A PROJECT REPORT
ON
" 3-D PRINTER ON FOOD PRINTING"

Submitted by

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In Partial fulfillment for the the award of the Degree
Of

BACHELOR OF ENGINEERING
IN
MECHANICAL ENGINEERING
UNDER THE GUIDANCE
Of
Prof. UBAID SHAH

DEPARTMENT OF MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the project entitled

3-D PRINTER ON FOOD PRINTING

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Of the Kalsekar Technical Campus,New Panvel is a record of bonafide work carried out by him under supervision and guidance,for partial fulfillment of the requirements for the award of the degree of Bachelor of Engineering in Mehanical Engineering as prescribed by University Of Mumbai is approved.

Signature of the Guidance	Signature of the HOD	Signature of the Principal
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DISSERTATION APPROVAL SHEET

This is to certify that this B.E. project titled, **3-D PRINTER ON FOOD PRODUCTION PRINTING,**submitted by

Satware Ajaz
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Approved for the DEGREE OF BACHELOR IN ENGINEERING, in MECHANICAL ENGINEERING from University of Mumbai. Certified further that, to the best of my knowledge this report represents the work carried out by this student.

Internal Examiner

Seal of the Institute

Date:

Dedication

Dedicated to my beloved family and friends & staff members

ACKNOWLEDGEMENTS

In the name of Allah, the Most Benevolent, the most Merciful. I wish to record immeasurable gratitude and thankfulness to the One and The Almighty Creator, the Lord and sustainer of the universe, and mankind in particular. It is only through His mercy and help that this work could be completed and it is ardently desired that this little effort be accepted by Him to be of some service to the cause of humanity.

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ABSTRACT

This study introduces the first generation food printer concept designs and workable prototypes that target to revolutionize customized food fabrication by 3D printing (3DP). Different from robotics based food manufacturing technologies designed to automate manual processes for mass production, 3D food printing integrates 3DP and digital gastronomy technique to manufacture food products with customization in shape, colour, flavor, texture and even nutrition. This introduces artistic capabilities to fine dining, and extend customization capabilities to industrial culinary sector. The selected prototypes are reviewed based on fabrication platforms and printing materials. A detailed discussion on specific 3DP technologies and their associate dispensing/printing process for 3D customized food fabrication are reported for single and multi-material applications. Eventually, impacts of food printing on personalized nutrition, on-demand food fabrication, food processing technologies and process design are reported. Their applications in domestic cooking or catering services can not only provide an engineering solution for customized food design and personalized nutrition control, but also a potential machine to reconfigure a customized food supply chain.

CHAPTER 1

INTRODUCTION

CHAPTER 1

1.1 INTRODUCTION:

There is an increasing market need for customized food products, most of which are currently designed and made by specially trained artisans. The cost for such a limited number of pieces is relatively high. Three-dimensional (3D) food printing, also known as Food Layered Manufacture can be one of potential alternatives to bridge this gap. It aims to produce 3D custom-designed food objects in a layer-by-layer manner, without object-specific tooling, molding, or human intervention. Thus, this technology can increase production efficiency and reduce manufacturing cost for customized food products fabrication.

Fig.1: 3-D Printer in Food printing

1.2 FOOD PRINTING AND ROBOTICS-BASED FOOD MANUFACTURING:

Cooking is one of the most important activities in our life, and a robotic chef capable of following recipes would have many applications in both household and industrial environments. For example, baking cookies robots can locate ingredients, mix them in correct order, and place a resulting dough in a baking tray of oven. These robots equipped with libraries can perform everyday manipulation tasks, and basic actions such as picking up an object, putting it down or pouring. These robotics-based techniques used in traditional food manufacturing for mass production, are generally designed to automate manual processes. They can greatly reduce workload, save labour cost, and improve food manufacturing efficiency. Food manufacturers are quite happy with such progresses, and are not clear about the reasons and motivation of developing food printing techniques and their unique features.

Hence, a comparison between the two techniques is necessary. Differentiated from such robotics-based technologies, food printing integrates 3D printing (3DP) and digital gastronomy techniques to manufacture food pieces with mass customization in shape, colour, flavor, texture and even nutritional value. 3DP is a digitally-controlled, robotic construction process which builds up complex solid forms layer by layer and applies phase transitions or chemical reactions to fuse layers together. Digital gastronomy is to implement cooking process knowledge in food fabrication so that our eating experiences go beyond taste to encompass all aspects oof gastronomy.

Combining 3DP and digital gastronomy techniques can digitally visualize food manipulation, therefore creating a new space for novel food fabrication at affordable price. As a result, a customised food design in a form of digital 3D model will be directly transformed to a finished product in a layered structure.

Fig.2: 3-D Printed Chocolate

1.3 OVERVIEW:

A number of articles and papers pertaining to food printing have been published over the past few years. Most of them focused on fabricated novel food items. Recently, some researchers started investigating fundamental-level issues in food printing, such as converting ingredients into tasty products for healthy and environmental reasons. However, such information is scattered in various publications with different technical focuses. The objective of this paper is to gather, analyze, categorize, and summarize information pertinent to the technology and its impact to food processing.

