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Rice Starch Anchor for Osteoporotic Bone Strengthening

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Abstract:

Background: Osteoporosis and osteopenia are important diseases for weakening and fracturing the bones of patients. Both diseases are caused by low bone mass and deterioration of bone structure until severe pain and unable to function normally. Most doctors will treat bone fractures using a metal plate and screw to hold the bone in place. Then fix and pull the bone back to its original position by using screws to fix the bone. But in osteoporosis, the screw is usually to be wobble without tighten bone fixation.

Objective: This research aims to increase bone mass in specific position that enhances bulk structure by implanting the rice starch bone anchor into the porous bone.

Materials and methods: Rice starch anchor (RSa) was carried out in third steps. Characteristics of the final products were then investigated scanning electron microscopy (SEM), XRD, and swelling ratio, PH and, pull out strength. 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. Materials characteristics were determined by scanning electron microscopy (SEM), X-ray diffraction (XRD) and swelling ratio.

Result: The material was completely biodegradable in the human body. The optimal composition of the material is 50% of rice starch, 50 wt % of additives. It had physical characteristics. In parts that can be used to hold human bones, such as the upper tibia below the knee joint. The rice anchor can be used 3.95 mm of metal screws with a pullout strength of 117.27 ± 1.58 N.

Conclusion: Rice starch anchor had chemical and mechanical properties suitable for used with metal screws to help hold screws tighten in decayed surfaces for human bone fixation. It was suitable material for bone strengthening of osteoporosis. In the future should be tested for compatibility in laboratory animals and further testing for safety and clinical efficacy.

Keywords: Rice starch, Anchor, Cow bone, Metal screw, Osteoporotic

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Introduction

In 2021, Thailand has reached to aging society. Thai population is over 60 years old or 14 million people (70 million of Thai population), while those over 60 years old are at risk of osteoporosis in bone mass. Due to the deficiency of calcium and phosphate minerals is more than growth a new bone and the weakening of organic matter and bone mass. So, the deteriorating elderly organs throughout the body deteriorate when accident or broken bone.[1] It can easily cause fractures. This case is extremely painful. Especially, if a bone is fractured at a load bearing body, such as a hip or leg, it requires bed rest for 2 to 3 months, putting the risk of bedridden and complications. Most doctors recommend surgery and fixing the fractured bone in place with bone plate and screws. For the reduce pain and the patient can move into weight within a few days. But in the condition of osteoporosis, standard screws may not be able to securely tighten. There is a risk of being completely disconnected from the fracture site. Because doctors need to use larger screws and reposition of the screw holes or use another treatment. This case was more serious consequences for the patient.[2]

Rice starch gel was cross-linked by macromolecules to form a hydrophilic polymer and allowing the material to swell in water or retain large amounts of water in the microstructure. From cross linking, the degree of swelling and the amount of water contained depends on two factors 1) the hydrophilic capacity of the polymer chain and 2) the cross-linking density.[3] Bonding can arise from physical crosslink between polymer molecules, such as ionic bonds, hydrogen bonds, van der Waals forces, or hydrophobic reactions. Researchers could apply gel to fabricate biomaterials for a wide application of academic fields, such as medicine, agriculture, and biology.[4] In this research, we developed a novel rice starch anchor which fix to bone weaken with medical screw for bone strengthening and using a composite material of rice starch, polyvinyl alcohol (PVA), gelatin and glycerol. The characteristic of rice starch anchor was then characterized by scanning electron microscopy (SEM), XRD, swelling ratio and, pull out strength.

Materials and Methods

Materials. Pharmaceutical grade rice starch (RS) was purchased from Chiang Mai, Thailand. Polyvinyl alcohol (PVA) with an average molecular weight of 8.5 x 10^4 g/mol and 99+% hydrolyzed was purchased from Sigma-Aldrich, Germany. Gelatin was purchased from Fluka, Switzerland. Cow bone derived from Macro supermarket. Maleic acid used as a cross linker and copper sulfate used as catalyst were purchased from Sigma-Aldrich, Germany. Glycerol was purchased from Fluka, Switzerland.

Sample preparation. Rice starch anchor (RSa) was carried out in third steps. In the first step, 42-50 wt% RS mixed with additives. The additives composed of 7 wt% cow bone, 7 wt% PVA, 7 wt% gelatin, 3.8 wt% maleic acid and 0.2 wt% copper sulfate. The mixture was dissolved in distilled water and 25 wt% glycerol solution. The resulting solution was stirred at 95°C for 1 hour. In the second step, metal screws dipped in the obtained solution then dried in hot air oven at 70°C for 30 min. This step was repeated 4 times. Finally, the part of RSa was removed from metal screw and dried in oven at 70°C for 24 hrs. This procedure followed by flow chart that shown in Figure 1.

Characterization. Characteristics of the final products were then investigated scanning electron microscopy (SEM), XRD, and swelling ratio, pH and, pull out strength. 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.

