InstaFood 3D Food Printing Industry
1934 Buchanan Hall
Santa Barbara, CA 93106

June 5, 2015

National Aeronautics and
Space Administration
Headquarters

300 E. Street SW, Suite 5R30
Washington, DC 20546

Dear NASA Headquarters:

InstaFood 3D Food Printing Industry is respectfully requesting a grant in the amount of $125,000 for our research on 3D food printing technology.

As the researchers of the 3D food industry, we recognize the importance of our InstaFood 3D food printer for the space food production. The InstaFood aims to provide food that meets the nutritional needs of the astronauts on a deep space mission. With thousands-year shelf-life ingredients, food can be printed freshly with personalized recipes. InstaFood also aims to reduce waste by turning any leftover into a newly synthesized dish.

InstaFood's main focus is on the production of the essential nutrients including carbohydrates, proteins, and fats. Simple sugars such as glycerol can now be successfully and efficiently printed in desired amount. Our commitment will be on a production of starch, a more highly complex carbohydrate. While more research on protein and fat syntheses is needed, we are using bioprinting techniques as an alternative way to produce protein meat.

With grants from NASA, we will complete as follows:

- Conduct a one-year research on protein and fat syntheses.
- Develop the InstaFood printer prototype.

Thank you for your consideration of our invention proposal. We are looking forward to your response. Please contact us at (805) 304-9889 or co@instafood.com if you have any questions regarding the proposal.

Sincerely,

InstaFood 3D Food Printing Industry

Encl.: 3D Food Printer Proposal

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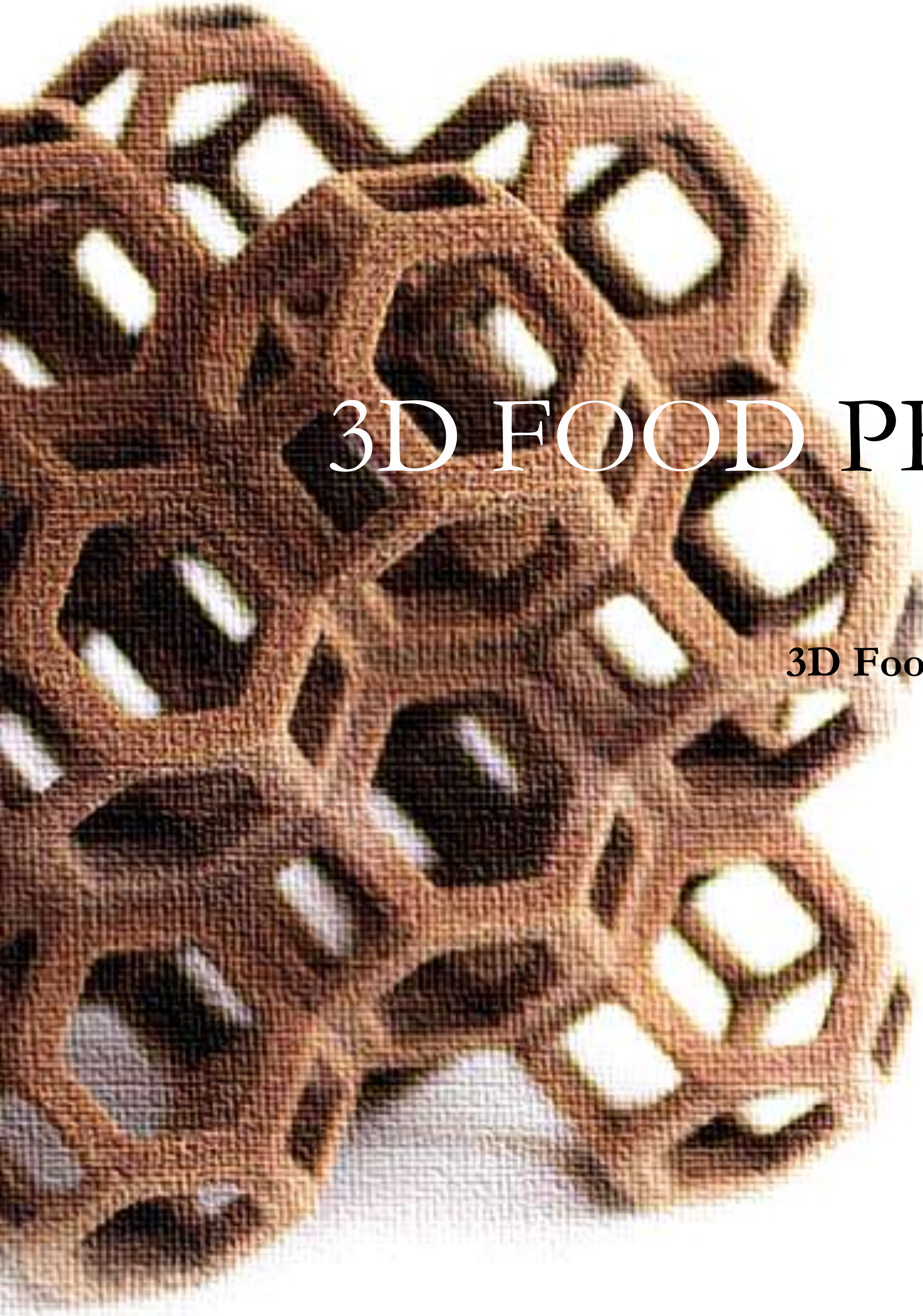

3D FOOD PRINTER

InstaFood

3D Food Printing Industry

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Executive Summary

The biggest impediment in space exploration is the short-term food storage. As the astronauts venture farther into outer space, they will require an improvement in the life support system such as food with long shelf life and high nutritional quality to support the crew's performance onboard. Because the amount of food that can be brought to space is limited, and the shipment of food to the space station is infrequent, long duration missions are often not possible. Our invention, the InstaFood 3D printer, is the solution.

InstaFood uses 3D printing technology to create a three-dimension object by printing layer upon layer of materials. This process is also known as the additive manufacturing. The InstaFood will print fresh food with all the essential nutrients needed by the body. The ingredients for the printer are simple building blocks that will take thousands of years to decay. These ingredients are guaranteed to never run out. For example, methane (CH_4), the ingredient used to synthesize sugars, can be obtained from the spaceship's engine combustion. This also eliminates food shipment to space. By synthesizing food at the molecular level, we ensure healthy food that meets the safety standard. Additionally, the astronauts will be opened to hundreds and thousands of meal choices like never before. Their favorite recipes can be printed out with just one click on a printer.

Currently, we are able to synthesize three essential nutrients: carbohydrates, proteins, and fats. Carbohydrates can be made by the physicochemical process, similar to that of photosynthesis in plants, but much simpler. Simple sugars such as glycerol and formose sugars can be produced by the InstaFood. We are now working forward on printing basic table sugars such as glucose and sucrose, and other long chains of sugar units such as starch. We are still on an early stage for protein and fat syntheses. Although breakthroughs in molecular 3D printing allow us to print simple organic compounds, the more complex ones require further in-depth study. Protein meat can also be produced by the InstaFood through bioprinting technology.

Unfortunately, the mechanism to synthesize vitamins and minerals are not available with our current technology and funding. If a grant is received, we will conduct an extensive research in the field of molecular technology. The largest portion of our research will be on vitamins and minerals. Through the study of building blocks, which are the basic units of life, we believe that we will be able to generate vitamins and minerals. A grant in the amount of $125,000 will cover all research and material costs of the nutrient synthesis. The funds are broken down for research on the synthesis of the following nutrients: 40% for vitamins and minerals, 36% for proteins and fats, and 24% for carbohydrates.