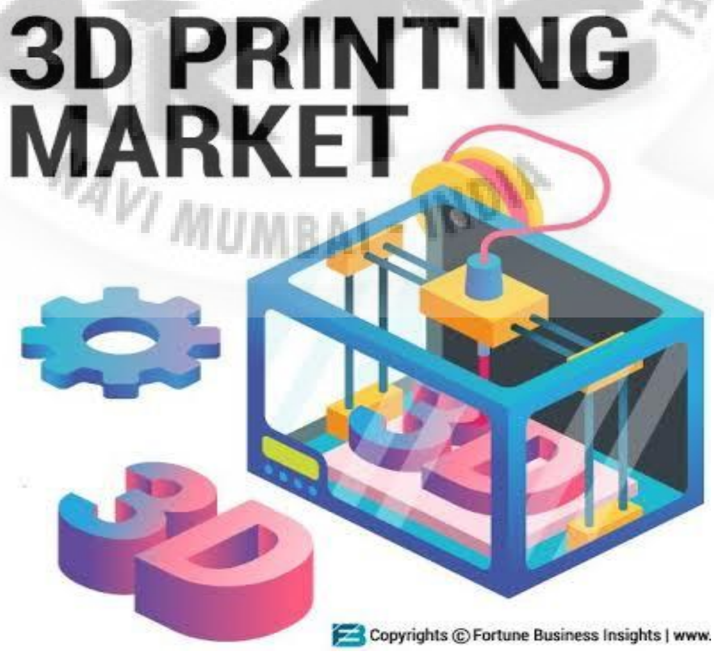

Fig.3: 3-D PRINTING MACHONE

The competition between companies of any industrial sector grows more and more each year. In this way, companies seek to reduce costs and deadlines and, at the same time, are pressured to develop and deliver products of high quality and performance. This competition generates the need to launch a new product in the market with a greater frequency and, consequently, the demand for new projects and development of new products grows. It is at this stage that 3D printing stands out.

Popularly known as 3D printing, this process has many other names such as rapid prototyping (RP), additive manufacturing (AM) additive techniques, additive processes, among others. Within a few minutes or hours, this manufacturing process allows to produce complete products from a CAD software, using the most diverse raw materials and without a great human intervention. 3D printing has as its characteristic to construct three-dimensional pieces by means of the addition of successive thin layers, one on top of the other, until the formation of the desired product.

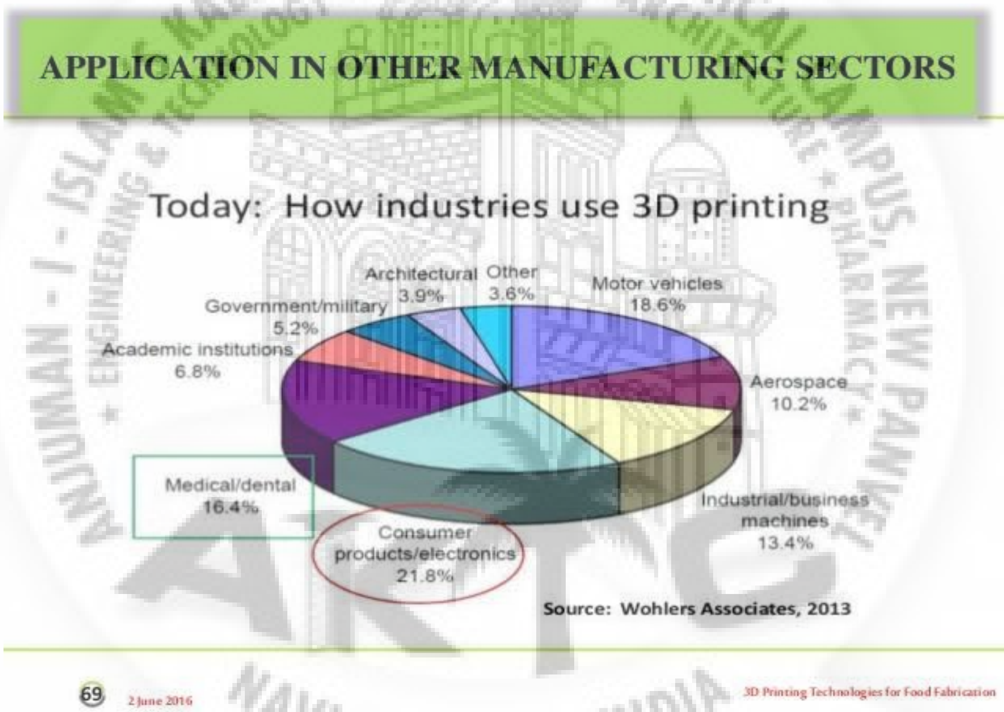

Fig.4: 3-D printing in industry

As mentioned earlier, additive manufacturing is an important technology in the development phase of the product. Its benefits are : less time in the product development phase, lower costs, possibility of performing several tests and prototypes, increase product complexity without increasing deadline, decrease in project delivery time.

1.4 HISTORIC:

The first known 3D printer was invented and patented by Charles W. Hull in 1986. In his patent he describes a method where it is possible to fabricate objects by solidifying layers of a photo polymer (resin). This process was called stereo-lithography. Three years later, in 1989, Scott Crump patented another 3D printing equipment that uses a different method than the

Charles Hull printer, called Fused Deposition Modelling (FDM). Through the ability to move along three axes, the nozzle of the printer deposits a molten material, and layer by layer the final object is produced.

However, the rapid prototyping process became better known and accessible in the early 2000s. With the expiration of FDM patents, Adrian Bowyer created the RepRap (Replicating Rapid Prototyper), where the software of the equipment is free, its source code is open and 57% of the mechanical 3D printer components are manufactured through the additive manufacturing process (concept of self-replicating machine). In this way, in 2004 the first low-cost 3D printer appeared. By having an open system, many people were interested in developing and enhancing Adrian Bowyer's original design, and thus, the 3D printer has become cheaper, more accessible and more efficient.

CHAPTER 2
LITERATURE-SURVEY

CHAPTER 2

LITERATURE SURVEY:

Over the years, the evolution of technology has had a major impact on the development of other 3D printing processes. The following are the most applied processes.

2.1 STEREO-LITHOGRAPHY (SLA)

As previously mentioned, stereo-lithography was the first 3D printing process created and, according to Abreu (2015), is the most used type of additive manufacture. By means of the incidence of an ultraviolet laser, a layer of liquid resin is solidified. After this step, the platform where the solidified resin layer is located is moved slightly downward, causing a layer of liquid resin to be added. Again, the laser solidifies the resin creating a second layer. This process is repeated until the object is completely constructed.

