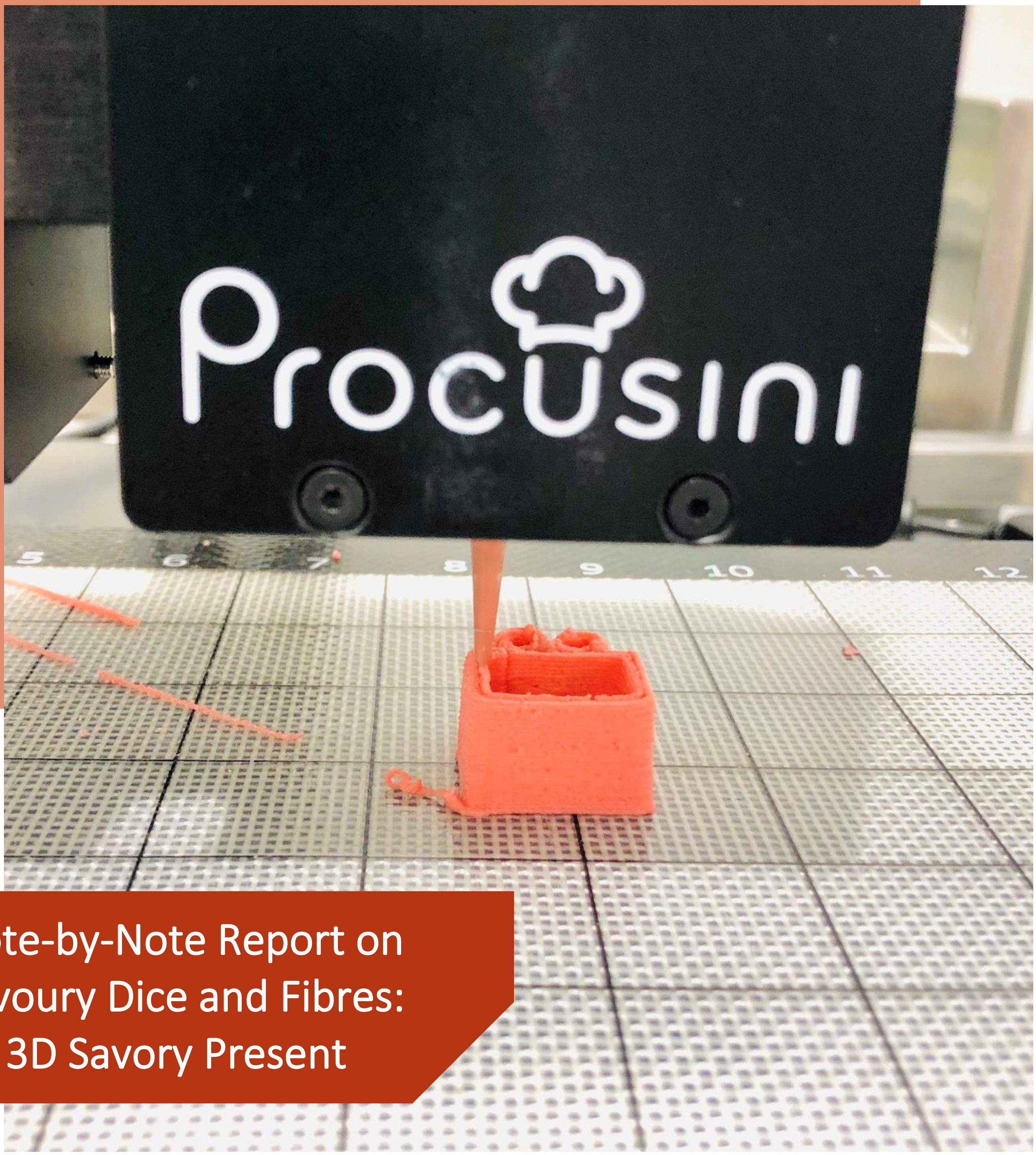

Note-by-Note Report on Savoury Dice and Fibres: 3D Savory Present

Advanced Molecular Gastronomy - TFCS9025

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TABLE OF CONTENTS

1. INTRODUCTION

Molecular gastronomy is a scientific discipline created in the 1980s that studies the mechanisms of phenomena occurring during the culinary process. It was meant to study the scientific process behind daily and common dishes that have been reneged by the food industry. Making scientific discoveries and calculations on the regular dishes was the goal, but it was rapidly adopted by famous chefs that used some of the scientific techniques to create new dishes, what is now known as molecular cooking or molecular cuisine. Since then, the concept of this discipline has been widely confused (R. Burke & Danaher, 2016) (Braken, 2015).

In this context, Note-by-note cooking was introduced in 1994 by the French Physical Chemist and Molecular Gastronomy Co-Founder, Hervé This (R. Burke & Danaher, 2016). Note-by-note cooking is a new culinary technique to create food and drinks where the ingredients are pure compounds (This Vo Kientza et al., 2021). He usually compares this innovative technique to the creation of synthetic music note by note. By using pure compounds or notes instead of the regular foods or musical instruments, the possibilities for the creation of new food or music are infinite. This innovative technology also allows the production of more sustainable food because it reduces transport costs, and it doesn't need to be refrigerated, even it could help with the food waste issue (Braken, 2015). The main aim of note-by-note is to invent new foods and dishes, more than the replication of the existing ones (Chandran, 2018).

3D food printing, or food layered manufacture (FLM) or additive manufacturing, is an emerging technique that builds computer design objects on a platform through a layer-by-layer deposition. The first 3D food printer was introduced around 12 years ago and has been used for specific and small-scale purposes like creating elaborate chocolates and pastry forms for top-end restaurants (Zhu et al., 2019).

The advantage of this technique is that allows the creation of versatile and personalized products incorporating new textures (control of aeration process, mechanical properties, cellular structure), tailored nutrition, and functional ingredients. Also, it can improve sensory perception by changing the distribution of taste in a food matrix (Fahmy et al., 2021; Burke-Shyne et al., 2021). Besides, 3D printing has a huge potential to create new sustainable foods, like alternative meat products. It can help reduce food waste by using fruit or vegetables that do not look appealing to consumers and give them a new life. And it can help reduce the carbon footprint by reducing transport costs (Vallely, 2019) (Burke-Shyne et al., 2021).

The most common technology is extrusion-based 3D printing, but there are other technologies like laser sintering or inkjet printing. In extrusion-based technology, the food matrix is extruded from a syringe to a platform where the object will be built layer by layer. Application of this technique is challenging because it requires in-depth knowledge of the rheological properties of the matrix or formulated “ink” (Jiang et al., 2019; Yang et al., 2017). The ease of deposition and the ability to hold its structure post-deposition are the two properties that determine the 3D-printability of the object and the success of 3D printing (Zhu et al., 2019). The macronutrient composition of the formulated “ink” is important because its properties and the interactions they create will determine the final rheological properties. In the case of proteins, the water holding capacity and water distribution are the most important properties. Fat crystallization and fat-melting point are key properties in the case of lipids. Finally, granule size and distribution, and swelling capacity are important properties of starches (Hussain et al., 2021; Pérez et al., 2019).

Several authors have studied the suitability of different food matrixes in 3D printing like fish surimi gel, layered bread, cereal cubes, protein bars, insect snacks, layered chocolate, artificial steak, etc. (Ma & Zhang, 2022; Ramachandraiah, 2021; TSAI & LIN, 2022). Creation of meat alternatives have become a necessity looking ahead to feed the increasing human population (This, 2014). Nevertheless, 3D food printing has not been fully exploited and there is a wide field to explore by coupling it with note-by-note cooking.

Every year a note-by-note cooking competition is held to promote the creation of new food and dishes. Culinary professionals, students, or amateurs from all over the world are invited to participate and create new dishes based on a theme. This year the theme is “Savoury dice and fibers” (excluding Rubik’s cube).

