PROJECT DESCRIPTION

Background

As the need for enough food to sustain the growing population increases, the amount of waste that is generated at the farm level also increases. According to a 2011 Food and Agricultural Organization research report by the United Nations, one-third of the world's edible fruits and vegetables are wasted every year. This amounts to about 1.3 billion tons of waste (Tu et al., 2018). Many fruits and vegetables are left on the field or tossed in processing because the produce is "ugly." The "ugly" produce is thrown out for cosmetic reasons ranging from color and size to odd shapes and blemishes on the peel. These fruits and vegetables have the same nutritional value as accepted fruits and vegetables, but never make it to the market because of their poor appearance (Hartmann et al., 2021).

3D food printing technology has made its beginning footsteps into the food industry with the capability of transforming manufacturing processes. Some of the notable capabilities for 3D food printing include personalization, on-demand production, and, as highlighted in this research, reduction of food waste (Derossi et al., 2021). Previously, 3D food printing has been used to create functional cookies from grape pomace, a food processing byproduct (Jagadiswaran et al., 2021). However, there is limited information on 3D food printing of "ugly" fruits and vegetables.

In this project, an extrusion-based 3D food printer is being utilized. The extrusion technique runs using a robotic arm that moves along a surface with a cylindrical cartridge that dispenses the food paste. There are certain parameters that must be considered when developing the food paste including: the capability of the food paste to be extruded through the nozzle, the ability for the food paste to have a sufficient viscosity for the layers to stack without defects, and the resolution of the final product due to stability and definition of the food paste (Le-Bail et al., 2020). The proper conditions for the extrusion rate are pre-determined by the food printer.

<u>Goal and Objectives</u>

Global food waste should not be overlooked. The fruits and vegetables that account for nearly a third of the total food production waste can be repurposed in forms that their shape is not constantly being examined. The goal of this research is to provide an outlet that can reduce the level of food waste at the farm level using a 3D food printing approach. We hypothesize that 3D food printing can convert the "ugly" fruits and vegetables into healthy snacks. The use of 3D food printing can help to improve the environment and increase sustainability on Arkansas farms. The specific objectives of this project are:

- Freeze-dry "ugly" vegetables/fruits and generate pastes at different ratios for 3D food printing
- Produce vegetable/fruit-based snacks using a 3D food printer

<u>Methods</u>

Study Design.

Different fruits and vegetables, including broccoli, carrot, potato, banana, will be used at different ratios (i.e., 30, 50, 70%) for preparing the pastes for the 3D food printing. All research will take place in the Food Science Building on the University of Arkansas campus.

3D Food Printing Paste Preparation.

Produce Selection. The "ugly" fruits and vegetables will be obtained from local farms and farmers markets. The vegetables will be refrigerated for no more than two days before their processing steps begin.

Preparation. On the day that blanching and freezing are to occur, the unpeeled vegetables are washed and sliced into pieces no larger than 4 cm in diameter.

Blanching. The vegetables are blanched in a Thermomix (Vorwerk, CA, USA). The raw vegetables are blanched in water at 90 °C for 4 minutes , where most enzymes become inactivated (Kidmose et al., 1999). After blanching, the vegetables will be packed into Ziploc bags and frozen for at least 24 hours. The goal of blanching is to inactivate enzymes that may cause flavor or color deterioration over time.

Freeze-drying. Once the vegetables have been frozen throughout, they will be placed in a freeze-drier (VirTis benchtop SLC, PA, USA) at -108 ºC and 0.015 kPa. The produce will be held at these conditions for 48 hours or until they are dry throughout.

Milling and Sieving. The dried produce is then milled into a fine powder. The fine powder is then placed in 30-50 gram increments in a sieve shaker for about 15 minutes or until most of the powder has passed through. A 450 µm sieve is used to separate out the larger particles. The powder at the bottom is then placed into a bag for storage purposes. Any remaining particles at the top will be saved and grinded in a coffee bean grinder to mill those pieces into a finer powder that will have the chance to pass through once again.

Paste Formation. The powders must be weighed out based on the desired ratio of powders. A table of the different formulations for a paste consisting of carrot, broccoli, and potatoes is included below (Table 1). Next, the powders are added to the Thermomix with 70 grams of water. The mixer will be set to about 60 °C and a mixing speed of 4.5 for 3 minutes. A paste that can be loaded into a printing capsule will be formed.

Table 1. Formulation of pastes for 3D food printing.

