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A REVIEW STUDY ON 3D CUSTOM PRINTING OF FOODSTUFFS

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ABSTRACT

For single and multi-material applications, a comprehensive review of various 3DP technologies and their associated dispensing/printing method for 3D personalized food manufacturing is presented. Food printing's effects on customized nutrition, on-demand food manufacturing, food processing technology, and process design are eventually discussed. Their use in home cooking and catering may offer not only an engineering solution for personalized meal design and nutrition management, but also a potential machine to reconfigure a customized food supply chain. The first generation food printer concept designs and working prototypes are presented in this research, with the goal of revolutionizing personalized food production via 3D printing (3DP). Unlike robotics-based food manufacturing technologies that aim to automate manual procedures for mass production, 3D food printing combines 3D printing with digital gastronomy to create food items that can be customized in form, color, taste, texture, and even nutrition. On the basis of fabrication platforms and printing materials, the chosen prototypes are evaluated. This expands customization possibilities to the industrial cooking industry while also introducing creative skills to fine dining.

KEYWORDS: *Customized, Food Fabrication, 3d Food Printing, Platform Design, Multi-Material.*

1. INTRODUCTION

Customized food items are in high demand, and the majority of them are presently developed and manufactured by highly educated craftsmen. The price is quite expensive for such a little number of components. One of the possible solutions to overcome this gap is three-dimensional (3D) food printing, also known as Food Layered Manufacture. Its goal is to layer-by-layer create 3D custom-designed food items without the need for object-specific equipment, molding, or human involvement. As a result, this technology may improve production efficiency and lower manufacturing costs for the creation of personalized food items.(1–5).

1.1. Food Printing and Robotics-based Food Manufacturing

Cooking is one of our most essential activities, and a robotic chef capable of following recipes would have a wide range of uses in both domestic and industrial settings. Baking cookies robots, for example, can find ingredients, combine them in the proper sequence, and put the resultant dough in an oven baking pan. These libraries-equipped robots can do daily manipulation tasks and fundamental motions like picking up, putting down, and pouring. These robotics-based methods are often employed in conventional food manufacturing for large production to automate manual operations. They can significantly decrease workload, labor costs, and food production efficiency. Food producers are ecstatic about such advancements, but they are unclear about the reasons for and motivations for creating food printing methods and their distinct characteristics. As a result, a comparison of the two methods is required(6–10).

Food printing differs from other robotics-based technologies in that it combines 3D printing (3DP) with digital gastronomy methods to create food items that can be mass customized in form, color, taste, texture, and even nutritional value. 3DP is a digitally controlled, robotic building technique that creates complicated solid structures layer by layer and fuses them together via phase transitions or chemical processes. The goal of digital gastronomy is to include cooking process information into food production so that our dining experiences extend beyond taste to include all elements of gastrin. Combining 3DP with digital gastronomy methods allows for digital visualization of food modification, opening up new possibilities for innovative food production at a low cost. As a consequence, a customized culinary design in the form of a digital 3D model will be converted immediately into a layered final product.

1.2. Food Printer Concepts and Platform Designs:

The first generation of food printer concept ideas and prototypes are becoming available to the general public. A few research projects, ranging from concept designs to in-depth study on material extrusion and deposition, have been completed in a short time.

1.2.1. Conceptual Ideas:

A fast prototyping and manufacturing technique for 3D food items, such as a custom-designed birthday cake, was patented by Nanotek Instruments Inc. in 2001. However, there was no actual prototype created. NicoKläber won the Electrolux Design Lab competition with a Molecular concept design that integrated molecular gastronomy with food printer design. The goal of this idea was to use a tiny robotic arm to print various materials and make a completely customized dinner out of ordinary food. Food cartridges were developed by Philips Food Creation Printer to produce custom-designed food products layer-by-layer.

To choose ingredients, amounts, forms, textures, and other culinary characteristics, an interactive graphical user interface was suggested. Ingredients in digital gastronomy may be decided based on online nutritional content, personal and societal preferences. Hypothetical ideas from the Massachusetts Institute of Technology (MIT) that incorporate a digital gastronomy concept into food printer design. Each one focused on a distinct element of cuisine, such as blending, modeling, and transformation. These ideas seem to be more realistic than earlier concept designs, although they are still far from being technically viable(11–15).

