

## 3D Printing-The Future In Culinary Arts!

*Dr. Jyoti Peshave, Associate Professor  
Bharati Vidyapeeth ( Deemed to be University)  
Institute of Hotel Management & Catering Technology, Pune*

*Ms. Awanti Hodlur, Associate Professor  
Bharati Vidyapeeth ( Deemed to be University)  
Institute of Hotel Management & Catering Technology, Pune*

### Introduction:

3D printed food is a meal prepared through an automated additive process. It is commonly known as additive manufacturing which is the process of creating three dimensional solid objects with high accuracy and quality finishing in their dimensions. The products are created layer by layer producing complex and intricate shapes fairly quick with quiet less ingredients than traditional manufacturing techniques. It can be widely adapted in areas such as customized and personalized food designs and nutrition, simplified supply chain with available food resources.

These foods are basically edible ingredients processed in such a way that they can be extruded through a nozzle onto a surface. The presentation of these foods is the key difference with respect to conventional food presentations. 3D printed foods can be created in complex, intricate and geometric patterns with enhanced nutrition and genuine flavors that are difficult to process manually or may require lot of time to create.

It is considered as a ground-breaking technology that can improve the nutritional value of meals taking care of hunger issues in countries where fresh and inexpensive ingredients are remotely available. Any individual meals comprises of certain set of ingredients with appropriate nutritional values. The goal of adopting this technology is to make food production more effectual and sustainable.

This technology has been developed since 1980 and incorporated in fields like aviation, automotive, engineering, construction, packaging, pharmaceuticals, military and the field of culinary.

The first 3D printed machine was built in 1983 and since this technology is fairly new, it still has a long way to go before it's universally accepted. The idea of pizza vending machines way back in 2015 can be considered as a primitive 3D printing food process wherein, the dough was prepared, extruded, topped with tomato sauce and cheese, and finally baked in the oven. Looking ahead in the year 2021 and we have elite 3D printing food restaurants with various types of food printers available to meet the demand of this rapid growth in both technology and people's interest. Sooner there is a possibility that these printers will be seen in almost all household kitchens as a part of kitchen equipment's.

3D printing is a technique used for the manufacture of three-dimensional objects with high accuracy and quality finishing in their dimensions. The technique finds applications in industries, 3D printing products and services are expected to take leap over \$425 million U.S. dollars by 2025 with an estimated growth rate of 26.4% every year from 2020 to 2040 as per STATISTA.

The cost of 3D printers has rapidly declined since the invention of the technology, allowing more benefits to the consumers and manufacturers. Few examples of manufacturers and restaurants practicing 3D printing are:

A fine dining restaurant in London - Food Ink has everything including food, décor, plates, tables with 3D printing theme.

A Spanish gourmet restaurant-Miramar serves food printed dishes allowing chefs to focus on their creativity. A company named Smooth Food serves 3D printed meals to more than 1,000 German nursing homes comprising of extruded foods like pork, chicken, pasta, potatoes, and peas puree that are easily printed and easy for chewing and swallowing for the older people. Thus, the 3D printed foods becomes visually appealing and appetizing.

NASA awarded a Small Business Innovation Research (SBIR) Phase I contract to a Texas based company for exploring the potential for printing food in space missions to transform bulk foods into modest size. Renowned Food Designer Chloé Rutzerveld and her Edible Growth project has come up with additive manufacturing creating “edible ecosystems” i.e. an edible mini garden. Kate Sullivan, an owner of Cake Power from New York makes specialized chocolate molds on 3D printers.

Hershey’s prints candies that are uniquely designed with a plastic printer.

PepsiCo creates colored potato chips to generate plastic prototypes with 3D printers.

Barilla manufactured a variety of differently shaped pasta, facilitating the customers to 3D print their own pasta designs quickly and easily.

Oreo created cookies using 3D printers with custom-made cream flavors and patterns

Tailor made chocolate and cookies are the most demanding products in the 3D printed food market having a significant growth. CSM Bakery Solutions and 3D Systems Corporation in collaboration have been developing and distributing 3D printers, products and materials for the food industry.

AlgaVia, a San Francisco based company has developed a protein powder utilizing a microalgae with preferred characteristics like non-allergenic, high source dietary fiber and gluten-free..

