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COMPRESSIVE STRENGTH EVALUATION OF POLY(LACTIC ACID) AND PLA BLENDED WITH BLEPHARIS MADERASPATENSIS FOR ORTHOPEDIC APPLICATIIONS

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ABSTRACT:

Poly(lactic acid) (PLA), is a biodegradable and biocompatible polymer, that has become more popular in orthopedic applications because of its environmental sustainability and ease of processing. Due to its intrinsic brittleness and low mechanical strength, the mechanical properties frequently need to be modified in order to be used in various applications like healthcare, textiles, agriculture etc. The mechanical characteristics of PLA-based 3D printed filaments combined with Blepharis maderaspatensis (elumbotti) are examined. According to ASTM standard D695, Compressive test was done to assess the prepared 3% weight of PLA- Blepharis maderaspatensis composites. The findings showed that, without sacrificing the filaments printability or structural integrity, the addition of Blepharis maderaspatensis greatly improved their mechanical properties. This study demonstrates PLA-Blepharis maderaspatensis composites potential as high-performance, sustainable materials for 3D-printed biomedical devices. The results open the door for the creation of adaptable, environmentally friendly solutions that are designed to satisfy the needs of contemporary healthcare applications.

Keywords: Poly(lactic acid) (PLA), Blepharis maderaspatensis, 3D-printed biomedical devices.

INTRODUCTION:

Polymers derived from natural sources are known as biopolymers. These can be biosynthesised by living things or artificially synthesised from biological ingredients. They consist of monomeric units joined by covalent connections. Larger molecules are formed by these monomeric units. Unlike most polymers, which are petroleum-based, biopolymers are renewable resources since they are made from living things like microorganisms and plants. Biopolymers typically decompose. They are employed in a wide range of sectors, including manufacturing, packaging, biomedical engineering, and the food industry. Because of their abundance, biocompatibility, and special qualities like non-toxicity, biopolymers are materials with great promise. Biopolymers are being explored for their use in an increasing number of methods, with some nano sized reinforcements to improve their characteristics and practical uses. Protein, starch, cellulose, DNA, RNA, lipids, collagen, carbohydrates, and so forth are examples of biopolymers.

PLA is a biodegradable and adaptable polymer made from renewable resources like sugarcane or maize starch. It has drawn a lot of attention because it may be a more environmentally friendly substitute for polymers made from petroleum. A major substance in this industry, poly(lactic acid) comes from renewable resources and is biodegradable. PLA is widely utilized in bone-regeneration scaffolds, screws, implants, and plates because it breaks down into lactic acid, a metabolite that the body naturally produces. Its potential for creating orthopedic devices tailored to individual patients is further enhanced by its adjustable mechanical qualities and processability using techniques like 3D printing.

At the same time, natural products like the medicinal plant Blepharis maderaspatensis have showed potential in improving orthopedic applications. The bioactive substances flavonoids, alkaloids, and tannins found in this plant, which is indigenous to tropical and subtropical areas, have anti-inflammatory, antibacterial, and wound-healing qualities. When combined with biomaterials, these qualities make it a desirable option for encouraging bone repair and lowering post-operative problems. With an emphasis on its appropriateness for orthopedic applications, this research examines the mechanical testing of 3D-printed poly(lactic acid) combined with Blepharis maderaspatensis. This study intends to demonstrate the potential of this novel bio-composite as a sustainable and bioactive substitute for orthopedic implants by assessing the material's mechanical characteristics and performance under physiologically simulated settings.

METHODOLOGY:

SELECTION OF MATERIAL

Polylactic Acid (PLA) blended with Blepharis maderaspatensis at a concentration of 3% by weight. For a base material weight of 485 g of poly(lactic acid), 15 g of Blepharis maderaspatensis powder is incorporated as a reinforcement. The selection of Polylactic Acid (PLA) reinforced with Blepharis maderaspatensis filaments represents an innovative approach to developing sustainable and eco-friendly composite materials.

Figure 1: Blepharis madders patensis powder

Figure 2: PLA pellets

FILAMENT PREPARATION:

The preparation of a poly(lactic acid) (PLA) filament blended with Blepharis maderaspatensis powder involves several steps to ensure homogeneity, structural integrity, and printability. This process combines the mechanical strength and degradability of PLA with the bioactive properties of the plant powder to produce a filament suitable for 3D printing orthopedic applications. PLA pellets and Blepharis maderaspatensis powder are dried separately in a vacuum oven at 50–60°C to remove moisture. This step prevents issues like hydrolytic degradation of PLA during processing. The dried PLA pellets are mixed with the Blepharis maderaspatensis powder in a predefined ratio to ensure uniform distribution.

Figure 3: Mixture of PLA and herbal powder

SELECTION OF MACHINE TYPE:

As the single-screw filament extruder machine is designed to handle both PLA and Blepharis maderaspatensis powder, the working principle of a single-screw filament extruder machine involves several stages that transform raw polymer materials, into a continuous filament suitable for 3D printing.

SINGLE SCREW FILAMENT EXTRUDER MACHINE SETUP:

To fulfill the objectives of present research, work on an indigenously designed single screw filament extruder set-up has been developed. The proposed ECDT setup consists of the following sub-system. a) Hopper, b) Screw and Barrel Assembly, c) Heating Elements, d) Die and Nozzle, e) Cooling System, f) Puller or Take-Up System, g) Spooling System, h) Control Panel. These subsystems work in harmony to transform raw plastic material into a uniform filament of the desired diameter and properties. The configuration and features of single-screw filament extruder machines may vary based on the specific application and manufacturer, and additional subsystems may be incorporated for specialized processes or materials. The Figure shows the schematic diagram of single screw filament extruder set-up.

Figure.4: Single Screw Filament Extruder machine setup

Figure 5: PLA – Blepharis maderspatensis powder obtained as filament

Filament type	PLA and Blepharis maderspatensis powder blend
Thickness	1.75mm

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Figure 6: 3D printer

3D PRINTING PARAMETERS:

- Layer thickness : 0.1mm
- Nozzle temperature : 180-210°C
- Infill density : 100%
- Infill patent : Rectangle

Figure 7: 3D printed material

RESULT AND DISCUSSION:

COMPRESSION TESTING

In compression testing, a material specimen is subjected to a compressive force, and the material's reaction is measured. Finding the material's compressive strength, yield strength, and other characteristics under compressive loads is the main objective. An apparatus for compression testing is used to compress a specimen between two plates. The device measures the material's deformation or change in dimensions while progressively increasing the load.

Figure 8: Compression testing machine

Figure 9: Compressed sample of blends

MATERIAL	COMPRESSIVESTRESS
Poly(lacticacid)	62.0MPa
Poly(lacticacid) blended with Blepharis maderaspatensis powder	78.3MPa

CONCLUTION:

The blending of 485g of virgin PLA with 15g of Blepharis maderaspatensis is likely to result in an increase in compressive strength compared to pure virgin PLA. This enhancement can be attributed to improved mechanical interlocking and load-bearing capacity due to the presence of herbal powder, which may mitigate brittleness and promote toughness. In conclusion, while virgin PLA offers substantial compressive strength, its brittleness poses limitations for certain applications. By incorporating Blepharis maderaspatensis, it is possible to create a composite material that not only retains or enhances compressive strength but also improves ductility and overall performance. Further empirical testing is recommended to quantify these improvements accurately and validate the mechanical performance of this blend in practical applications.

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