



## 3D PRINTING IN FOOD PROCESSING INDUSTRIES -A PATHWAY TO INNOVATIONS

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### **Abstract**

Food processing industry is high innovation demanding industry. Innovation when supported by technology shows significant success. Three dimensional (3D) printing is a technology which is getting introduced in food processing industry and is emerging as a great tool for innovations. 3D food printing is a process of creating food products by successive layering. A 3D food could be customized and personalised according to the wish of the consumers to provide a nutritious option and the best quality of food. 3D Printing technology has shown its remarkable progress in various sectors, but its application in food processing sector is yet at naive stages. The technology nowadays is being widely investigated in food sector for past few years and has surfaced multiple advantages like providing customized and personalised food, improving the nutrition intake among people, improving the food supply chain and moving forward towards mass customization of food. For now 3D food printing is used in military and space food, for elderly people, confectionary industries as well as in savoury sector. In Indian market, it has entered recently in the confectionary sector. This paper is a conceptual study about applications of 3D printing in food sector as well as role of 3D printing in food supply chain. This paper is an effort towards reflecting the present status and future dimensions of possible applications of 3D printing technology in processed food sector. There exists a lot of research gap in this domain which may be seen as a potential area for future interventions. This paper also discusses the pros and cons of 3D printing machines and how can it be of help in the future.

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## **Introduction**

In our modern time science & technology are upgrading day by day. The driving force behind upgrading the technology is the lifestyle of the 21<sup>st</sup> century people which demand innovations for a convenient living. A vital requirement, is full filled, by something what we eat “food”. The demand for ready to eat food is increasing but along with that consumers look for nutrition also in their food. Food processing industry therefore is getting very high innovation demanding industry (Liu, Z et al. 2017). Innovation when supported by technology shows significant success. Three dimensional (3D) printing is a technology which is getting introduced in food processing industry and is emerging as a great tool for innovations. 3 D Printing technology has shown its remarkable progress in various sectors, like health and medicine, aerospace, engineering, crafts, garments etc. (Derossi A., 2018; Javeed S.M, 2016; Alvaro Goyanes et al., 2014). but its application in food processing sector is yet at naive stages. The technology nowadays is being widely investigated in food sector for past few years and has surfaced multiple advantages like providing customized and personalised food, improving the nutrition intake among people, improving the food supply chain and moving forward towards mass customization of food.

## **3D Food**

3D food is the food which is prepared by creating successive layers of food by using a 3D printer till the product gets the complete shape. The 3D food can be directly consumed or it can also be steamed or fried before consuming as per the products specification (Hanley, A. B., 2016) It could be customized and personalised according to the wish of the consumers to provide a nutritious and the best quality of food. Traditional methods of food production, where mass production is carried out, could not provide personalised food to customers, which impacts company’s responsiveness. (Zoran and Coelho, 2011; Sun.J. et al. 2018)

The technology behind 3D Food is known as Additive Manufacturing (AM) and 3 D printing is one of the applications of Additive manufacturing technology. Very recently 3 D printing has entered in food sector. For now 3D food printing is used in military and space food, for elderly people, confectionary industries as well as in savoury sector. In Indian market, it has entered recently in the confectionary sector.

“3D food printing permits to digitize and personalize the nutrition and energy requirements of an individual person according to their physical and nutrition status” (Severini C. et al. 2016; T.F. Wegrzyn, 2012; Yang, Zhang, & Bhandari, 2015)

3 D food printing could make a pathway for leading food processing industries to come up with an innovative approach in making their products nutritious, fresh and at the same time look pretty. With the help of just few cartridges, nozzle and a printer and type of food could be personalized according to the energy requirements of different human beings. This has paved the way for many industries to be acknowledged globally and be more technically equipped (Houser. F., 2017)

3D printing technology doesn't simply require transforming production, rather that's just the beginning, before implementing additive manufacturing in any company. For this purpose a well designed supply chain is a must because this will provide a network between the manufacturers and the customers. “Companies need to re-architect research & development, demand signals, asset management, logistics, partner management and more” (Singh. P, Raghav. A., 2018) .“Supply Chain Perspective, companies take advantage of scale economics offered by additive manufacturing as a potential enabler of transportation for the products they offer” (Pinna, C., et al.2016.)

Until 2014, 3D food printers focused predominantly on intricate, sugar-heavy confectionaries. Later on, one Barcelona-based company made strides towards 3D-printing something which a person could actually eat for dinner (Mohammed. G. F., 2016)

### **3D Printing and Innovations**

3 D food printers are the latest technology which helps make food nutritious, tastier, fancier and easier to prepare. 3D printing of food will change the conventional methods of producing food. 3D printing can be implemented in processes of supply chain, medicinal foods with specific nutrients, in hotels and restaurants. Presently, this technology is in nascent stages, but in upcoming years it can be seen in every commercial place because of its effectiveness. It could be used commercially as well.

