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3D Food Printing- An Innovation in Process

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Abstract—*Agriculture has come a long way in the past century due to the rise of many agricultural revolutions. More and more food is being produced but our current model is unsustainable. The world's population is increasing at an alarming rate due to medical innovations, improved lifestyle etc, hence, modern food production methods will need a radical transformation to keep up. To cope up with the demanding pressure, an introduction of new range of technologies might make it possible. 3D food printing is one of them.3D food printing is the latest innovative trend in the additive food manufacturing industry. Recent innovations in food printing have made it possible to print, cook and serve foods on a mass scale. It offers a range of potential benefits. 3D printing of food allows enormous freedom of design in terms of shape, composition, structure, texture and most importantly taste. An innovative manufacturing process whereby an object is built up layer by layer, from a 3D computer design using a variety of printing technologies. It can be healthy and good for the environment because it can help to convert alternative ingredients such as proteins from algae, beet leaves, or insects into tasty products. It also opens the door to food customization and therefore tune up with individual needs and preferences. An ambitious research level projects on 3D food printing are being carried out on development and improvement of this production process that might replace much larger parts such as multiple steps or even the complete food production process.*

1. INTRODUCTION

A population of 10 to 15 percent over the age of 50 years suffer from difficulties in swallowing. Foods are available in the form of liquefied products like purees but those are unappealing and unappetizing [10]. Many food forming or food structuring techniques are optimized for mass production. Foods are being designed and customized by specially trained artisans using techniques involving assembling various prefabricated components to meet customer's preferences [14].The mass customization is done on shapes, colours, flavours, textures, and nutrition for many food products like personalized hamburgers, coffees, ice creams, cakes and biscuits. 3D food printing paves an excellent way towards improved product customization. 3D printing technology has been in existence for the last 3 decades. Only recently has it become readily available and inexpensive enough to be used by the general public [6][7]. 3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layers of material from a 3D computer design using a variety of technologies. This process is also referred to as additive manufacturing (AM), rapid prototyping (RP), or solid free-form technology (SFF). It is a is a mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. The 3D printing concept of custom manufacturing is exciting to nearly everyone. This revolutionary method for creating 3D models with the use of inkjet technology saves time and cost by eliminating the need to design; print and glue together separate model parts. By using 3D printing technology, suitable ingredients can be mixed and then processed into the most intricate shapes and structures which are impossible to be made or are uneconomical to produce under traditional manufacturing process. These kinds of food can have entirely novel textures and flavors that are unimaginable to be produced through traditional cooking processes. Thus, it is predicted that 3D printing technology can bring the processing or food preparation technologies into the digital age. Wide variety of ingredients can be automatically mixed during printing on the basis of certain selected recipes and be made in the absence of operator by introducing advanced settings. [17]

History of 3D Printing

The technology for printing physical 3D objects from digital data was first developed by Charles Hull in 1984 which he called "stereolithography," in the early 1980s Schubert. He named the technique as Stereo lithography and obtained a patent for the technique in 1986. Hull later founded the company 3D Systems, which developed the first 3D printer, called a "stereolithography apparatus." In 1988, 3DSystems introduced the first commercially available 3D printer, the SLA-250 [5].While Stereo lithography systems had become popular by the end of 1980s, other similar technologies such as Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS) were introduced. In 1993, Massachusetts Institute of Technology (MIT) patented another technology, named "3 Dimensional Printing techniques", which is similar to the inkjet technology used in 2D Printers. In 1996, three major products, "Genisys" from Stratasys, "Actua 2100" from 3D Systems and "Z402" from Z Corporation, were introduced. In 2005, Z Corp. launched a breakthrough product, named Spectrum Z510, which was the first high definition color 3D

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Printer in the market. Another breakthrough in 3D Printing occurred in 2006 with the initiation of an open source project, named Reprap, which was aimed at developing a self-replicating 3D printer. In 1938,the very first part of the 3D object was printed by Chuck Hull who invented 3D printing . 3D printing technology is initially used in military field. With the efforts made by researchers this technology has been experimented to wider applications. Recently, 3D printing technology has also been experimented into various kinds of food systems, that is, Food Layered Manufacture [16].

Principle

The basic principles include materials cartridges, flexibility of output, and translation of code into a visible pattern. 3D Printers are machines that produce physical 3D models from digital data by printing layer by layer. It can make physical models of objects either designed with a CAD program or scanned with a 3D Scanner. The process of 3D food printing encompasses three processes viz; modelling, printing and finishing. 3D printable models can be created by using a computer aided design package, which have reduced errors and can be corrected before printing, allowing verification in the design of object before it is printed.. Before printing a 3D model from an STL(stereolithography) file, it must be examined for errors, and the errors in the original model are fixed by STL process by a step known as repair After the repair, the STL file needs to be processed by a piece of software called a "slicer" which converts model into a series of thin layers and produces a G-code file containing instructions customized to a particular type of 3D printer. The final step involves finishing of the printed product. Although the resolution printed by a 3D printer is sufficient in most of the applications, for printing slightly oversized version of the desired object in standard resolution and then removing material with a higher resolution subtractive process can achieve greater precision.

