3D Printing MicroFactory

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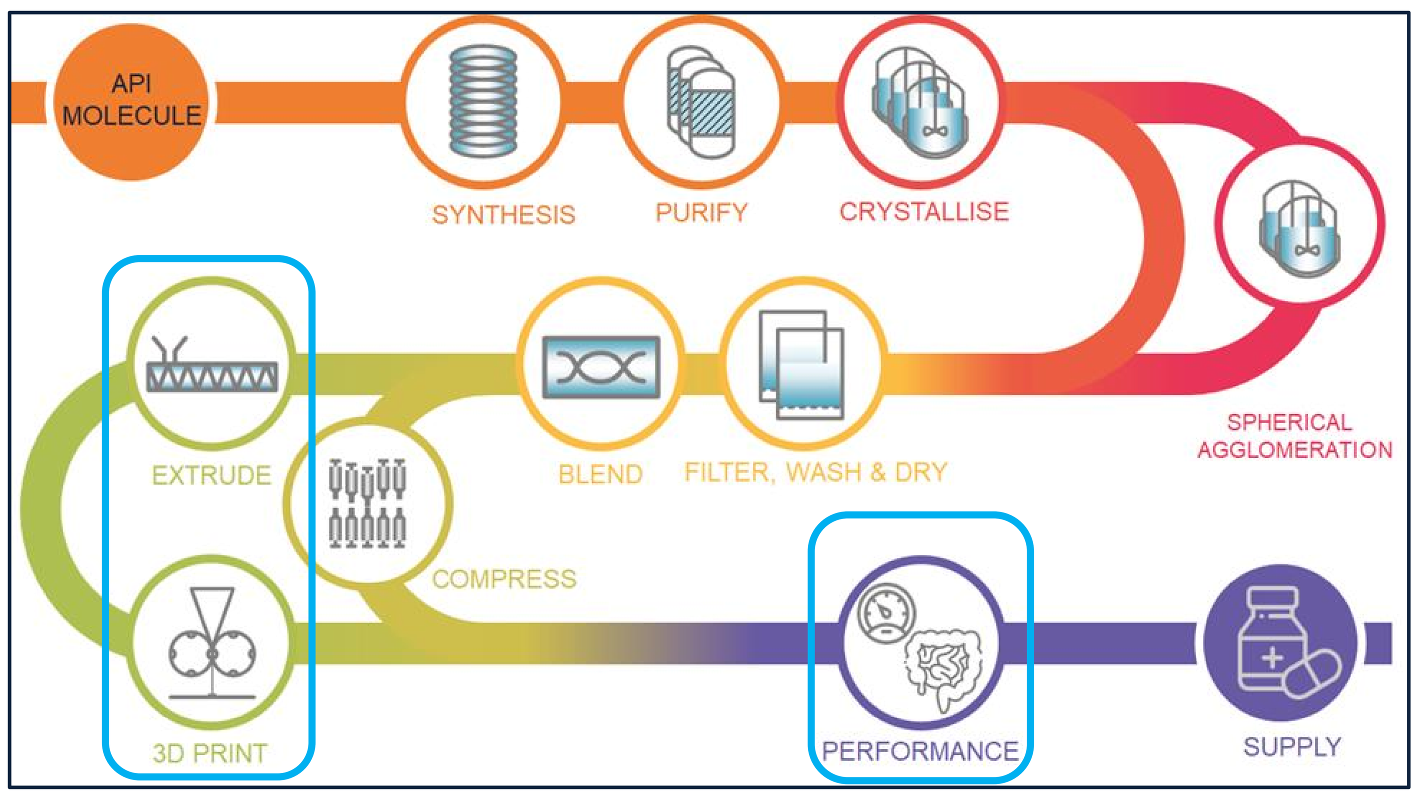
Context and Aim of Work

The aim of the HUB MicroFactory is to develop a continuous end to end process with as little material as possible.

