EXTENSION

3-D Printed Parts for Food Contact

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Introduction

The purpose of this fact sheet is to help the reader make informed choices for 3-D printed parts used in food processing.

Many 3-D printing technologies have been developed to make parts and equipment. This fact sheet focuses on FDM (Fused Deposition Modeling) or FFF (Fused Filament Deposition) print technology because of its popularity, accessibility and variety of filaments available. Choices discussed include feedstock material selection (for FDM the feedstock material is in filament form), filament use, part design and post-processing of parts. Helpful tips for printing parts for food contact services are also provided.

Filament Selection

Composition of filaments must be approved for food contact and meet the design conditions listed in the “part design” section below. Table 1 (adapted from Formlabs, 2020) shows a list of filaments meeting FDA requirements for food contact. An FDA status of “compliant” means that the material meets requirements for food contact, but has not been expressly approved.

Guide to Filament Use

Excessive moisture in the filament is a major cause of print failure, and it is very difficult to identify. Filament spools should be stored in a moisture free environment. If possible, maintain the original packaging. While loading the filament spool on FDM/FFF printers, make sure it is loaded according to provided instructions. Load the filament spool only when the printer is ready to print. Immediately store the used filament spool in an airtight box, and include a desiccant pack for extra protection.

Part Design

Three broad categories should be considered when designing 3-D printed parts that are involved in processing food: printability, cleanability and durability. The three categories are briefly discussed in this section.

Printability

3-D printing processes build parts layer-by-layer and unique geometries can be printed with ease. There are some important design rules that must be considered before printing parts. The successful print will be a combination of a good surface finish and dimensional accuracy with the desired functional properties.

In 3-D printing, printability is most often linked with the geometric design. The majority of print failures are associated with design features. Examples of important design features for FDM/ FFF include supports, overhangs, horizontal bridges, supported and unsupported vertical walls, holes, connecting and moving parts, minimum features and pin diameter tolerances. Key design considerations for 3-D printing are described by Brockotter (2021), available at: https://www.hubs.com/knowledge-base/key-design-considerations-3d-printing/.

Slicing is the next step after developing a printable geometric design. Slicing software helps to determine the best orientation for the part on the print bed. In addition, the build direction, hole orientation, support structure, shell and infill type and percentage are important aspects of preparing the print file. After these factors are considered, the print file is fed into the model and the user sets up the printing parameters. The most important printing parameters are bed temperature (to avoid warping), extruder temperature (optimized to print filament materials) and build layer thickness.

When considering the 3-D printing guidance given above, the user will achieve a successful print that ultimately provides the expected surface finish, dimensional accuracy and the desired functional properties.

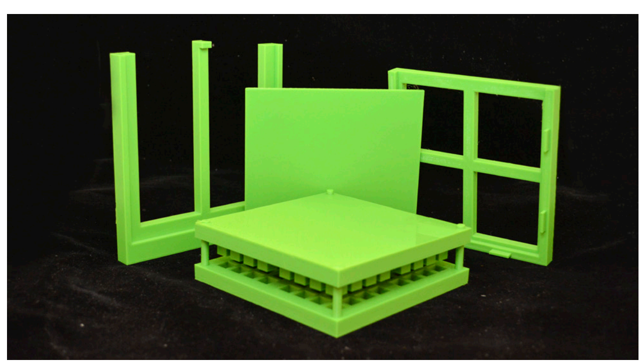

Figure 1. A mold printed in Dr. Vora's lab.

Table 1. Filaments that are rated for use in food-contact applications.

Filament	Brand	FDA Status	Smoothable	Dish-washer safe	Hot liquids
ABS	Adwire PRO	Approved	Yes, acetone	Yes	Yes
ABS	Innofil3D	Approved except red, orange, and pink	Yes, acetone	Yes	Yes
Co-Polyester	Colorfabb XT	Approved	No	Yes	Yes
HIPS	Easyfil	Compliant	Yes, d-limonene	Yes	No
HIPS	InnoFil3D	Approved	Yes, d-limonene	Yes	No
Nylon	Taulman Nylon 680	Compliant		No	No
PEI	ULTEM® 1000	Compliant		Yes	Yes
PET	InnoPet EPR	Approved except red and orange	Yes, ethyl acetate	No	No
PET	Refil	Approved	Yes, ethyl acetate	No	No
PET	Taulman T-Glase	Approved	Yes, ethyl acetate	No	No
PET	Verbatim	Compliant	Yes, ethyl acetate	No	No
PET-G	HDGlass	Approved	Yes, ethyl acetate	No	No
PLA	Filaments.ca TrueFS	Approved	No	No	No
PLA	Innofil3D	Approved except red, orange, pink, apricot skin, grey, and magenta	No	No	No
PLA	Copper3D PLActive Antibacterial	Approved	No	No	No
PLA	Makergeeks	Approved	No	No	No
PLA	Purement Antibacterial	Approved	No	No	No
PLA-HT	Makergeeks Raptor	Approved	No	Yes	Yes
PLA-HT	Makergeeks Raptor	Approved	No	Yes	Yes
PP	Centaur	Compliant	No	Yes	Yes
PP	InnoFil3D	Approved	No	Yes	Yes
PP	Nunus	Compliant	No	Yes	Yes
PP	Verbatim	Compliant	No	Yes	Yes