Our InstaFood 3D printer is the best alternative to current food production both in space and on Earth. Beyond doubt, the InstaFood outcompetes the space food system. Similarly, our invention has surpassed the closest competitive technologies like the genetically modified food, meat processing factories, and cultured meat. The highly advanced technology of the InstaFood is far more efficient at producing fresh food with high nutritional value, without any use of hormones or other ingredients that can lead to bad side effects. The significance of the InstaFood is anticipated at the global level with its ability to feed the world, and ease many issues such as the emission of greenhouse gases, water shortage, habitat destruction, and food waste.

Our product will be marketed mainly to NASA after being patented. We will sign a contract with NASA, whom we will work closely with to our best ability to provide fresh food to the astronauts. When the contract is over, NASA will be invited to invest in the implementation of the InstaFood to the market. Our implementation plan is as follows:

- Advertise to the wealthy in order to lower the cost.
- Feed the hunger for charity and spread the awareness of the printer's global impact.
- Advertise to the food industries, restaurants, and middle class for profit.

InstaFood's potentials are immense not only in space, but also all around the globe. With NASA's funding for our invention, we hope to revolutionize the entire food production in the near future.

TABLE OF CONTENTS

InstaFood
3D Food Printing Industry

List of Figures

Page

List of Tables

1.0 Introduction

1.1 History of Space Food

Early space food came in toothpaste-type tubes and was unappetizing. Although disliked by many, space food intended to provide sufficient nutrition for space flight. [1]

In the Mercury Missions (1959-1963), the choice of food is very limited, consisting of "bite-sized cubes, freeze-dried (cooked) powders, and semi-liquids stuffed in aluminum tubes." [2] Many Mercury astronauts had a hard time eating as they squeezed the tubes and sucked up the liquid through straws. The bite-sized cubes were very dried and could only be rehydrated inside the astronauts' mouths. Other food available to the astronauts came in small packets, including mushroom soup, orange-grapefruit juice, cocoa beverage, pineapple juice, chicken with gravy, pears, strawberries, and beef and vegetables. [4]

Figure 1. (left) Early Project Mercury Food Tube [3]
Figure 2. (right) Improved Food on the Gemini Missions [5]

Two years later, there had been some improvements in food during the Gemini Mission launched in 1965. More options were added to the menu, including shrimp cocktails, turkey bites, cream of chicken soup and butterscotch pudding. The Gemini astronauts seemed to be satisfied with this improvement. Since the food was freeze-dried, a simple rehydration method was introduced. The astronauts no longer needed to rehydrate food with their saliva but by injecting water into the food package with a water gun. [4]

By the time of the Apollo Missions to the moon, hot water was made available in the outer space. Improvement on the food taste was further accelerated. Dried food was easily rehydrated for appetite. The Apollo astronauts were also the first to use the “spoon bowl,” in which they ate food in a plastic container with a spoon. [2] Thermo-stabilized pouches, or wetpacks, were also introduced to preserve food moisture. [4]

Figure 3. (left) An Apollo Spoon Bowl Package [2]
Figure 4. (right) Skylab Packets of Dehydrated Food and a Food Tray [6]

During the Skylab mission in 1973, refrigeration became available onboard. The Skylab astronauts were also able to enjoy their heated food on the food warmer trays from 72 different food options. [4]

By the launch of the first space shuttle in the early 1980s, the menu was extended to 74 different food and 20 drinks. At this point, the astronauts’ meals are very similar to what they ate on Earth, in which food can be prepared in an oven. [4]

Figure 5. Today’s Space Food [6]

1.2 Purpose

One of the biggest problems of current space food is the preservation of food. Because the cost of resupplying is very high, as much as $1000 per pound of materials, the space shuttle can only be re-supplied once in every six months or longer. [7] For longer travel distance, the cost will accelerate and the transportation method might become obsolete. Unless food has long-term storage or can be recycled and reproduced, there would be a need for food shipment. [7] Even with a long shelf life, food will not be kept fresh. Any fresh produce will only be available for a short time after the launching of the shuttle.

Our invention, the InstaFood 3D printer, will provide a way for astronauts to prepare fresh food in space. Each menu on the list will no longer be pre-chosen. There will be no packages of pre-made food because it will be printed from scratch. Astronauts will be opened to unlimited meal choices and beverages. Another advantage of the InstaFood is the personalized nutrition that provides special dietary needs for astronauts. The concern about food preservation will also be solved. The only ingredients needed for the InstaFood are the basic building blocks that are not easily spoiled, and can be reused and recycled to reduce waste.

The InstaFood uses 3D printing technology to create a three-dimension object through additive processes, in which successive layers of material are laid down under computer control. [8]
In the same way as other 3D printers print out layers of plastic or metal, but instead we print food. 3D food printing has immense benefits:

- Nutritional properties of food can be directly control through our choice of ingredients and varying food composition
- Revolutionized shapes and textures of food made possible by Computer-Aided Design (CAD) program will overturn our experience of eating

Despite the short-term benefits, the future potentials of 3D printing are endless. In long term, our InstaFood can replace food production system in many industries and restaurants for a faster and more efficient way of processing food. Additionally, global impacts of the 3D printer include the enormous reduction of greenhouse gases, food waste, agricultural and pastoral land uses, and water consumption.

2.0 Product Design

2.1 Overview

The InstaFood 3D technology aims to improve food production for NASA space exploration. During long mission, nutritional stability in food is critical to maintaining the health and performance of crew members. The current space food system has a shelf life of less than five years, which does not meet the time required for a mission to Mars, or other remote planets. [9] At the molecular level, our 3D printer will engineer food with essential nutrients and a long storage life that will enable the possibility of longer space travel. In addition, InstaFood will minimize food resources by breaking down food waste into basic chemical components, and resynthesizing the compounds for a new dish.

Our main focus is on the implementation of the essential nutrients in the 3D printed food. Essential nutrients needed to sustain life are carbohydrates, proteins, fats, vitamins, and minerals. The InstaFood printer will print these basic components in proper amount in accordance with the Institute of Medicine's dietary reference intakes (DRIs) for a balanced diet.

Dietary Reference Intakes for Adults	
Carbohydrates	45-65%
Proteins	10-35%
Fats	20-35%
*The table shows the percentage of total calories consumption. *Added sugars should comprise no more than 25 percent of total calories consumed. *Recommended intakes for vitamins and minerals vary by age and body weight.	