A Belgium based Chocolate factory’ Miam “uses four specialty 3D printers to create ready-to-eat delicious edibles from milk, dark and white chocolate. The Miam Factory also created 3D printed chocolate beer bottles as award following an Easter egg hunt.

A Ukrainian based pastry chef uses 3D printing to produce unique spherical cake molds that are made of food-safe silicone

Barry Callebaut-a Zurich-based high-quality chocolate manufacturer of cocoa products, has a 3D printing studio making personalized 3D printed chocolates on a large scale. It has tied up with a global brand Mona Lisa’s Pastry chefs- Jordi Roca to create ‘Flor de Cacao,’ a master 3D piece made out of chocolate. It signifies a cocoa bean that opens up like a cacao flower after getting in touch with hot chocolate sauce.

Novameat has developed 3D printed meat using printable plant-based materials that has taste, smell, and texture of real meat.

The Beehex Company prints 12-inch pizzas under five minutes which is ideal for use in space and in potential pizza outlets and takeaways.

Sushi Singularity a restaurant in Tokyo, Japan shares with guests a health test kit that assesses guests unique biometrics nutritional needs, allowing them to use tailored 3D printers to serve a personalized meal.

Choc Edge has 3D printer with two versions that can make all types of chocolate designs. The 3Drag printer uses technology (FD) that can almost print any chocolate design that the customer desires.

The Sugar Lab from 3D Systems has developed 3D printers specialized in printing of creative 3D shapes sugar candies.

A design company KinneirDufort printed a “face pancake” .

Hellmann’s a mayonnaise manufacturer offered customers the option to 3D print their face on burger buns.

Modern Meadow a Brooklyn-based company printed 3D steak chips made from synthetic animal protein.

## How it works?

The aim of this printer is to create meals as per the customers demand. A simple file can be downloaded that includes the healthier food options, taste, shape, ingredients, nutritional aspect, and allergy requirements with environmental friendly methods of cooking.. The process comprises of a controlled robotic action that builds up a dish layer by layer in a 3D computer assisted design. The design is created on a CAD program and the information is then fed to a printer .The desired raw material flows smoothly from the print cartridge on the printing platform and a structure gets created on the platform in layers and starts depositing in a cross sectional pattern till a complete model/shape

is ready. The edible filaments are deposited into desired shapes, one layer at a time, creating a three-dimensional food. Equipment's like nozzles, fine materials, lasers, and robotic arms are used to create these 3D figures. The raw material used must be low in viscosity at the same time thick enough so that the shape and properties can be maintained after printing. Examples include chocolate, pizza dough, sugar confectioneries, cheese and sauce.

## What ingredients can be used?

Any ingredients that are in a paste or semi-liquid state or can be converted into the right consistency like puréed vegetables, batters, doughs, cheeses, and sweets such as jellies, frostings, sugar decorations, chocolate, and mashed fruits can be used for 3D printing. Usually, the 3D printed foods are either ready for consumption or has to be further processed (baked, fried) to be consumed. They are mostly used for actually creating intricate shapes and designs and not actually cooking the food. There are exceptions like, The PancakeBot machine that only makes pancakes by extruding the batter directly onto a hotplate that requires only a person to flip it. Rest all is done by the machine. There are various techniques involved in 3D food printing. The three main procedures are:

**TABLE 1: 3D Printer Types and Food Materials Manufactured**

3D Printer Type	Food Material Type	Raw Material Used
Extrusion Base	Soft foods such as chocolate, cheese, dough, and meat puree	Polymers, hydrogels, and biogels
Inkjet-based	Low viscosity materials like fruit puree and pizza sauce	Liquid/solid phase (ink, fruit concentrated, and fruit juice)
Binder Jetting	Powdered materials like sugar, starch, and flour	Sugar and starch mixtures
Selective Laser Sintering	Powdered materials like fat chocolate and sugar	Non-sticky powdered materials without any tendency to agglomerate

Source: Secondary Research and FutureBridge Analysis

### Extrusion-based method:

It builds a food model by *extruding* edible food materials that are generally soft, paste like consistency for eg. *mashed potatoes, puree of meats, melted chocolate* or dough having a low viscosity. The final taste, appearance and quality of the product depends on the diameter of the nozzle, speed, and extrusion rate of the material. Products like cake frosting, cookies, and processed cheese are manufactured from raw edible materials like algae and insects.