Cleanability

Cleanability may not be an issue if the part is designed for single-use. Single-use parts (like plastic tableware) are expected to be thrown away after one use. Single-use parts may be economical and efficient when a means of cleaning is not available, or cleaning is expensive. Multi-use parts used in food processing must be cleanable to a microbiological level. The following design principles will help maintain cleanability of 3-D printed parts (AMI, 2008; Schmidt and Erickson, 2017):

- Maintain smooth and crevice free surfaces (eliminate niches, cracks pits, seams, gaps, hollow areas, threads, etc., where soils may collect)
- Design parts for simple assembly and disassembly to facilitate cleaning
- Surface coatings (if present) must not pit, flake or chip
- Round internal angles to at least ¼" radii
- Maintain visibility of surfaces for accessibility and cleaning
- Slope surfaces for self-drainage. Accumulated liquids may promote bacterial growth

Washing 3-D printed parts in high-temperature water could cause damage (based on the material properties of the part). When possible, use lukewarm water and mild detergents for cleaning. Parts may be sanitized, using a compatible chemical, such as alcohol.

Durability

Durability of the 3-D printed parts depends on four major factors: (i) type of filament material, (ii) part geometry, (iii) print process, and (iv) use. Of these four, the user needs to pay extra attention to selecting the correct filament material to achieve the desired functional properties for the applications in mind. Trial and error are generally needed for filament selection.

Post Processing of Parts

Post processing of parts refers to work done on the part after the printing is complete. Many parts will require one or more of the following operations:

- Residue removal
- Support removal
- Polishing
- Chemical smoothing. Chemical smoothing is possible by using solvents such as d-Limonene, acetone and ethyl acetate.

Some parts may be coated with a food-safe material to enable their use in food processing. A list of food-safe coatings (with FDA approval for food contact) follows:

1. Epoxy
   - ArtResin Epoxy Resin
   - Permabond 2-part epoxies ET5143, ET5145, ET5147 (Permabond, 2020)
   - Masterbond EP42HT-2FG
   - Max Clear Grade Epoxy Resin System
   - ZDSticky Epoxy Resin
2. Shellac: Zinsser Bulls Eye Shellac
3. Wax
   - Howard Wax-It-All
   - Parowax
4. Polyurethane
   - AcriGlaze Safecoat
   - Masterbond EP42HT-2FG
   - PTFE (Teflon®)

Tips for Printing Parts for Food Contact

1. Avoid cross-contamination from residues of previously printed parts.
2. Consider leaching from print heads. Some brass print nozzles may contain lead.
3. When cleaning parts and assemblies in a dishwasher, determine if the material can handle the temperatures. Turning off the dishwasher's drying cycle may help.
4. Use 3-D printed shapes to make a mold for other materials that may be more suitable for food-contact.
5. Print at the lowest layer height to avoid narrow crevices between layers.
6. Check into printing of ceramic parts using technology such as Direct Ink Writing (DIW) that can be glazed and fired prior to use in a food contact operation.

Conclusion

Printing 3-D parts for food contact applications can be an excellent means to manage spare parts, increase system uptime and reduce waste. It can also be a convenient and rapid means of prototyping custom parts and equipment. Making informed choices on part design and execution will help improve success rates. The cost of 3-D printing has continuously dropped, while the familiarity and ease of use has improved. Make it a goal to incorporate 3-D printing technology in your food processing operation. Contact fapc@okstate.edu for assistance or additional information.

> With a 3D printer on-site, organizations are going to be more nimble, with less downtime and less waste.
> *Matt Gannon, VP of Operations, Markforged.*

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