Table 1. Dietary Reference Intakes for Adults [10]

2.2 Mechanism

The mechanism will discuss the production of the essential components of life. Three main sections are

1) Carbohydrate Synthesis
2) Proteins and Fat Syntheses
3) Vitamins and Minerals

Carbohydrate Synthesis

Carbohydrates, which comprise about two-third of our diet, can be synthesized by "Physicochemical Syntheses." In this process, carbon dioxide (CO_2) and water are combined to form simple sugar molecules, similar to photosynthesis in plants, but much simpler. The starting materials for carbohydrate synthesis can be obtained from food. In fact, 94% of the carbon from food is exhaled as carbon dioxide and 83% of hydrogen as water. This amount is sufficient for the resynthesis of 65% of carbohydrate as part of the diet. [11]

Another method for synthesizing carbohydrates is through the conversion of methane (CH_4) to formose sugars or glycerol. In practice, utilizing methane is more convenient because it eliminates "carbon dioxide to methane conversion pathway." Furthermore, methane is released as a by-product of the atmosphere control system by the space shuttle, and therefore is available in sufficient amount for food synthesis. [11]

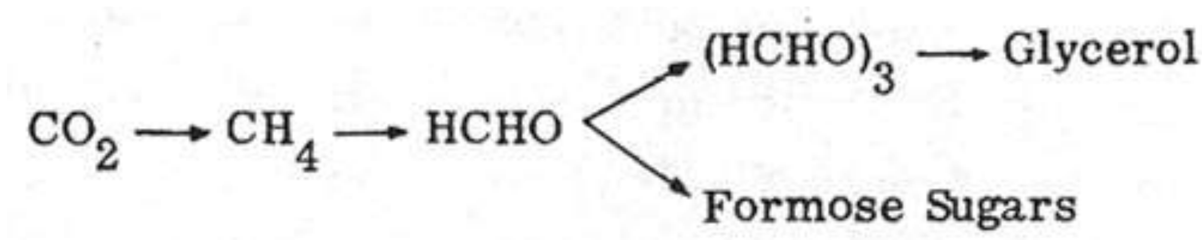


Figure 6. Physicochemical Synthesis of Simple Sugars [11]

Through the formose reaction, a hexose, which is a simple form of sugar like glucose and fructose, can also be synthesized. The net equations for the synthesis of a hexose along with the required energy input are listed in the Appendix A. The energy supply to initialize the chemical reaction will come from the electrolysis of water, or the dissociation of water molecules to oxygen and hydrogen gases. [11] The electrolysis of water is the process used to power batteries in our daily life.

Protein and Fat Syntheses

Protein and fat syntheses are very complicated processes, unlike the synthesis of carbohydrates, and are not yet economical; however, the recent breakthrough of the molecular 3D printer allows for the possibility of printing billions of compounds, including proteins and fats, from simple chemical building blocks. These "building blocks" consist of basic elements and compounds that can be purchased in the commercial market. [12]

Currently, the 3D printing technology is able to print small organic molecules or break down complex molecules into a simple unit, which can be reassembled and reused to generate new compounds. Using a "catch-and-release" method, the 3D printer is also able to separate any unwanted by-products from the chemical reaction. The analogy of a building block as a LEGO brick clearly illustrates the "catch-and-release" process. To form a compound, two or more LEGOs join to form a larger brick. Similarly, to break a compound, LEGOs are taken apart into individual pieces. In addition, any unwanted pieces can be removed. [12]

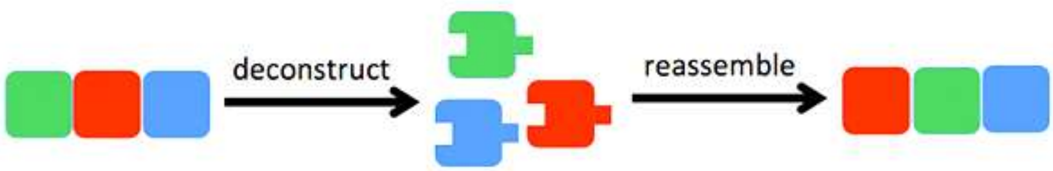
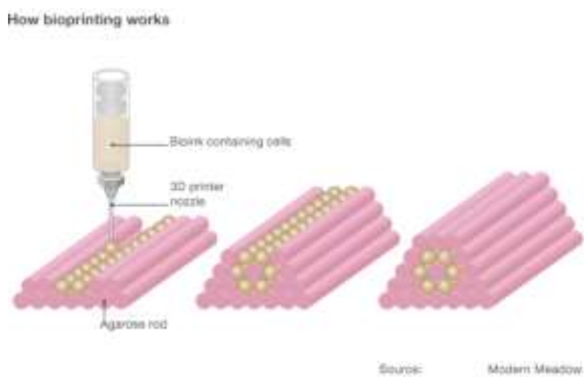


Figure 7. Deconstruction and Reassembly of the Building Blocks [12]

Alternatively, proteins can be produced via bioprinting techniques. Although this process does not allow for the breakdown of waste, it is currently more feasible than the concept of "building blocks" mentioned earlier. On a small scale, the protein printed meat can give a nutritional quality that meets the health standard by providing all essential amino acids required by the body. [13]

Bioprinting uses a bio ink that contains the stem cells of livestock animals. Stem cells are undifferentiated cells that can differentiate into more specialized cells and can replicate many times to produce more copies. The stem cells from animals are obtained via a biological procedure called biopsy. Once extracted, the stem cells will be multiplied to sufficient numbers. Instead of using a growth serum to speed up the cell replication, we will use a biocatalyst, which is a natural protein enzyme, often used in pharmaceutical industry. [14] After the replication, the cells are put into a bio-cartridge ready to be printed. During the printing process, a highly controlled inkjet nozzle prints the bioink particles layer by layer to form a desired shape. The printed layers will naturally fuse to form living tissue. Lastly, the cells are put into a bioreactor for maturation, a process that promotes the growth of tissue into the mature muscle fibers that are ready to be cooked and eaten. [15]



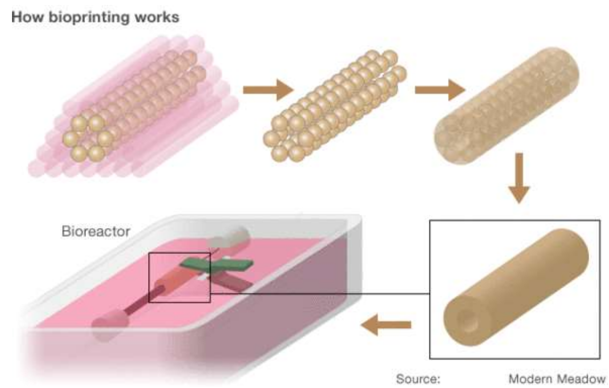


Figure 8. (left) Bioink in Agarose Gel. [15]
Figure 9. (right) Tissue in Bioreactor. [15]

In addition to high protein content, fat levels in the printed meat can also be controlled. Genetic manipulation of the muscle cells can reduce saturated fat content that contributes to cardiovascular disease. The cells can further be altered in favor for beneficial fatty acids such as omega-3 polyunsaturated fats. [16]

Vitamins and Minerals

One major problem of long-duration storage of food is the breakdown of nutrients [17]. This problem cannot be solved by synthesizing vitamins and minerals readily since the process is often very difficult and involves a more complex chemical pathway than that of proteins and fats. One alternative is the injection of powdered vitamins and minerals into food during the printing process. The amount of injection is customizable to meet each individual's recommended intakes. Powdered vitamins and minerals available in our current market can last from 2-10 years if unopened and properly stored [18]. The shelf life of the powder can further be increased by removing all the moisture. As a result, these powdered micronutrients may last up to 30 years [19].

