National Aeronautics and Space Administration

Johnson Space Center (JSC)

3D Printed Prototype to Enhance the Space Food System

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Technology Area (TA): 6.1.4 Habitation **TRL:** start 3 / current 4

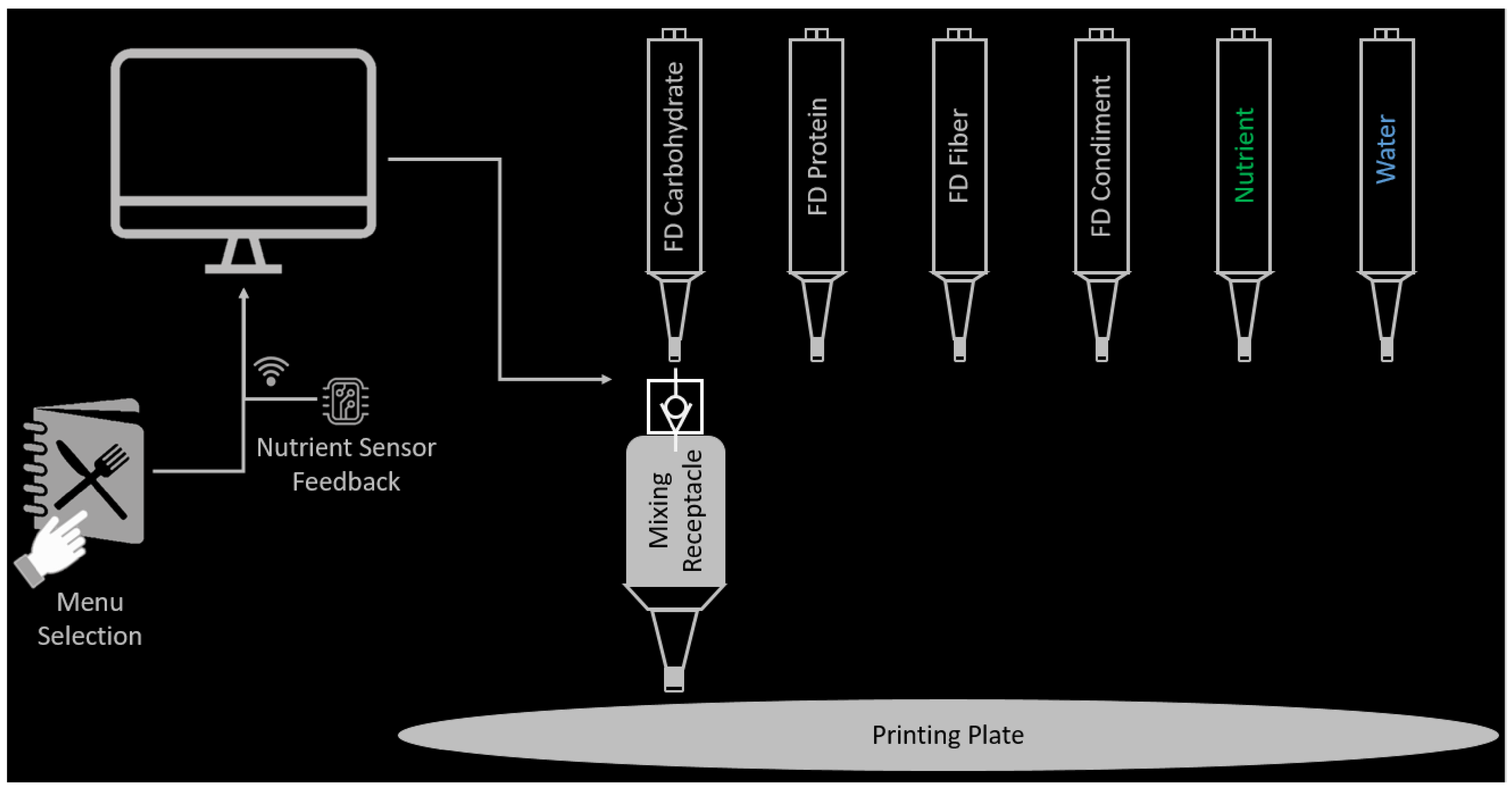
ICA PROJECT OVERVIEW

3D printing is a novel food processing technology with the potential to benefit human space exploration by allowing meal customization reflecting the astronauts needs and eating preferences. Benefits may include precise delivery of nutrients in response to biometrics data, adjustments in nutrient and caloric density to allow variation in the meal size actually consumed, and adjustments in texture and flavor to meet the sensory preference of each astronaut. Additionally, 3D printing may provide attractive presentations to increase appetite.