### Binder jetting method:

A multiple layers of powders are assembled with the aid of binder. In this process very small droplets of liquid binder is deposited into a bed surface of powder further exposing it to a fixed degree of heat in a cyclic manner for each layer until the food model is complete. In this method the food gets constructed faster and complex structures can be fabricated at a considerable low cost ingredients. Foreg. bakery goods tend to be prepared by powdered ingredients. The finished products are generally with rough texture which may not be suitable for intricate decorations and candies.

**Inkjet printing of foods:** This method is used to decorate foods such as cookies, cakes and pizza toppings like meat purees, cheese, icings or jams. A stream of edible material droplets are distributed by a thermal or piezoelectrical head on to the desired surface.

This technique is widely used in food decorations that require precision, high resolution images laid on surface of cookies, cakes, crackers and biscuits.

**Selective laser sintering:** Also known as powder bed printing, wherein a laser or liquid is used to fix layers of powder and create desired shapes. Usually powdered sugar is used.

### Benefits of 3D printing are:

Customization is a big advantage with this technology: Food customization is major advantage of 3D printing. 3D printer can deliver meals tailored to each person's standards of taste, convenience, budget, along with any dietary restrictions. This could be applicable in hospitals where restricted diets are commonly offered to the patients.

- **Innovation and product differentiation:** The complete process can be automated and innovative and intricate designs can be produced. A new dish can be created by customizing ingredients. Additionally, an innovative dish can be created by composing two or more recipes together. Nutritious plants and protein-rich insect's purees can be presented in attractive way.
- **Customer relationship:** Customers are closer or in direct contact with food manufacturers, which helps in decreasing in transportation, additional cost of packaging and distribution.
- **Sustainability of food:** Reduction in food waste is possible by using nutrient sources like insects, plant based high fiber materials or byproducts. Ingredients like duckweed, grass, insects, or algae can be used resembling the original dishes. Eating insects for protein source can be the future. Meat consumption needs to be reduced and hence environment friendly insect proteins can be used. With the new technology the insects will be made more appealing to consume. To curb the food wastage the leftover food like vegetables, meat, and fish will be printed into more appetizing shapes.
- **Saves time and energy:** Perfection can be achieved with less efforts and time.
- **Environmentally-friendly meat:** 3D printers may enable to supply meat without killing farm animals. Companies like Redefine Meat and Novameat are developing 3D printed meat that tastes, smell, and feels like real meat, using printable, plant-based materials.
- **Space food:** NASA is experimenting with 3D printed pizza as an alternative to typical boring astronaut food. The Beehex Company can 3D print entire 12-inch pizzas in under five minutes, which are ideal not only for use in space but also potentially in pizza restaurants and takeaways.
- **Biometric 3D Printed Sushi:** Open-Meals are going to revolutionize the way people eat with their digitized food. When making reservations at Sushi Singularity (a restaurant in Tokyo, Japan), guests receive a health test kit that will give the restaurant information about their unique biometrics nutritional needs, which allows the restaurant to customize meals according to the needs.
- **Food for people who have difficulty chewing:** Nursing homes in Germany serve a 3D-printed food product called Smoothfoods to elderly residents who have trouble chewing and swallowing.
- **Additive technology:** 3D food printing also termed as additive technology is used for producing edible food products like syrups, sauces, and printed meat. In most cases, 3D food printers use resin-based inks to print edible food materials like candies, chips, chocolate, chocolates, juices, and even meats. Vinyl is the most popular ingredient used as additive in 3D printing.
- **Health opportunities:** Children today resist nutritional food like broccoli, spinach etc. These foods can be 3D printed in attractive shapes, thus creating positive experiences. Also, 3D printing can meet the growing trends of people following special diets like veganism, gluten-free and dairy-free etc. Fitness freaks can get customized meals with specific calorie foods fed and printed by 3D printers. Hospitals can serve 3D printed diet foods to meet the patient's nutritional needs and better recovery. Examples of projects like Biozoon helps serving patients a 3D printed diet menu in a more pleasant consistency thus, increasing the standard of living of many old people.
- **Serve large number of customers**

The 3D-printed food items are customizable and can be designed for specific needs thus, providing different options for catering to different group's. Customized Plate ware and silverware can be printed by most catering companies for beverage containers, plates, and silverware for wide range of customers. The same is true for takeout companies that use 3D printing.