Figure 10. Powdered Vitamins [20]

2.3 Component Design

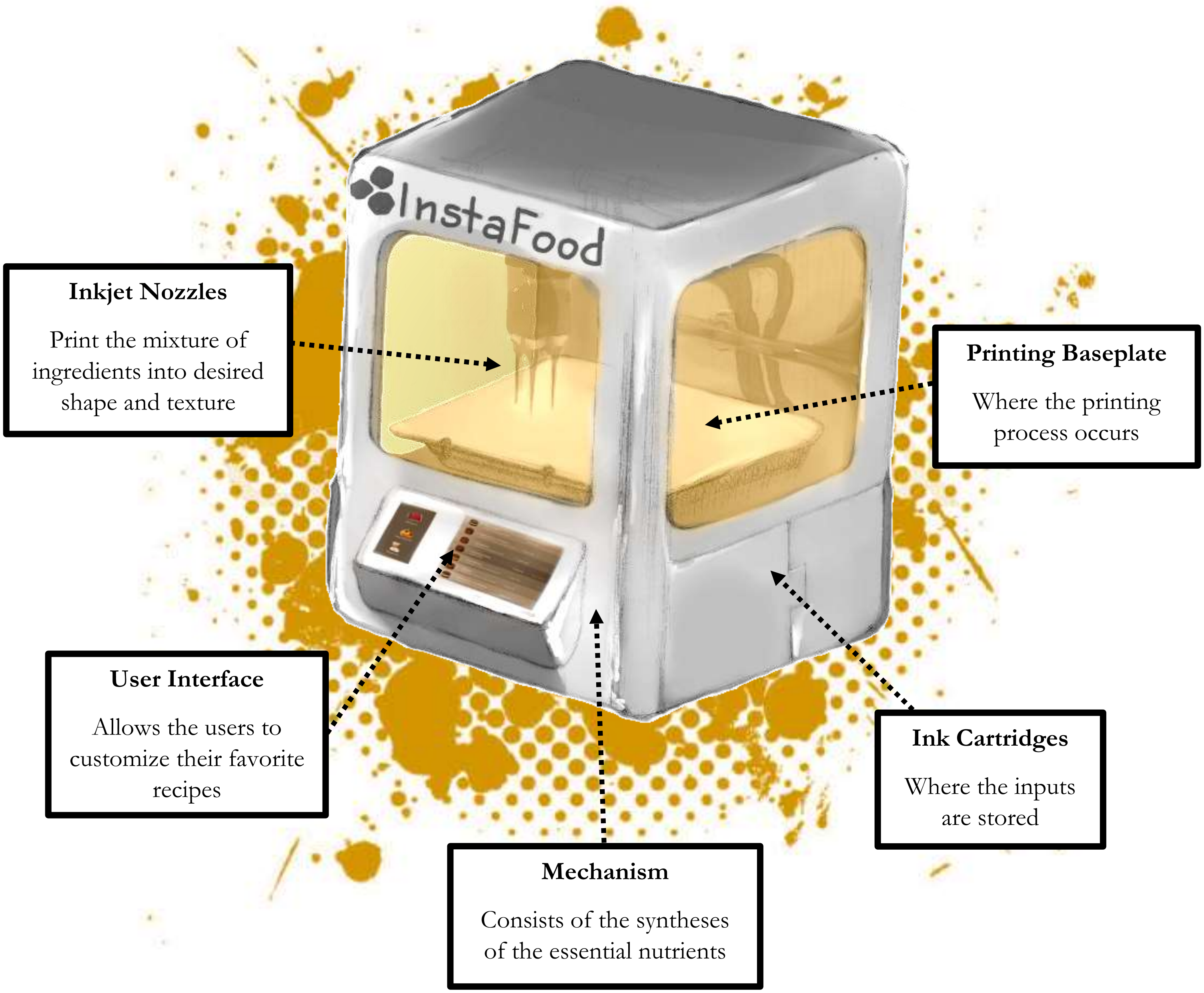


Figure 11. InstaFood 3D Printer's Components

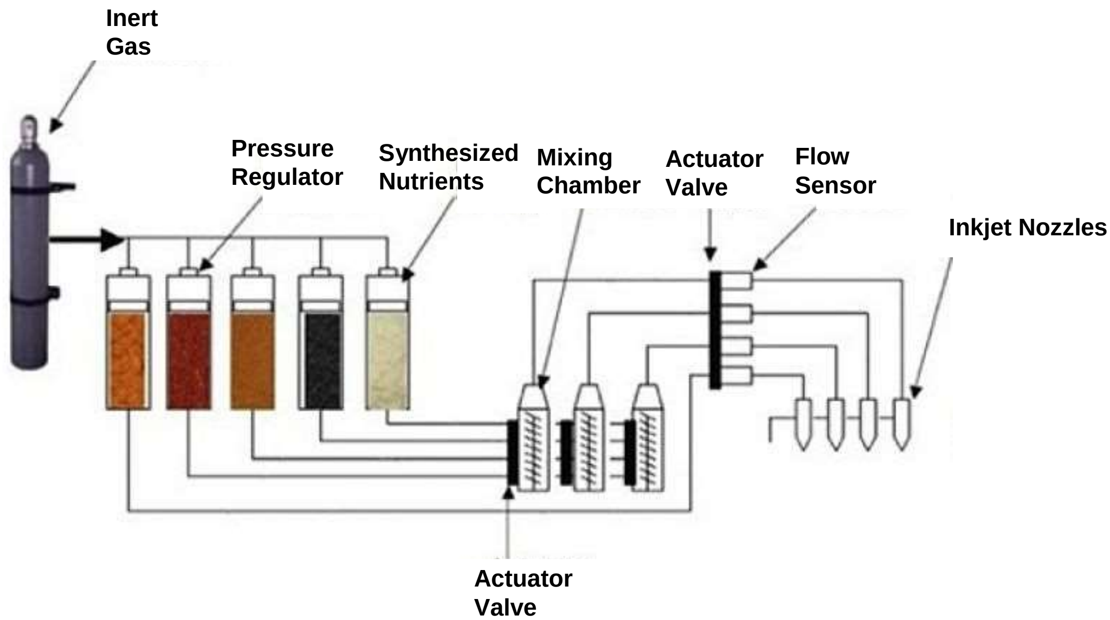


Figure 12. Mechanism of the InstaFood 3D Printer [19]

Simplification of the Mechanism

The simplified diagram of the mechanism above illustrates the flow of inputs to the outputs. The fluid flow is regulated by the concept of physics fluid mechanics.

- **Synthesized Nutrients** include synthesized carbohydrates, proteins, fats, and other vitamins and minerals.

- **Inert Gas** exerts pressure into the tube causing a pressure difference that allows the inputs to traverse across the tube.

- **Pressure Regulator** controls the speed of the fluid flow by regulating pressure difference within the tube.

- **Actuator Valve** opens and closes the valve in which the inputs pass through

- **Mixing Chamber** mixes the inputs.

- **Flow Sensor** measures the rate of the fluid flow in the tube.

2.4 Food Aesthetics

InstaFood recognizes the importance of food appearance to the consumers. The crew members will not be consuming purely synthesized nutrients without modification of flavorings. We will ensure that the printed food is aesthetically pleasing by the manipulation of food shapes, textures, and flavors.

Shapes

Various shapes of the food can be made by the CAD software no matter how complex they are. CAD allows the structure of food to be designed on any three-dimensional axes. After the design is created, this information will be sent to the printer and tells it to print the pre-programmed model of food one layer at a time. The consistency of shapes, which depends heavily on the chemical composition, will be guaranteed by our mechanism of compound synthesis. The 3D printed sugar pieces are just a few of examples of breathtaking creations by the printer.


