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# Assessing the Usability of Reusable Cartridges in Semi-Solid Extrusion 3D Printing for Pharmaceutical Drug Fabrication

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**Abstract:** Semi-solid extrusion (SSE) 3D printing is a promising technique for fabricating personalized medications. This study evaluates the usability of reusable cartridges in SSE 3D printing for drug fabrication. The research assesses the ease of use, cleaning efficiency, material compatibility, and print quality using reusable cartridges, comparing them to single-use counterparts. The findings highlight the potential of reusable cartridges to reduce waste and improve the sustainability of 3D-printed pharmaceuticals, while maintaining print quality and process efficiency.

**Keywords:** Semi-Solid Extrusion (SSE), 3D Printing, Pharmaceutical Manufacturing, Drug Fabrication, Personalized Medicine, Reusable Cartridges, Additive Manufacturing, Printability, Formulation Stability, Material Compatibility.

**Introduction:** Three-dimensional (3D) printing has emerged as a transformative technology in the pharmaceutical field, offering the potential for personalized drug delivery systems (Dumpa et al., 2021; Tracy et al., 2023; Wang et al., 2023). Among the various 3D printing techniques, semi-solid extrusion (SSE) is particularly advantageous for drug fabrication due to its ability to process a wide range of materials, including viscous formulations and temperature-sensitive drugs (Seoane-Viaño et al., 2021; Govender et al., 2021). SSE 3D printing involves extruding a semi-solid material through a nozzle to create a 3D object, allowing for precise control over the shape, size, and internal structure of the final product (Mazarura et al., 2022; Johannesson et al., 2021).

A critical aspect of SSE 3D printing is the material delivery system, typically involving cartridges that hold the semi-solid formulation. Traditionally, single-use cartridges have been employed, raising concerns about increased plastic waste and environmental impact (Elliott et al., 2020; Cowan et al., 2021). In response to these concerns, reusable cartridges have been introduced as a more sustainable alternative. However, the usability of these reusable cartridges in the context of pharmaceutical applications, where stringent hygiene and quality control are paramount, requires thorough evaluation (Parhi, 2021).

This study aims to evaluate the usability of reusable cartridges in SSE 3D printing for drug fabrication. It assesses the ease of use, cleaning efficiency, material compatibility, and print quality achievable with reusable cartridges, comparing them to single-use counterparts. The findings will provide valuable insights into the potential of reusable cartridges to enhance the sustainability of 3D-printed pharmaceuticals without compromising product quality or safety.

## METHODS

The study involved a comparative evaluation of reusable and single-use cartridges in SSE 3D printing. The following methods were employed:

1. Materials: A range of semi-solid formulations

with varying viscosities and compositions, were used. representative of typical pharmaceutical materials,

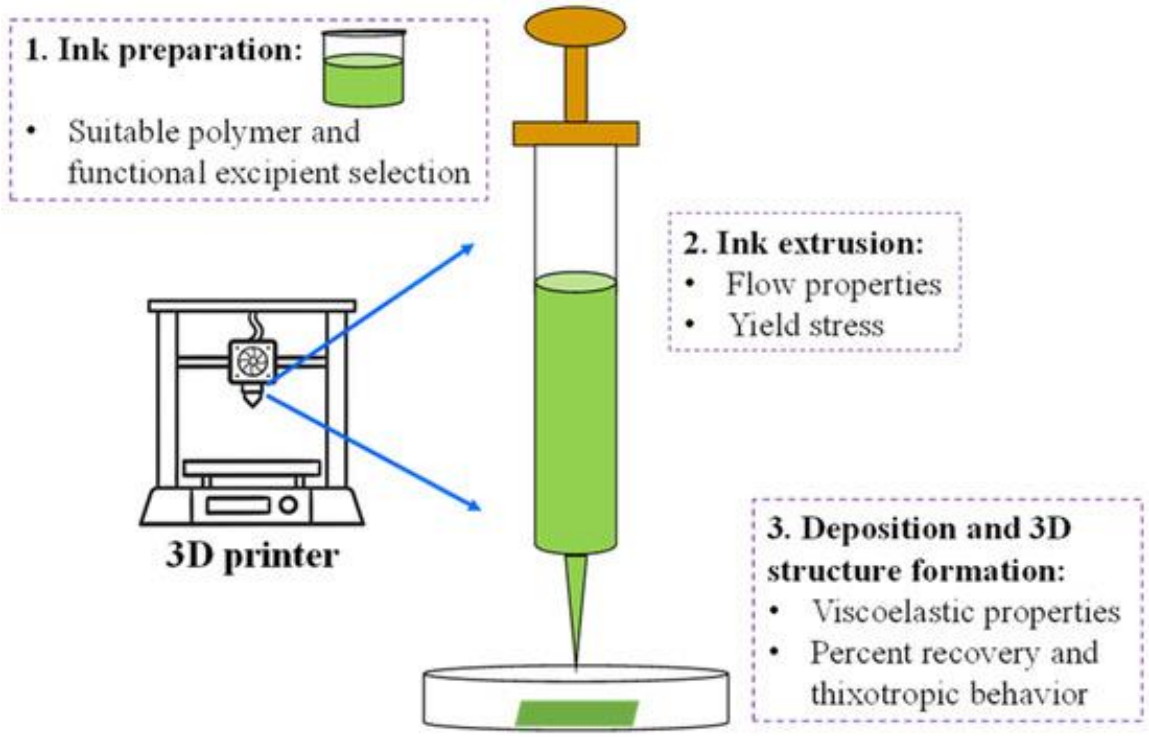


**Fig. Schematic presentation of the steps involved in the pressure-assisted microsyringe (PAM)-type extrusion-based 3D printing process.**

2. 3D Printing System: A commercially available SSE 3D printer was used, equipped with both reusable and single-use cartridge systems.