In this context, the idea of developing a new note-by-note recipe with the help of the 3D printing technique was born. The project aims to create a completely new recipe that does not imitate any existing food, to be aligned with the most important and innovative goals of note-by-note cooking. Consumers can benefit from the mix of the two approaches as both have advantages like the creation of tastier, healthier, and more sustainable food. For example, the use of pure compounds can reduce the cost of transportation and the product footprint while it can be replicated wherever there is a 3D printer available. The developed dish will open consumer imagination and senses to a new perspective of food development.

2. AIM OF THE ASSIGMENT

To create and optimize the taste and texture, of a note-by-note savory recipe completely innovative that do not mimic any existing dish and includes fiber and a dice shape, through practical experimentation in TU Dublin laboratories.

To achieve this aim, specific objectives were set:

- To test different protein sources and savory flavors for the creation of food "ink" that can achieve the right texture to work in the 3D printer.
- To produce a savory recipe that contains at least 5% of soluble fiber.
- To print the recipes in the 3D printer with the shape of a present
- To test the printability characteristics of the recipe by visual assessment.
- To determine the optimal time and temperature to cook the 3D savory present.
- To produce a filling sauce that can accompany the 3D savory present.
- To make a sensory evaluation of the final dish.

3. MATERIALS & METHODS

3.1. INGREDIENTS

Ingredients, their brands, and exact quantities are described for the final recipe of the 3D savory present. Taking into consideration the aim of note-by-note cooking, all the ingredients in the recipe are considered mainly pure compounds except the red colorant that has food grade carriers. Table 2 shows the picture of the principal ingredients that were used for the development of the note-by-note cooking.

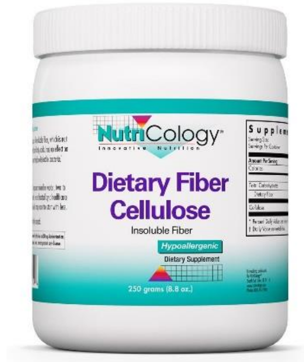
Table 1. Ingredients and Its details for the 3D savory present recipe

Ingredient name	Quantity	Brand	Composition	Reference
Corn Starch	61 g	Gem	High in amylopectin	(Horstmann et al., 2017)
Pea Protein Isolate	32 g	My Vegan	75% of protein	My Vegan, n.d.
Cellulose Dietary Fibre	17.5 g	NutriCology	Cellulose	NutriCology n.d.
Olive Oil	14.3 g	Supervalu	High in oleic acid	(Blekas et al., 2006)
Caster Sugar	2 g	Gem	Sucrose	(Róisín Burke et al., 2021)
Salt	1 g	No brand specific	Sodium Chloride	(Róisín Burke et al., 2021)
Conq Flavour	3 drops	Iquemusu	Component of cucumber and other vegetables	Iquemusu, n.d.
Berthome Flavour	4 drops	Iquemusu	Component of cheeses	Iquemusu, n.d.
Onium Flavour	2 drops	Iquemusu	Component of the essential oil of *Allium savi*	Iquemusu, n.d.
Color E124	5 drops	Wonder	Synthetic color made of coal tar	Wonder, n.d.
Water	127 g	No brand specific		

Table 2. Picture of the principal ingredients for the 3D savory present recipe

<table>
<tr>
<td>

Corn Flour</td>
<td>

Pea Protein Isolate</td>
<td>

Cellulose Dietary Fiber</td>
<td>

Caster sugar</td>
<td>

Common salt</td>
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<tr>
<td>

Olive oil</td>
<td>

Berthome flavor</td>
<td>

Conq flavor</td>
<td>

Onium flavor</td>
<td>

Red colorant</td>
</tr>
</table>

3.2. EQUIPMENT REQUIRED

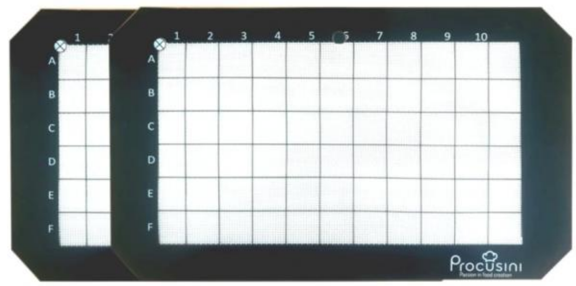
The 3D savory present recipe required the following equipment and materials. In Table 3 we can see the picture of the most important equipment, in this case the 3D printer and its accessories.

- 3D Printer – Procusini 3.0 Dual Model
- Silicone mat – Procusini Brand
- Laptop with the 3D Printer programme – HP Brand
- Plastic syringe – Procusini Brand
- Plastic tips for the syringe – Procusini Brand
- Oven – Electrolux Skyline Premium Model
- Scales with 1 decimal – Salter 1063 model
- Piping plastic bag

- Spoons
- Bowls
- Spatula
- Whipper
- Sieve

Table 3. Picture of the 3D Printer - 3.0 Dual Procusini Model and its accessories.

<table>
<tr><td rowspan="3">

3D Printer - 3.0 Dual Procusini Model</td><td>

Silicone mat</td></tr>
<tr><td>
Plastic syringe</td></tr>
<tr><td>
Plastic tips</td></tr>
</table>

3.3. METHOD

a. <u>PASTA MAKING</u>

First step for the development of the dish was the preparation of the food "ink". Steps are outlined below and are inspired in a previous development of a note-by-note soya lobster recipe (Róisín Burke et al., 2021)

1. Weigh all the dry ingredients and mix it with a spoon (Figure 1).

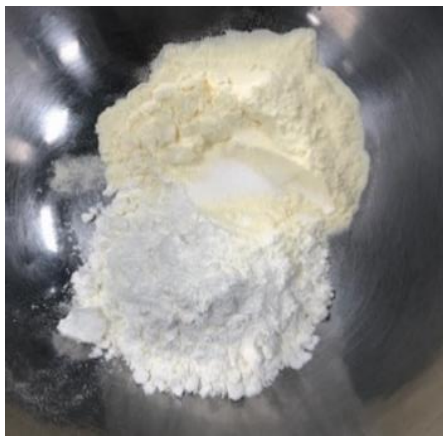


Figure 1. Ingredients for recipe weighed

2. Sieve the dry ingredients to ensure they are properly mixed (Figure 2).

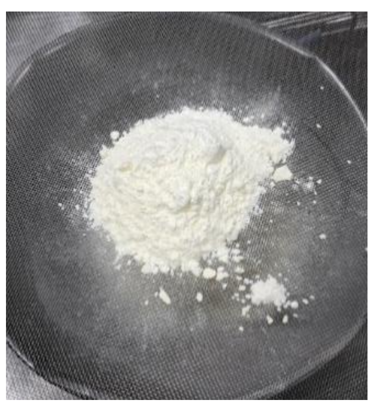


Figure 2. Sieve of ingredients

3. Add the oil and mix with a whipper.
4. Premix the color and flavors with the water.
5. Add the water slowly and mix well with a whipper removing any lumps. Final texture must be as shown in Figure 3.

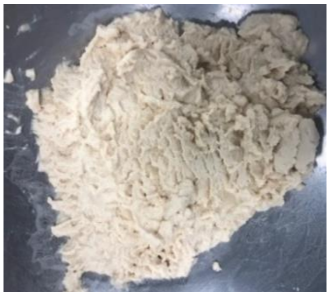


Figure 3. Right texture of the pasta recipe

6. Introduce the paste to the piping bag and remove bubble airs (Figure 4)

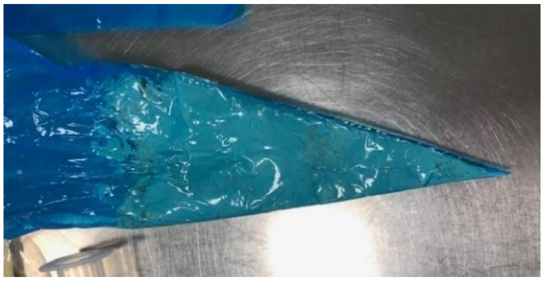


Figure 4. Piping bag with recipe

7. Fill the syringe with the paste in the piping bag making sure to not include air bubbles.

b. PRINTING

Following the food "ink" was printed according to the next steps using the 3D Printer - 3.0 Dual Procusini Model.