Figure 13. 3D Printed Sugars [21] [22]

Another way to manipulate the shape is by spherification, a molecular gastronomy technique of shaping liquids into tiny droplets. In this process, the nozzle ejects a small liquid sphere that contains a substance called sodium alginate into a bowl of soluble calcium salt. A very thin membrane of the submerged liquid will soon formed. These caviar-sized spheres can also be used as garnishes for desserts. [23]


Figure 14. (left) Spherificated Apple Juice [23]
Figure 15. (right) 3D Printed Raspberry [23]

Textures

Food textures can be controlled by the CAD program, heating and cooling processes, and chemical composition. CAD aids the layering mechanism by varying the amount of extruded nutrients and the thickness of each printed layer. As a complement to the layering process, food is heated and cooled during deposition to create different level of surface hardness. [24] The assimilated textures will look as close to the original ones.

For printed meat, the texture will be simulated by adjusting the fat content during the mixing process. We recognize that it is hard to achieve the exact texture of the meat, so there will be trail-and-error experiments by food experts.

Flavors

Glycerol will be used as food sweetener. Glycerol is a simple sugar compound which can be produced by our InstaFood 3D printer through the physicochemical synthesis. [11] It is approved by the FDA (Food and Drug Administration) to be safe for consumption in small quantities. It will also benefit the diabetic consumers due to the low Calorie as low as 4 Calories per gram. [25]

3.0 Costs

3.1 Overview

One of the biggest advantages of InstaFood is that it can provide food with needed nutrition to human beings in some extreme conditions. We know that some NASA manned missions to destination deep in the solar system require food that can be produced in space instantly, and also last for a long time. Therefore, InstaFood is extremely useful for NASA to feed astronauts on those long space missions. This section gives information about general costs to produce a 3D food printer. We make sure that you know specifically where the funding goes, and that your investment is rewardable. The majority of the money will be used for research on the syntheses of essential nutrients. NASA may want to cooperate with us to achieve our long-term goal to make InstaFood as household food printers. This way we can make profits by marketing our products or selling the patent. One unit of InstaFood prototype costs $3000. The input cost for one meal is approximately $50. More details on marketing can be found in the "Implementation Plan" section.

3.2 Research Cost

We will spend most of the funding on material research, because some input materials required for our printers are still not available in the commercial market. The project includes substantial federal scientific or programmatic involvement. It means that the funding goes to providing awards for scientific or program staffs who assist, guide, coordinate, or participate in project activities. The grant also covers laboratory maintenance fee.

In Project Design, we propose three mechanisms to generate food through our 3D printer. The estimated cost of each technology is in the table below.

Carbohydrate Synthesis	Proteins & Fat Synthesis	Vitamins & Minerals
$30,300	$45,000	$49,700

Table 2. Research Cost

We anticipate a total of $125,000 funds for research on relevant technologies. [26]

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3D Food Printing Industry

3.3 Input Cost

The following table shows the cost of input materials for InstaFood.

Carbon Dioxide (CO_2)	Methane (CH_4)	Bio Ink*	Powdered Vitamins & Minerals*	Building Blocks* (Amino Acids)
$13.2 per barrel	$5 per thousand cubic feet	N/A	$2 per serving	$4 per ounce
* Scientific definition of each term can be found in "Project Design" section				

Table 3. Input Cost [28] [29] [30] [31] [32]

The costs of CO_2 and CH_4 shown above are industrial prices according to the American Oil & Gas Reporter. In space, however, CH_4 and CO_2 are available from engine combustion. Therefore, the input price is even lower for the astronauts. The cost of bio ink is unavailable because the current research on it is incomplete, and we need to cooperate with other material labs to do more in-depth research. The powdered chemicals and amino acids are low-cost products, but synthesizing them into basic nutrients requires much more money. The cost of a specific nutrient varies from $50 to over $200. [27] A complete profile could cost up to $1,000. [27] More information about research cost is listed in the "Research Cost" section.

Based on the data above, we mark the price of the input materials as $50 per meal. The price is relatively high compared to the market price, but it will eventually decrease as our technology further develops. We expect each meal to cost around $5 in the future.

3.4 Component Cost

InstaFood will be available in the market soon after NASA utilizes it successfully. We illustrate the estimated cost of a full-assembly InstaFood prototype in the following table.

Control System	Cartridges & Nozzle	Frame	Touch Screen (11*10 inches)	Assembly
$1000	$650 per set	$1000	$200	$150 per unit

Table 4. Component Cost [33]

The control system in the InstaFood is similar to the one in other 3D printers. The cost includes the entire CAD package which processes input information, analyzes digital data, and controls the nozzle. Unlike those in normal printers, the nozzle in InstaFood contains heat and motion sensors. The nozzle is subtle and dedicated enough to be able to control the properties of the output flow. Hence, the cost of our printing set is significantly higher compared to that of the regular ones. The cost of the frame includes the basic box and parts of the machine such as mechanical arms, gears, and valves. Generally, a simple 3D food printer is composed of a control system, cartridges and a nozzle set, a basic frame, and a touch screen. The total cost per unit of a simple full-assembly food printer is $3000. For personalized product, consumers can choose to include more than one cartridges and nozzle set, or a different size of a touch screen.

4.0 Material Research

4.1 Overview

In our "Product Design" section, we propose three mechanisms to synthesize essential nutrients in food. They are carbohydrate synthesis, protein and fat syntheses, and vitamins and minerals. The first two mechanisms need corresponding starting materials in order to produce the final products. For carbohydrate synthesis, the starting materials, carbon dioxide (CO_2), water (H_2O), and methane (CH_4) are industrial raw materials that we can obtain directly from relative suppliers. For protein and fat syntheses, however, no one has complete knowledge about this technology at the moment. In fact, material research on it has been a major challenge to 3D printing industry for many decades. Fortunately, InstaFood has found several breakthroughs in our recent studies. This section may require a little scientific background. It gives a brief introduction to two potential materials we found: building blocks and bio ink. These two materials can be used as raw materials to generate proteins and fats, which is the key to successfully "printing out" a real food. If we are given more investment on our research, we believe we can make this technology applicable and even marketable in the near future. We hope that you feel confident in cooperating with us after reading this section.

4.2 Building Blocks

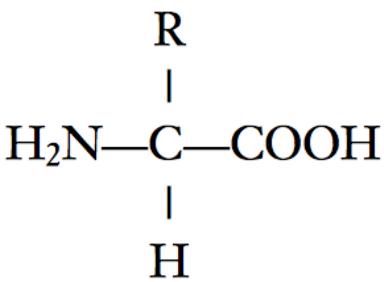
We know in biochemistry that proteins and fats are organics. But unlike some simple organic molecules, they are large complex assemblies called macromolecules. [34] These macromolecules are often polymers, built from a small but similar chemical subunits, like metal pieces linked together to form a metal chain. [34] For example, proteins are polymers of amino acids, and fats are polymers of glycerol and three fatty acids. In other word, amino acids are the building blocks of proteins, and glycerol and three fatty acids are the building blocks of fats.

Every complex molecule can be broken down into its basic chemical building blocks. Reversely, it is possible that we can synthesize complex molecules such as proteins and fats by constructing their building blocks.