- **App based designing of food**

Foodini – a food printer develops software for food design and prints them as well. There are special food capsules which is then pressed out of through a controlled nozzle precisely creating the desired shape and design. Three dimensional shapes are then formed by stacking layer on layer. There exists



a 'library' full of designs and recipes to refer. Users can also make their own designs using a special app.

- **Spectacular designs**

A tailor-made menu and spectacular designs can be printed with 3D printers transforming the food waste into unique designs. AnDoleweerd has created fish skin crisp at restaurant Adam by printing the fish skin in the shape of a fish bone, drying and baking it further.

- **Professional use**

Apart from professional use of 3D printers in restaurants and healthcare industry, it is used to create special decorations, logos, and personalized shapes for major hotel groups, universities, food producers, and healthcare institutions.

### **Challenges of 3D printing are as follows:**

- Growth of microorganisms: As the production time of 3D printing is quiet quick, due to fluctuation in temperature, microbes can grow and contaminate the food.
- Limited quantity cooking: All ingredients cannot be used at a time in 3D printing. All other parameters of storage and optimum temperature needs to be met.
- Skilled personnel and high cost of training: Skillful personnel is required to operate 3D printing of food. High training cost is incurred to train an individual to operate 3D printers. 3D printers are expensive and requires skilled labor to operate.
- Food requires to be in ground and pasted form only.
- Safety concerns with regards to shelf life and stability of products is a concern. *Products changes it form and structure* Most purees and doughs are subjected to change in *their structure* after a few hours of its production.
- Extra time and labor is invested in cleaning and sanitizing the equipment's.
- Mostly suitable for bakery and confectionery products and more research is required for obesity and food insecurity crisis.
- There seems to be still lack in technical progress to be made in 3D printers before it becomes a common house equipment. Today's printers still do not completely cook food. They cannot reheat the food. Lot of optimization still requires to be done in the processing and working of 3D printers. Precision lasers may be incorporated in the printers to heat or even fully cook the product.

## Examples of 3D printer machines:

**TABLE 2: 3D Printing Companies and their Applications**

Company Name	Type of Company	Technology Offered
BeeHex	Start-up	B2B food printer – it can print customized meals ultra-fast
byFlow	Start-up	byFlow printer is for easy to transport and is lightweight
Print2taste	Start-up	Bocusini – plug and play 3D food printing machines
Foodbot	Start-up	High accuracy 3D food printing machines
NuFood robot	Start-up	NuFood printer is equivalent to the size of a wine bottle, and with NuFood app you can acquire recipes
Mmuse	Start-up	3D printing machines for sweets and savory making
3D Systems	Established Player	ChefJet Pro – to print food materials
Choc Edge	Established Player	3D printing machine dispenses chocolate from syringes in beautifully melty patterns
Natural Machines	Established Player	Foodini – to print delicious, fresh savory, and sweet food
CandyFab	Established Player	3D printing machines for making sweet candies of different size
WASP	Established Player	DeltaWasp – to print all sorts of food
Biozoon Food Innovations	Established Player	3D printing machine for making meals for seniors who struggle to process solid foods

Source: Secondary Research and FutureBridge Analysis

## Conclusion

3D printing technology in food industry offers new possibilities, such as automation in cooking, innovation and product differentiation, personalized nutrition, sustainable and environmental food, reduction in food wastage, etc. This technology is set to make revolution and meet the demand and availability of food. It is a progressing technology that has huge benefits like saving time, healthy, environmentally sustainable, and highly efficient and many more. The scarcity of food resources is a growing concern in some parts of the world where the 3D food printing will be a great help reducing the amount of food wastage.

This technology will continue to evolve as an emerging technology in the food tech industry. A variety of prototype printers are available for food production all over the world. However, more and more companies will come forward to adopt this technology with product innovation and customization.

## Future:

There's a great opportunity for a new generation entrepreneurs, scientists and farmers to take a leap in a technologically advanced direction towards a healthier lifestyle and more environmentally sustainable ways of consuming our natural resources. Food-tech startups such as [Redefine Meat](#) and [Nova Meat are](#) looking forward to print 3D printed meat products to reduce the carbon footprint associated with the industry by using plant-based meat textures. [Natural Machines](#) see a faster future with precise operations producing more texture rich products.