3. Usability Assessment:

o Ease of Use: The ease of filling, assembly, and disassembly of both cartridge types was evaluated through user trials with trained technicians.

o Cleaning Efficiency: A standardized cleaning protocol was developed, and the effectiveness of cleaning procedures for reusable cartridges was assessed using visual inspection and residual material analysis.

o Material Compatibility: The chemical compatibility of cartridge materials with the selected formulations was assessed to ensure no degradation or leaching occurred.

o Print Quality: The dimensional accuracy, uniformity, and structural integrity of printed objects were evaluated using techniques such as microscopy and texture analysis.

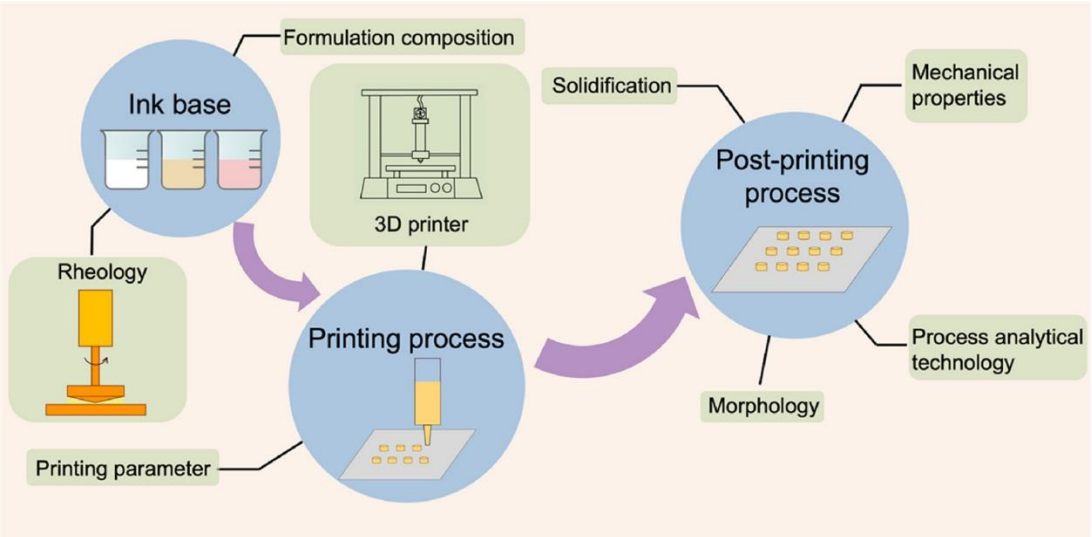


**Fig. Lessons to learn for 3D printing of drug products by semisolid extrusion (SSE)**

4. Regulatory Considerations: The study considered the regulatory perspectives on 3D printing in pharmaceuticals, particularly regarding the use of reusable components and potential cross-contamination risks (Khairuzzaman, 2018).

**RESULTS**

The results of the study indicate the following:

- Ease of Use: Reusable cartridges were found to be slightly more complex to assemble and disassemble compared to single-use cartridges. However, with proper training, the process was manageable.
- Cleaning Efficiency: The established cleaning protocol effectively removed residual material from the reusable cartridges, with no significant carryover observed.
- Material Compatibility: The cartridge materials exhibited good compatibility with the tested formulations, showing no signs of degradation or leaching.
- Print Quality: The print quality achieved with reusable cartridges was comparable to that of single-use cartridges, with no significant differences in dimensional accuracy, uniformity, or structural integrity.

**DISCUSSION**

The findings suggest that reusable cartridges offer a viable alternative to single-use cartridges in SSE 3D printing for drug fabrication. While there may be a slight increase in complexity regarding assembly and disassembly, the cleaning protocols can be effective in preventing cross-contamination.

The adoption of reusable cartridges can significantly reduce plastic waste, aligning with the growing emphasis on sustainability in pharmaceutical manufacturing (Kasznik & Łapniewska, 2023). The economic benefits of reduced material consumption and waste disposal costs further support their implementation.

It is crucial to adhere to stringent cleaning and sterilization procedures to mitigate the risk of cross-contamination, especially when processing different drug formulations. Further research is needed to optimize cartridge design and cleaning protocols, and to address long-term durability and performance.

**CONCLUSION**

Reusable cartridges present a promising approach to enhance the sustainability of SSE 3D printing for drug fabrication. With proper handling and cleaning procedures, they can effectively replace single-use cartridges without compromising print quality or safety. The adoption of this technology can contribute to a more environmentally friendly and economically viable approach to personalized medicine.

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