Amino Acids

There are 20 amino acids, arranged in specific order, in a chain of polymers that contribute to the complexity and uniqueness of the protein molecules. Research shows that the oceans that existed in the early history of the Earth contained a wide variety of amino acids. An amino acid is a molecule containing an amino group (—NH2), a carboxyl group (—COOH), and a hydrogen atom, all bonded to a central carbon atom. Each amino acid has unique chemical properties determined by its covalently-bonded side group R. This is the reason why there are so many kinds of amino acids. [34]

Two amino acids can undergo a condensation reaction by losing one hydroxyl group (—OH) and a hydrogen atom (H) and form a covalent bond. This process can be repeated where the covalent bonds link different amino acids in a certain sequence into a chain (polypeptide chain). [34]



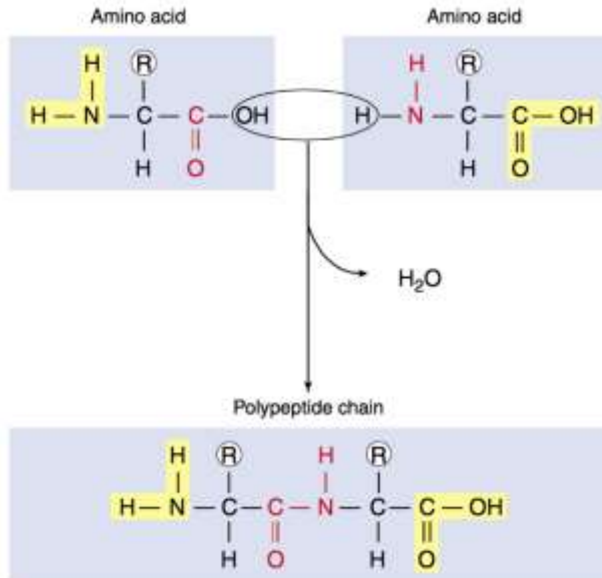


Figure 16. (left) Amino Acid Structure [34]
Figure 17. (right) The Peptide Bond [34]

A protein is composed of one or more chains in various shapes and space structures. It is the shape of the amino acid chain that determines the functions of proteins. After some complex chemical processes, the chains fold, coil, cluster with each other, and finally form the structure of protein. [34]

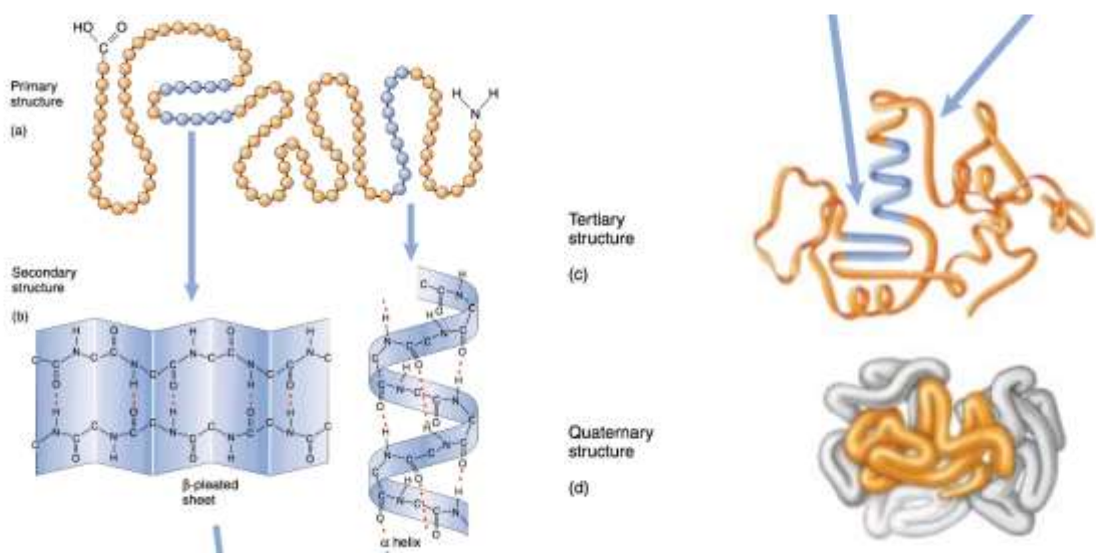


Figure 18. Levels of Protein Structure [34]

Glycerol and Three Fatty Acids

Fats are one kind of lipid that consist of a glycerol molecule that is attached to three fatty acids, one to each carbon of the glycerol backbone. Glycerol is a three-carbon alcohol with each carbon attached to a hydroxyl group (—OH). Glycerol forms the backbone of the lipid molecule. Fatty acids are long chains of C—H bonds (hydrocarbon chains) that end in a carboxyl (—COOH) group. Three fatty acids are attached to the glycerol backbone in a fat molecule. Because glycerol contains three fatty acids, a fat molecule is called a triacylglycerol. [34]

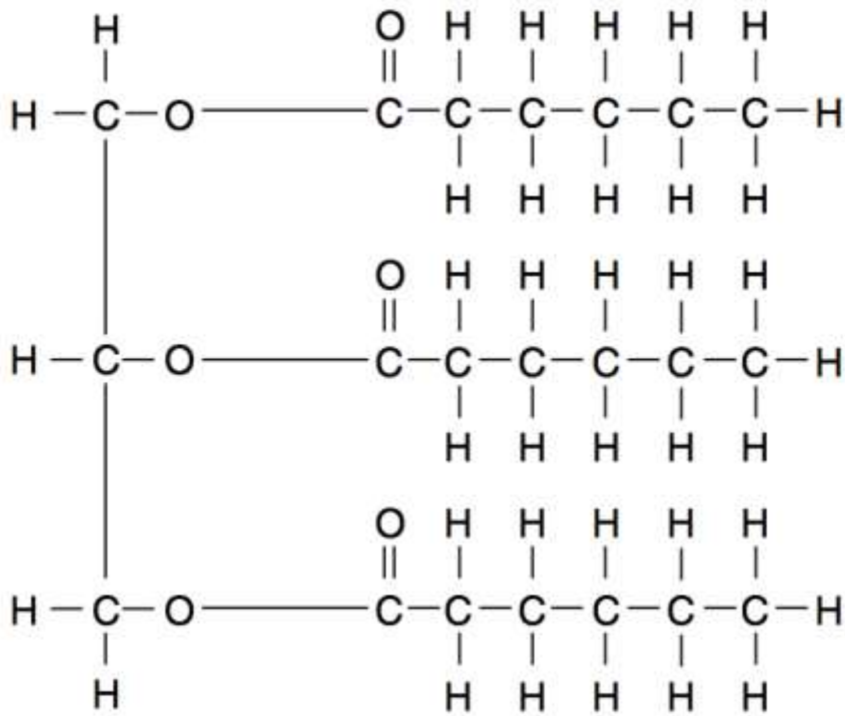


Figure 19. Triacylglycerol Molecule [34]

4.3 Bio Ink

Generally, the bio ink contains stem cells or specialized cells from a living creature, which are able to replicate themselves many times, and also can turn into other specialized cells.

Stem Cells

Stem cells are undifferentiated biological cells that can differentiate into specialized cells and can replicate many times to generate more copies of themselves. [35] We obtain cell lines that are capable of differentiation from ATCC (American Type Culture Collection). Another way to obtain stem cells is through a biological process called biopsy, a removal of a piece of tissues from a living body.