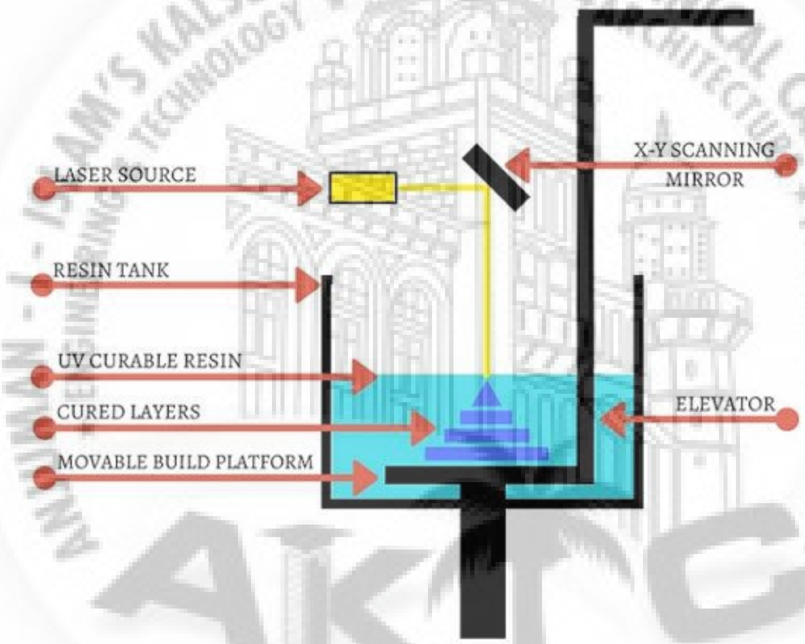

Fig.5: Stereo-lithography

2. 2 FUSED DEPOSITION MODELLING (FDM)

As explained earlier, the FDM process was the second type of additive manufacture created and is one of the most used processes because ofits low cost. In this process, thermoplastic filaments are heated in the extruder and deposited on the construction platform by means of the extrusion nozzle. The construction platform has a lower temperature than the deposited thermoplastic, causing it to solidify rapidly. The platform moves down, and the nozzle of the extruder deposits the second layer of material. This process is repeated until the object is created.

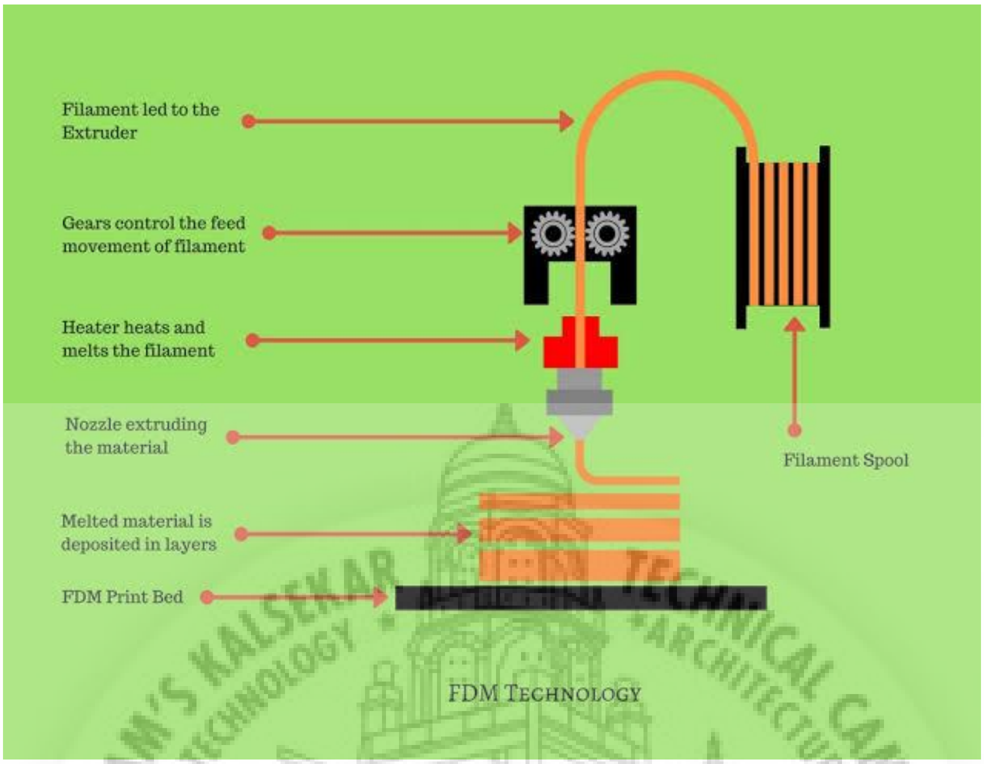

Fig.6: FDM Technology

2. 3 3DP

Unlike the processes mentioned above, the 3DP uses as a raw material a ceramic powder and a liquid binding agent. In the first step, a layer of ceramic powder is evenly distributed on the building surface. Subsequently, the liquid binding agent is applied over the desired area by means of a jet. In the third step, a piston recedes, causing the object's construction surface to move downwards. Thereafter, a new layer of ceramic powder is added, followed by the liquid binder. This procedure is repeated until the piece reaches its final shape. The piece is removed from the machine and a jet of compressed air is applied in order to remove uncoated powder from the model. The prototypes manufactured using the 3DP method are fragile, and to make them more rigid it is necessary to subject them to a process of infiltration of resins.

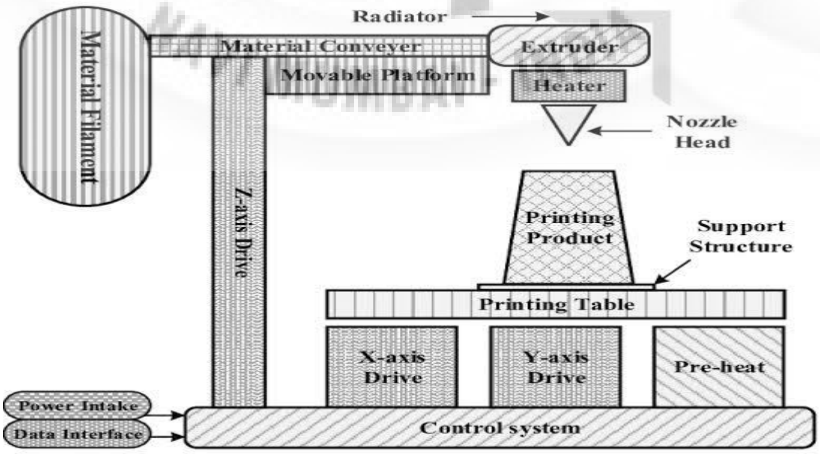

Fig.7: 3DP

2. 4 SELECTIVE LASER SINTERING (SLS)

Like the 3DP process, selective laser sintering also uses a powder (usually thermoplastic, nylon or metal) as the raw material. This material is arranged in a homogeneous layer and a laser is applied to melt its particles, and thus solidify the material. This procedure is performed many times until the part is ready.

