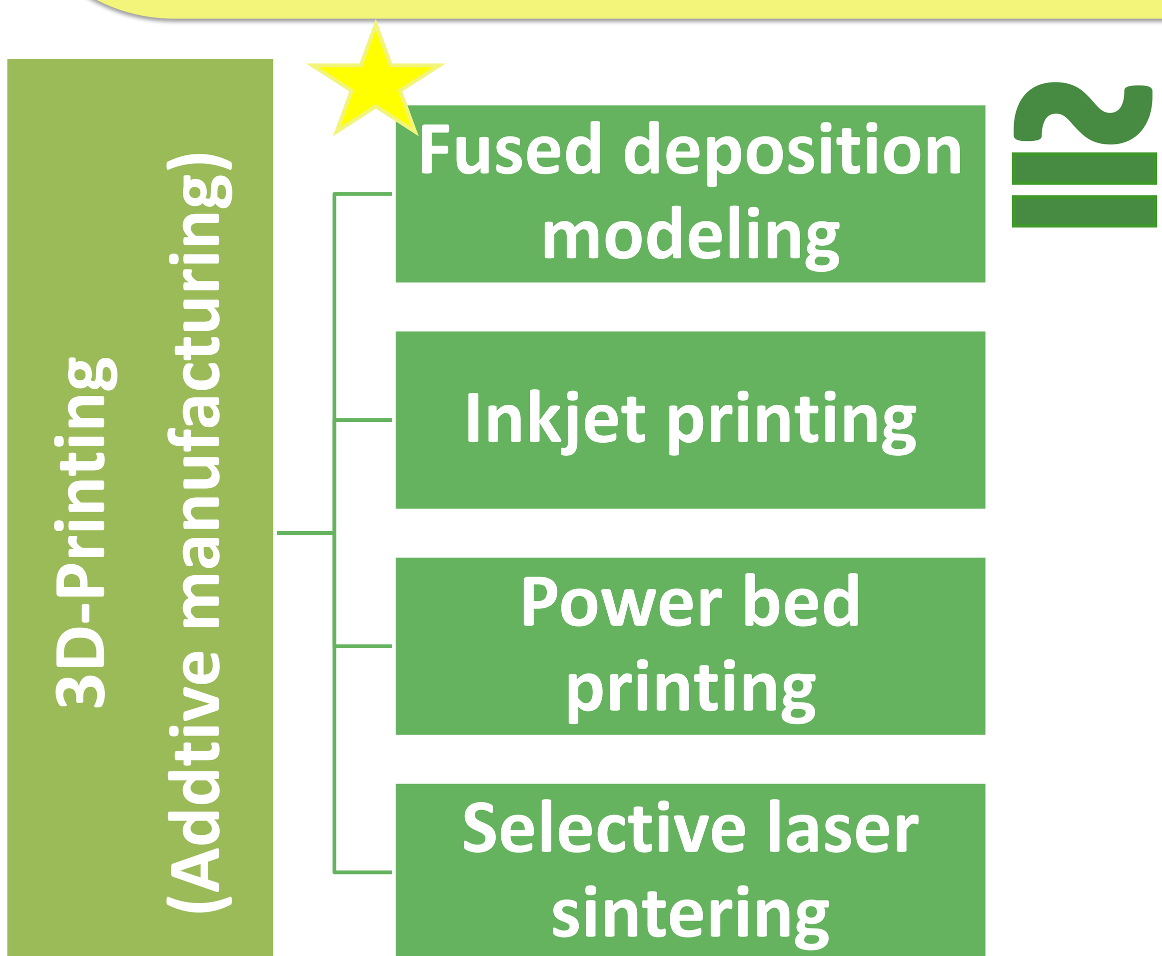
Using 3D Printing Technology in Cookie Production

Gamze Nil Yazici*, Mehmet Sertac Ozer
Department of Food Engineering, Faculty of Agriculture, Cukurova University, 01330 Adana, Turkey
*gnboran@cu.edu.tr