1. Choose the "Present 2" template from Christmas group of the Procusini Club (Figure 5)

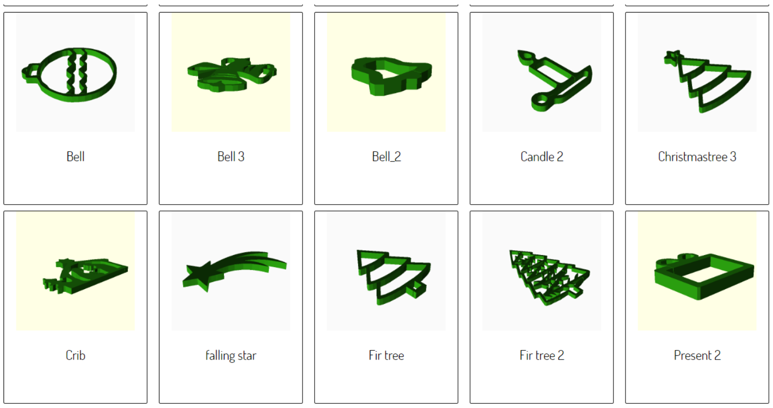


Figure 5. Chocolate templates interface of the Procusini Club.

2. Scale it to the desired measures and save it. In this case the measures were: long 27.94 mm, wide 28.45 mm and high 24 mm. The file name was “Cube” (Figure 6).

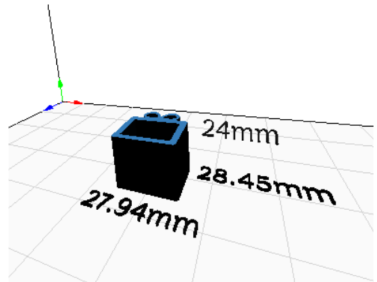


Figure 6. Scale of the 3D object “present 2”

3. Export the template to the 3D printer program.
4. Join the printer network and open the printer program.
5. Select the “Produce Object” bottom and open the chocolate category.
6. Introduce the syringe containing 60ml of food “ink” in the 3D printer.
7. The device was calibrated, and the pre-heating process was skipped.
8. Select the template “Cube” by clicking on the relevant bottom.
9. Production of the object started by clicking on the start bottom.
10. Stop the production if the tip is too close to the silicone mat and adjust the high of the printer head accordingly.
11. Start the 3D printing process again (Figure 7).

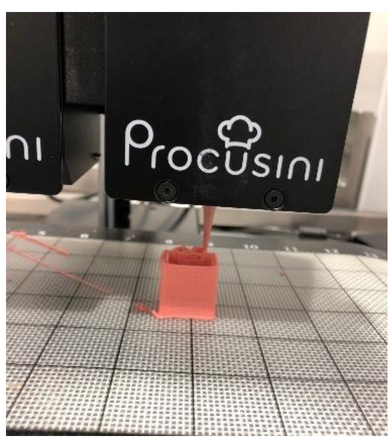


Figure 7. 3D printing of the savory present

The 3D object was produced the silicone mat to be ready to bake. The 3D printer took 8 minutes to complete the 3D object.

c. BAKING

The 3D object was baked according to the following steps:

1. Pre-heat the oven at 150°C (Figure 8).

Figure 8. Oven pre-heated

2. Put the 3D object in the silicon mat in a trail and put in the oven (Figure 9).

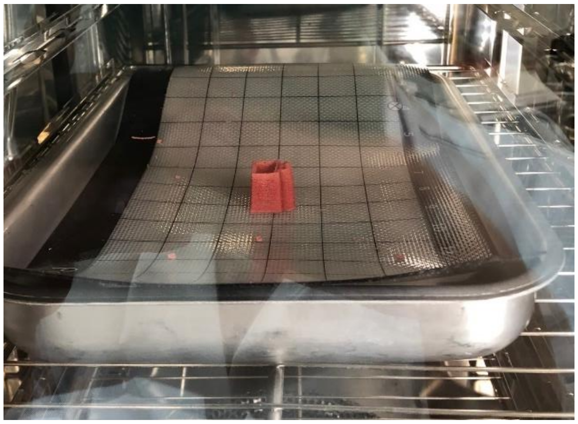


Figure 9. 3D savory present in the oven

3. Bake the 3D object for 15 min.
4. Take the 3D object out of the oven and let it cool down.
5. Plate the 3D object (Figure 10).

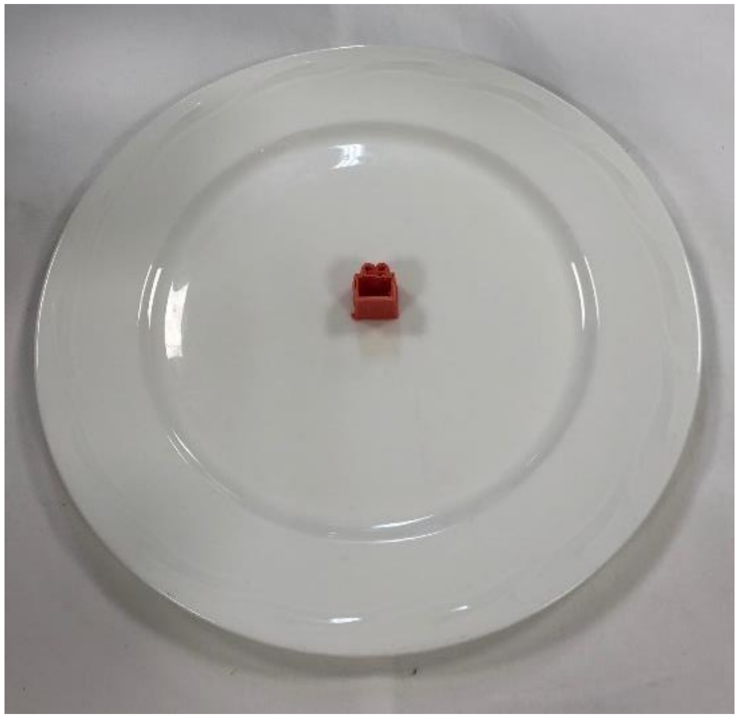


Figure 10. Final 3D Savory Present

4. RESULTS

4.1. 3D SAVORY PRESENT

5 recipes were tried each of them containing different ingredients. Table 4 shows the detail of each recipe in percentage, so it is easier to compare them.

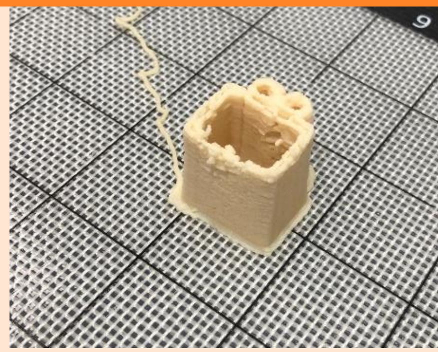
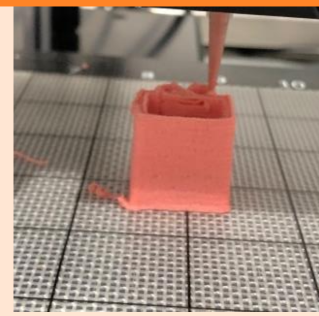
Table 4. Pasta recipes tried

Ingredients	Recipe 1	Recipe 2	Recipe 3	Recipe 4	Recipe 5
Corn starch	27.2%	33.4%	8.1%	24.9%	23.83%
Potato starch	-	-	13.1%	-	-
Pea Protein	11.5%	-	18.1%	14.5%	12.50%
Albumin	-	11.2%	-	-	-
Dietary fiber	4.7%	3.7%	5.4%	5.2%	6.84%
Vegetable oil	5.8%	9.8%	6.3%	5.9%	5.57%
Caster Sugar	0.8%	0.6%	0.9%	0.8%	0.78%
Salt	0.4%	0.3%	0.5%	0.4%	0.59%
Conq flavor	49.5%	41.0%	47.5%	48.2%	0.06%
Berthome Flavor	-	-	-	-	0.08%
Onium flavor	-	-	-	-	0.04%
Red colorant	-	-	-	-	0.10%
Water	-	-	-	-	49.62%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Right texture of the recipe was considered achieved when the pasta can be smashed with a fork and leave a patron like shown in Figure 3. All the recipes in Table 4 passed this assessment and were considered suitable to continue to the 3D printer step.