The aims of this work are

- to identify and overcome limitations of pharmaceutical formulations for 3D printing,
- to implement an **Additive Manufacturing MicroFactory**,
- to define the operating space of a novel, filament free 3D Printer.



Linking HME with 3D printing

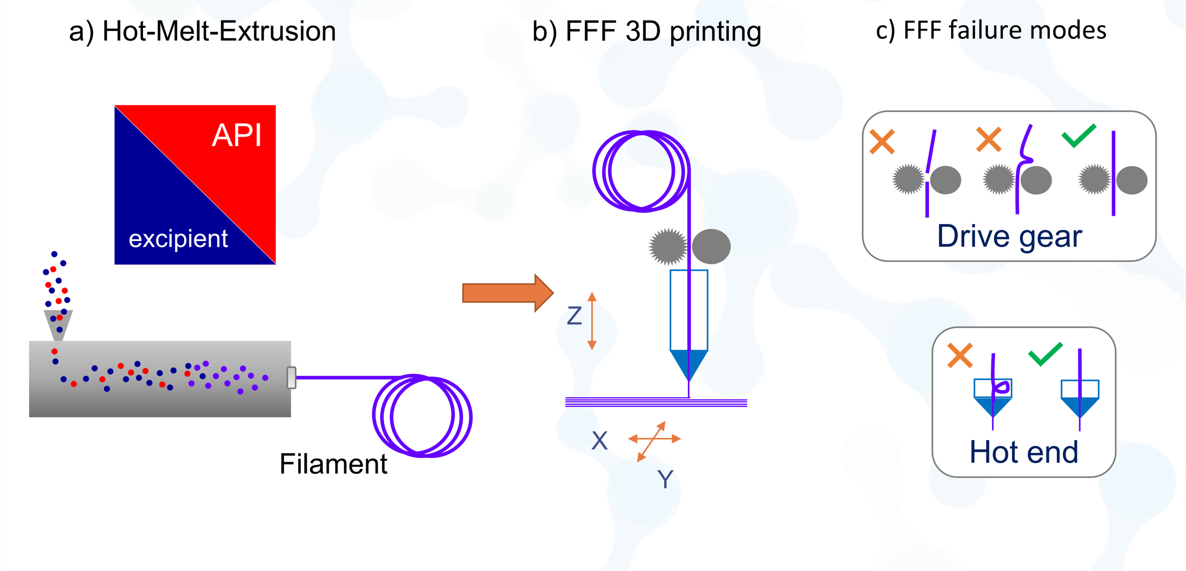


Figure 1: Linking HME (a) to FFF 3D printing (b). Failure modes of filaments in drive gear or hot end of 3D printer (c).

