



Effects of Gamma radiation on biopolymer processed by 3D printing

Karina de O. Gonçalves¹, José N. de
Almeida Jr.¹, Djalma B. Dias¹, Orlando
R. Junior¹, Solange K. Sakata¹.

¹ *karina.goncalves@ipen.br, Instituto de
Pesquisas Energéticas e Nucleares (IPEN /
CNEN - SP) Av. Professor Lineu Prestes
2242 05508-000 São Paulo, SP*

1. Introduction

The use of biopolymers for medical applications presents recent advances, as they are biocompatible and biodegradable [1]. Therefore, several applications are possible, such as grafts, tissue repairs, implants for oral applications, knee, and hip joints and for the manufacture of cardiovascular implants [2-5]. Biopolymers such as polylactic acid (PLA) can be molded, producing personalized pieces that can adapt to different parts of the body. 3D printing is a process of manufacturing objects in layers through the deposition of material, following a prototype developed on a computer, with the capacity to produce personalized parts with complex structures [6]. However, the widespread use of this technology is limited by the lack of sustainable materials for processing and biopolymers that can meet the manufacturing and performance requirements of the products. Ionizing radiation can be applied to polymers and biopolymers, promoting different effects, which can be directed to obtain materials with special characteristics [7]. One of the advantages of using ionizing radiation in the processing of these materials does not lie in the fact that this technology is considered environmentally correct, as it reduces the number of chemical additives used, volatile waste generated, and energy consumed. Therefore, the objective of this study was to print specimens with the PLA biopolymer and evaluate possible changes that radiation can cause in the properties of this printed material. To this end, we studied doses of 12, 25 and 40 kGy. The irradiation procedures were carried out at the IPEN-CNEN Radiation Technology Center in a ⁶⁰Co panoramic source. The results showed that, for the dose of 25 kGy, there is an increase in the elastic modulus of the printed bodies.

2. Methodology

2.1. 3D printing

To produce specimens made with PLA, the design was made using CAD software, following the dimensions established in the ASTM standard: D638-10 [8]. To produce the models, the Raise3D PRO2 printer was used, with the polymer in the form of a filament, in natural color and 1.75 mm in diameter. The extruder printing parameters used were heating to 205°C for PLA melting at table temperature at 60°C and speed of 50 mm/s. The 3D prints were made with two types of part infill: 15 and 50% infill.

2.2 Irradiation of 3D prints

After 3D printing, the PLA specimens were organized into groups and went to the irradiation stage in the

panoramic source using ^{60}Co as an isotope (Yoshizawa Kiko Co.) at the Radiation Technology Center (IPEN/CNEN – SP), using the following doses: 12, 25 and 40 kGy. Non-irradiated specimens were also analyzed.

2.3 Mechanical tests

To evaluate the changes caused by irradiation in 3D prints, tension/strain tests were carried out. For this purpose, the INSTRON 5567 equipment was used.

3. Results and Discussion

Mechanical tests with specimens printed with two types of filling: 15% (yellow) and 50% (blue), were evaluated after the irradiation process, in the case of the experimental groups. For statistical analysis, it was decided to print 5 specimens for each group analyzed.

The mechanical tests with the printed and irradiated and non-irradiated specimens were carried out with the purpose of analyzing whether the polymer suffered any type of change in its structure when irradiated. In Figure 1 we have photographs of the specimens with 15% (yellow) and 50% non-irradiated filling after the mechanical tests.

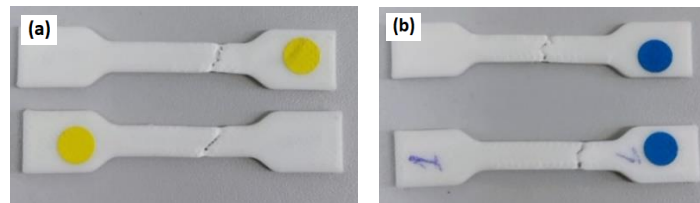


Figure 1: Samples of specimens produced by non-irradiated FDM printing, after fractures: (a) with 15% filling, (b) with 50% filling.

The tensile tests carried out are presented in Figure 2. For each test, measurements were taken of the five specimens, for each type of filling.