Nowadays, 3D food printing, in other words, food layered manufacture, has gained more importance. The most common driving forces behind of using 3D technology in the food sector is designing complex external and internal food structure, customizability of sensorial and nutritional features and the relationship between the sustainability. In this regard, 3D printed cereal-based products, especially cookies are one of the most common food products. According to studies in which have used 3D printing technology for cookie production, some food additives like hydrocolloids, in particular xanthan gum, could be used to increase mechanical strength in the post-processing steps as baking, frying, or steaming. However, the concentration of hydrocolloids is important due to influencing extrudability and also porosity which could bring about poor textural properties. On the other hand, it is possible to produce 3D printed cookies without hydrocolloids or stabilizers with modifying the cookie recipes by means of changing fat and flour type or concentration of sugar. Besides, applying the pre-heating process in cookie dough could enhance the resistance of deformation and could be implemented as 3D printing inks, which is giving better results in flours with lower starch content rather than higher starch content like tapioca. Moreover, 3D printed technology make also available fortifying cookies with some microalgae like *Arthrospira platensis* and *Chlorella vulgaris*, culminate in enhancing printability and stability. Moreover, to obtain novel functional foods with high nutritional properties, pea protein, grape skin powder, jackfruit seed powder, and finger millet powder have also been used in 3D printed cookies. To sum up, 3D printing technology has great potential and is a promising solution for personalized cookies with complex shapes and textures by taking into consideration the contribution of ingredients and printing parameters to produce high quality end-products with higher repeatability and accuracy.

Keywords: 3D printing; cookie; fortification; sustainability



Fusel deposition modeling (FDM) is a shaping tool which modifiynig food structure and create new texture. Moreover, FDM could be referred as micro-extrusion process which deposits flaments in XYZ coordinates, and is generally utilizing for the production of 3D-printed cookies **(Noort et al., 2017).**