Due to time constrains and several issues to set up the 3D printer, only recipe 1, 4 and 5 could be printed. Among them, only recipes 4 and 5 could achieve the desired “present” shape. Table 5 shows the final shape of the 3 recipes.

Table 5. 3D printed pasta recipes

Recipe 1	Recipe 4	Recipe 5
		

From these recipes, only recipes 4 and 5 were baked because recipe 1 did not have the ability to hold its structure after the deposition. Table 6 shows the 3D objects before and after the baking and Table 7 shows the change in the dimensions of the 3D object. Color of the 3D objects also changed during the baking, making the objects slightly darker and opaque.

Table 6. 3D objects before and after baking

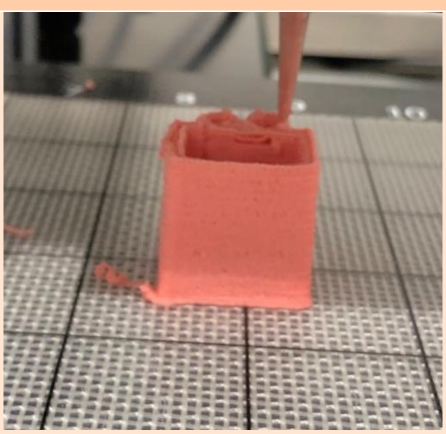
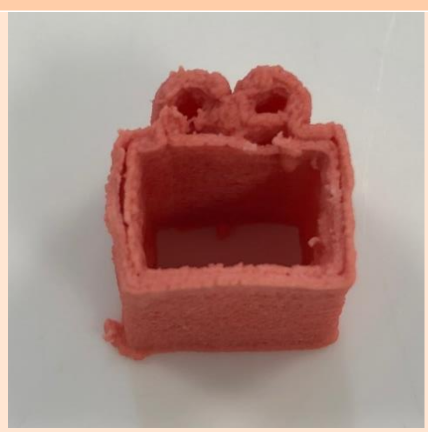
Recipe	Before Baking	After Baking
Recipe 4		
Recipe 5		

Table 7. 3D objects measures before and after baking

	Before Baking	After baking	Reduction
Long (mm)	31	28	3
Wide (considering the bow) (mm)	34	30	4
High (mm)	35	32	3
Cubic area (cm^3)	36.89	26.88	10.01
Total reduction (cm^3)	27.13%		

Sensory analysis of the recipes was done through a consensus with 3 panelists due to the small quantity of samples available. Results are shown in Table 8 for the attributes evaluated. Panelists evaluated overall attributes of the samples using a hedonic 9-point scale from dislike extremely to like extremely. Panelist evaluated specific attributes of the samples using a Just Right Scale.

Table 8. Sensory results for the recipe 4 and recipe 5 of the 3D Savory Present

Attributes	Recipe 4		Recipe 5	
	Assessment	Comments	Assessment	Comments
Overall Appearance	Like Very Much	Look cute, looks tiny but has details. It doesn't look like a present but it's cute.	Like Very Much	Looks small and cute. The color is nice. It looks like a gift.
Color	Too pale	Color look like it's raw. Looks tasteless.	Slightly too pale	Color looks nice and pinky. Could be more colorful
Surface texture	Slightly rough	It has some holes, and it is rough when touching	Slightly rough	It has some imperfections. In general, looks good
Overall aroma	Neither like nor dislike	Almost not aroma. Slightly like raw pasta	Like slightly	It smells like vegetables
Aroma intensity	Just detectable		Mild	
Overall flavor	Dislike moderately	Strong pea flavor	Neither like nor dislike	Pea flavor strong with other vegetable flavors
Saltiness	Neither like nor dislike		Like slightly	Good level of salt.
Bitterness	Too much	Pea protein gives bitter taste	Slightly too much	Still a bit of bitterness due to pea protein.

4.2. TOMATO SAUCE

A tomato sauce was designed to accompany the 3D savory present but due to time constrains it was not possible to fully develop it. The ingredients and methods of the tomato sauce are not included in Section 3. Materials and Methods of the report because it was not part of the final dish, and it was not optimized due to time constrains. Nevertheless, the ingredients and methods can be seen in Section 8. Logbook, in week 2.

Table 9 shows the recipes tried to achieve the desired texture of a smooth paste that can fill the 3D object.

Table 9. Recipes of note-by-note tomato sauce

	Recipe 1 (g)	Recipe 2 (g)	Recipe 3 (g)
Water	175	175	175
Potato Starch	40	20	15
Red Colorant	0.4	0.5	0.5
Salt	1	1	1
Berthome Flavor	0.25	0.25	0.25
Conq Flavor	0.15	0.15	0.15

Table 10 shows picture of the different textures due to the different quantities of the potato starch. Recipe 3 had the desired smooth texture that could fill the 3D object.

Table 10. Tomato sauce recipes images

Recipe 1	Recipe 2	Recipe 3
		

Sensory analysis of recipe 3 was done through a consensus with 3 panelists because it was a preliminary result. Results are shown in Table 11 for the attributes evaluated. Panelists evaluated overall attributes of the sample.

Table 11. Preliminary sensory results of recipe 3 of the tomato sauce

Attributes	Recipe 3	
	Assessment	**Comments**
Overall Appearance	Like Very Much	Red very intense
Surface texture	Like Very much	Smooth texture
Overall aroma	Neither like nor dislike	Almost not aroma.
Overall flavor	Neither like nor dislike	Plane flavor, a little like tomato but not enough. Needs more salt or other flavor.

5. DISCUSSIONS

The recipe composition of the food "ink" was inspired by the recipe of Róisín Burke et al. (2021) who created a 3D printed note-by-note recipe for a soya lobster. This recipe is based on the nutrient composition of the Procusini 3D pasta (Appendix 1), the product that the supplier has already developed for 3D Printing solutions. But the soya lobster recipe had slight changes, mainly to replace non-pure compounds with pure compounds to make it a note-by-note recipe.

Since there was no soy protein available, this recipe was not tried. Instead, soy protein was replaced with pea protein and egg albumin as they both are good sources of protein. As seen in Table 4, there are four recipes with different pea protein concentrations, and one with egg albumin. Recipes 1 and 3 were tested in the first session, and the right texture was obtained easily (Figure 11). Nevertheless, Recipe 2, containing egg albumin protein, did not absorb the water as the pea protein, and it was too fluid (Figure 12).

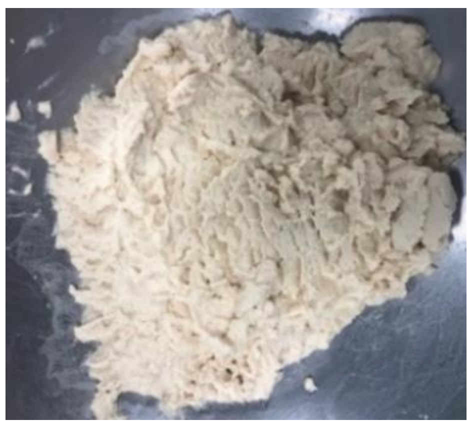


Figure 11. The texture of the recipe 1 and 3

Figure 12. The texture of Recipe 2

To achieve the right texture, it was necessary to add more corn starch, egg albumin, and vegetable oil. Compared with the other recipes containing similar protein content, recipe 2 contains almost 50% less water and almost double of oil and corn starch. This is because different protein sources have different properties. Albumin is characterized by its property to form stable foams due to its high-water solubility and its adsorption ability at the air-water interface. This means that it needs less water to form a viscous paste (Razi, Motamedzadegan, Shahidi, et al., 2019).

