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3D Printing: A Step towards Revolutionizing Food Industry

Naseer Ahmed*, Praneet Chauhan, Yogeeta Thakur, Tajendra Pal Singh
DKSG Akal College of Agriculture,
Eternal University,
Baru Sahib (HP)
*Corresponding author: ewsjammu@gmail.com
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Today's 3D food printers are mainly deposition printers, which means they deposit input materials layers in a process known as additive manufacturing. A new form of 3D printer-binding machines-mixes materials with a form of edible cement. Nowadays, 3D food printers use nozzles, fine fabrics, lasers, and robotic arms to create candy sculptures, ornate sweets, and decorative pastry. In specific, one printer, the Chef Jet from 3D Systems, crystallizes thin layers of fine-grain sugar into a variety of geometric shapes. The Choc Edge from Barcelona-based Natural Foods, dispenses chocolate from nozzles in beautiful patterns.

A three-dimensional (3D) printing, called additive manufacturing, established since 1980s, have been developed and applied in variety applications for many industries. Additive manufacturing crates model by adding material layer by layer from a computerized 3D solid model. An advantage of additive manufacturing is to construct a complexity model without mold and die, fixtures, cutting tools and coolants. The application of construction additive manufacturing model has been wildly used in many fields of industry such as automotive, architecture, medical and fashion design. Including, food manufacturing also applies this technology to fabricate food design. However, a sustainable nutrition and food security are the global agenda and key themes, which are considered during, apply 3D food printing. There are several techniques to construct 3D food printing that are an extrusion-based printing, binder jetting and inkjet printing. This paper aims to review those techniques based on printability, productivity, properties of material, effect parameters and mechanism of 3D food printing techniques. Including, the advantages and disadvantages of those techniques are also established.

Category of 3D Food Printing Technique

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The 3D food printing technique has been classified into three categories that are an extrusion-based printing, binder jetting and inkjet printing

1. **Extrusion-based printing**

The extrusion-based printing constructs food model by extruding food through a nozzle with a constant pressure. This technique is similar to a conventional Fused Deposition Modeling. However, the starting material of extrusion-based printing can be both solid and paste (soft) with low viscosity, while the starting material of Fused Deposition Modeling is wire. In this extrusion-based printing process, material is loaded in extruder (cylinder) before it is extruded through nozzle by ram pressure to create food shape layer – by – layer.

The examples of food, fabricated via this technique, are dough meat paste and cheese

2. **Soft-materials extrusion:**

In AM, soft-materials extrusion has been applied to print 3D constructs by mixing and depositing self supporting layers of materials such as dough, meat paste and processed cheese. The viscosity of the material is critical to be both low enough to allow extrusion through a fine nozzle and high enough to support the structure post-deposition. Rheological modifiers, or additives, can be used to achieve the desired rheological properties but must comply with food safety standards.

3. **Melting extrusion**

Melting extrusion has so far been applied to print chocolate 3D objects, denoting a working temperature which ranges from about 28 ^{0}C to 40^{0}C. The formulation of chocolate self-supporting layers is challenging due to the complex crystallization behavior exhibited by cocoa butter, the main structuring material in chocolate and confections.

4. **Hydrogel-forming extrusion**

The extrusion of hygrogel-forming materials is critically dependent on the polymer rheological properties and the gel forming mechanism. At first, the polymer solution should present visco-elastic characteristic, and then turn into self-supporting gels prior the consecutive layers are deposited. To prevent premature gelation of the polymer solution

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inside the printer, temporal control of the gelation mechanisms must be carried out. Generally, the hydrogel-forming mechanisms can be classified in three categories: (1) chemical cross185 linking, (2) ionotropic cross-linking and (3) complex coacervate forma

5. Inkjet Printing (IJP)

The inkjet printing dispenses a material stream of droplets from a thermal head to certain regions for creating the surface filling or decorating on food surfaces, such as cookie, cake, and pizza, as shown in figure 5. This process generally operates by using thermal or piezoelectric heads. In a thermal inkjet printer, the print head is electrically heated to establish pulses of pressure that push droplets from the nozzle. There are two types of inkjet printing methods: a continuous jet printing and a drop-on-demand printing. For the continuous jet printer, an ink is ejected continuously through a piezoelectric crystal by vibrating with a constant frequency. In order to obtain a desired flow ability of the ink, some conductive agents had been added. For a drop-on-demand printer, a valve is a controller ink to eject out from heads under designed pressure. The printing rates of drop-on-demand systems are generally slower than the continuous jet systems, beside the resolution and precision of produced images are higher. The inkjet printer normally handles low viscosity materials; therefore, it does not find application on the construction of complex food structure. Typical deposited materials are chocolate, liquid dough, sugar icing, meat paste, cheese, jams, gels and etc.

6. Binder jetting

The binder jetting, which is an additive manufacturing technology, constructs model by using a binder to selectively bond layers of powders. In this process, small droplets of binder with diameters less than 100 μm are successively deposited on to the powder bed surface, which those are a drop-on-demand print head based on rater scanning pattern. After deposition of the liquid binder, the entire surface of the powder bed is exposed to a fixed amount of heat, which commonly use a heat lamp, for establishing an appropriated mechanical strength via partially cured binder within the generated layer to withstand the shear and gravitational compressive forces involved in the spreading and printing of subsequent layers. These steps are repeated for each layer until the whole feature was completed

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Technique	Principle	Binding Mechanism	Application
Soft-materials extrusion	Extrusion and deposition	No phase change, accommodation of layers controlled by rheological properties of the material	Frosting, processed cheese, dough, meat puree
Melting extrusion	Extrusion and deposition	Solidification upon cooling	Chocolate, confection
Hydrogel-forming Extrusion	Extrusion and deposition	Ionic or enzymic cross-linking No phase change, accommodation of layers	Xanthan gum and gelatin Chocolate, liquid dough,
Ink Jet Printing	Drop-on-demand deposition	controlled by rheological properties of the material	sugar icing, meat paste, cheese, jams, gels
Bioprinting	Drop-on-demand deposition	Self-assembly of the cells	Meat

Conclusion:

In view of today's scenario of public health and population it will not be long that 3D food printing will take over other conventional food manufacturing system. Not only does it pay attention to individual's dietary need but also gives a large option in aesthetics. 3D printing is one automated food preparation method which already delivers enhanced artistry and could be used to deliver these data driven delights. With time, more innovations in this technology will help mankind with mass production of food and health benefits.