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STUDY OF HARDNESS AND DENSITY OF POLYHYDROXYALKANOATE (PHA) REINFORCED WITH BIPHASIC CALCIUM PHOSPHATE (BCP) FROM EGGSHELL WASTE

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ABSTRACT

In this study, biocomposite material was developed using polyhydroxyalkanoate (PHA) as the polymer matrix, biphasic calcium phosphate (BCP) as the reinforcement, and polyethylene glycol (PEG) as the binder for potential usage in bone scaffold. By using conventional compounding and injection moulding, biocomposite materials with BCP that ranged from 3 to 15 wt% were produced. Using the Shore D Hardness Test, the effect of BCP loading on PHA matrix was evaluated. Density testing was used to establish the materials' physical characteristics. According to the findings, PHA biocomposite exhibits increasing hardness value as BCP loading increases. The highest hardness recorded at 15 wt% of BCP was 46, while the lowest hardness recorded at 3 wt% was 34.14. When the BCP content in PHA increases, the density test's value increases. The maximum density measured at 15 wt% of BCP was 1.36 g/cm^3, while the lowest density measured at neat PHA was 1.24 g/cm^3. Overall findings support the biocomposite relevance from a mechanical and physical aspect since it has characteristics that make it appropriate for usage in human femoral bone.

KEYWORD

Polyhydroxyalkanoate (PHA), biphasic calcium phosphate (BCP), hardness, density, biocomposite

INTRODUCTION

A biocomposite is a substance comprised of two or more distinct constituent materials, at least one of which is derived naturally, that are combined to create a new substance that performs better than the sum of the parts. These materials usually share structural similarities with the living components used in the process, sustaining the matrix's tensile strength while also guaranteeing biocompatibility. Researchers discovered that the industry became interested in producing and using byproducts as an alternative to new reinforcement/filler materials because they are easily accessible or naturally renewable at a reasonable price. This is due to the ever-increasing demand for low cost in materials processing. Materials reinforced with eggshell waste have distinct interfaces (boundaries) between particles with high strength and modulus that are fixed in or bonded to a matrix. In this state, eggshell powder (which contains $CaCO_3$) and matrix maintain their physical and chemical identities, and as a result, they will produce a combination of qualities that are not possible when one of the materials is functioning alone.

Biocomposites PHA (matrix), BCP (reinforcement), which were extracted from eggshell waste from a previous work, and Polyethylene glycol (PEG) as a binder were produced by conventional melt compounding using a Brabender plastography machine in this study. In order to create pellets, which are used as the raw materials for injection moulding, the compound is subsequently crushed with a crusher. This study focuses on the mechanical and physical properties of PHA/BCP/PEG biocomposite, which will contribute to new data that will be used to determine the best ratio to create biomaterials depending on their intended use. Additionally, rather than manufactured bioceramic, the bioceramic used in this work is generated from a natural source (EW), which is an improvement in sustainability.

MATERIAL AND METHODOLOGY

PHA medical grade was supplied by Ecomann Biotechnology, Inc (United States) as Ecomann® Bioresin EM10080 in a pellet form. The osteoconductive filler of BCP powder was synthesized via wet chemical precipitation based on previous work. PEG 10000 MW grade 500 g was supplied by Ecomann Biotechnology, Inc (United States).

Both of PHA pellets and BCP powder were separately dried beforehand at 60℃ for at least 6 h in drying oven to eliminate any remaining moisture and minimizing any chemical breakdown of a compound due to reaction with water (hydrolysis effects) during the manufacturing of biocomposite. The materials were then mixed in brabender plastography machine with mixing temperature at 130℃ over rotating speed of 30 rpm for about 20 minutes. These parameters were set up for all compositions of PHA biocomposite with different BCP contents presented in Table 1.

Table 1. Compositions of the samples prepared in accordance to the weight content (wt%) of PHA, BCP and PEG.

Sample	PHA [wt%]	BCP [wt%]	PEG [wt%]
100PHA	100	-	-
87PHA	87	3	10
83PHA	83	7	10
79PHA	79	11	10
75PHA	75	15	10

The different respective ratios of PHA, BCP and PEG mixtures weighing 50 g were pre-mixed manually in closed container before melt-compounded using a Brabender plastography machine that features integrated control panels that displays actual values of speed and temperature (3 zones), die heads, mixer blades geometries and extruder screws with real torque measurement up to 200 Nm. Next, all the blended mixtures were then pelletized using crusher machine and kept in drying box at constant temperature of 30℃ before further to injection molding process. Injection molding was performed by using Nissei Injection Unit NP7 Real Mini horizontal screw type. Setting parameter for heat controller from feed to nozzle are; 50℃-150℃-155℃-160℃-160℃-165℃.

The Shore-D hardness test was carried out based on ASTM D2240. The density test was carried out based on Test Method A of ASTM D792.

RESULT AND DISCUSSION

The reading of Shore-D hardness test and density test for all sample is summarize in Table 2.

Table 2. Summary of Shore-D hardness test and density test for all test

Sample	Shore-D hardness test	Density test [g/cm^3]
100PHA	45	1.24
87PHA	34.14	1.25
83PHA	42.86	1.31
79PHA	45	1.35
75PHA	46	1.36

Based on result in Table 2, it shown that when weight percentage of BCP increase, the hardness and density of sample increase. BCP is group of ceramic which known have the good hardness have contribute to increasing the hardness of PHA/BCP biocomposite. BCP from group ceramic are well known for having a higher density than polymer (PHA).

CONCLUSION

From this study, it can be concluded that the mechanical and physical properties of PHA/BCP biocomposite play an important role in development of scaffold for bone tissue engineering. In this work, PHA biopolymer had been successfully compounded with different ratio of BCP alongside PEG binder. Thus, showed the presence of good affinity between polymer and the reinforcement. By employing various BCP ratio, hardness and density of composite can be examined and reviewed. The maximum hardness of PHA/BCP composite were at 15 wt% BCP inclusion 46. For density test, 15 wt% of BCP shows the highest value (1.36 g/cm^3).

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