Egg albumin has already been used in several 3D applications like the production of alternative meat (TSAI & LIN, 2022). Recipe 2 achieved the right texture with 11% of egg albumin. Similar concentrations (9.4%) have been pointed to as the optimal for the formulation of food "ink" composed of wheat starch and egg albumin (Fahmy et al., 2021).

The use of egg albumin to create food inks is complex. The presence of ions like salt can increase the solubility of albumin because it influences the charged protein molecules. pH and water activity are also critical parameters that can substantially affect water retention of protein-polysaccharide matrices (Razi, Motamedzadegan, Matia-Merino, et al., 2019). For example, Higo & Noguchi (n.d.) .) evaluated 17 kinds of protein powders and determined that all had different bound water content from 0.038 to 0.276 g of water per g of dry matter. Even the composition of egg albumin can change depending on the poultry species. Sun et al., (2019) analyzed the water holding capacity of different heat-induced egg gels and found different values from 84.9% up to 96.3%. It is important to specify the source of albumin because this protein can also be found in vegetables and have different properties (Wang et al., 2022).

Considering all these variables it would be important to measure water retention and pH to understand the difference between the recipes and the interaction of their components. Due to time and equipment limitations, this was not possible during the project. Hence, it was decided not to go further with egg albumin protein and continue the development of the 3D Savory Present only with pea protein.

Pea protein is an excellent source of plant-based protein containing a balanced proportion of amino acids that help boost immunity, high digestibility of 98%, and promotes healthy blood flow circulation and muscle growth (Hussain et al., 2021)(TSAI & LIN, 2022). It represents a good alternative to soy or regular meat products because it has environmental benefits like nitrogen fixation on the soil, minimal requirement for fertilizers, low carbon and food wastage footprints, water efficiency, and low-cost production. This makes pea protein a promising ingredient aligned with the sustainable benefits of note-by-note cooking and the 3D printing technique (Boukid et al., 2021).

Nevertheless, pea protein is usually associated with off-flavors perceived as “green”, “grassy”, and “pea pod” that come from the presence of aldehydes, ketones, furans, and alcohols in pea. There are processing techniques that are being assessed to reduce these off-flavors like fermentation or chemical modification, but further studies are needed to make industrial production. We expect that in the coming years this can be achieved to broaden the application of pea protein and not have sensory constraints like now (Boukid et al., 2021). This was the reason to reduce the pea protein content in Recipes 4 and 5.

Pea protein has low solubility and water holding capacity, contrary to egg albumin. And their main proteins are 70% globulin and 30% albumin approximately. When insoluble proteins interact with polysaccharides, the protein entraps starch granules to create a strong building network that controls the structure and texture of the food. It plays a critical role in contributing to the improvement of cohesiveness and adhesiveness, being a good combination with starch. Hence, the inclusion of pea protein leads to improves the texture of the product providing rapid control of the material flow, and improving nutrition content (Kim et al., 2021) (TSAI & LIN, 2022).

The final recipe, number 5, had a pea protein content of 12.5%. Kim et al. (2021) created a paste with banana puree and pea protein and found that 10% was the optimal quantity. 20% of pea protein in the formulation leads to discontinuous layers which were observed in some parts of recipe 4 (Table 6, recipe 4 before baking). TSAI & LIN (2022),), used different concentrations of pea protein and egg albumin, and their optimal recipe had 8% egg albumin and 9.5% of pea protein regarding sustainability, but regarding marketing orientation, the optimal recipe had 9.5% of egg albumen and 5.5% of pea protein. Hussain et al. (2021), created a protein-enriched 3D printing material and its best formulation had 4% of pea protein isolated. In another study, Chuanxing et al. 2018 cited by Pérez et al. (2019) included pea protein into a potato starch matrix and found that the maximum optimal quantity of pea protein was 1%. This shows that the pea protein content can widely vary between 3D printing recipes.

All the recipes included corn starch. Corn starch is a polysaccharide extracted from maize/corn and it gives high viscosity once fully hydrated. It has twice the thickening power of flour (Lersch, 2007). This is a versatile starch and it has demonstrated good texture properties coupled with pea protein. Recipe 3 included potato starch, which has been used to create 3D recipes by some authors. For example, Liu, Zhang, Bhandari, and Yang (2018) cited by Zhu et al. (2019) related the rheological properties of a mashed potato formulation; concluding that 2% of potato starch gave the best printability properties. Both starches have a similar ratio of amylopectin and amylose, but they have different morphologies

(Horstmann et al., 2017). To simplify the development of the 3D food ink, it was chosen to continue the development only with corn starch.

Cellulose dietary fiber was included in the recipe to comply with the note-by-note competition. Dietary fiber consists of edible parts of a plant resistant to digestion and absorption in the human small intestine and undergoes partial or complete fermentation in the large intestine. It consists of non-starch polysaccharides like cellulose. Most dietary fiber cannot be used alone in 3D printing because they show no plasticity and have poor self-support abilities. Hence, it is used as an additive mixed with other ingredients like in this case (Jiang et al., 2019). Mueller, Llewellin, and Mader 2009 cited by Jiang et al. (2019) used soluble dairy fiber powder to obtain a paste with higher apparent viscosity. The network was easily formed with the presence of dietary fiber due to more particle interactions. Lille et al. 2018 cited by Jiang et al. (2019)) used cellulose nanofiber in combination with milk powder to obtain samples with gel-like structures that were suitable for 3D printing. Recipes developed had 3-7% dietary content, and no adverse effect on the texture was observed due to its addition.

The recipe also contains olive oil, an oil-rich in unsaturated fatty acids that are liquid at room temperature (free of crystallized material) (Róisín Burke et al., 2021). The addition of oil can produce oil-in-water emulsions, which creates a more stable food system. Also, it helps to give a smoother texture and to prevent moisture loss (TSAI & LIN, 2022). The composition of olive oil is approx. 99% triacylglycerols from which 55-83% are oleic fatty acids, an unsaturated fat. Composition varies depending on the grade of virgin olive oils and other production and agronomy factors (Blekas et al., 2006). Oil content in the recipes was around 5-6% and gave a smoother texture to the food ink.

Recipe 5 included flavors from the Iqemusu company. These flavors are pure notes found in different food products in nature, and their combination offers an infinite range of flavors (Iqemusu, n.d.). The chosen flavors had mainly vegetable notes (cucumber, tomato, onion, garlic) and other notes that consumers prefer (cheese and egg). According to the European Regulation (EC) No 1334/2008 on flavorings, certain substances can not be added as flavors, and other flavors have maximum limits. The regulation also states that flavor companies should suggest a dosage. Iqemusu company does not state the chemical name of their pure compounds, so it was not possible to check if one of the pure compounds had a maximum limit. However, the company recommends using 1 teaspoon of flavor per 100 g of product which is around 4% in a final recipe. Recipe 5 contained less than 1% of each flavor.

Recipe 5 contained color E 124. Ponceau 4R, or cocineal Red. According to Regulation (EC) No 1333/2008 on food additives, this color is permitted to use in foods but the maximum concentration changes depending on the matrix. For fine bakery wares, the closest category to the current recipe, the limit is 200 mg/kg or 0.02%. Recipe 5 contained 0.1% of the color solution that also had carriers such as glycerin and water. Nevertheless, it is advisable to change to a natural colorant because of the negative perception of artificial colors.

The recipe did not contain any other hydrocolloids or additives, even though they are common in food inks composition (Pérez et al., 2019). For example, sodium alginate, xanthan gum, and other additives were used to create a paste that mimicked a meat steak (TSAI & LIN, 2022). Oyinloye & Yoon (2020) used pea protein with alginate to construct a food ink. These additives were not considered to have a clean label recipe and simplify their development.