Working

Different from traditional printers, 3D printers use various kinds of other materials such as architecture materials and food materials as ink. The products which come out of the machine can be parts or models or foods or machines [17]. The model to be manufactured is built up a layer at a time. A layer of powder is automatically deposited in the model tray. The print head then applies resin in the shape of the model. The layer dries solid almost immediately. The model tray then moves down the distance of a layer and another layer of power is deposited in position, in the model tray. The print head again applies resin in the shape of the model, binding it to the first layer. This sequence occurs one layer at a time until the model is complete.

Benefits

3D food printing allows enormous freedom of design, not only in terms of 3D shape but also the composition of ingredients and their ratios, structure, texture, and most importantly taste.(TNO).

- 3D food printing has an ability to give food products any shape and form as per customization requirements.
- Novelity in case of design and texture is one of the prominent benefits of 3D food printing.
- Products can be tailored as per consumer requirements making truly personalized food for a wide variety of consumers.
- 3D food printing allows a broader adaptation and combination range of food ingredients, food flavours, giving rise to demandable variety.
- Using a broad range of alternative food components and underutilized ingredients, novel food structuring can be achieved by 3D food printing.
- 3D printing allows artists to create objects that would be incredibly difficult, costly, or time intensive using traditional processes.

Applications of 3D food printing

With the development of 3D printing technology, we may be able to avail the opportunity to use not only new nutrient-dense but nearly infinite food materials including exotic foods such as insects that are not accepted by the majority of people as ingredients to create new popular food to feed all the global population [10]. 3D printing can also be serve as a new potential cooking way. Increasingly revolutionary changes is expected to happen on certain traditional foods such as chocolate, cookies, cakes and ice creams.(Yang et al). The applications of 3D printing food products can be based on two aspects. (1) New nutrient-dense and potential usage of any food materials (2) Improvement on traditional food products' appearance and texture by the control of food materials at macro- and micro-structural levels [10]. 3D Food printers introduce artistic capabilities to fine dining and extend mass customization capabilities to the industrial culinary sector. They also provide a re-search tool to manipulate food structure at multiple scales [14].The 3D food printing platform allows the process of fabricating culinary designs from professionals at any place by downloading the original data files. By importing the respective fabrication files, which contain culinary knowledge and artistic skills from nutrition experts, chefs, and food designers, users can reproduce the original work of perfection. The products can be built in front of the customers using their personal 3D food printer after downloading the corresponding files. It is a new context of household product making, which would have been impossible to achieve using the existing methods.

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Development of alternate foods

The world's population is increasing at an alarming rate due to medical innovations, improved lifestyle etc, hence, modern food production methods will need a radical transformation to keep up. At least 1 million malnourished children die each year. An additional 34 million children suffer from severe acute malnutrition. To cope up with the demanding pressure, an introduction of new range of foods through alternate technologies might make it possible. The European Union and the World Food Organization recognize the fact that making insects into proper food might be one of the ways to cope with this this problem, as insects could be abundant resources that can be made into flour in order to prepare various nutritious healthy meals [3]. Insects grow at an ever increasing rate on cheaper foods but contain a rich amount of proteins, carbohydrates and dietary fibre. although insects are nutrient dense, they are not accepted as food materials for the majority of people owing to their odd original looks and flavors. British scientists have been attempting to combine the ―3D printing‖ and ―insects‖ to develop a technique which can turn insects into appetizing meals [10].

Texture and appearance improvement of Traditional Food Products

The properties of food materials such as glass transition, gelation, rheology and melting properties play an important role in final product quality of printed material. In addition to these, the inherent characteristics of various ingredients, heat resistance and cooking properties material's biochemical and microbiological properties and biological variation also affect it. One available solution to enable the majority of appealing natural food material such as vegetables and meat to apply in 3D food printing is adding hydrocolloids such as xanthan gum and gelatin to achieve desirable textures and remain satisfying shapes after post-processing [4].

Quality improvement of Chocolates.

The behaviour of fat component in chocolates plays a significant role in in storage stability and final quality attributes. The melting and crystallization behaviors of fat present in chocolate will be important to understand from the point of view of deposition temperature and change occurring in deposited chocolate [17] The study reports indicate that there is a need to optimize the rate and resolution of deposition of the product during 3D printing [18]. To successfully create layer-by-layer structure, the physical properties of food material or ingredients, especially the melting and crystallization behaviors, are vital to be considered and continuously optimized. Also, some properties of 3D printers, such as speed (e.g. axis movement rate and extrusion rate) and accuracy have impact on the final products which are successful or not [17]. In 2013, the National Aeronautics and Space Administration awarded an engineering firm based in Texas a 6-month grant worth $125,000 to create the world's first 3D food printer.43 It was announced at the 2014 Consumer Electronics Symposium in Las Vegas that 2 food-creating 3D printers will be released later in the year [2]. Both models have the ability to print using chocolate or sugar infused with vanilla, mint, sour apple, cherry, and watermelon flavors. This technology has the potential to be life-saving for the many malnourished children in the developing world [8].