Global problems like obesity, scarcity of ingredients, growing population leading to world-hunger, malnutrition epidemics, affordable ingredients and nutritional deficiencies could be very effectively curbed as diets could be more rigidly adhered to without compromising the taste.

3D printing will definitely not be the answer to all of our problems, but this technology can definitely get all of us one step closer. NASA also believes that 3D printing is the future, especially to feed its

astronauts while in space since they are unable to carry everything that they need to eat and cooking a meal in zero gravity looks hard. 3D printed food will create balanced, healthy and nutritious dishes that would be needed for such long missions which will also eliminate the generation of food waste. Such edibles can even last for 30 years in special plastic bags. This is extremely important in space under high-stress situations and long missions. A Texas-based company SMRC ([Systems and Materials Research Corporation](#)) has developed a [pizza printing system](#) that combines powdered foods with necessary nutrients. Printed meats will be an innovative option in the world of nutrition giving choice to get healthy, nutritious and balanced calorie counted dish at a press of button for people who need to follow strict diets.

3D-printed food may help feed the world's population in a simultaneously sustainable and nutritious manner. People in all over the world will have access to healthy, safe, and nutritious food. The food recycling concept will convert food waste into edible materials. Major global issue of food shortage could be dealt by this technology.

## References

1. Bloomberg. 2015. Video. How Hershey's is using 3-D printers to make chocolate kisses. <https://www.youtube.com/watch?v=9FajGAeJ840>
2. Brody, A. 2014. 3-D printing: Rapid prototyping from food to food packaging. Food Technology. Institute of Food Technologists. pp 107
3. Hall, L. 2013. 3D Printing: Food in Space. NASA. [https://www.nasa.gov/directorates/spacetech/home/feature\\_3d\\_food.html](https://www.nasa.gov/directorates/spacetech/home/feature_3d_food.html)
4. Hannum, K. 2018. Is 3-D food printing the next microwave? Science Meets Food. <http://sciencemeetsfood.org/3d-food-printing-next-microwave/>
5. McHugh, T. Bilbao-Sanz, C. 2017. 3-D Food printing: A new dimension in food production processes. Food Technology. Institute of Food Technologists. pp 123-125
6. McCue, T.J. 2018. 3D food printing may provide way to feed the world. Forbes. <https://www.forbes.com/sites/tjmccue/2018/10/30/3d-food-printing-may-provide-way-to-feed-the-world/#46cb7015817c>
7. Rutzerveld, C. 2015. Video 3D Printed Food: The Future of Healthy Eating. TedxYYC. <https://www.youtube.com/watch?v=hw321SwC6kA>
8. Wiggers, K. 2017. From pixels to plate, food has become 3D printing's delicious new frontier. Digital Trends- Emerging Tech. <https://www.digitaltrends.com/cool-tech/3d-food-printers-how-they-could-change-what-you-eat/>
9. <https://www.outsource2india.com/eso/mechanical/articles/3d-printing-impact-food-industry.asp>
10. <https://www.3dnatives.com/en/fused-deposition-modeling100420174/>
11. <https://www2.deloitte.com/us/en/insights/focus/3d-opportunity/3d-printing-in-the-food-industry.html>
12. <https://turbofuture.com/consumer-electronics/3D-Printers-For-Food-Technology-and-Applications>
13. <https://www.forbes.com/sites/tjmccue/2018/10/30/3d-food-printing-may-provide-way-to-feed-the-world/#77c55a035817>
14. <https://blog.grabcad.com/blog/2019/06/17/3d-printed-food-companies/>
15. <https://www.aniwaa.com/food-3d-printers/>
16. <https://www.disruptordaily.com/3d-printing-watch-food-industry/>
17. <https://pdfs.semanticscholar.org/d8e0/edd23846992b6eb8e1d25a51b752b4335879.pdf>
18. <https://www.barry-callebaut.com/en/group/media/news-stories/barry-callebaut-opens-worlds-first-3d-printing-studio-craft-unseen>
19. <https://www.forbes.com/sites/louiscolombus/2019/05/27/the-state-of-3d-printing-2019/#27b44bc46c2c>