Regarding the printing process, only recipes 1, 4, and 5 were printed. During the first trial for printing recipe 1, the performance of the pasta was not good (Table 5, recipe 1). The texture was lumpy and not like the texture of the production day, and it was impossible to achieve the desired shape. This could be explained by the storage conditions. The pasta was stored at room temperature for 5 days when it was supposed to be refrigerated. Fahmy et al. (2021) store their vacuum-packed samples at -22°C for a maximum of 3 days, which are stricter conditions that the proposed. Hence, for the following trials, recipes were prepared and printed on the same day.

Recipes 4 and 5 performed well in the 3D printer after some adjustments (Table 5, recipes 4 and 5). For example, in the first trial of recipe 4, a tailing phenomenon was visible, and the desired shape was not achieved (Figure 13). The distance between the syringe tip and the silicone mat was too big, and the pasta could not be correctly shaped. This issue was fixed by adjusting the high of the syringe to be closer to the silicone mat, then trials 2 and 3 were successful (Table 5, recipe 4). According to Kim et al. (2021), printing performance and viscoelastic properties are highly correlated, nevertheless, other factors can give lower resolution in the printing even though its viscoelastic properties are appropriate. Other factors include printing settings, like line distance, nozzle diameter, writing speed, and layer thickness (Yang et al., 2017).

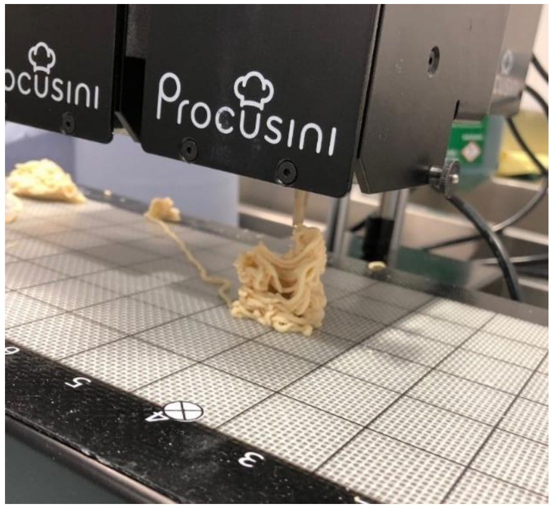


Figure 13. The first trial of recipe 4

Regarding recipe 5, the printing performance changed due to recipe modifications. Following the recommendations of the sensory panel, pea protein was replaced with dietary fiber to decrease bitterness. The reduction was meant to be 5% because a bigger reduction will impact the texture. Flavors and colorants were added to improve the sensory characteristics of the pasta (flavor and color), but these ingredients were in liquid form. During the final mixing, the pasta was moister, and more pea protein and corn starch had to be added to achieve the right texture. Nevertheless, another water adjustment had to be made together with a change for a smaller nozzle to achieve the desired shape of the 3D object. The extrusion force is higher with the smaller nozzle diameter but the resolution is better (Zhu et al. 2019).

In general, the optimization of the 3D printing was a challenging process. The rheological properties are key, and it is complex to design the texture of a new food product (Wilms et al., 2021; Róisín Burke et al., 2021). The 3D object should be stable and maintain its shape during printing and further processing. The printing characteristics of food materials containing protein-polysaccharide complex depend on the chain structures. Nevertheless, limited information on recipes and products with protein and lipid matrices makes this process harder since most of the research up to now has targeted carbohydrate-based food matrices.

Usually, 3D printing is optimized on a trial-and-error approach, which is time-consuming. This was proven during the development of the food ink recipe in the present report . Zhu et al., (2019) studied the behavior of a tomato paste and proposed a more "rational approach" using the flow stress as an indicator to assess printing stability and extrusion force. For future studies, it is advisable to follow this approach.

The setting of the 3D printer parameters was the biggest issue during the development. A considerable amount of time was used to set the template of the recipe, enter the program, connect the printer with the network, and have the "ok" bottom available to extrude the pasta out of the syringe.

Table 6 shows the baking effect. After baking, the 3D object reduces its size because of water evaporation. Size reduction represents 27% of loss, but the shape is well maintained. Also, the baking process reduced the shininess and gave an opaque color.

According to the sensory evaluation, overall sensory characteristics were improved from recipes 4 to 5. This was due to the decrease in pea protein and the inclusion of vegetable flavors. Regarding recipe 5, its appearance and overall aroma were accepted. On the other hand, the overall flavor had a note of "neither like nor dislike", because of the bitter taste of the pea protein. According to Głuchowski et al. (2021), food neophobia influences the acceptability of note-by-note recipes. In their study, overall liking scores of note-by-note dishes were always lower than traditional foods. This is the main reason why some note-by-note recipes try to imitate traditional foods, to fight against neophobia (R. M. Burke et al., 2020).

According to Fahmy et al. (2021) and Ma & Zhang (2022) sensory properties can be enhanced by using layers with different salt or sugar concentration. The heterogeneous spatial distribution of salt or sugar in the food gives a stronger intensity of flavor. Hence, the 3D printing technology has the potential to develop healthier products by reducing the sodium or sugar content while maintaining the same flavor.

Regarding the tomato sauce, the right texture was achieved but further development needs to be done regarding the flavor (Tables 10 and 11). The flavor of the tomato sauce was a little bland and needed more tomato flavor and glutamate to improve its taste.

6. CONCLUSIONS

- An optimized note-by-note savory recipe was created with a completely innovative flavor and shape that did not mimic any existing dish. It included 5% of dietary fiber and 12.5% of pea protein isolate. Recipe flavor is a mixture of vegetables and popular ingredients like cheese and eggs.
- Practical experimentation using the 3D Printer 3.0 of Procusini was conducted, as well as the sensory evaluation of the final dish.
- Two different protein sources (pea protein and egg albumin) were used to create the food “ink”. Pea protein was chosen among them because of its rheological properties. Egg albumin was discarded due to its high solubility in water which created a high viscous food “ink”.
- 5% fiber content was easily integrated into the food "ink" obtaining the right texture for 3D printing.
- The "present" shape was achieved with recipes 4 and 5 because they had good printability properties, their deposition after the extrusion was easy, and they could hold their structure after the deposition.
- For the 3D Savory Present with the dimensions specified in this report, the optimal time and temperature for baking was 150°C for 15 min. A reduction of 27.13% of the initial volume and a slight loss of color were observed after the baking.
- A tomato sauce was developed to accompany the 3D savory present. The texture was optimized by reducing the amount of potato starch. Nevertheless, the flavor could not be optimized due to time constraints.
- The overall appearance of the product was well accepted during the sensory evaluation. The aroma was slightly accepted, and the flavor had a neutral score. Pea protein flavor in the recipe was still strong, which increased the product bitterness.
- The 3D printing technique is the most promising technique to be used in the note-by-note cooking approach. It allows the mixture of different components; it can improve food texture and it shares the sustainability advantage that note-by-note cooking is also aiming for.
- Handling the 3D printing was challenging due to several issues within the interface that incurred time wastage.

7. RECOMMENDATIONS

- Maintenance of the 3D printer should be carried out to assure that the automatic calibration works correctly.
- Check the 3D printer features to ensure that the marzipan templates can be exported to the 3D printer.
- The Internet connection of the printer should be improved.
- A short manual with all the steps and tips and tricks of using the 3D printer could be developed to save time.
- Red color could be increased in the initial recipe considering the loss of color during baking.
- Further investigations should follow the present work to include egg albumin in a food “ink” matrix because its rheological properties differ from pea or soy proteins.
- Further research should follow the present work to improve the flavor properties of the final recipe. A decrease in the pea protein and an increase in the flavor content are advisable.
- Further development of the tomato sauce flavor could be achieved by the addition of glutamate and Berthome flavor.
- Using the 2 heads of the 3D printer using 2 food “ink” matrices with different flavors could improve the sensory perception.
- pH and water activity and water retention should be measure during the development of the food “ink”

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9. LOGBOOK

9.1. LOGBOOK WEEK 1

MODULE CODE: TFCS9025 2021-22 **FOOD PRODUCT: 3D Savoury Present**
MODULE TITLE: Advanced Molecular Gastronomy
STUDENT NAME: Maria Grazzia S. Peña Niebuhr
WEEK NO.: 1 **DATE: 28/03/22**

1. **Weekly Aims and Objectives**

1.1 Aim: To create and optimize the taste and texture, of a note-by-note savoury recipe that includes fibre and a dice shape through practical experimentation in TU Dublin laboratories.