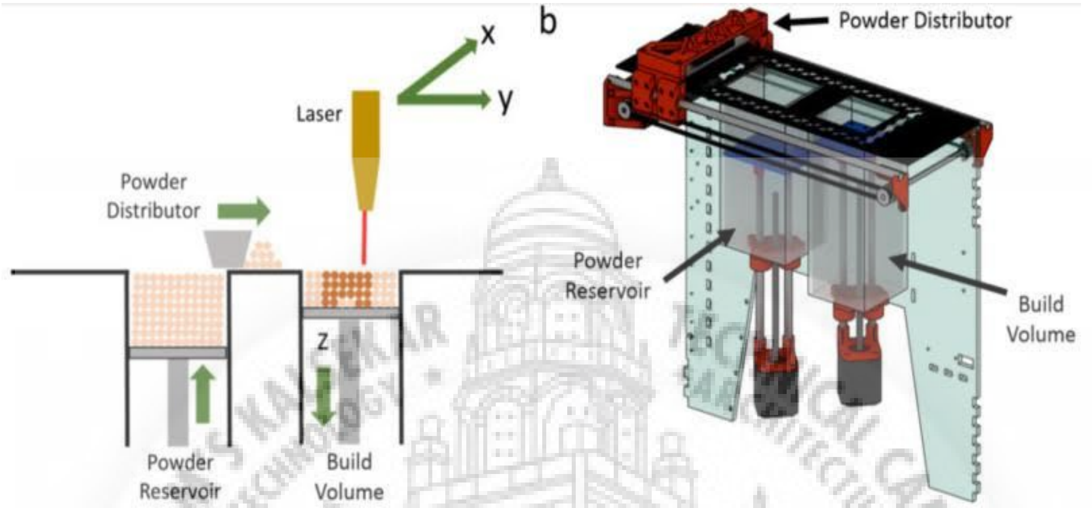

Fig.8: Selective Laser Sintering

2. 5 LAMINATED OBJECT MANUFACTURING (LOM)

This process can use different types of raw material, such as paper, plastic or metal. The material is laminated by a heated roller and glued to the bottom layer. Thereafter, it is cut by means of a laser.

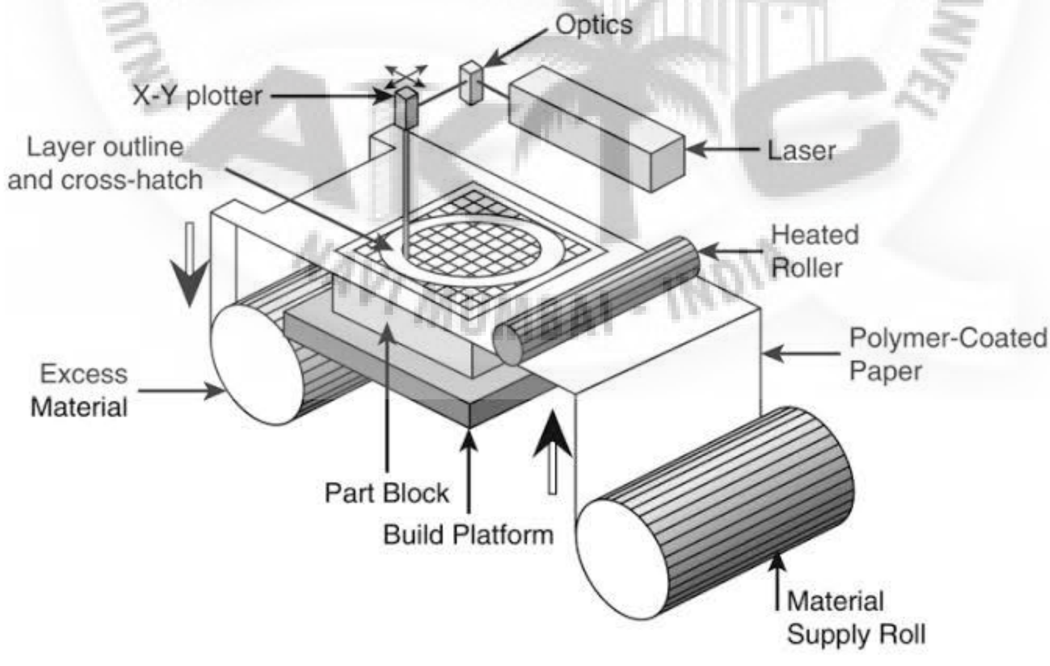

Fig.9: Laminated Object manufacturing

CHAPTER 3

FOOD PRINTER CONCEPTS AND PLATFORM DESIGNS

CHAPTER 3

FOOD PRINTER CONCEPTS AND PLATFORM DESIGNS:

The first generation of food printer concept designs and prototypes is emerging into the public domain. Within a short history, a few research projects were conducted from concept designs to in depth research on material extrusion and deposition.

Conceptual Ideas Nanotek Instruments Inc. patented a rapid prototyping and fabrication method for 3D food objects in 2001, such as a custom-designed birthday cake. However, no physical prototype was built. Nico Kläber came out a Moléculaire concept design in Electrolux Design Lab competition, which incorporated molecular gastronomy into food printer design. This concept aimed to print multiple materials using a small robotic arm and created a fully customised meal using normal food. Philips Food Creation Printer introduced food cartridges to create custom-designed food product in a layer-by-layer manner. An interactive graphical user interface was proposed to select ingredients, quantities, shapes, textures and other food properties. This idea may be applicable for any type of customized 3D food printing. However, all of these concept designs seem vastly unrealistic and no implementation potential.