Dough Improvement

The early attempts for 3D food printing were all made using simple dough that hardened when dried or cooled. These kinds of paste-based diet might suit certain specific consumers (such as astronauts), but it is too limited for the mass in their daily lives [17.]If we want the food printers to be on the market, the printers will require a much larger range of ingredients, recipes and cooking temperatures [10]. Some researchers mixed gelling agents like carrageenan, xanthan gum and gum arabic with other ingredients including supplements and then mix them into the printer to create edible constructs like raspberry domes, mushroom-shaped bananas and cubes of milk [10]. Jeffrey Lipton (2015) successfully made deep-fried scallops, turkey and celery which have creatively customize food shapes. Turkey, scallop and celery were modified using transglutaminase to enable them to be hot processed after printing [17].

Innovative Food Products

Meat analogues such as soy-based or gluten based form an important part of Buddhist cuisines and after cooking the taste of these dishes is very similar to meat. Lipton conducted a research and proved the concept of creating a wider range of textures and tastes by mixing small group of hydrocolloids and flavor additives. Thus, it is possible to create a wide range of food items with very similar taste and shape by using a limited number of raw materials. If such knowledge is embedded into the food printing process, more innovative food products and unique dining experiences can be created [14].

Personalized Nutrition

During recent years, besides giving preferences to general nutrition, a lot of emphasis is given to individual's health status and requirements of a particular body type [15]. The integration of food printing with a nutrition model, helps users to calculate exact data of calories and other ingredients of fabricated products to provide the prototype of nutritional distribution. By selecting the exact proportion and controlling corresponding fabrication parameters through user interface, customers / users can take control of their diet. Therefore, to digitalize people's nutrition and energy intake, 3D food printing provides a convenient way and offers a better control of individual dietary. Personalized nutrition in food products can be determined according to online information on nutritional content, personal, and social preferences[14].

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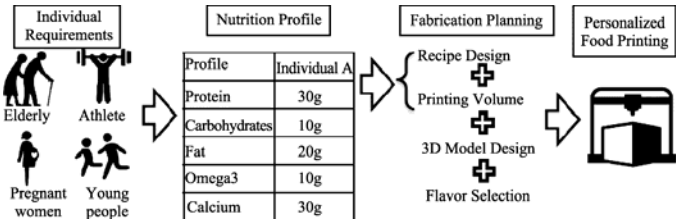

Figure 1. Customized food with personalized nutrition [14]

Customized Food Supply Chain

With a target of higher production efficiency and lower overriding cost, food printing targets a built- to- order strategy. Consumers may configure or transact food designs under e-commerce platform and fabricate physical products using a nearby production facility. From design to market, to attain zero lead-time, plenty of innovative food design websites and mobile apps can help users on design and order customized food products [10] This will initiate a great improvement and change in customized food supply chains, thereby reducing the distribution costs, simplifying customized food service, and bringing products to consumers in a shorter time gap. A description of this new, customized food supply chain is shown in Figure 2. It starts with customers searching for an online food design platform based on their needs, and selecting a food design. The corresponding design data is transferred to a neighborhood Printing Service Bureau. The selected food designs are fabricated at this Bureau and are eventually delivered to the customers.[14].

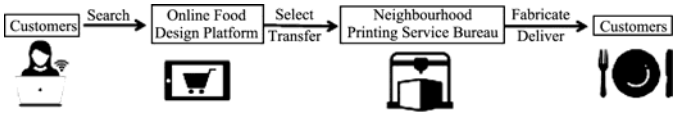

Figure 2. Customized food supply chain [14]

Challenges

Although being an innovative process, 3D food printing is far more daedal than the way it looks. A plethora of conditions need to be optimized for the same and it includes appropriate use of mechanical force, suitability of printer feeding ingredients, and careful design of digital recipe. A broad range of operating conditions need to be operated and controlled including application of different food formulations are with different pressures.

Conclusions

An innovatory developing process, 3D food printing offers the potentiality of framing/ manufacturing precisely designed objects inexpensively and readily. With proper optimization techniques, 3D food printing can be explored for developing new food products by use of specific food materials or ingredient recipes suitable for printing. The systematic investigation of printing technologies, platform designs, printing materials and their influences on food fabrication is necessary to achieve consistency in 3D food printing and fabrication. Being a quick and inexpensive process, 3D food printing can be used to deliver better quality and freshly prepared food products to consumers with customized/ personalized nutrition. The overall effect it generates is paving a way for creating a range of shapes, textures, recipies and newer flavours for a peculiar and unique eating experience.

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