1.2 Objectives of the week: To produce recipes with different protein sources that have the right texture to work in the 3D printer.

2. **Materials and Method (Ingredients, Equipment and Method)**

2.1 INGREDIENTS

3D Savoury Pasta

Table 1. Ingredients for 3D printer pasta

Ingredients	Quantity (g)		
	Recipe 1	Recipe 2	Recipe 3
Corn starch	66	104.5	18
Potato starch	-	-	29
Pea Protein	28	-	40
Egg Albumin	-	35	-
Dietary fibre	11.5	11.5	12
Vegetable oil	14	30.5	14
Caster Sugar	2	2	2
Salt	1	1	1
Water	66	128	105

2.2 EQUIPMENT REQUIRED

- Scale
- Spoons
- Bowls
- Whipper
- Sieve
- Spatula
- Vacuum sealer
- Vacuum sealer bags

2.3 METHOD

1. Weigh the dry ingredients

Figure 1. Ingredients for recipe 2 weighed

2. Mix with a spoon the dry ingredients and sieve it to ensure they are properly mixed.

Figure 2. Sieve of ingredients

3. Add the oil and mix with a whipper.
4. Add the water slowly and mix well with a whipper.
5. Put the pasta in a vacuum sealer bad and seal it in the vacuum sealer.
6. Put a label in the bad to identify the sample
7. Put the samples in the refrigerator until used (4-5°C)

3. Results and Discussion

Recipe 1 was inspired by the recipe created by (Róisín Burke et al., 2021) who created a 3D printed note-by-note recipe for a soya lobster. Since there was no soy protein available, this recipe was not tried. Instead, soy protein was replaced with pea protein in recipe one and egg Albumin in recipe 2 as they both are good source of protein and they were the 2 only protein ingredients available in the kitchen. Recipe 3 had pea protein in higher content and replace some of the corn starch with potato starch to try a different source. Both starches have similar ratio of amylopectin and amylose, but they have different morphologies (Horstmann et al., 2017). Detail of the recipes in percentage can be found in Table 2.

Table 2. Pasta recipes in percentage

Ingredients	**Percentage**		
	Recipe 1	Recipe 2	Recipe 3
Corn starch	27.2%	33.4%	8.1%
Potato starch	0.0%	0.0%	13.1%
Pea Protein	11.5%	0.0%	18.1%
Egg Albumin	0.0%	11.2%	0.0%
Dietary fiber	4.7%	3.7%	5.4%
Vegetable oil	5.8%	9.8%	6.3%
Caster Sugar	0.8%	0.6%	0.9%
Salt	0.4%	0.3%	0.5%
Water	49.5%	41.0%	47.5%
Total	100%	100%	100%

Right texture of the recipe was considered achieved when the pasta can be smashed with a fork and leave a patron like shown in Figure 3. For recipe 1 and 3, the right texture was achieved without difficulties.

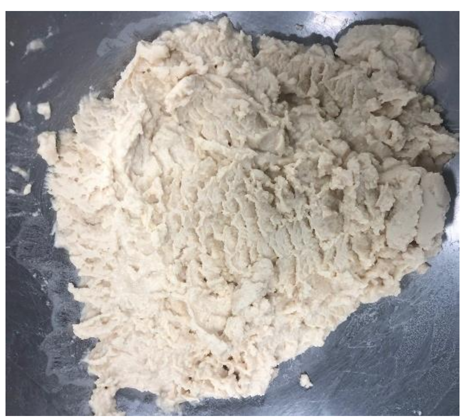

Figure 3. Texture of the recipe 1

Recipe 2, containing egg Albumin protein did not absorbed the water of the recipe as the pea protein and it was too fluid (Figure 4). To achieve the right texture, it was necessary to add more corn starch, egg Albumin, and vegetable oil. In comparison with the other recipes that contain similar protein content, recipe 2 contains almost 50% less water and almost double content of oil and corn starch. This is because different proteins sources have different properties. For example, (Higo & Noguchi, n.d.) evaluated 17 kinds of protein powders and determined that all had different bound water content from 0.038 to 0.276 g of water per g of dry matter. Albumin is characterized by its property to form stable foams which is due to its solubility in water and because it has adsorption ability at the air-water interface. This means that albumin is very soluble in water and needs less water to form a viscous paste. The presence of ion like salt in the recipe can increase the solubility of albumin because it has an effect on the charged protein molecules (Razi, Motamedzadegan, Shahidi, et al., 2019).

Figure 4. Fluidity of recipe 2 at the beginning

Recipes were sealed and labeled as seen in Figure 5 to be stored to the next session to be printed.

Figure 5. Recipe 1 ready for vacuum seal.

4. Conclusions

- Pea protein can replace soy protein 1:1 to obtain the same texture necessary for 3D printing.
- Egg Albumin protein has a different behaviour than pea and soy proteins and the recipe to obtain the same texture had to changed completely.

5. Recommendations for following week.

- Print the paste using the 3D printer in the shape of a cube.
- Choose the best recipe to continue the development of the note-by-note dish.

9.2. LOGBOOK WEEK 2

MODULE CODE: TFCS9025 2021-22 **FOOD PRODUCT: 3D Savoury Present MODULE**
TITLE: Advanced Molecular Gastronomy
STUDENT NAME: Maria Grazzia S. Peña Niebuhr
WEEK NO.: 2 **DATE: 01/04/22**

1. **Weekly Aims and Objectives**

1.1 Aim: To create and optimize the taste and texture, of a note-by-note savoury recipe that includes fibre and a dice shape through practical experimentation in TU Dublin laboratories.

1.2 Objectives of the week: To print the 3 recipes in the 3D printer and choose the right one to bake and taste. To produce the filling sauce of the dish and improve its taste.

2. **Materials and Method (Ingredients, Equipment and Method)**

2.1 INGREDIENTS

3D Savoury Pasta

Recipes prepared las week.

Table 1. Ingredients for the savoury sauce

Ingredients	Quantity (g)		
	Recipe 1	Recipe 2	Recipe 3
Corn starch	66	104.5	18
Potato starch	-	-	29
Pea Protein	28	-	40
Egg Albumin	-	35	-
Dietary fibre	11.5	11.5	12
Vegetable oil	14	30.5	14
Caster Sugar	2	2	2
Salt	1	1	1
Water	120	128	105

Tomato Sauce

- 175 g of water
- 15 g of potato starch
- 10 drops of red colorant
- 1 g of salt
- 5 drops of Berthome flavor
- 3 drops of Conq flavor

2.2 EQUIPMENT REQUIRED

- Procusini 3D Printer
- Silicone mat
- Laptop with the 3D Printer programme
- Plastic syringe
- Plastic tips for the syringe
- Spatula
- Whipper
- Sieve
- Pots
- Stove
- Piping bag
- Scale
- Spoons
- Bowls

2.3 METHOD

Printing

1. Choose the template from the Procusini Club and scale it to the desired measures.
2. Export the template to the 3D printer programme.
3. In the printer programme choose the personalized template.
4. Introduce the paste to the piping bag and remove bubble airs.
5. Fill the syringe with the paste in the piping bag making sure to not include air bubbles.
6. Introduce the syringe in the 3D printer.
7. Run the 3D printer.

Tomato Sauce

1. Mix the water with the colorant, salt and flavours in a bowl.
2. Add the potato starch to the mixture and transfer the mixture to a pot.
3. Heat the sauce in a stove at medium heat while whipping.
4. Stop the cooking when the sauce starts to boil.

3. Results and Discussion

Setting up the 3D printer took longer than expected due to the use of new settings. Procusini provides different templates for 3D objects in their webpage Procusini Club. The “present” template from the Christmas section in the Marzipan group was chosen due to the topic of the competition.