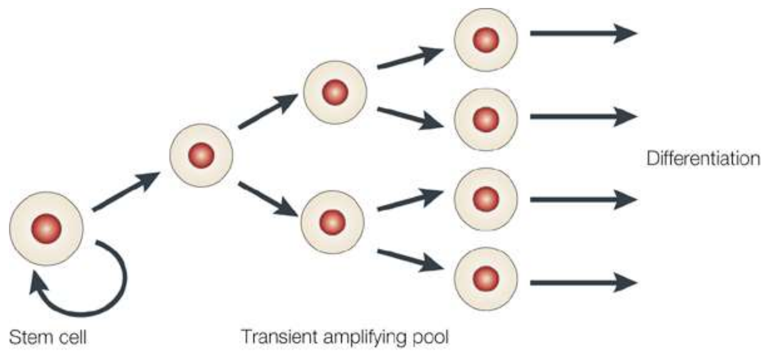


Figure 20. Replication of Stem Cells [36]

Bio Printing

Printed patterns of bio ink are designed by the CAD software in the control system. After the structure is printed out layer by layer into molds made from special biomaterial such as bio paper, and because the cells still retain the ability to differentiate, the bio ink particles will naturally fuse to form a living tissue. [37]

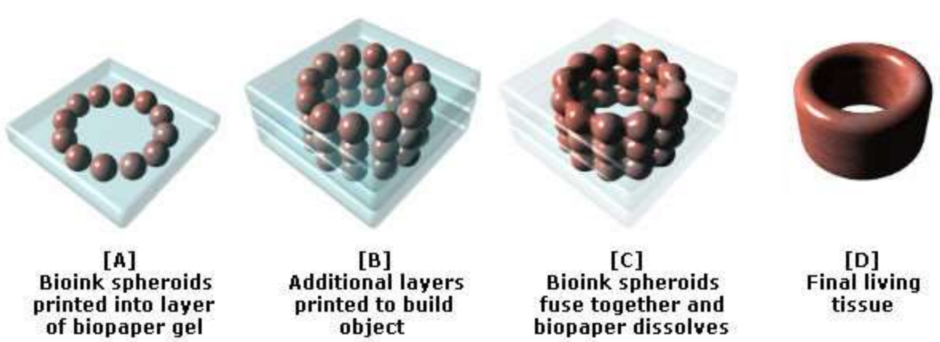


Figure 21. Bio Ink Printed in Layers [38]

5.0 Technology Comparisons

Genetically modified food was the biggest step in history to dramatically increase the yield production of crops. Our invention is created for the similar reason, which is to help facilitate food distribution among the growing population. Genetically modified food was engineered to increase crop yield, and so the crop itself would be bigger than before. However, it still requires soil and plenty of water to grow. The InstaFood will only require common elements found in everyday food. This will eliminate water use, and can benefit a place such as California where water levels are at all-time record low. Furthermore, engineered crops run the risk of being contaminated by bacteria and viruses. Our design will eliminate all types of viral and bacterial infections since the food will be freshly made each time. Finally, some countries do not have as rich soil as other countries. As a result, our invention will also eliminate this issue. Food can be grown anywhere whether soil is rich in nutrient or if the soil has gone badly due to current environmental issues such as fracking. Since our invention is independent of the soil, it can further advance how we feed the world.

Figure 22. (left) Genetically Modified Food [39]
Figure 23. (right) Meat Processing Factories [40]

Meat processing factories were engineered to process food as efficient as possible in order to meet the demands of the growing population. In order to have sufficient meat, farmers inject hormones into their animals so they grow bigger and fatter much quicker than they are intended to. Slaughterhouses are known to be one of the filthiest conditions for animals. Animals are usually covered in their own filth and crammed into a small area. In order to keep the animals in perfect health, animals are injected with several antibiotics. Antibiotics and excessive hormones are not generally good for our health. Furthermore, they are then processed in enormous factories, which are not inspected as often as they should be by the FDA. However, our invention gets rid of need for hormones and antibiotics. Our invention will have the capabilities to make pure organic meat on the spot. Animals will no longer have to suffer, and there will no longer be talk about the sanitation conditions on meat processing factories. Since our product will cause no animals harm, this could also lead vegans and vegetarians to start eating protein-rich foods.

In our modern world, fast food restaurants dominate the way Americans get access to quick food; however, thanks to fast food restaurants this has led to the greatest increase in obesity and type-2 diabetes. Fast food is usually low in nutrients with high levels of fat and sugar. This is what Americans usually lean on when they are short on time but need food. Nonetheless, our product combines the idea of fast food and nutrition. The InstaFood can get someone food as fast as 10 minutes, which is usually around the time that fast food places can give you your order. For college students, there will be no more ordering out and paying for delivery. People can now get fast healthy food instantly.

In the future, scientists believe that the food demand will increase by more than two-thirds. As a result, scientists believe that cultured meat could be one way to solve this issue. Cultured meat is made by first taking stem cells and then growing them in a laboratory. It is claimed that this process is harmless and painless to the animals. Once the cells are grown, they form muscle cells which can be cooked and eaten. This process does solve some issues such as feeding the world, helping vegetarians that oppose meat due to animal torture, and reducing the water use for livestock; however, several people disapprove of the idea of cultured meat because they argue that the hormones use to rapidly grow the cells are unhealthy to humans. Furthermore, they claim that it can have future health problems. Our invention will also solve all the issues that cultured meat will solve, but our 3D food printer will not use hormones to help meat grow. The InstaFood will create meat that is similar in structure of organic meat without any hormones. Furthermore, with a 3D food printer, food can easily be printed at home. Whereas cultured meat is growing in a laboratory and treated with preservatives before it gets to the table.

6.0 Marketing Plan

The InstaFood 3D printer will mainly be targeted to NASA. Our product will be advertised as a personal chef in outer space. Currently, the food for astronauts is very limited due to a variety of reasons; however, with our 3D printer astronauts can have fresh food with a push of a button. They will no longer be limited to eat food such as dehydrated food. They can eat a variety of dishes.

In addition, the ingredients that will go into making the food, chemical compounds, will take a long time to decay. For example, carbon molecules take around 5,730 years to decay. Therefore, one will have all that time to use their 3D food printer. This will be necessary as we start to explore places far away from the Earth. Not only will astronauts be able to eat various fresh food, but they will also be able to use our 3D printer for millenniums provided they have enough chemical compounds to print food. For example, if we ever try to make a colony on Mars, we could only ship items to mars every year given if we have the available funds to send supplies that often. Therefore, since our printer could be used for thousands of years, this will ease some stresses on the issue of supplying humans on Mars in the scenario that Mars is not a fertile planet.

Having such device on spaceships could significantly reduce the cost of NASA to ship food. InstaFood is the solution for feeding people worldwide, and NASA will expand that to planets or galaxies provided that NASA expands their technology for space exploration.

Initially, we can have a solid contract with NASA stating that only they will have access to our product. Furthermore, we could offer NASA a deal to start implementing our design in their spaceships. Not only will this benefit the company, but NASA will also benefit as well since they will get an exclusive offer with us. As part of the contract, we will update our product based on NASA's needs. This will benefit them since they will quickly get a new product for being our only customers at the time. This will also benefit our company because NASA will help us improve our design, since a product is only as good as the customer states it is. When the contract is done, our profit will be stable enough that we will be able to invest in a larger market.

7.0 Implementation Plan

Before advertising to NASA, first we will get a patent on InstaFood because this is a one-of-a-kind invention. This will be the first investment in our product. And, we believe that the patent will be a small price to pay for such a big invention. From the start we will not even consider buy-outs until we have at least accomplished our long-term goal.