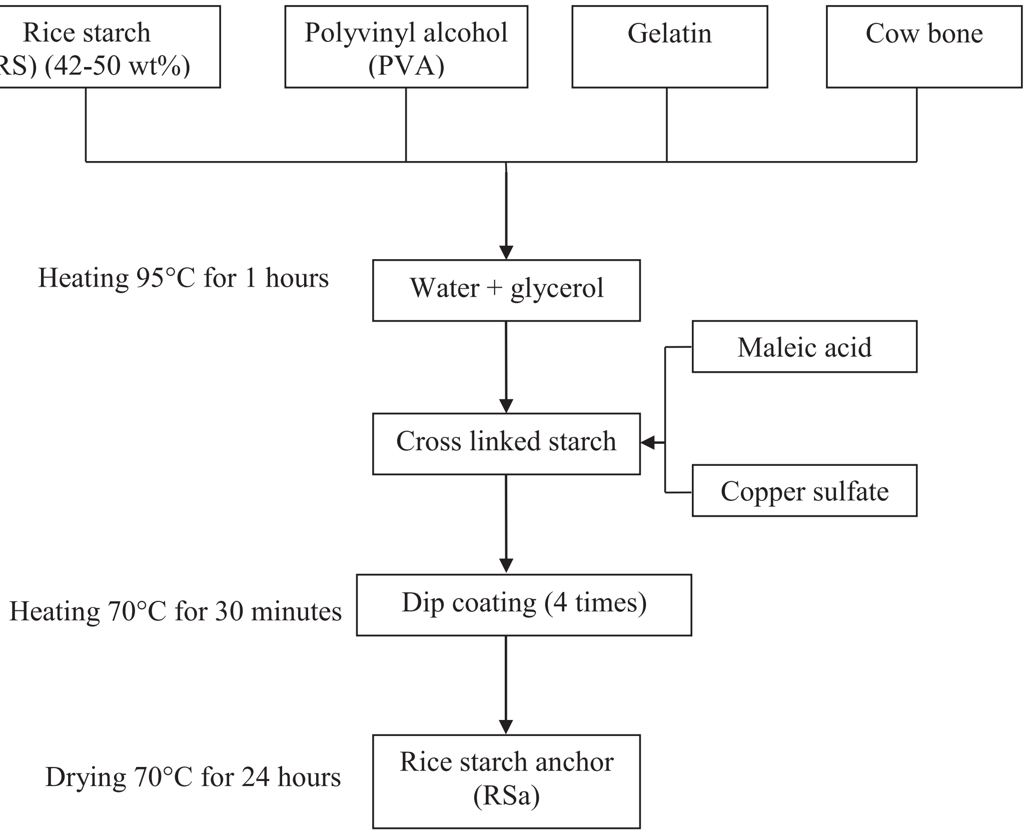

Figure 1 Flow chart of RSa process

Results

Prototype of rice starch anchor for treatment of osteoporosis for bone strengthening shown in Figure 2 and 3. Figure 2 shows that the dimension of rice anchor was inner diameter of 3.95 mm. and length as 14.75 mm. Figure 3 showed metal screw with Rsa.

Figure 2 Prototype of rice starch anchor

Figure 3 Samples of rice starch anchor with metal screw

SEM of surface microstructure of RSa is illustrated in Figure 4. The crossection the fracture rice starch anchor indicated that microstructure of cow bone powder embeded under the sufface of RSa in size about 100 nm (Figure 5). The cow bone powder might be assisted for strength and bioactivity of rice starch bone anchor.[5]

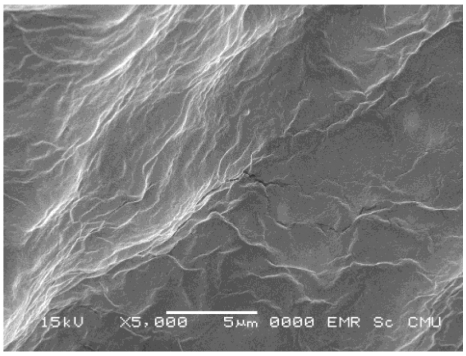

Figure 4 SEM of Rsa surface

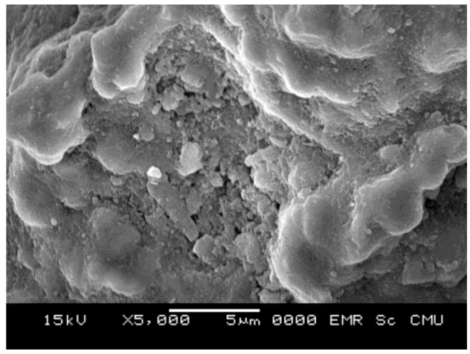

Figure 5 SEM of cross section area of Rsa

Starch hydrogel are amorphous phase which obtained from thermal and chemical cross linked of rice starch with maleic acid, copper sulfate and glycerol. Figure 6 showed the best condition of RSa compared with rice starch gel and cow bone.