1.2.2. Platform for Food Printing:

The fundamental components of a food printer platform are an XYZ three-axis stage (Cartesian coordinate system), dispensing/sintering devices, and a user interface. Such platforms can manipulate food in real-time thanks to a computer-controlled three-axis motorized stage and material feeding system. According to computerized design modeling and route planning, food composition may be deposited/sintered basically point by point and layer by layer. At least four functions are suggested to create and customize new meals rather than merely automate the conventional food manufacturing process: measuring, mixing, dispensing, and cooking (heating or cooling). In the present commercial or self-developed food printing systems, only the dispensing and cooking features are provided.

1.2.3. Food printers based on commercial platforms:

Researchers adapted commercially available open source 3D printing platforms for food printing to simplify the development process and save development time. One typical modification is to replace the original print head with a specifically built dispensing unit with an extra valve to regulate the material flow rate, or to replace the conventional inkjet binder with food-grade substance such as starch mixes. Although not particularly intended for culinary applications, the Fab@Home system was one of the first desktop fabricators compatible with food ingredients. Frost ruder MK2 was also utilized on the Maker Bot platform to extrude frost, with two solenoid valves controlling the flow rate of creamy peanut butter, jelly, and Nutella (Millen et al., 2012). A food printing platform with a print head developed at the National University of Singapore is shown in Figure 1. The platform is based on a Prusa i3 platform that has been modified to include a self-developed extrusion print head.

1.3. Available Printing Materials:

Pre-processing materials for 3D printing and increasing their thermal stability during post-processing have received a lot of attention. TNO proposes printing pureed meals to assist older individuals with chewing and swallowing issues. TNO also proposes customizing meals for elderly, athletes, and expecting women by changing dietary component amounts such as protein and fat. In general, the printability of available printing materials may be divided into two groups.

1.3.1. Natively printable materials:

Hydrogel, cake icing, cheese, hummus, and chocolate are all natively printed materials that can be extruded smoothly from a syringe. In a powder/binder 3D printer, a combination of sugars, starch, and mashed potato was tried as a powder material. For demonstration purposes, a number of sugar teeth were created. None of these, however, are the primary dish of a meal. The most effective material for a printability research utilizing Fabaronic was pasta dough, which was evaluated by viscosity, consistency, and solidifying characteristics.

Taste, nutritional value, and texture of food items produced using natively printed materials may all be precisely regulated. Some natively printed materials are stable enough to retain their form after deposition and do not need further post processing, making them ideal for medical and space applications. Other composite formulations, such as batters and protein pastes, may require a heating step after deposition. It will be more difficult for food products to maintain their forms as a result.

1.3.2. Non-printable traditional food material:

Rice, meat, fruit, and vegetables, which are widely eaten on a daily basis, are not printable by nature. Adding hydrocolloids to these solid materials has been authorized and used in various culinary areas to allow their extrusion capacity. Simple additions were used to alter conventional food recipes, resulting in complicated geometries and new formulas. Although culinary techniques have previously been used to make solid meals and semi-solid liquids printed, it is impossible to test and alter the whole list. One possibility was to utilize a limited number of components to build a platform with a wide range of texture and taste options. A broad variety of textures (i.e. mouthfeels) may be produced by fine-tuning hydrocolloid concentrations(16–20).

1.3.3. Post-processing:

To fully eliminate liquid ingredients from food composition, the food printing method does not need a significant energy source. Fabricated layers do not need to be fully solidified, but they must be stiff and strong enough to sustain their own weight as well as the weight of succeeding layers without deforming or changing shape significantly. After shaping, the bulk of traditional foods need post-deposition cooking, such as baking, steaming, or frying. Different degrees of heat penetration are involved in these processes, resulting in non-homogeneous texture.

1.4. DP Technologies in Food Printing:

In high-value, low-volume food production, 3D food printing offers considerable benefits, especially for customized products in the food service industry. To load and print food ingredients, several print head designs are used. To sinter or melt powder, some utilized thermal energy from a laser/hot air/heating element, while others used inkjet-type printing heads to precisely spray binder or solvent. A list of 3DP technologies that may be used is shown below.

1.5. Current 3DP Technologies' Applications:

1.5.1. Binder jetting:

Each powder layer is uniformly dispersed over the fabrication platform in conventional binder jetting technology, and a liquid binder sprays to bond two successive powder layers. To reduce the disruption caused by binder distribution, the powder material is typically stabilized with water mist. Sugar and starch combinations were used as the powder material in the edible 3D printing project, and a Z Corporation powder/binder 3D printer was used as the platform to create bespoke shapes with complicated structures.