Our long term goal is for our 3D food printer to be affordable so the majority of people could personally own one in their house. Our short term goal will be to get government funding by advertising to NASA. Initially, our printer will only be available to NASA, due to the high cost to make the printer and the input materials needed to print out food. As a result, we will first invest and do research on our product while advertising to NASA so we could hopefully bring down the cost lower.

When our printer first hits the markets, we would only advertise to wealthy people. By advertising to wealthy people, we could further increase our income since owning a food printer would be a novelty for them. Similar to how several rich people own expensive items to display their wealth in their homes. This would continue for a couple of years.

After reaching a stable economic situation, we would then start using our 3D printer for charity uses. We would open up a charity website so people could donate and help us use our 3D printer to help fight homelessness around the world. This could not only help starving people, but can also help spread the news of our invention all over the world. By this time we hope that the cost of our product would have dramatically decreased since the first few models.

Once the cost are affordable, we would then be able to advertise our product as a common kitchen appliance one can use in his or her everyday life. We would advertise our product as the only product that can get you food as fast as a fast food restaurants; however, it would be fresh and healthy. Hopefully, this could help people get fresh food fast without having to rely on junk food. Once the majority of people use this product, it is expected that obesity and diabetes rates go down. This will make our product more famous, and in the future our product could be the new method to feed the world.

At this point, we should be at the most stable point in our financial status. Once we make it this far, we will start developing different models for different types of people along with accessories. For example, some will be able to print out faster than others. In addition, we will also be able to start making add-ons to each individual model. We can sell "software" that will allow the models to upgrade and perform much faster. The InstaFood would be similar to current cars and computers that will allow users to buy different models and upgrade them as the user desires. For safety reasons, we can also add software such as parent control where parents could control the amount and types of food printed out by children.

8.0 Global Impact

There are several disadvantages of the current food industries. We believe that our invention, the 3D food printer, could be a promising solution to these problems.

8.1 Greenhouse Gases Emission

One of the disadvantages of the food industry is the greenhouse gas emission. Agricultural and farming practices contribute to emissions in many ways. One of which is the production of methane (CH_4) from the livestock through their digestion, or the process called enteric fermentation. Methane is also emitted through rice cultivation and crop residue burning. Another is the emission of nitrous oxide (N_2O) from irrigation and tillage practices. [41]

According to the research, greenhouse gas emissions from agriculture account for approximately 30% of total U.S. greenhouse gas emissions, which constitutes a large portion of emission. [42] Our product will eliminate the emission by putting an end to crop and livestock production. Additionally, greenhouse gases in air can further be reduced because the InstaFood printer uses carbon dioxide and methane, the most common greenhouse gases, as the basic ingredients to synthesize food. Consequently, the global warming can be greatly eased.

8.2 Water Shortage

Another disadvantage of the food industry is the high level of water consumption. Approximately 43% of water is used in farming in the United States. [43] Today, water shortage is one of the largest problem faced by the United States and the rest of the World. Due to the increase in population growth rate, the increase in the rate of water consumption is inevitable. Because water resources cannot compete with the doubling of the population, 1.6 billion people or one quarter of the world's people are currently facing water scarcity. [44]

Our InstaFood will also reduce water consumption by cutting down the farming methods for making food. Since agriculture constitutes most of ground and surface water usage, the issue of water scarcity can be resolved.

8.3 Habitat Destruction

Agricultural production uses the majority of the land as much as 51% of the United States' land. [45] Although 50% of the world's habitable land has already been used for farming, the expansion of land use for agriculture is not going to stop anytime soon as the human population continues to surge. It is predicted that 120 million hectares of land in developing countries will be converted to farmland by 2050 in order to provide sufficient food to everyone. [45] As a result, biodiversity will be reduced.

According to the World Wildlife Fund, habitat destruction is the major cause for the 50% loss of the Earth's wildlife in the past 40 years. [46] This problem can be solved by habitat restoration for endangered animals. In other words, we have to transform current farm lands back into habitable land for animals while being able to feed today's human population. The InstaFood is an ideal solution because no farm lands are required for food production.

8.4 Food Waste

In our society, many leftovers are thrown away every day even when they have not yet expired, whereas in the Third World countries, many people suffer from malnutrition and hunger. We believe that our invention will help the hunger by reducing food wastes. The InstaFood printer will break down any waste into basic molecules, which will be reused to make a new plate of food, unlike the traditional cooking where every unwanted piece of food such as the orange skins are peeled and disposed of.

9.0 Conclusions

9.1 Food in Space

When the space missions get deeper and longer, food resources become more unstable as the nutrients deteriorate with time. As a consequence, the astronauts are subject to poorly-balanced diet and will not be able to perform their best. Our invention, the InstaFood 3D printer, successfully addresses these problems. Because food is made at the molecular level, the health of the consumers are ensured. Nutritional quality in food can be fully controlled through molecular synthesis in carbohydrates, proteins, and fats. The content of each nutrients will be based on DRIs and nutrient recommendations for space diets.

Another great service provided by the InstaFood is a personal chef. The InstaFood will save time for food preparation, which usually takes about half an hour for setting up and heating. Meal choices are infinite as long as specific ingredients needed for food synthesis are available. Food can also be printed in custom designs that are aesthetically pleasing to the consumers. The variety of food options and appearances will greatly affect the success of the missions by providing the astronauts with unique dining experiences from a long confinement in the outer space.

Our InstaFood will eliminate the space station food system. Thus, the transportation cost for sending food supplies to individual spaceship can be saved since the InstaFood can provide sufficient food with unlimited ingredients, which can be obtained from the combustion reaction of the space engine. Correspondingly, material waste can be reduced. The InstaFood will replace the current packaging system that uses disposable containers since the food is no longer needed to be prepared before the missions, but can be printed instantly by our 3D technology. With all of its numerous benefits, InstaFood is a promising option for the space explorers.

9.2 Food on Earth

InstaFood's potential is not only limited to the space flight, but also to the rest of us on Earth. Many problems today such as global warming, shortage of food supply, and unsustainable human activities can be resolved by our product. InstaFood will reduce a great portion of carbon dioxide and methane, the major greenhouse gases, in the air by converting them into edible carbohydrates as part of our diet. Moreover, the technology of 3D meat printing will end the torture of livestock animals, restore natural habitats of endangered species, and reduce water consumption. It is our mission to revolutionize the food industry and help the world. Through the InstaFood 3D technology, the possibilities are endless.

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11.0 Appendices

Appendix A

Net Equation for the Synthesis of Hexose [11]

Reaction	[Delta] H
$24\ H_2O \rightarrow 24\ H_2 + 12\ O_2$	+1638.2 Kcal
$6\ CO_2 + 24\ H_2 \rightarrow 6\ CH_4 + 12\ H_2O$	- 362.4
$6\ CH_4 + 6\ O_2 \rightarrow 6\ HCHO + 6\ H_2O$	-468.6
$6\ HCHO \rightarrow C_6H_{12}0_6$	-135.2
$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$	+672.0

The table above shows the net equation for the synthesis of hexose and the required energy for each reaction to undergo. Energy produced from the electrolysis of water will drive the reaction of water to hydrogen gas and oxygen gas, ($24\ H_2O \rightarrow 24\ H_2 + 12\ O_2$), which needed 1638.2 Kcal of input energy. The next three reactions do not require energy input because they are exothermic, a reaction that releases energy. This released energy will be used to drive the last reaction, ($6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$), that produces a sugar and oxygen gas.

Appendix B

Survey: Percentage of People Who Would Knowingly Eat 3D Printed Food [44]