In digital gastronomy, ingredients can be determined according to on-line information on nutritional content, personal and social preference. Massachusetts Institute of Technology (MIT) introduced a digital gastronomy concept into food printer design and presented three conceptual designs as shown in Table. Each focused on different aspects of gastronomy from mixing, modelling to transformation. These concepts seem more realistic compared with previous conceptual designs but are still far away to be technically feasible.

	Concept Focus	Design Platform	Difficulties
Virtuoso Mixer	combine and mix diverse ingredients to control their quantities, types and source.	• top layer: storage containers to monitor temperature, humidity and weight • 2nd layer: processing chambers dedicated to mixing, whisking and crushing • bottom layer: extrusion unit with thermo control	• distribution and metering design between the layers, • machine cleaning • waste minimization.
Digital Fabricator	model and cook ingredients combination into specific shapes with defined dimensions	• refrigerated canisters of food • a three-axis mixing/printing head onto the printing surface • a fabricator chamber	• refilling canisters • machine cleaning • material supply to mixing head and storage system
Robotic Chef	transform existing ingredients into new flavour and design pattern	• two five-degree of freedom robotic arms • a tool head to localise transformations such as drilling, cutting and dispensing via syringes • a heating bed for cutting/cooking/ sintering	• design and program to fabricate diverse food shapes • complicated manipulation

Fig.3.1: Block Diagram

Food printer platform basically consists of a XYZ three axis stage (Cartesian coordinate system), dispensing/sintering units, and user interface. With computer controlled three axes motorized stage and material feeding system, such platforms can manipulate food in a real-time way. Food composition can be deposited/sintered essentially point by point and layer by layer according to a computerized design modeling and path planning.

To invent and personalize new dishes rather than simply automate traditional food fabrication process, at least four functions are proposed: metering, mixing, dispensing and cooking (heating or cooling). Only the dispensing and cooking functions are available in the current commercial or self-developed food printing platforms.

3.1 FOOD PRINTERS BASED ON COMMERCIAL PLATFORMS:

To simplify development process and shorten development time, researchers modified commercial available open source 3D printing platforms for food printing purpose. One common modification is to

This is made of mild steel material. The whole parts are mounted on this frame structure with the suitable arrangement. Boring of bearing sizes and open bores done in one setting so as to align the bearings properly while assembling. Provisions are made to cover the bearings with grease. replace original print head with specially designed dispensing unit and an additional valve to control material feed rate, or replace standard inkjet binder with food grade material like starch mixtures.

The Fab Home system was one of universal desktop fabricators compatible with food materials, although it is not specifically designed for food applications. Researchers also integrated Frostruder MK2 on Maker Bot platform to extrude frost, where two solenoid valves were used to control the flow rate of creamy peanut butter, jelly and Nutella (Millen et al., 2012). Fig.1 shows a food printing platform with a print head developed at National University of Singapore. The platform is built based on a modified Prusa i3 platform with a self-developed extrusion printhead.

Fig.10: 3-D Printing In Food Production

With modified commercial platform, researchers can quickly create complex food shapes, and compare various food materials' property and fabrication processes. While, those platforms lack of flexibility on further improvement, and are only applicable for a limited range of materials, which cannot support in-depth research.

3.2 FOOD PRINTERS BASED ON SELF-DEVELOPED PLATFORM:

Self-developed platforms are built based on specific requirements, such as creating 3D sugar structures with a computer controlled laser machine, building cheese and chocolate 3D objects from edible ingredients, or reducing cost associated with freeform fabrication of sugar products with open-source hardware. They provide more choices for material dispensing so that a suitable print head can be designed and implemented among a few candidates, dispensing parameters and fabrication process can be more flexible and optimized.

In both commercial and self-developed platforms, mechanical movements of substrate and dispensing head(s) are achieved through computer controlled stage. In printing process, a digital 3D model can be converted into multiple layer data (STL files), and then these data will be interpreted into driving signals to stage driver motors through the regulated controller. The same procedures of moving and dispensing are repeated for each layer with its own characteristic shape and dimensions. The combination and consolidation of these layers forms a complete 3D object.

3.3 USER CONTROL INTERFACE DESIGN:

User control means the full control of shape, ingredients and materials, which may significantly impact food creativity design. User control interface design involves three functions:

1) providing tools on shape design and material selection for customized food piece design,

2) transforming this design into a computerized 3D model, and

3) planning dispensing pathway and processing associated parameters.

Thus, developing an interactive user interface linking with an open-access web-based template library is essential. With such interface, customers can design their own personalized food pieces, obtain design files online through a technology service provider or share their design with other users. The products can then be built in front of the customers using personal 3D food printer in a new context of household product making, which would be impossible to achieve based on existing methods.

3.4 AVAILABLE PRINTING MATERIALS:

Substantial efforts have been made to pre-process materials suitable for 3D printing, and increase their thermal stability during post-processing. Printing pureed food proposed by TNO can help elderly people with chewing and swallowing problems. TNO has also suggested printing customized meals for seniors, athletes, expectant mothers through varying food component levels like protein and fat. Generally, the available printing materials can be classified into two categories based on their printability.

3.5 NATIVELY PRINTABLE MATERIALS:

Natively printable materials like hydrogel, cake frosting, cheese, hummus and chocolate can be extruded smoothly from syringe. The mixture of sugars, starch, and mashed potato were tested as powder materials in Z Corporation powder/binder 3D printer. A number of sugar teeth were fabricated for demonstration. However, none of them is the main course of meals. Some traditional foods were tested for printability study using Fabaroni, and the most successful material was pasta dough, judged by viscosity, consistency and solidifying properties. Food products made by natively printable materials can be fully controlled on taste, nutritional value, and texture. Some of natively printable materials are stable enough to hold the shape after deposition, do not require further post processing and can be reserved for medical and space applications. Other composite formulations such as batters and protein pastes may require a post-deposition cooking process. This will make food product structures more difficult to retain their shapes.