Non-printable Formulation

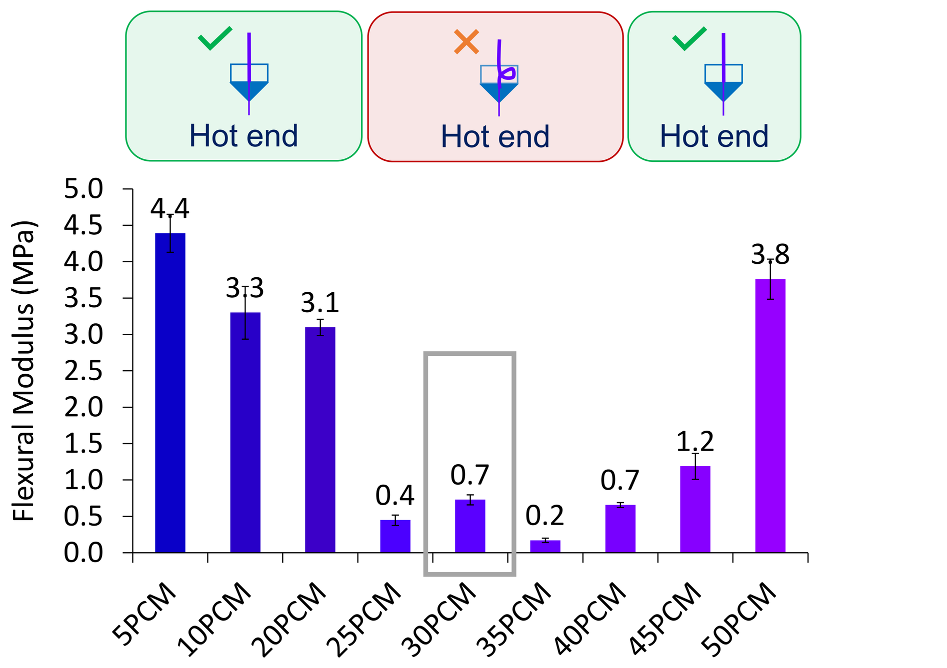


Figure 2: Flexural modulus of 5 – 50% w/w Paracetamol in Affinisol™ 15LV filaments for FDM 3D printing [1]. Associated filament failure modes are indicated.

Filament Free Printing

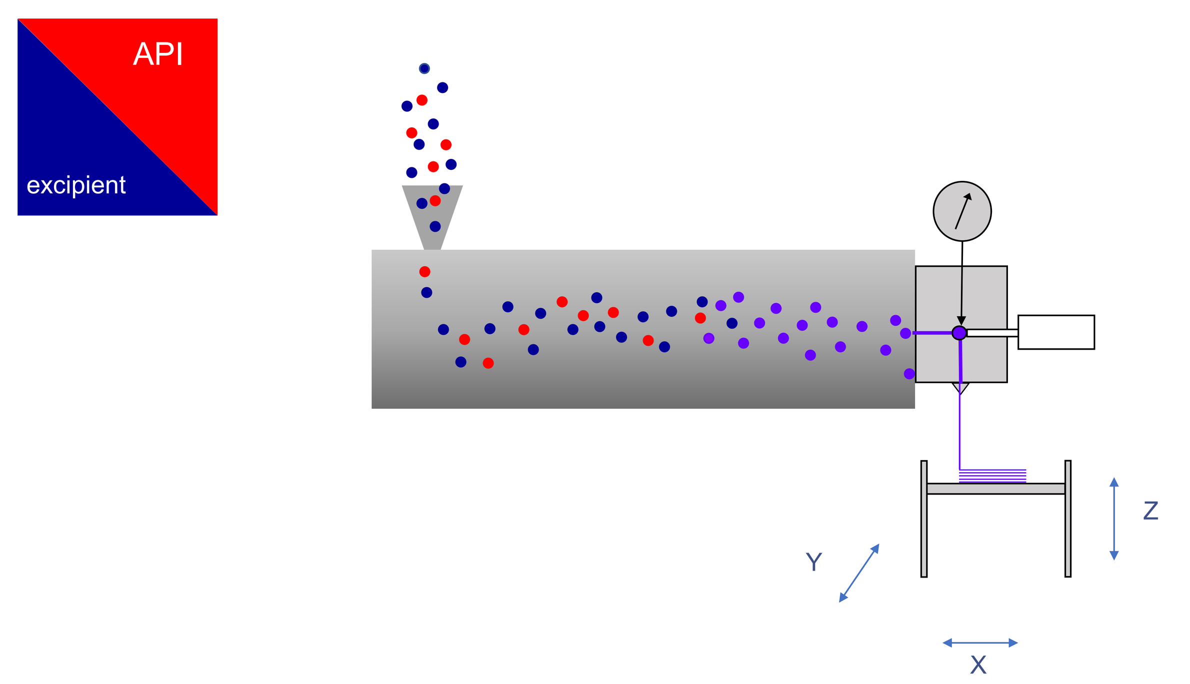


Figure 3: Schematic of Novel filament free Hot-Melt-Extrusion 3D printer.