Ready-to-eat freeze-dried ingredients (Starch, Gelatin), food components (Hummus, Almond Butter, Tofu, Sausage Patties, Mozzarella/ Monterey Jack/Cheddar Cheese Sauces, Brussels Sprouts), and food matrices (Vegetable Quiche, Spaghetti with Meat Sauce, and Chicken Pineapple Salad) were successfully 3D printed.

Chemical and physical approaches were explored to introduce texture complexity. The chemical methods that precipitate or bond molecules to provide different mouthfeels, such as pH adjustments and use of chelating agents, would not work under micro gravity environment (abundant free water was required for the reactions to occur). However, physical size manipulation proved to be a successful solution. Tests showed that the texture of a crunchy vegetable can be perceived within the 0.094”-0.132” particle size range which fits in the nozzle extruder of a 3D printer.

Based on these findings, ‘*Hummus Crunch*’, ‘*Asian Salad Bar*’, ‘*Cheese Sandwich*’, and ‘*Space Jello*’, were prepared as final prototypes providing precise nutrition, meal customization, and individualized palatability.

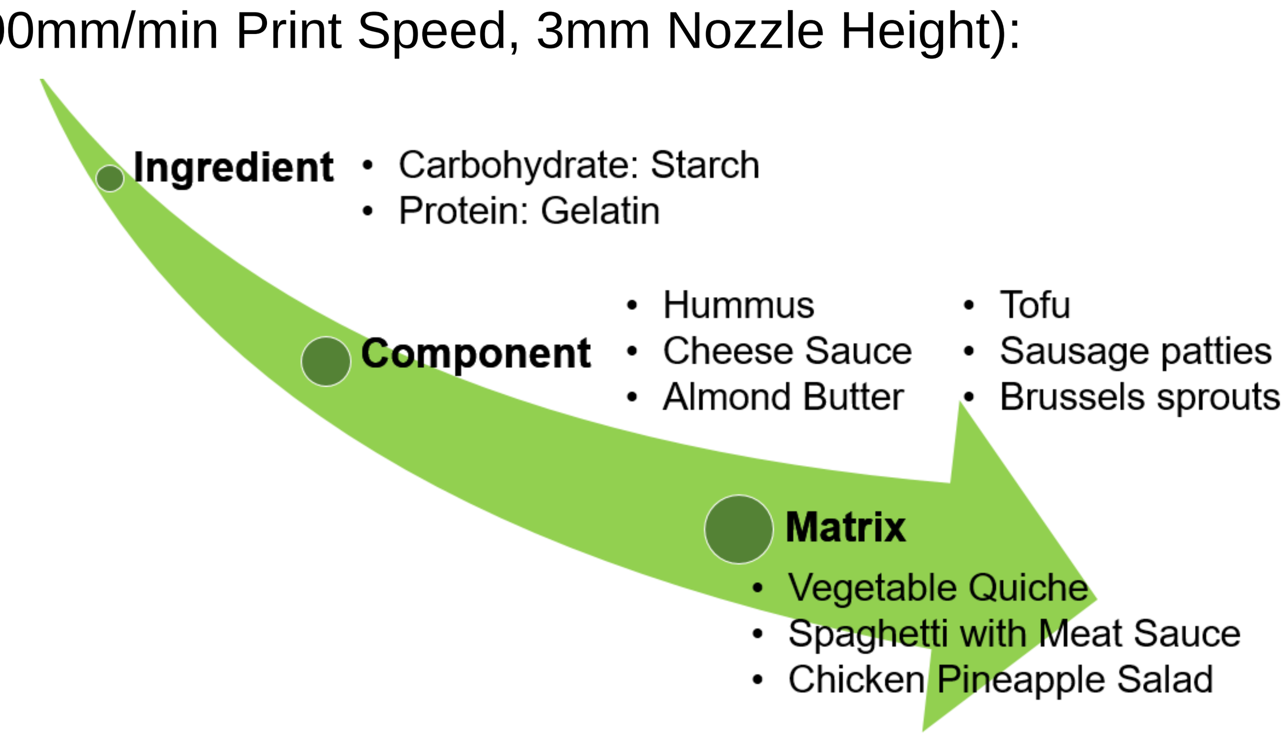


INNOVATION

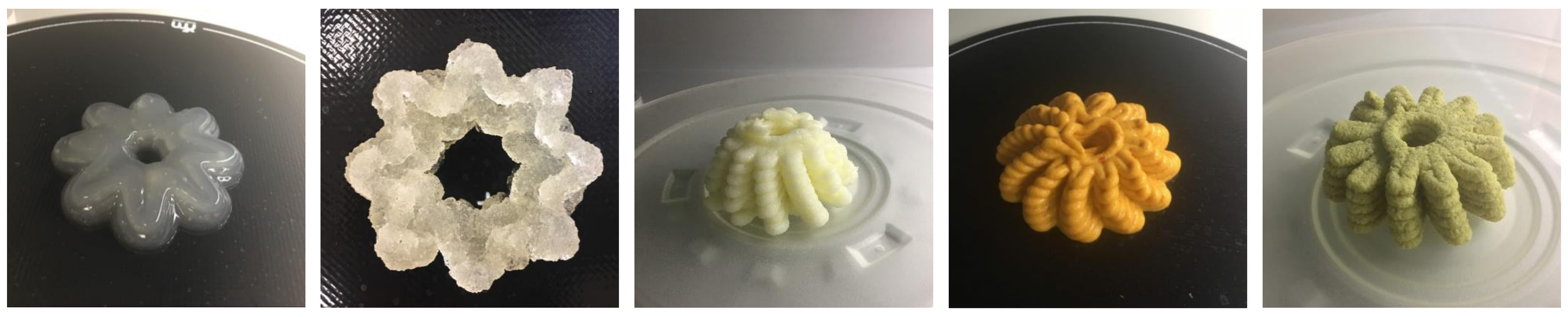