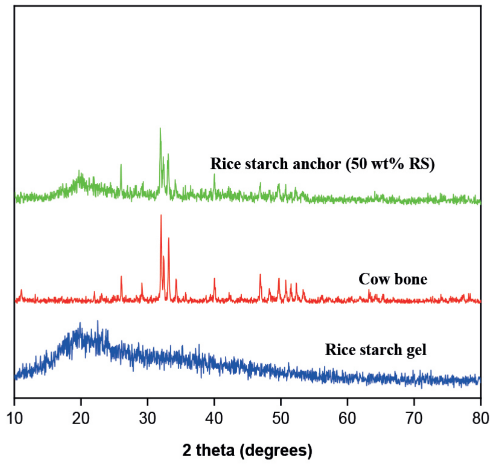

Figure 6 XRD pattern of RS gel, cow bone and RSa

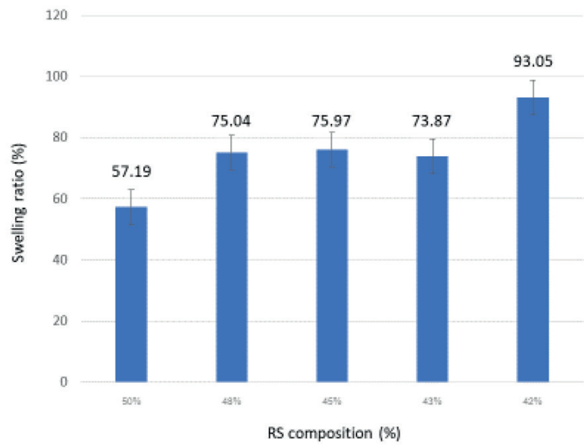

Figure 7 Effect of RS on swelling ratio of RSa

Rice starch gel is amorphous structure and the main XRD patterns of the cow bone were 25.88, 31.78, 32.18, 32.91, 39.82, 46.71 and 49.47°. This result was in agreement with previous work.[5] When rice starch was crosslinked with additive such as cow bone, PVA, gelatin, maleic acid, and, $CuSO_4$. Afterthat, the XRD pattern of the rice starch hydrogel blended with the additves at a ratios of RS:additive of 42:58, 43:57, 45:55, 48:52 and 50:50 wt%, respectively. The peak intensity of gel were increased at 25.88°, 31.78°, 32.18° and 32.91°, respectively. This showed that the intensity of the XRD pattern of the hydrogel increased with increasing proportions of the cow bone in the blend. This is due to the impregnation of cow bone powder during the gelatinization process.

The physical properties of the RS hydrogel were evaluated by measuring the degree of swelling in distill water. The effect of the ratio of RS and additive and cow bone on the swelling of the polymer hydrogel in water is shown in Figure 7. It is clear that the swelling ratio of the hydrogel decreased to a minimum with increasing RS content and then increased with further increases in the proportion of RS in the mixture. For instance, the swelling ratio of the hydrogels with ratio of RS:additive of 42:58, 43:57, 45:55, 48:52 and 50:50 wt% were 93.05%, 73.87%, 75.97%, 75.04%, and 57.19%, respectively. This was due to the hydrophilic behavior of RS and polymer additives.[6] However, these data indicate that at high proportions of cow bone in the hydrogel, there is a loss of rice starch from the hydrogel, especially at ratio of 42:58 due to the phase separation between cow bone and RS.

A suitable ingredient of these ratios of the production of Rsa, it was found that all five ingredients had pH about 6, weak acid, which had no effect on human use. It was found that ratio 50:50 suitable for the production of Rsa. Because the water absorption is 57.19 % and the surface expansion is 32.00%, which is the lowest value compared to other ratios. This indicates that ratio of 50:50 mixtures has slow water absorption causing less area expansion accordingly and there is likely a degree of cross-linking between rice starch and additives.[7] This ratio is suitable for production of bone anchor and flexibility to fasten metal screws without decaying too quickly.

Good mechanical is vital for bone anchor in bone fixation of osteoporotic. The effects of the RS content on the pull out strength of the RS:additive was 117.27 $\pm$ 1.58 Newton which in level of pull out strength ranged (56-1230 N) of metal screw compared with human tibial plateau.[8,9]

Conclusion

Rice starch anchor was material for bone strengthening of osteoporosis. The material was completely biodegradable in the human body. The optimal composition of the material is 50% of rice starch, 50 wt% of additives. It had physical characteristics, chemical and mechanical properties suitable for used with metal screws to help hold screws tighten in decayed surfaces for human bone fixation. In parts that can be used to hold human bones, such as the upper tibia below the knee joint. The rice anchor can be used 3.95 mm of metal screws with a pullout strength of 117.27 $\pm$ 1.58 N. In the future should be tested for compatibility in laboratory animals and further testing for safety and clinical efficacy.

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