Sugar Lab created intricate sculpted desserts for weddings and other important occasions using sugar and various flavor binders. The material and manufacturing method fulfilled all food safety standards, and the fabrication using 3D Systems' Color Jet Printing technology. Binder jetting has benefits such as quicker fabrication and lower material costs, but also has drawbacks such as a poor surface quality and a high equipment cost. Post-processing, such as curing at a higher temperature to enhance the bonding, may be necessary.

1.5.2. Inkjet printing:

Inkjet food printing uses a syringe-type printer to discharge stream/droplets on demand. A layer structure is used to produce 3D edible food products such as cookies, cakes, and pastries, which requires pre-patterning food items at several processing stages. The FoodJet Printer by De Grood Innovations utilized pneumatic membrane nozzle-jets to deposit material droplets on pizza bases, biscuits, and cupcakes. The ejected stream/droplets descend to the ground due to gravity, impact on the substrate, and evaporation of the solvent. As a decorative or surface fill, the droplets may create a two-and-a-half-dimensional digital picture(21).

1.5.3. Multi-material and Multi-Printheads:

In bespoke food design and manufacturing, the use of various materials is very frequent. Some of these components are derived from conventional food recipes, while others are non-traditional edible elements (mainly non-food, such as substances derived from algae, beets, or even insects). In the 'Insects Au Gratin' experiment, insect powders were combined with extrudable icing and soft cheese to create delicious culinary shapes. Consumers may take control of the design and production of various materials thanks to the variety of printing materials available. Researchers used a Fab@Home 3D printer to test icing, chocolate, processed cheese, muffin mix, hydrocolloid combinations, and caramel and cookie dough using numerous print heads. Dual-material printing was only possible with separate deposition heads for a restricted range of materials, and the secondary material was only used to assist manufacturing and was then removed. Our group at the National University of Singapore created several three-material food samples(22).

1.6. Impacts from 3D Food Printing:

Food printers offer mass-customization skills to the industrial culinary industry while also introducing creative possibilities to gourmet dining. This allows for a high-value, low-volume food personalization process that is presently difficult to accomplish. It also includes research methods for manipulating the structure of solid food items at various sizes. Because this technology is still in its early stages of development, it is critical to comprehend its fundamental value and prospective commercial applications. Simultaneously, it is essential to keep track on technological advancements and related applications in order to determine how this new technology will satisfy customers' requirements and, possibly, alter people's lifestyles.

1.6.1. Personalised nutrition

- Simplifying customized foods supply chain
- Reformulating food processing technologies
- Process design and digitalization

2. DISCUSSION

A mathematical model that can accurately represent this process including inputs, outputs, and process type will be very helpful in gaining a better knowledge of 3D food printing processes. The main driving factor behind the development of such a model is the customization of the food production process and the design of the food printer. Temperature and moisture, as well as dietary characteristics like density, thermal and electrical conductivity, viscosity, and permeability, are often linked. Before mathematical manipulation, it is essential to digitalize complete cooking operations, which varies significantly from conventional food processing models. To obtain consistent fabrication outcomes, the fabrication process should be characterized, and a simulation model linking design and manufacturing with nutrition management should be created. Meals printers may become part of an ecological system, where networked machines may order new ingredients, make beloved food on demand, and even cooperate with physicians to design better diets, if an interactive open web-based user interface is developed.

3. CONCLUSION

3D food printing has shown its worth by creating customized chocolates and basic homogeneous snacks. These apps, on the other hand, remain basic, with restricted internal structures and repetitive textures. A systematic approach to investigating printing materials, platform design, printing methods, and their effects on food production is required. Meanwhile, the food design process should be organized in a way that encourages user innovation. This article examines the evolution of food printing technology from idea to commercial equipment. The two printing systems are utilized, and the printing experiment uses both natively printable and nonprintable conventional food components. Although there are a variety of food printing technologies available, there is still a long way to go before they can be used commercially. Food printing has the potential to have a major impact on many kinds of food processing, since it allows designers/users to modify shapes and materials with improved and unprecedented capacity, as seen in this technology evaluation. When used to domestic cooking or catering, this flexibility may increase efficiency in delivering high-quality, freshly cooked food to customers, provide customized nutrition, and allow users to experiment with different tastes, textures, and forms to create completely new eating experiences.

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