artificial skull exhibited the greatest volumetric expansion of 1.2%, starting at 20 min to 40 min after the onset of decomposition of the sample surface, until greater decomposition of the bone powder was observed at 60 min. However, the shape of the sample remains 90% intact without complete dissolution or disintegration into small pieces. The image remains intact until after 2 hours (Figure 5) and an expansion of 1.2%, starting at 20 min to 40 min after the onset of decomposition of the sample surface, until greater decomposition of the bone powder is observed at 60 min. However, the shape of the sample remains 90% intact without complete dissolution or disintegration into small pieces. The image remains intact until after 2 hours (Figure 5 and 6). Figure 7 and 8 show the comparison of the surface shapes of the samples. It was found that the skin was normal, smooth, and firm before the test. However, after the immersion test in water, the skin was bubbly and swelled due to the hydrolysis of water, so the surface of the samples absorbed water. Meanwhile, the shape of the specimens is still intact until they are completely broken in a short time. Foreign artificial skulls are made of polymethyl methacrylate plastic, which does not have the properties to stimulate bone growth, although it is light, strong, and durable.[17] Rice starch was the hydrogel state that swelled and was hydrophilic. This leads to natural degradation. PVA, on the other hand, is a synthetic polymer and stable polymer in nature. Therefore, HA in combination with rice and PVA can cause cross linking between the OH groups of rice starch and the hydrogen groups of PVA.

Conclusion

An artificial skull made of cow bone mixed with rice starch and PVA was the dense artificial skull in this study. It has basic physical properties that make it possible to be used as a prosthetic skull made of Thai agricultural materials. Because the theory of an artificial skull is not less than 0.5 mm thick and resistant to impact, skull fixation materials can be used to hold a prosthetic skull made of cow bone powder and rice starch to blend seamlessly into a real human skull with a real human head. After suturing the skull, the size of the skull is comparable to that of a real human skull.

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