3D printer has edible cement which helps in making layers of food without any breakage. The printers come in different forms like nozzles, lasers, fine materials and robotic arms (Orosz. C, 2017). A semi solid additive is generally used for making pizzas, pastas and chocolates but for the purpose of icing where a powdery material is used material properties like particle size, flowability, bulk density and wettability have a great impact on the precision and accuracy of the printer.

It's a revolutionary innovation which has the capability to change and improve the

conventional food production methods. This technology has countless applications for producing various types of foods. 3D technology is driving significant innovations in food processing sector because of its capability of fabrication of complex shapes, textures and customised nutritional contents(Fernanda C.Godoi et al. 2016) Few of the notable benefits for using 3D printing of foods may be discussed as follows (Mohammed. G. F., 2016)

- Customised food products with product designing done very close to customer and as per their requirements.
- Cheaper cost of production for commercially produced foods
- Shapes & Designs can be made which are not possible by merely moulding or casting.
- Time efficient in terms of designing food which requires minute detailing in their designs.
- Functional foods can be prepared by injecting specific nutrition into the raw materials as per the requirement of consumer.

Food Sustainability can be achieved with the help of 3D printing technology, because firstly such ingredients can be used for making bases which are abundantly available but difficult to use in traditional food production methods like grass,insects,algae etc. Secondly, 3 D printing minimises wastages to a great extent ( Liu. Z et al. 2017)

### 3D Printing and Food Supply Chain

Application of 3D printing in the area of supply chain is well recognised by industry people and researchers as well. Fosso Wamba, S.2017 through his research cum review paper has identified 67 journal articles which discussed about research carried out in the field of 3D printing and supply chain management. 3 D printing can support growth of food supply chain in several ways. The foremost of them may be application of 3 D food printing towards achievement of Extended Supply Chain. An extended supply chain is a form of supply chain that integrates supply chain with design, manufacturing, and asset management and is able to respond quickly and accurately (Thalbauer. H, 2016)

Four major driving factors identified for an extended supply chain are:

1. **Customised Product:** Consumers demand for more individualised and customised food products. 3 D printers can provide this option to consumers by allowing the product designing as per customer wish. As the food could be customized to any person's wish, this need changes and support from R&D as well as asset management team of the company.
2. **Strong Networking:** The technology of 3D printing supports short and integrated supply chain by electronically connecting backward and forward ends.
3. **Resource Availability:** Scarcity of resources hampers the morale and functioning of workers dealing with a completely new technology and also it creates pressures in terms of raw material wastages also.
4. **Customer Focus:** Customer acceptance plays the most significant role in the success of 3D printing technology in case of food processing industry, and is therefore one of the significant drivers (Howells. R, 2016)

Focus of various companies is on E-commerce utilization for creating a supply chain, which will need less time to create a food which requires high precision or time and delivering it to the consumer via local 3d printing joints. Because of 3D printing, response time to the change in requirement of customers demand is flexible and quick. After the service is provided, the customer's suggestions can be implemented quickly because of less intermediaries involved between the producer & consumer.

Inventory management becomes easier as food manufacturers could manufacture food based on the demand from the consumers. Handling of inventory for raw materials like powder and filament coils is easy and cheaper as compared to handling of perishable products which contain high moisture value or semi processed goods (Mohr S.. & Omera Khan, 2015). 3D printers are coming up as a cheaper alternative for a more sustainable food. As there will be less food wastage hence optimum utilisation and management of resources is there. FMCG food manufacturers also benefit from the 3D printers as it promises to provide a healthier

variety of chips (Mosendz. P, 2014)

### 3D Printing Techniques and Processes

Depending on the need and type of product, various techniques of 3D printing are available. To discuss few of the technologies there are extrusion based printing, binder jetting, inkjet printing, (Fernanda C.Godoi et al., 2016) and Deposition printer (Liu Z et.al. 2017)

1. **Extrusion Based Printing-** It is used in extrusion of hot chocolate, mashed potatoes or meat puree (Figure 1).
2. **Binder Jetting-** As the name signifies this printer helps into binding of two different layers. It requires two things which make it different from deposition printer that is powder and a binding agent with a mixture of water & alcohol (solution composition varies with the products). It offers fast fabrication, building complex structures and has low cost of material (Figure 2).
3. **Inkjet Printing-** It is used in surface filling and image decoration. It is mainly used to decorate cakes and pastries (Figure 3).
4. **Deposition Printing-** When a food item is being prepared by deposition printer it makes layers of the component by which the food is made till it completes the shape as per data fed into the system (Figure 4).