3.6 NON-PRINTABLE TRADITIONAL FOOD MATERIAL:

Food like rice, meat, fruit and vegetables, largely consumed by people every day, are not printable by nature. To enable their capability of extrusion, adding hydrocolloids in these solid materials has been approved and utilized in many culinary fields used simple additives to modify traditional food recipes and created complex geometries and novel formulations. Although solid foods and semi-solid liquids have already been manipulated to become printable by gastronomic tricks, it is difficult to test and modify the whole list. One potential solution was to use a small group of ingredients to create a platform with many degrees of freedom on texture and flavor. By fine tuning hydrocolloids' concentrations, a very wide range of textures (i.e. mouthfeels) can be achieved experimented food texture using two hydrocolloid systems, and explored structural requirements for post-processing materials such as protein pastes and cake mixtures.

3.7 POST-PROCESSING:

Food printing process does not require a high energy source to completely remove liquid ingredient from food composition. Fabricated layers do not need to be completely solidified, but has sufficient rigidity and strength to support its own weight and the weight of subsequent layers without a significant deformation or shape change. The majority of traditional edibles need post-deposition cooking after shapes are constructed, such as baking, steaming or frying. These processes involve different levels of heat penetration and result in non-homogenous texture. The printed complex internal geometries using a cookie recipe with cocoa modified material could retain its shape after baking process.

CHAPTER 4

3DP TECHNOLOGIES IN FOOD PRINTING

CHAPTER 4

3DP TECHNOLOGIES IN FOOD PRINTING:

3D food printing has significant advantages in high-value, low volume food fabrication, particularly for customized items in food service. Diverse print head designs are applied to load and print food materials. Some used thermal energy from laser/hot air/heating element to sinter or melt powder, and others used inkjet-type printing heads to accurately spray binder or solvent. Below is a summary of applicable 3DP technologies.

4.1 CURRENT 3DP TECHNOLOGIES' APPLICATIONS:

4.1.1 SELECTIVE SINTERING TECHNOLOGY:

Sugars and sugar-rich powders can be selectively sintered to form complex shapes. After a layer of fresh powder is spread, a sintering source (hot air in Fig. (a) or laser in Fig. (b)) will move along X and Y axes to fuse powder particles so that they can bind together and form a solid layer. This process is repeated by continuously covering the fused surface with a new layer of material particles until completing a 3D object. TNO's Food Jetting Print applied laser to sinter sugars and NesQuik powders. The sintered material formed the part whilst the un-sintered powder remained in place to support the structure which may be recycled. The CandyFab applied a selective low-velocity stream of hot air to sinter and melt a bed of sugar. The fabrication powder bed is heated to just below the material melting point to minimize thermal distortion and facilitate fusion to the previous layer. Selective sintering offers the freedom to quickly build complex food items in a short time without post curing. This technology is suitable for sugar and fat based materials with relatively low melting points. However, the fabrication operation is complicated as many variables involved.

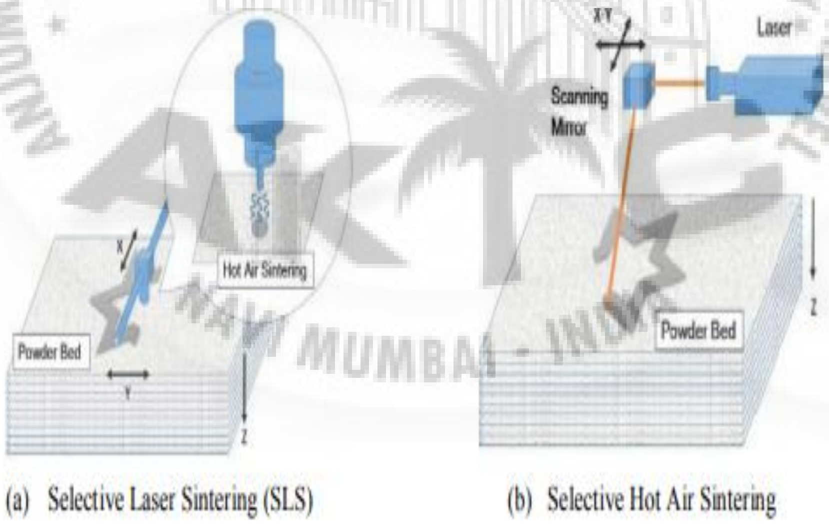

Fig.11: Selective laser Sintering

4.2 HOT MELT EXTRUSION:

Hot-melt extrusion also called fused deposition modeling (FDM), was firstly described in Crump's work. In given Fig. melted semi-solid thermoplastic material is extruded from a movable

FDM head and then deposited onto a substrate. The material is heated slightly above its melting point so that it solidifies almost immediately after extrusion and welds to the previous layers. In food printing, hot-melt extrusion is applied to create personalised 3D chocolate products compared the material properties among various food stuffs and printed 3D chocolate products with different shapes and sizes. MIT Researchers used hot melt chocolate as dispensing liquid and developed a functional prototype named “digital chocolatier” to fabricate customised chocolate candy. In this research, the compressed air was applied to melt chocolate and force it out of the chambers. A ‘3D Food-Inks Printer’ with embedded 3D colour images on extruded base material may also fall into this category, while a post-deposition cooking step was required to fuse layers together.

The food printer designed based on hot-melt extrusion has a compact size, and low maintenance cost. The disadvantages such as seam line between layers, long fabrication time, and delamination caused by temperature fluctuation, need to be further investigated.

