**3D FOOD PRINTING TECHNOLOGY**

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**Abstract**

**3D Food Printing technique consists of extrusion- based printing and is an emerging technology in the field of food production technology. The advantage of using 3D food printing is the ability to produce complex food model with the scope of developing unique design patterns. In the 3D food printing technology, food materials such as sugar, chocolate and cheese are used in creating designs in the form of layers. This chapter emphasizes on the categorization, printability, productivity, properties of materials and mechanisms of 3D food printing technology and discuss the future prospect of 3d food printing technology in the field of food production.**

**Introduction**

3D food printing also called additive manufacturing (AM) has been developed and found to be applied in different industries. It was established since 1980s.AM model is formed by adding material layer by layer from a computerized 3D model. The advantage of creating AM is to develop a complex model without the use of mold and dye fixtures, cutting tools and coolants. The development of AM model have been wide application in different fields of industry such as automotive, architecture, medical and fashion design.In addition, food manufacturing industry also applies this technology to create food designs.However, 3D food printing technology is applied with the key aim of ensuring sustainable nutrition and food security globally.There are different methods of constructing 3D food printing technology which includes extrusion-based printing, binder jetting and inkjet printing. Those techniques will be discussed in this chapter based on the printability, productivity, properties of material, effective parameters and mechanism of different 3D food printing technique(Annoni et al., 2016; Shannon et al., 2017; Teresa et al., 2012; Lee et al., 2017; Nguyen et al., 2017; Jayakuma et al., 2017).

**Classification of 3D Food Printing Techniques**

The 3d food printing technique has been categorized into three categories that are- extrusion-based printing, binder jetting and inkjet printing as shown in figure 1.

Additive Manufacturing technology

Inkjet printing

Binder jetting

Extrusion based printing

Figure 1. Classification of 3D printing technique (Pitayachaval et al., 2018)

**Extrusion based printing**

The extrusion based food printing method creates food model by extruding food through a nozzle with a constant pressure. This method is similar to that of conventional Fused Deposition Modeling(FDM).The difference between extrusion based food printing method and FMD method is that, the starting material of extrusion based printing can be both solid and paste (soft) with low viscosity, while the starting material of FDM is wire. In the extrusion based food printing process, material is loaded in ectruder (cylinder) before it is extruded through nozzle by application of ram pressure to create food shape layer-by-layer, as shown in figure 2.The examples of food, created via this technique, are dough meat paste and cheese. Fanli Yang, et al.,(2018) conducted a study through application of extrusion at room temperature to print lemon juice gel using the extruder conveying screw, as shown in figure 2.The results of the study revealed that the nozzle diameter, the nozzle movement speed and the extrusion rate affect the quality of 3D food printing, excluding the nozzle height. M.Lanaro et al.,(2017), to print solid stating material, investigated on melting extrusion for printing complex chocolate model based on machine designing, including mechanism design.The results of the study showed that there are two important areas of design in which (1) designing the extruder assembly to be as rigid as possible, thereby reducing flexion and enabling more accurate deposition of chocolate and (2) improving the design active cooling system to quench the chocolate at lower temperature, as shown in figure 3.



**Figure 2.** The 3D printing technique based on soft-material (A. Anchor, B. Gecko, C. Snowflake, D. Ring, E. Tetrahedron). L. Wang et al. (2018)



**Figure 3.** The 3D printing technique based on melting extrusion. (Lanaro, et al. 2017)

**Inkjet Printing (IJP)**

The inkjet printing method creates food designs by dispensing 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 4. This process generally operates by using thermal or piezoelectric heads. In the process of thermal inkjet printing, the print head is electrically heated to establish pulses of pressure that push droplets from the nozzle (Fernanda et al., 2016).There are two types of inkjet printing methos: a continuous jet printing and a drop-on-demand printing.In the process of continuous jet printing, 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. The process of drop-on-demand printing method involves a valve as 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(Liu et al., 2017). The inkjet printer normally handle 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 (Fernanda et al., 2016).



**Figure 4.** Inkjet printing (IJP) (Peng, Zhou, Jerry, Hong, and Annette, 2015)

**Binder jetting**

The binder jetting method is an additive manufacturing technology which creates 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 (Miyanajiet al., 2018). For binder jetting process, properties of powdered material and binder are important to the successful fabrication of parts. The binder has to be suitable low viscosity in which surface tension and ink density are suitable properties to prevent spreading from nozzles(Sun et al., 2015).



**Figure 5.** Binder jetting (IJP) (Peng, Zhou, Jerry, Hong, and Annette, 2015)

**Summary**

The Additive manufacturing technologies have been wildly used in several industries including food manufacturing to crate the fantastic food shape. There are variety techniques such as extrusion-based printing, binder jetting and inkjet printing.

In extrusion-based printing, food materials are extruded through nozzle to create food designed shape layer – by – layer. Based on the low viscosity property of material, the suitable materials in this technique are solid-based and paste material. The processing factor of this technique are printing head height, nozzle diameter and nozzle movement rate. The advantage of this technique are the low cost of the entry-level machines, a variety of raw materials are available and easy to customize while the low level of precision and long build time are the disadvantage of extrusion-based printing.

In inkjet printing, food materials are loaded in print head then they is electrically heated to establish pulses of pressure that push droplets from the nozzle. There are two types of printing; a jet printing and a drop-on-demand printing. By using the low viscosity property of material, the suitable materials in this technique is liquid-based. The processing factor of this technique are temperature print head, nozzle diameter and printing rate. The advantages of this technique are high resolution, accuracy and multiple materials while post-processing may damage thin and small features, which is disadvantage of inkjet printing.

In binder jetting, food materials are successively deposited on to the powder bed surface through nozzle. Based on the low viscosity, surface tension and ink density, the suitable material in this technique are liquid-based, powder-based. The processing factor of this technique are printing head type, nozzle diameter and layer thickness. The advantage of this technique are the very high production speed, support structures are included automatically in layer fabrication while the disadvantage are rough or grainy appearance, post-processing required to remove moisture or improve strength of binder jetting.

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7. New technology often builds on old technology. Understanding how the present printers work and discovering their advantages and disadvantages may help people create more useful food printers in the future.

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