This project analyzed the printability of hydrated ready-to-eat freeze-dried ingredients with the advantages of light weight and long shelf life and requiring minimum on-board post-processing. Although printing time is a current limitation for food industry applications, this is not a concern in the context of a space mission. This approach has not been studied in the space food program despite the novel advantages here identified.

OUTCOME

1. Most freeze-dried materials were successfully 3D printed after grinding and rehydration under the following parameters: 4mm Nozzle Size, 8000mm/min Print Speed, 3mm Nozzle Height):

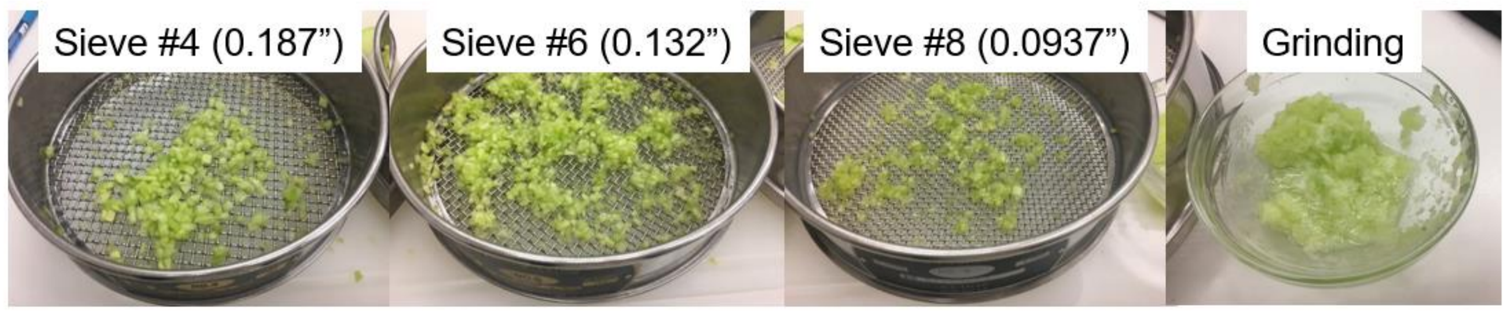


Swiss | Gouda | Mozzarella | Cheddar | Monterey Jack



Starch | Gelatin | Mozzarella | Hummus | Vegetable Quiche

2. Texture of crunchy vegetables/nuts can be perceived for pieces in the 0.094”-0.132” range providing mouthfeel complexity when consumed.



Texture perception: Crunchy | Crunchy | Crunchy | Mushy and Watery

3. By utilizing food that mushy texture is perceived to be acceptable as the substrate and combining with crunchy ingredients at the size within the 3D printing capability, we created 4 prototypes:

Hummus Crunch | *Asian Salad Bar* | *Cheese Sandwich* | *Space Jello*

FUTURE WORK

Findings from this project established the groundwork for future research incorporating in-place post-processing to create more complex products and add personalized nutrition. Precise site & temperature-controlled Laser heating during 3-D printing can enhance textures and accelerate desirable browning reactions (color/flavor).