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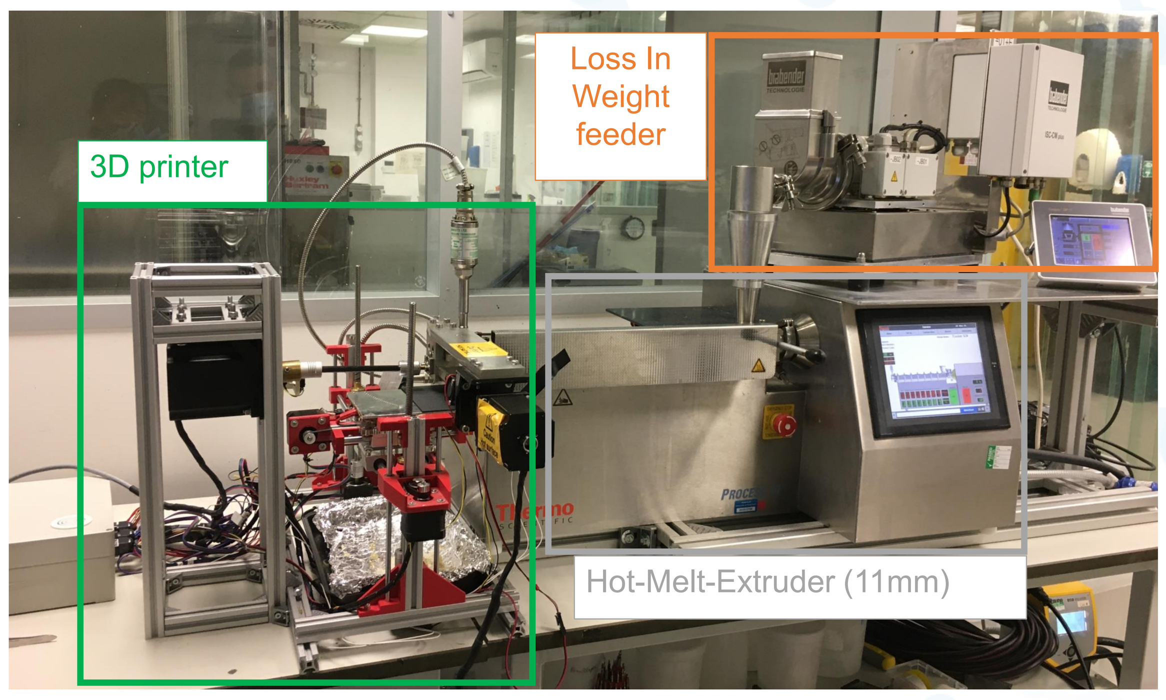

Figure 4: Novel filament free Hot-Melt-Extrusion 3D printer: Loss in Weight Feeder, HME (Process 11, Thermo Fisher) and 3D printer unit.