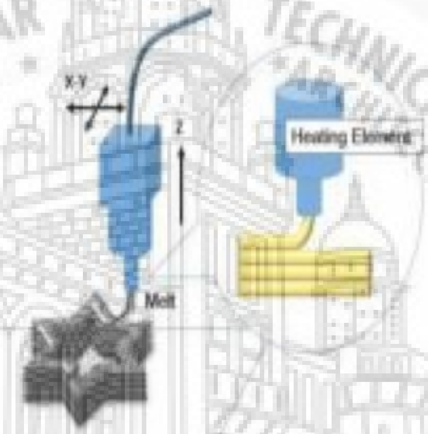

Fig.12: Hot Metal Extrusion

4.3 BINDER JETTING:

In standard binder jetting technology, each powder layer is distributed evenly across the fabrication platform, and liquid binder sprays to bind two consecutive powder layers. As Fig. the powder material is usually stabilized through water mist to minimize disturbance caused by binder dispensing. In edible 3D printing project, utilized sugars and starch mixtures as the powder material and a Z Corporation powder/binder 3D printer as platform to fabricate customized shape with complex structures. Sugar Lab used sugar and different flavour binders to fabricate complex sculptural cakes for weddings and other special events. This fabrication adopted 3D Systems’ Colour Jet Printing technology, and the material and fabrication process met all food safety requirements. Binder jetting offers advantages such as faster fabrication and low materials cost, but suffers from rough surface finish and high machine cost. Post-processing may be required, such as curing at higher temperature to further strengthen the bonding.

4.4 INKJET PRINTING:

In given Fig, inkjet food printing dispenses stream/droplet from syringe-type printhead in a drop-on demand way. 3D edible food products such as cookies, cakes, or pastries are created in a layer structure, which involves pre-patterning food items at multiple layers of processing. The De Grood Innovations' FoodJet Printer (Foodjet, 2014) used pneumatic membrane nozzle-jets to deposit selected material drops onto pizza bases, biscuits and cupcakes. The ejected stream/droplets fall under gravity, impact on the substrate, and dry through solvent evaporation. The drops can form a two and half dimensional digital image as decoration or surface fill.

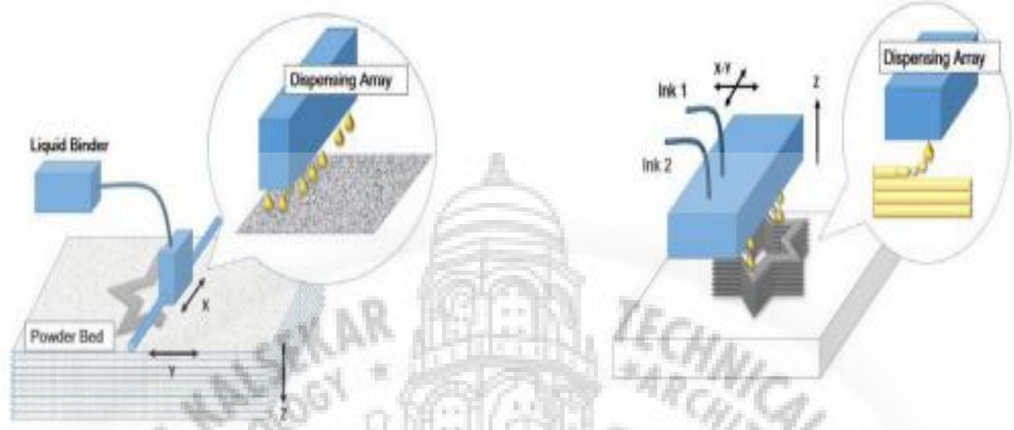

Fig.13: Inkjet Printing

Compared with manually customized food fabrication, 3D food printing does not require costly setup and hence is economical in small quantity production. The quality of fabricated food items depends on the process and planning rather than people's skill. As such, fabrication can be easily and accurately controlled based on customer demand. It plays increasingly important role in food processing as a complementing technology. Table 2 is a summary of current 3DP techniques' applications in food printing, with the comparison of applicable materials, fabrication platforms, and products.

	Hot-melt extrusion	Sintering technology	Inkjet powder printing	Inkjet printing
Materials	Food polymers such as chocolate	Low melting powder such as sugar, NesQuik or fat	Powder such as sugars, starch, cornflour, flavours, and liquid binder	Low viscosity material such as paste or puree
Platform	• Motorized stage • Heating unit • Extrusion device	• Motorized stage • Sintering source (laser or hot air) • Powder bed	• Motorized stage • Powder bed • Inkjet printhead for binder printing	• Motorized stage • Inkjet printhead • Thermal control unit
Fabricated products	Customized chocolates	Food-grade art objects, Toffee shapes	Sugar cube in full-color	Customized cookies, Bench-top food paste shaping
Machine	Choc Creator	Food Jetting Printer	Chefjet	Foodjet
Company	Chocedge	TNO	3D systems	De Grood Innovations

Table.2: Different Type of Technology

4.5 MULTI-MATERIAL AND MULTI-PRINT HEADS:

Applying multiple-material is quite common in customized food design and fabrication. Some of these materials are from traditional food recipes, additives and others are non-traditional edible materials (primarily non-food such as ingredients extracted from algae, beet or even insects. In the 'Insects Au Gratin' project, insect powders mixed with extrudable icing and soft cheese to shape food structures and make tasty pieces. The diversity of printing material empowers consumers to take control of different materials design and fabrication.

Most of food printer projects such as ChocALM, Insects Au Gratin, are developed using single print head extrusion for one material or a mixture of multiple material. When one print head is used to print the mixture of food materials, it is not capable to control material distribution or composition within each layer or in a whole structure. To achieve controlled material deposition and distribution in a drop-on-demand way, more print heads are proposed. For multiple-print head, the data from individual layer is directed to a platform controller (either in commercial or DIY platform), which selectively activates the motors to move the corresponding dispensing head, and control its feeding rate. Hence, food printers may deliver multi-material object fabrication with higher geometric complexity and self-supporting structure.

Fig.14: Food design Made by 3DP

Researchers tried multiple-print head using Fab Home 3D printer, and tested frosting, chocolate, processed cheese, muffin mix, hydrocolloid mixtures, caramel and cookie dough. Dual-material printing was only achieved using separated deposition heads for a limited material set, and the secondary material was utilized to support fabrication, which can be removed after that. Fig. shows some three-material food samples fabricated by our group at the National University of Singapore. The basic biscuit recipe consists of flour, butter, sugar and egg white.

