3D printing technology: Supply chain independent single-use plastic ware and bioreactors for cell culture

Lena Achleitner

Peter Satzer

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Emergent:
3D printing technology for cell culture

Lena Achleitner¹, ², Peter Satzer ²
¹ acib - Austrian Centre of Industrial Biotechnology, Muthgasse 11, Vienna, RG Alois Jungbauer
² Department of Biotechnology, Institute of Bioprocess Engineering, University of Natural Resources and Life Sciences, Vienna (BOKU), Muthgasse 18, 1190 Vienna, Austria
Emergent → Sustainability

- Emergent technologies should be researched in a sustainable manner
- Moving life science towards a sustainable circular economy
Sustainability – Numbers

13x more plastic waste than a household
- Life science worldwide produces 5.5 million tons plastic/year
- India produces 3 mio tons plastic

65x more electricity than a household
- 60 MWh per year for autoclaving (25 researchers)
- 1800 m³ of water

*values for an R&D lab with 25 people
Sustainability – Problem

- Waste Treatment
- Energy consumption
- Supply chain dependence
- Material sources
Emergent technology – 3D Printing

- Biodegradable materials
- Raw material storage
- Distributed manufacturing
- Supply chain independence
- Biosourced materials
Emergent technology – 3D Printing

3D printing with FDM

- Technology: melting and extruding
- Materials: thermoplastics
- Layer height: >50 µm
- Nozzle size: >100 µm
3D printing technology for cell culture

- GMP printing material
- GMP printing process
- Legal framework from authorities
- Scale up
- Extractable and leachable components (bioactive and not bioactive)
Previous research

- Successful cultivation of different cells in 3D printed SFs
- PLA performs equally well as commercially available product
- PLA SFs can be autoclaved
3D printed bioreactor

- Geometric freedom for design of new reactor vessels and types
- Additional printed parts with geometric freedom (stirrer, baffles etc.)

Advantages:
- Direct connection to CFD
- Direct connection to a digital twin
- Digital transferability

→ Open-source bioreactor: hardware and software
3D printed bioreactor

- Geometric freedom for design of new reactor vessels and types
- Fit into conventional system – Eppendorf DASGIP
Characterizing 3D printed BR – Temperature sensitivity

Mammalian cells (Temperature 37°C → 32°C)

Insect cells (Temperature 27°C → 22°C)
Characterizing 3D printed BR – kLa measurements

Mammalian cells (3 SLPH, 200 rpm, 37 °C)  Insect cells (0.3 SLPH, 200 rpm, 27 °C)
Sterilization

• Autoclaving: depends on material, printing settings and geometry
  • Works for SF
  • Does not work for larger objects
• Sterilization with Propan-2-ol: low throughput
Sterilization
Sterilization

- Autoclavation: depends on material, printing settings and geometry
- Sterilization with Propan-2-ol: low throughput
- Sterile printing: best and most sustainable option
  - UHT pasteurization: 138 °C for 2s
  - Printing: 190-240 °C for 10-120 s
  - Sterile printing saves 100% water
  - Reduces energy costs by 95%
## Cost Analysis – Q2 2023

<table>
<thead>
<tr>
<th></th>
<th>3D printed SF</th>
<th>Commercially available SU-SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs per piece</td>
<td>~0.6€¹</td>
<td>~10 €²</td>
</tr>
<tr>
<td>Demand per week</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Costs per week</td>
<td>€ 12,-</td>
<td>€ 200,-</td>
</tr>
<tr>
<td>Production time</td>
<td>10 days</td>
<td>2.5 days (1 h)</td>
</tr>
<tr>
<td>Printers</td>
<td>2 (€ 1500)</td>
<td>1 (€ 170)</td>
</tr>
<tr>
<td>Break-even</td>
<td>5.4 weeks (107 SF)</td>
<td>1 week (19 SF)</td>
</tr>
</tbody>
</table>

*Sterilisation is not considered*

¹ PLA, ² List pricing
## Cost Analysis – Q2 2023

<table>
<thead>
<tr>
<th></th>
<th>3D printed SF</th>
<th>Commercially available MU-SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand per week</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Sterilisation</td>
<td>Sterile printing</td>
<td>Autoclaving</td>
</tr>
<tr>
<td>Duration</td>
<td>20 h laminar flow hood</td>
<td>1 autoclaving cycle</td>
</tr>
<tr>
<td>Energy</td>
<td>~6.8 kWh</td>
<td>~80 kWh</td>
</tr>
<tr>
<td>Water</td>
<td>0 L</td>
<td>150 L</td>
</tr>
</tbody>
</table>

*Manufacturing of MU-SF is not considered*
Applications

• R&D purpose
• Rapid prototyping of new unit operations
• Low-income laboratories
• Sustainable laboratories
• Remote, rural areas
• Non pharmaceutical products
Contact Details

Lena Achleitner
acib – Austrian centre of industrial biotechnology
University of Natural Resources and Life Sciences, Vienna
Email: lenaachleitner@acib.at
@Lena Achleitner

Peter Satzer
acib – Austrian centre of industrial biotechnology
University of Natural Resources and Life Sciences, Vienna
Email: peter.satzer@boku.ac.at
@Peter Satzer
The Vision

- GMP printing material
- GMP validated printing process
- 3D printing is established in R&D
- Framework for 3D printing at authorities
- Compostable bioprocess
This PhD thesis is part of the acib project “Next generation virus, VLP, exosome and cell downstream processing” and funded by 3M
Sources

p.3: https://greenlabsaustria.at/
p.17,18: https://www.laborjournal.de/editorials/2593.php