Rheology screening

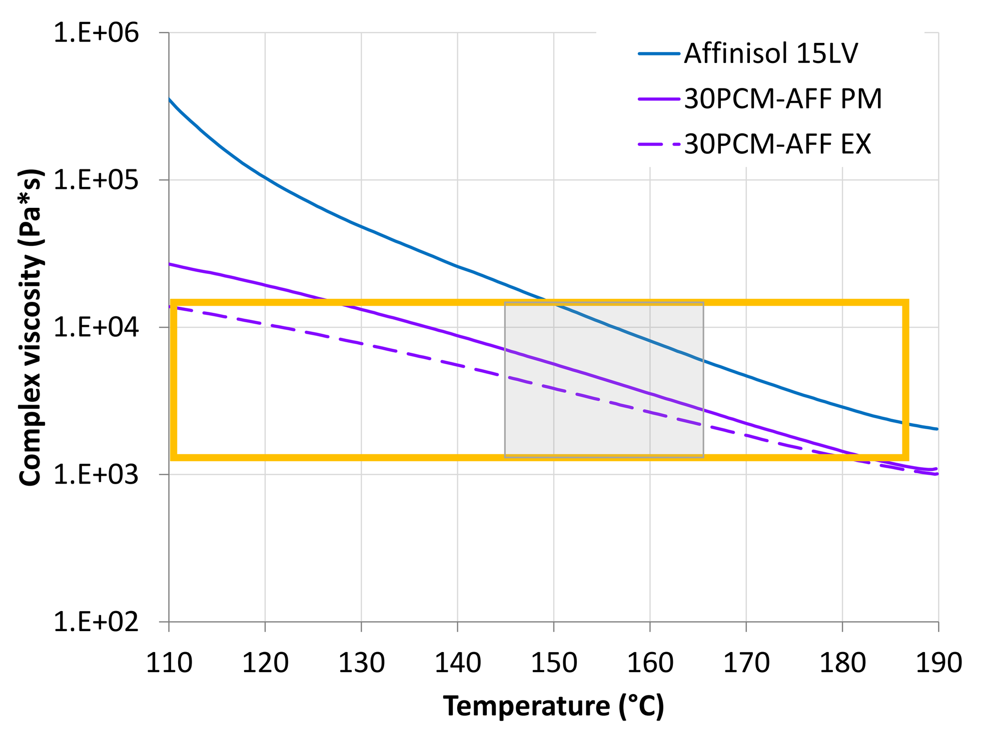

Figure 5: Oscillatory Temperature Sweep: Complex viscosity versus temperature of Affinisol™ 15LV (AFF) and 30% w/w Paracetamol – Affinisol™ 15LV (30PCM-AFF) physical mixture (PM) and extrudate (EX). Ideal viscosity range shaded yellow.