Figure 1: <https://www.bcn3dtechnologies.com/en/3d-printer/bcn3d-sigma/>



Figure2:<https://www.aniwaa.com/product/3d-printers/3d-systems-cocojet/>



Figure 3:<https://www.coroflot.com/nicoklaeber/moleculaire- food-printer-concept>



**Figure 4:** <https://www.coroflot.com/nicoklaeber/moleculaire-food-printer-concept>




## Types of Food Printers

For different sectors of food and for different purposes various types of printers are used. Few types of food printers are:

**Table 1: Different types of food printers available in market**

Types	Uses	Image
Chef Jet Pro	It is the first kitchen ready printer. It has different varieties of metal printers, plastic printers as well as full colour printers.	 <p><a href="https://www.google.co.in/search?q=chef+jet+pro&amp;hl=en-">https://www.google.co.in/search?q=chef+jet+pro&amp;hl=en-</a></p>
Foodini	It uses 5 different capsules at same time for processing. It provides nutritious ingredients which are fresh and not pre processed. It gives more healthy meals. It has ingredients in savoury and sweet version.	 <p><a href="https://www.google.co.in/search?q=foodini&amp;source=lnms&amp;tbn=isch&amp;sa=X&amp;ved=0ahUKEwiph5Hah5DdAhVMYIAKHaxTDUkQ_AUICygC&amp;biw=1821&amp;bih=841&amp;dpr=0.75#imgsrc=pSFlj3zObdn9uM:">https://www.google.co.in/search?q=foodini&amp;source=lnms&amp;tbn=isch&amp;sa=X&amp;ved=0ahUKEwiph5Hah5DdAhVMYIAKHaxTDUkQ_AUICygC&amp;biw=1821&amp;bih=841&amp;dpr=0.75#imgsrc=pSFlj3zObdn9uM:</a></p>

Candy	It is the first confectionary focussed printer. It can print semi solid food and the person can do it at home. The person can choose own extruders and ingredients for a customized version.	<a href="https://3dprint.com/12096/candy-3d-printer/">https://3dprint.com/12096/candy-3d-printer/</a>
Bocusini	It is the first plug and play printer. It can be retrofitted on the already existing printer. The person needs to insert a food cartridge, connect the device to wifi design and print. Pre filled food cartridge allows to change taste from one to another. It has wide range of different edibles including- cookie dough, fudge, jelly, butter, icing and many more.	<a href="https://www.google.co.in/search?q=bocusini&amp;hl=en-IN&amp;source=lnms&amp;tbm=isch&amp;sa=X&amp;ved=0ahUKEwiC9ontxYXdAhVLa1AKHQGAK0QAUICyqC&amp;biw=1821&amp;bih=776#imgrc=tYU2">https://www.google.co.in/search?q=bocusini&amp;hl=en-IN&amp;source=lnms&amp;tbm=isch&amp;sa=X&amp;ved=0ahUKEwiC9ontxYXdAhVLa1AKHQGAK0QAUICyqC&amp;biw=1821&amp;bih=776#imgrc=tYU2</a>

<p>TNO Pasta Printer</p>	<p>It is the first printer for making 3 D pastas.It only uses durum wheat semolina and water.</p>	 <p><a href="https://www.google.co.in/search?q=TNO">https://www.google.co.in/search?q=TNO</a></p>
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### **3 D Printers in Indian Market**

With the ongoing process in the development of new and new 3 D printers, Chocobot is the first made in India commercial chocolate printer. The total price of this printer is Rs. 91600 including taxes. The operating temperature is 34 degrees Celsius and it has a 60ml syringe. With this any type of dark, white, milk chocolate could be made (Alec, 2015).

As it is noticed that in India the work is more labor intensive and because of it there are chances of more and more error. With the advancement of 3 D printers the load could be minimized. Moreover, the accuracy and precision rate would increase.

A lot of gravy foods could be revamped to give it a better and more intensified look thus satisfying the need of the Indian consumers.