Fig 1. The methods of 3D-printing

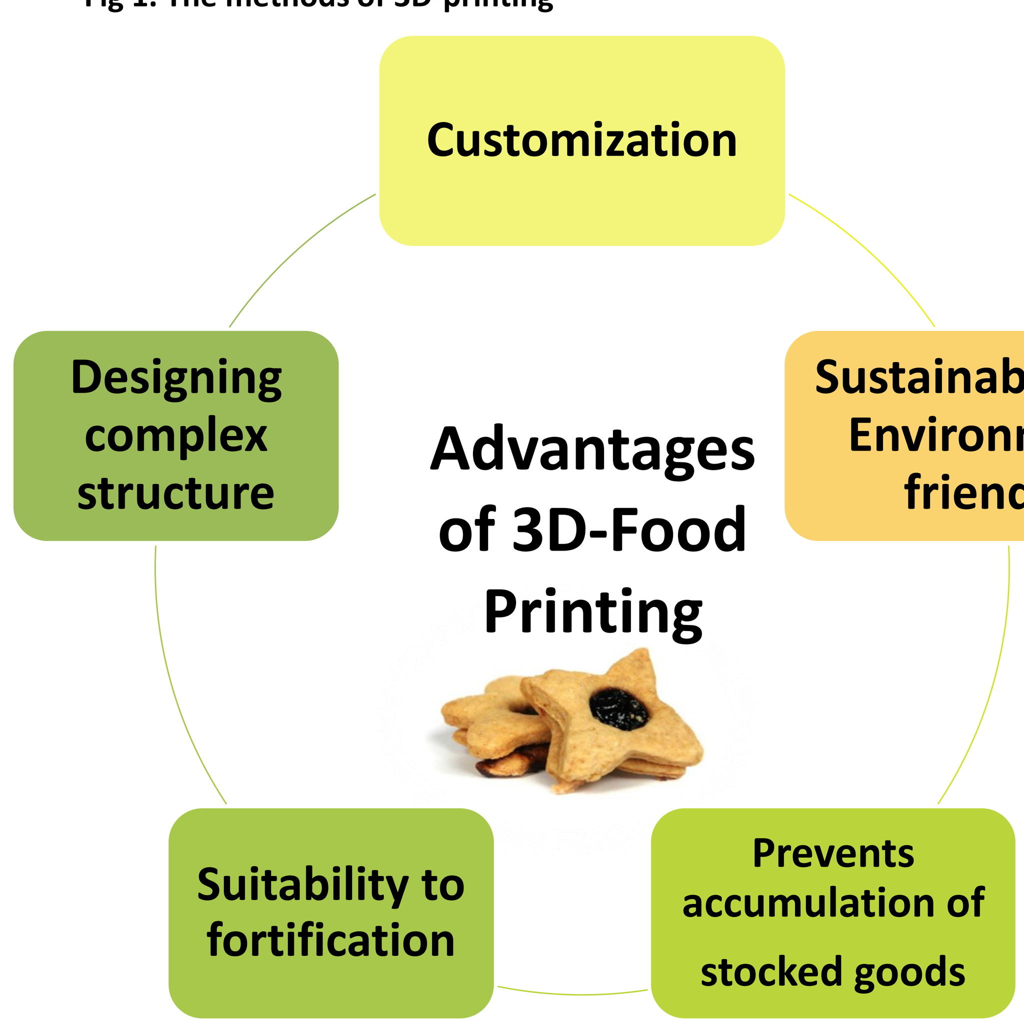


Fig 2. The advantages of 3D-food printing (Dankar et al., 2018).