Operating space: Layer height

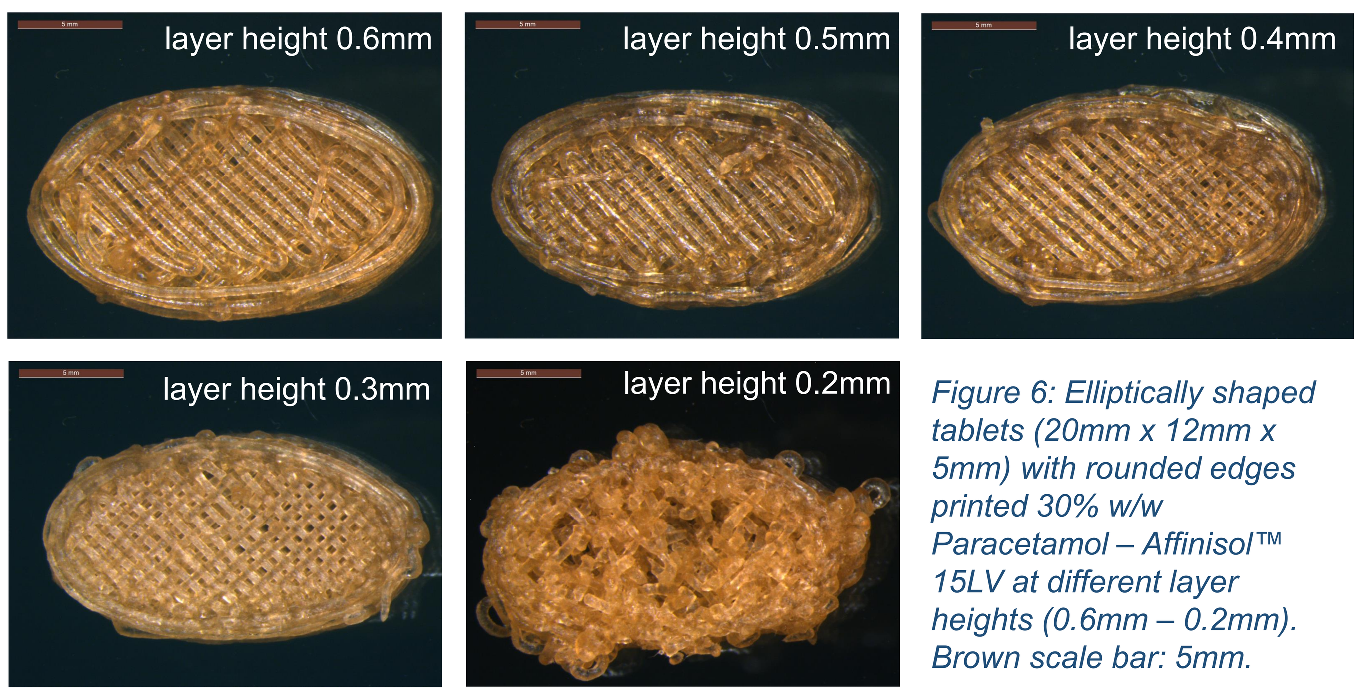

Figure 6: Elliptically shaped tablets (20mm x 12mm x 5mm) with rounded edges printed 30% w/w Paracetamol – Affinisol™ 15LV at different layer heights (0.6mm – 0.2mm). Brown scale bar: 5mm.

Process data

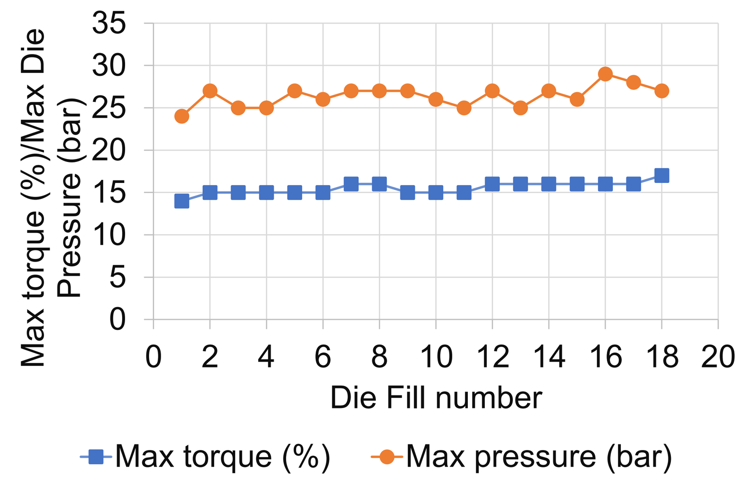

Figure 7: Process data from MicroFactory operated at 165°C. Orange circles: maximum die pressure (bar) during die fill; blue squares – Max torque (%) during die fill.

Table 1: Average, standard deviation (stdev) and relative standard deviation (%RSD) of weight, width and thickness of tablets from Fig.6.

Print	weight (mg)	width (mm)	thickness (mm)
average	388.04	12.60	3.87
stdev	6.16	0.11	0.07
%RSD	**1.59**	**0.91**	**1.94**