### **Few Successful Cases**

#### **1. FoodInk**

One of the example of 3D printing can be seen in a hotel called FoodInk situated in London. In 2016 it was the first hotel which served 3D printed food to their guests which included different cuisine dishes which were made by 3D printing only (Porter. K. et. al., 2015)

#### **2. Melisse Restaurant**

It is a classy scale up restaurant in Santa Monica. They serve contemporary American cuisine. They use 3D printers to craft design for the crouton in onion soup. (Ahmad. R, 2017)

#### **3. La Boscana**

It is a classy gourmet eatery. The restaurant uses a Byflow Focus 3D printer. (Ahmad. R, 2017)

#### **4. Biozoon's Smoothfood**

This is particularly developed to print food for senior citizens who cannot chew. The ink has puree which prevents the consumers from choking. It is an innovation created in Germany.(Mosendz. P, 2014)

#### **5. 3D printed meat**

Trialed by the professors in Netherlands reduces greenhouse gas emission to 96% compared to conventional beef production. (Orosz. C, 2017)

#### **6. AlgaVia**

It is a San Francisco based company which utilises microalgae to form a protein powder from the printer which is gluten free and is high in dietary fibres. It helps in fortification for vegans (Flatworldsolutions)

#### **7. Opening of first permanent 3D restaurant**

Byflow a dutch company and chef Jan Smink are pairing to establish a first ever permanent 3D restaurant in Netherlands by September 2018.(Watkin. H, 2018)

## 8. Pepsico

It uses 3D printers for making plastic prototypes of different shapes and colours of potat chips (3D printing progress, 2018)

## 9. Oreo

It uses 3D printers to create customised crème patterns and flavors to draw a huge crowd towards this product (3D printing progress, 2018)

### **Improvements over Traditional Food Production Methods:**

3D printing technique is making significant improvements in the traditional food production methods in ways like:

- a) 3D printing being automated and computer software based process, itovercomes the problem of labour intensiveness of traditional method.
- b) 3D printing methods require limited supply of raw materials as compared to huge supplies required in traditional methods.
- c) While traditional methods does not allow food customisation, 3 D printing provides a customised and personalised product.
- d) As 3D printing is automated and quick process so less chances of error and cross contamination are there as compared to traditional methods which takes longer working hours with high chances of error and cross contaminations.

### **Few Notable benefits from 3D Printer**

1. 3D printers reduce waste by increasing the efficiency of use of raw materials and production process.
2. 3D printers encourage on-site processing.
3. A mix of different food items could be used to make raw material.
4. 3D printers have the potential to revolutionize storage, distribution process in the supply chain.
5. NASA wanted to use 3D food printing to meet the requirement of food safety, nutritional stability and acceptability of mealsfor long space missions, while using the least amount of spacecraft resources(Severini C. et al. 2016;T.F. Wegrzyn,2012; Yang, Zhang, & Bhandari, 2015)
6. 3D printers can be used to deliver macro as well as micronutrients.
7. The food could be made tasty and nutritious for the elderly who cannot chew food.

### **Shortcomings of the 3D Printer**

1. Presently,3D printers operate at less speed and it is noticed that by increasing the printing speed there

is loss of precision in printing objects.

2. Multi nozzle printer is used to increase the precision of objects but it leads to a more complex system and makes it hard to control it.

3. Several attempts have been made in improving the colour, flavour and texture of the food but it is not used widely.

## Conclusion

3D Food Printing can help in creating customized & personalized food as per the consumers demand & producing it in less time with less physical effort. Its applications are being researched & developed for creating space food for astronauts in space by NASA, functional foods having enriched nutrient composition & in confectionery & savoury sectors. 3D Printing or Additive Manufacturing is revolutionizing the supply chain system by designing a whole new supply chain network specific for 3D printed foods. Many countries are developing & trying to implement 3D printed food in their food sectors. As in India 3D food printing is yet to come but once it reaches the Indian market it would surely prove to be a remarkable start into modernization of the Indian food industry. As 3D printing provide options of creating their own type of food to people who can't cook. Having a 3D printer at home will be quite convenient and will save time and transportation cost. Being time efficient and having less cost of production these printers will be in high demand for the generations to come.

## Future Suggestions

- 1) Reducing the time of printing the food will be a major enhancement in 3D printing because small food sizes can be prepared quickly but in case of bigger, complex & multilayer foods the preparation process is very time consuming.
- 2) To produce meat product or dishes via 3D printing is a very complex procedure which seems like impossible but a start-up called Modern Meadow in U.S. is already trying to implement this idea practically (Alyson Shontell, 2016)
- 3) A 3D printer which cannot only print the food but also cook it. For ex Pizza can be 3D printed but cannot be consumed directly, first it needs to be cooked in an oven . So if a 3D printer has the application of not just printing the food but to cook it also, this can be a major modification too (Severini C. et al. 2016;T.F. Wegrzyn,2012; Yang, Zhang, & Bhandari, 2015)

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