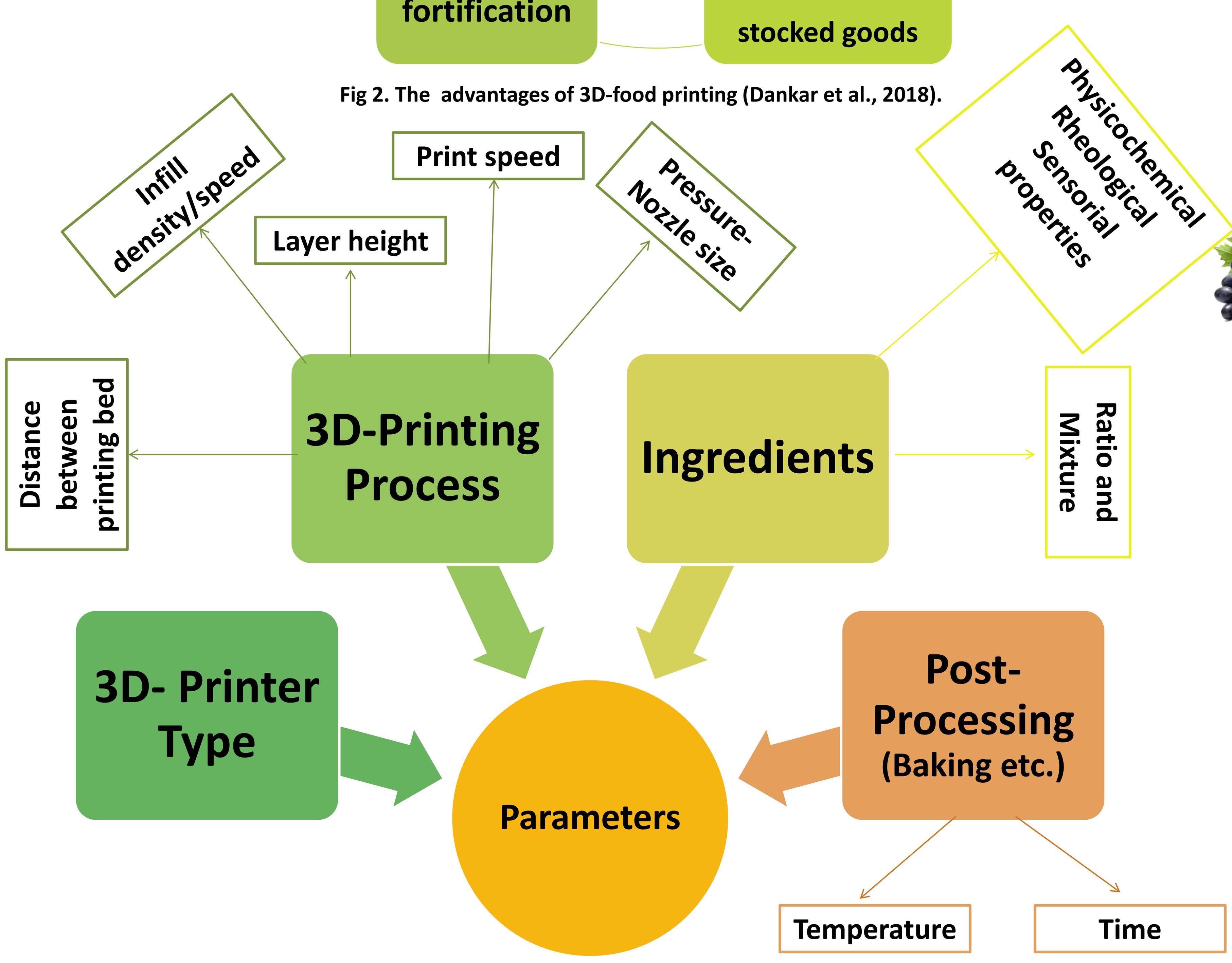


Fig 3. The parameters which influence the 3D-printed cookies and properties of other bakery products

Addition of Hydrocolloid

- Two different hydrocolloids (xanthan gum and methylcellulose) were used at three different concentrations (0.5, 1, 2, and 3 g/100 g) to solve the deformation problem throughout baking. In this regard using xanthan gum at 0.5% concentration caused smooth printing and retaining dimensional stability during post-processing. However, extrusion hardness was increased inordinately at the high concentrations of xanthan gum, and thus extruding was not conducted successfully. On the other hand, dimensional error increased, height values decreased, and no significant difference was observed in mechanical strength when using methylcellulose regardless of the concentration **(Kim et al., 2019).**

Fortification with Probiotic Sources and Edible Insects

- 3D cookie-like snacks were enriched with larvae of yellow mealworms (*Tenebrio molitor*) as a novel portein source, at two different concentration (10, 20%) and baked at different baking time (14, 18, 22 min) and temperature (180, 200, 220°C). The highest baking time and the middle temperature had the highest desirability values. Increasing in edible insect amount resulted in softer products and essential amino acid content **(Severini et al., 2018**). In a study, the cookie-like food product wirh two different design as honeycomb and concentric including probiotic source (*Lactobacillus plantarum*), were produced and then baked at three different temperatures (145, 175 and 205°C). The baking time decreased when surface-to-volume ratio increased, and thus the viability of probiotics were 2 log higher in honeycomb structure (exceeded10^6 CFU/g) at 145 °C than concentric structure **(Zhang et al., 2018).**

Fortification with Microalgae

- The addition of *Arthrospira platensis* and *Chlorella vulgaris* to 3D printed cookies, improved not only printability, in regards to dimensional feature, but also elastic behavior which caused easier recovery of deformation and greater mechanical resistance to baking, and thus have been obtained more stable cookies. The spirulina-added cookies had higher values of G' and G'' because of its higher protein content than chlorella, according to rheologial analysis **(Uribe-Wandurraga et al., 2021).** In another study, *Arthrospira platensis* was also used for its antioxidant potential for developing a new functional food **(Vieira et al., 2020).**

Fortification with Fruit, Legume or Grain-Based Compounds

- To produce functional and healthy 3D-printed cookies, the grape-skin extract was used and the antioxidant activity increased, as expected. Moreover, the decrease of antioxidant activity in the percent of 20% throughout baking, was also prevented. by encapsulation method **(Oliveira et al., 2021).** The pea protein isolate was used at the 30% concentration to produce nutritionally rich 3D-printed cookies by using extrusion-based 3D food printer. **(Hussain et al., 2020).** In another study, jackfruit seed powder and finger millet powder were utilized in 3D-printed cookies for enhancing nutritional value **(Varghese et al., 2020).**

Fig 3. The studies related with the fortification of 3D-printed cookie and cookie-like products with difeerent compounds

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