Tablet mass versus Infill %

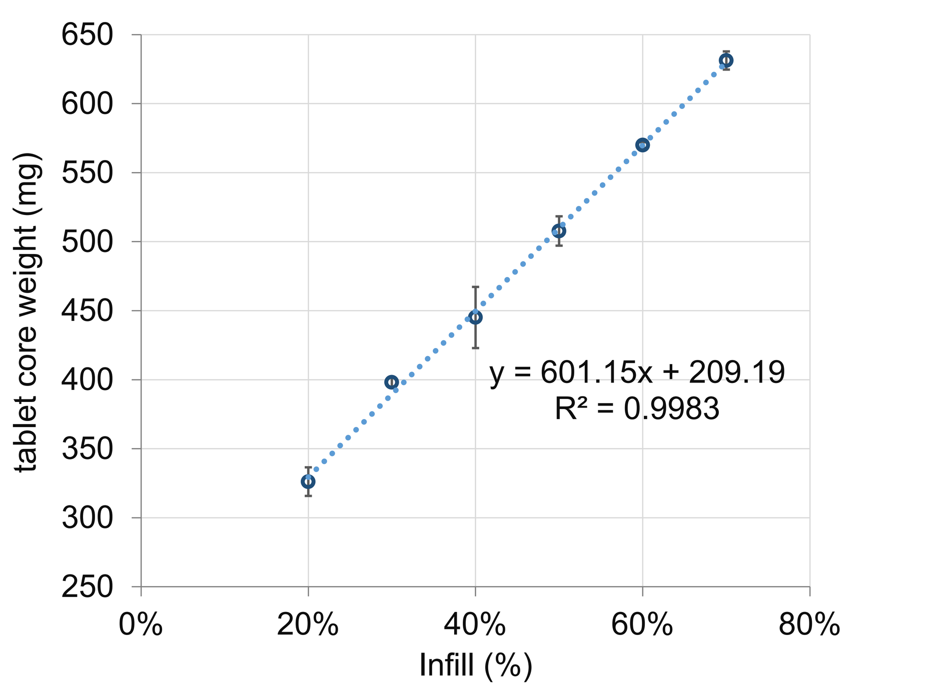

Figure 8: Tablet core weight versus infill % of elliptically shaped tablets (20mm x 12mm x 5mm) with rounded edges printed with 30% w/w Paracetamol – Affinisol™ 15LV at 0.4mm layer height (n=3).

Tablet Infill: 20 – 70 %

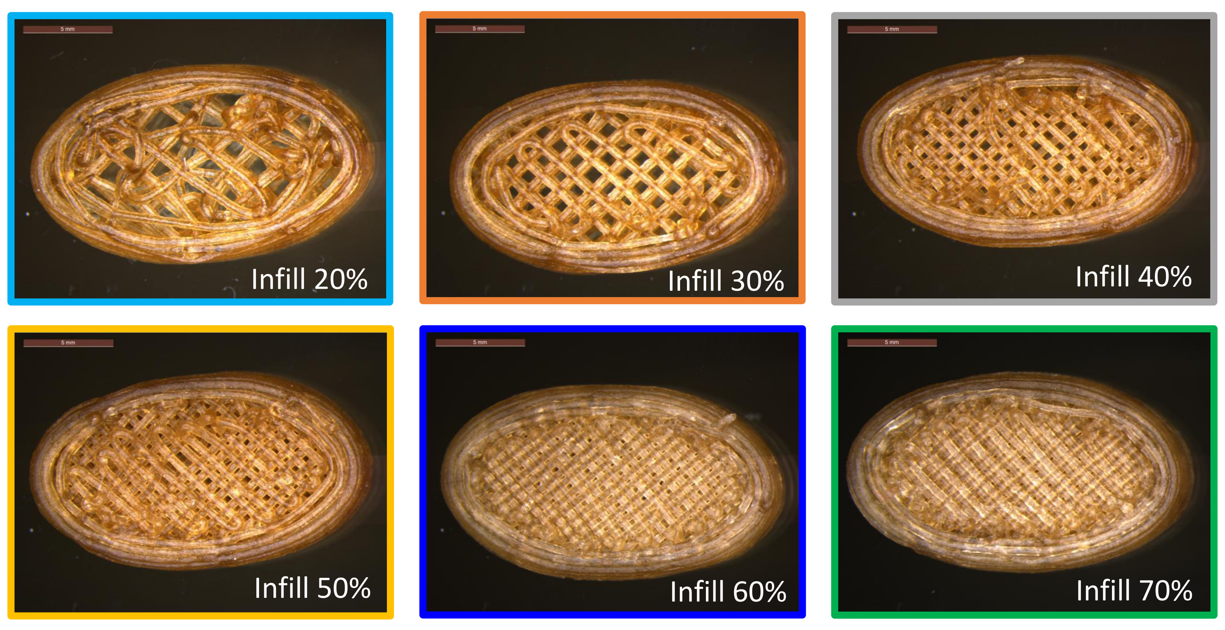

Figure 9: Elliptically shaped tablets (20mm x 12mm x 5mm) with rounded edges printed 30% w/w Paracetamol – Affinisol™ 15LV at layer height 0.4mm with Infill % ranging from 20% – 70%. Brown scale bar: 5mm.