Formulation of paste					
Trial	1	2	3	4	5
Ratio (C-B-P)	20-20-40	30-30-40	40-40-20	45-45-10	50-50-0
Carrot	6 g	9 g	12 g	13.5 g	15 g
Broccoli	6 g	9 g	12 g	13.5 g	15 g
Potato	18 g	12 g	6 g	3 g	0 g
Water	70 g	70 g	70 g	70 g	70 g

Printing. The paste will be loaded into the Foodini printing capsule with a 1.5 mm nozzle size. In this study, an extrusion-based 3D food printer (Natural Machines, Foodini, Spain) will be used. The print speed, extrusion rate, and other parameters will be assessed and programmed by and for the software. To assess the printability of the paste, a twisted star that decreases in diameter over the course of 10 layers will be printed on the silicone mat.

Characterization. Rheological tests will be able to characterize the viscoelastic properties of foods by using simple shear or compression, or bulk compression. Additionally, color and texture analysis will be able to determine whether the blanching was able to inactivate the enzymes.

Timeline

Table 2. Timeline of the project.

Timeline	Description of the work
March-May 2022	Obtain the “ugly” fruits and vegetables
May-July 2022	Conduct 3D food printing preliminary experiments
July-September 2022	Determine rheological properties of the vegetable/fruit pastes
September-November 2022	Optimize the 3D food printing parameters and produce snacks
November 2022-January 2023	Determine textural properties and color of the 3D-printed snacks
January-March 2023	Compile the results and conduct statistical analysis
March-May 2023	Prepare a manuscript describing the finding of the study Presentation of the results

References

Derossi, A., Paolillo, M., Verboven, P., Nicolai, B., & Severini, C. (2022). Extending 3D food printing application: Apple Tissue Microstructure as a digital model to create innovative cereal-based snacks. *Journal of Food Engineering*, *316*, 110845. https://doi.org/10.1016/j.jfoodeng.2021.110845

Hartmann, T., Jahnke, B., & Hamm, U. (2021). Making ugly food beautiful: Consumer barriers to purchase and marketing options for suboptimal food at retail level – a systematic review. *Food Quality and Preference*, *90*, 104179. https://doi.org/10.1016/j.foodqual.2021.104179

Hingston, S. T., & Noseworthy, T. J. (2020). On the epidemic of food waste: Idealized prototypes and the aversion to misshapen fruits and vegetables. *Food Quality and Preference*, *86*, 103999. https://doi.org/10.1016/j.foodqual.2020.103999

Jagadiswaran, B., Alagarasan, V., Palanivelu, P., Theagarajan, R., Moses, J. A., & Anandharamakrishnan, C. (2021). Valorization of food industry waste and by-products using 3D printing: A study on the development of value-added functional cookies. *Future Foods*, *4*, 100036. https://doi.org/10.1016/j.fufo.2021.100036

Kidmose, U., & Martens, H. (1999). Changes in texture, microstructure and nutritional quality of carrot slices during blanching and freezing. *Journal of the Science of Food and Agriculture*, *79*(12), 1747–1753. https://doi.org/https://doi.org/10.1002/(SICI)1097-0010(199909)79:12<1747::AID-JSFA429>3.0.CO;2-B

Le-Bail, A., Maniglia, B. C., & Le-Bail, P. (2020). Recent advances and future perspective in additive manufacturing of foods based on 3D printing. *Current Opinion in Food Science*, *35*, 54–64. https://doi.org/10.1016/j.cofs.2020.01.009

Tu, J.-C., Lee, Y.-L., & Wei, M.-Y. (2018). Analysis and research on the key success factors of marketing ugly fruits and vegetables. *Sustainability*, *10*(8), 2783. https://doi.org/10.3390/su10082783

BUDGET

Item	Price	Justification
Broccoli	$20.00	The component being studied. 30 g of freeze-dried product is required per trial run, and is ran through very quickly.
Carrots	$25.00	The component being studied. 30 g of freeze-dried product is required per trial run, and is ran through very quickly.
Bananas	$25.00	The component being studied. 30 g of freeze-dried product is required per trial run, and is ran through very quickly.
Potato	$20.00	The component being studied. 30 g of freeze-dried product is required per trial run, and is ran through very quickly.
Grinder	$200.00	Grinder will be used to mill the vegetables/fruits after drying for smooth3D food printing.
Sieve set	$150.00	Sieve set will reduce the sieving and enable creating larger amounts of vegetable/fruit powders for 3D food printing.
Foodini Accessory Set (Nozzles, Cartridges, Silicone Mats)	$400.00	The accessory set will enable us to investigate the printability of vegetable/fruit pastes using different nozzle sizes. The advantage of additional silicone mats will cause for an easier transition from one trial to the next. Minimizes the need to wait between trials for material to dry.
Lab Supplies	$150.00	Gloves, Pipettes, Weighing Paper, Test Tubes, Aluminum Foil, Wax Paper, Ziploc Bags Basic lab materials that will be required for different aspects of the research.
Total	$990.00	