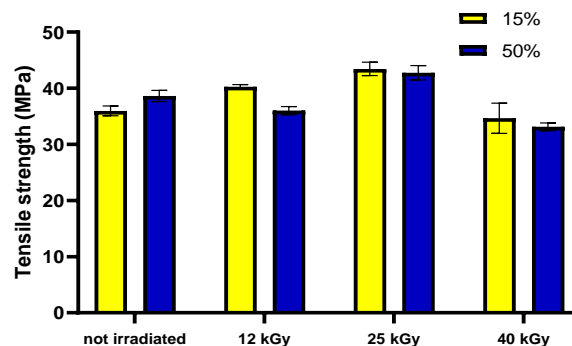


Figure 2: Tensile tests carried out with non-irradiated and irradiated specimens, showing a small increase in tensile strength for bodies irradiated with 25 kGy.

In addition to the increase in tensile strength, it was observed that, when irradiated, bodies printed with PLA also had a decrease in the elastic phase (Fig. 3).

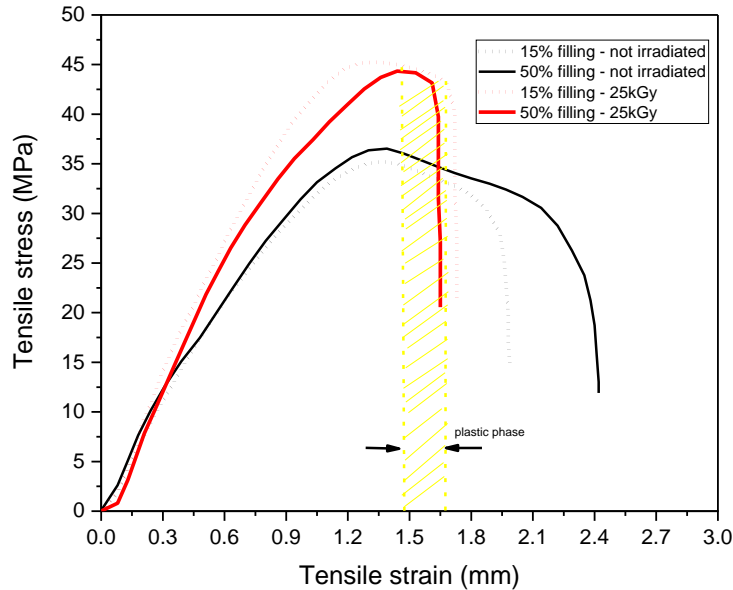


Figure 3: Graph of the tensile strength curves of non-irradiated and irradiated PLA specimens with 25 kGy. The graph also shows the decrease in the elastic phase of the irradiated bodies.

4. Conclusions

The use of ionizing radiation showed improvements in the mechanical properties of bodies printed with PLA biopolymer, which can be an alternative to the use of conventional chemical processes, in addition to also promoting, in the same process, the sterilization of the part produced, which is an important factor, when thinking about biopolymers for use as prostheses.

Acknowledgements

The Inter-Center Research IPEN/CNEN, n°: 2020.06.IPEN.39.PD.

References

- [1] U. Gowthama Prabu *et al.* “Biopolymers and composites: Properties, characterization and their applications in food, medical and pharmaceutical industries”. *Journal of Environmental Chemical Engineering*, v. 9, n. 4, pp. 105322- 105344, (2021).
- [2] S. R. Malviya, R., Prajapati, B. G., Puri, D., Limmatvapirat, S., & Sriamornsak, P. “Recent advances in biopolymer-based mucoadhesive drug delivery systems for oral application,”. *Journal of Drug Delivery Science and Technology*, vol. 91, pp. 105227- 105245, (2023).

[3] RG, Asuwin Prabu et al. “A review on the recent applications of synthetic biopolymers in 3D printing for biomedical applications”. *Journal of Materials Science: Materials in Medicine*, v. 34, n. 12, pp. 62-84, (2023).

[4] MURPHY, Caroline A. et al. “Biopolymers and polymers in the search of alternative treatments for meniscal regeneration: state of the art and future trends”. *Applied materials today*, v. 12, pp. 51-71, (2018).

[5] NOGUEIRA, Grinia M. et al. “Bovine pericardium coated with biopolymeric films as an alternative to prevent calcification: In vitro calcification and cytotoxicity results”. *Materials Science and Engineering: C*, v. 30, n. 4, pp. 575-582, (2010).

[6] LI, N. et al. “3D printing to innovate biopolymer materials for demanding applications: A review”. *Materials Today Chemistry*, v. 20, pp. 100459-100500, (2021).

[7] ASHFAQ, Aiysha et al. “Polymerization reactions and modifications of polymers by ionizing radiation”. *Polymers*, v. 12, n. 12, pp. 2877-2944, (2020).

[8] Standard Test Method for Tensile Properties of Plastics. Materials, ASTM-American Society for Testing and. West Conshohocken, PA : ASTM International, 2014. ASTM D638-10.