Infill % versus Performance

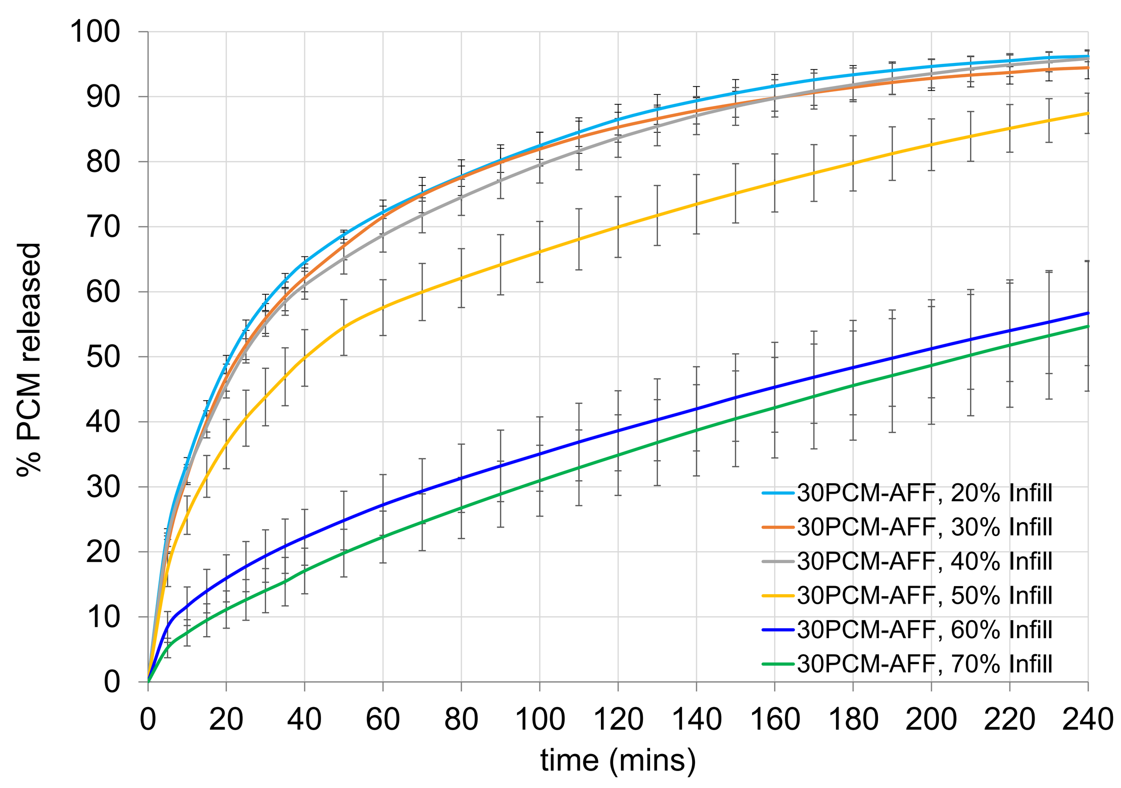

Figure 10: % PCM released versus time for 30PCM-AFF 3D printed tablets with 20 (blue), 30 (orange), 40 (grey), 50 (yellow), 60 (royal blue) and 70% (green) Infill.

References

1. Prasad, E., M. T. Islam, D. J. Goodwin, A. J. Megarry, G. W. Halbert, A. J. Florence and J. Robertson (2019). "Development of a hot-melt extrusion (HME) process to produce drug loaded Affinisol™ 15LV filaments for fused filament fabrication (FFF) 3D printing." Additive Manufacturing 29: 100776.
2. Prasad, E., J. Robertson, A. J. Florence and G. W. Halbert (2023). "Expanding the pharmaceutical formulation space in material extrusion 3D printing applications." Additive Manufacturing: 103803.

Conclusion

Limitations of pharmaceutical formulations for FFF have been identified and characterised. By implementing a novel integrated HME-3D printer, an intermediate feedstock filament in an FDM process is no longer required. This opens up the formulation space highly plasticised polymers in 3D printing of pharmaceutical dosage forms.

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