Multi-material may generate multi-scale ingredients after processing, and require corresponding fabrication techniques. Gray proposed using electro-spinning to produce multiple food sub-components at micro-scale and further assemble them into multi-component composite structures for a variety of materials. This is a new solution to shape non-traditional food materials under multi-scale into appealing edible structures.

CHAPTER 5

IMPACTS FROM 3D FOOD PRINTING

CHAPTER 5

5.1 IMPACTS FROM 3D FOOD PRINTING:

Food printers introduce artistic capabilities to fine dining, and extend mass-customization capabilities to industrial culinary sector. This benefits a high-value, low volume customization food fabrication process that would be impossible to achieve currently. It also provides research tools to manipulate structure development of solid food materials at multiple scales. This technology is still under development stage; hence, it is important to understand its core value and potential applications in the market. At the same time it is also necessary to follow up with technology progress and relevant applications in order to investigate how this new technology will meet the customers' needs and potentially change people's lifestyle.

5.2 CUSTOMIZED FOOD DESIGN:

Most of food manufacturing techniques are developed for mass production, while food creativity and user control on shapes, structures and flavours are usually sacrificed. Food printer provides a platform for consumer experimentation with food forms and flavours. Previously, this customization process involves specifically hand-made skills with low production rate and high cost. Food printing technologies could potentially overcome these barriers by offering more freedom in food customisation design on shapes, colours and flavours for home users. It may generate more design solutions such as customised chocolate shaping, and personalized full-colour images onto solid food formats. Fig. shows some customized food pieces samples fabricated by our group.

Fig.15: 3DP Design Chocolate

5.3 PERSONALISED NUTRITION:

Except existing nutritional preferences, individual dietary has highlighted the concept of personalised nutrition in terms of individual's health status and body-type requirement. Food printing can enable a precise control of people's diet, and ensure fresh and healthy dishes that exactly meet the needs and preferences of individuals. It would significantly improve population wellbeing. In this case, food ingredients even with well-known material properties must be tailored to specific formulations under each fabrication. More efforts are required to bring such highly customized food products into every home.

5.4 SIMPLIFYING CUSTOMIZED FOODS SUPPLY CHAIN:

Food printers will facilitate the implementation of a build-to-order strategy with low overriding cost. It is economical to locate production facilities near the end customers. This can help to reconfigure the customized food supply chain and bring products to consumers within a shorter time, acceptable price while utilizing fewer resources.

5.5 REFORMULATING FOOD PROCESSING TECHNOLOGIES:

Most of food processing technologies associated with chemical and physical changes may not match requirements of 3D printing technologies. This applies to composition (ingredients and their interactions), structure, texture, and taste. Ingredient formulations with varied combinations and manipulation conditions can generate various textures in products, which may go beyond a manageable level. Also, printing material property should be rigid and strong enough to support the weight of subsequently deposited layers as well as the thermal effects from post-cooking process. Briefly, conventional food processing technologies are unlikely to fit into such a complicated scenario, and the whole processes should be reformulated. For example pre-conducting some process (e.g. gluten formation and leavening) and replacing remaining processes (e.g. shaping and baking).

5.6 Process design and digitalization:

To achieve a better understanding of 3D food printing processing, a mathematic model that can realistically describe this process with inputs, outputs and process type will be essentially useful. Customized food fabrication process and food printer design are the major driving force for developing such a model. Key process parameters such as temperature, moisture, and food properties such as density, thermal and electrical conductivity, viscosity, permeability are often coupled. It is very necessary to digitalize comprehensive cooking processes before mathematically manipulation, which greatly differs from traditional food processing models. Data on food properties can be obtained from measurement, computerized database, handbook and theoretical calculations. In reality, food properties often vary from batch to batch due to difference in formulations, etc. By varying the property data and geometry around the expected value in the simulation model, one can bracket the properties and predict the results of particular food processing for a certain range of properties. To develop this simulation model, researchers will further explored to model specifically-designed printing process with the 3D object geometry, perform data quantification for each process (ingredients metering and mixing, printing, baking and so on), and determine communication protocols between different functions or processes.

CHAPTER 6

FUTURE WORK AND CONCLUSION

CHAPTER 6

FUTURE WORK AND CONCLUSION

3D food printing has demonstrated its capability on making personalised chocolates or producing simple homogenous snacks. However, these applications are still primitive with limited internal structures or monotonous textures. It is necessary to develop a systematic way to investigate printing materials, platform design, printing technologies and their influences on food fabrication. Meanwhile, the food design process should be structured to promote user's creativity, the fabrication process should be quantified to achieve consistent fabrication results, and a simulation model should be developed to link design and fabrication with nutrient control. With the development of an interactive open web-based user interface, food printers may become part of an ecology system, where networked machines can order new ingredients, prepare favorite food on demand and even collaborate with doctors to develop healthier diets.

This paper reviews food printing development from conceptual design till available commercial machines. The two printing platforms are employed, and both natively printable materials and non-printable traditional food materials are used for printing experiment. Although quite a number of food printing technologies are available, there is still a long way to further develop them for commercial usage. From this technology review, it can be seen that food printing may exert a significant influence on various types of food processing, which allow designers/users to manipulate forms and materials with enhanced and unprecedented capability. This versatility, applied to domestic cooking or catering service, can improve efficiency to deliver high quality, freshly-prepared food items to consumers, deliver personalized nutrition and enable users to develop new flavors, textures and shapes to create entirely new eating experiences.

CHAPTRER 07
FUTURE SCOPE

CHAPTRER 07

FUTURE SCOPE

Among the advantages of 3D food printing, the following may be mentioned:

i. Food personalization,
ii. Meal composition adapted to individual diet,
iii. The use of new components, which are not used or are not popular among consumers,
iv. Ease and simplicity of preparation of meals,
v. Both aesthetic and functional customization can be achieved at the same time,
vi. Novel food textures,
vii. Longer shelf life,
viii. Ease of transportation even to the most remote corners of the world or into space (NASA),
ix. New opportunities to create dishes, their artistic design - creating culinary works of art,
x. The ability to design your own food – being a food designer,
xi. Economical and efficient technique of mass personalization

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