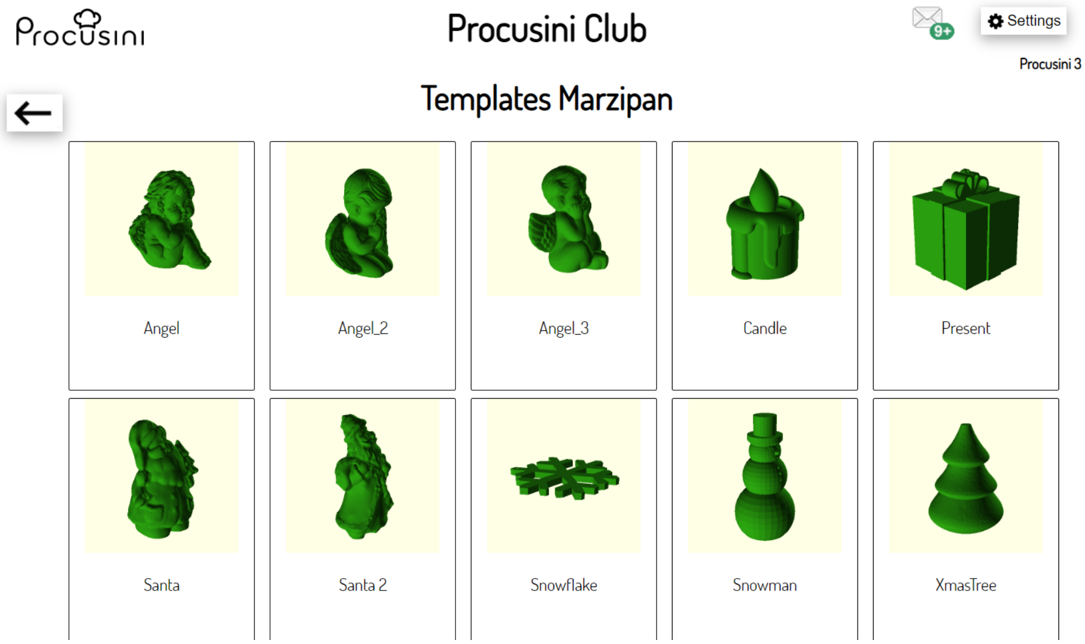

Figure 1. Marzipan templates interface of the Procusini Club.

The 3D object was scaled with measurements as close as a cube, as far as the programme allow it (Figure 2). The template was saved several times in the usual location but when trying to export it to the 3D printer, it was not found.

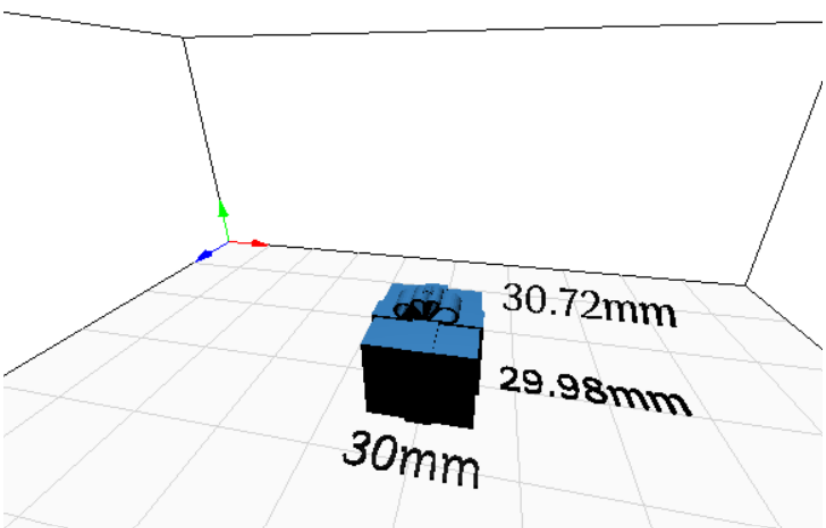

Figure 2. Scale of the 3D object “present”

After several trials to try to export the 3D object, it was decided not to go further with this template. Since chocolate templates have been used before successfully, a template from that section was selected. In the Christmas group, a "present 2" object was selected (Figure 3).

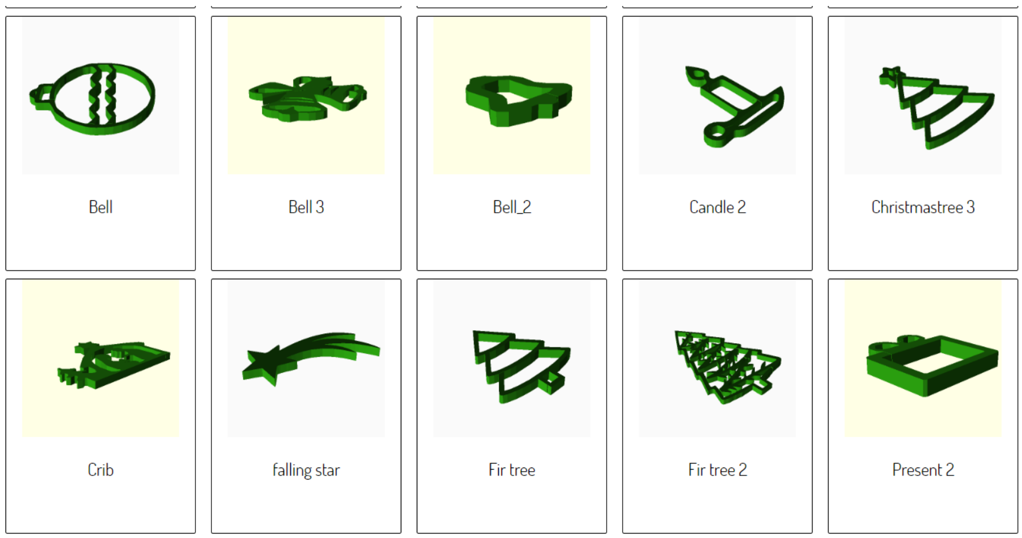

Figure 3. Chocolate templates interface of the Procusini Club.

Once again, the 3D object was scaled with measurements as close as a cube, as far as the programme allow it. Measures of the object can be seen in Figure 4. With this setup the template could be saved and exported to the 3D printer successfully. The 3D object was saved as "Cube" and different views of it can be seen in Figure 5 and 6.

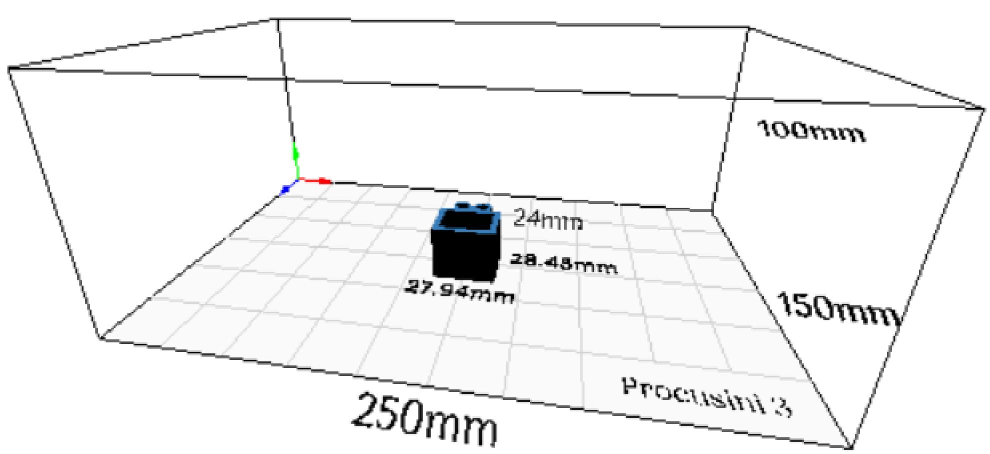

Figure 4. Scale of the 3D object "present 2"

Figure 5. Top view of the 3D object "present 2"

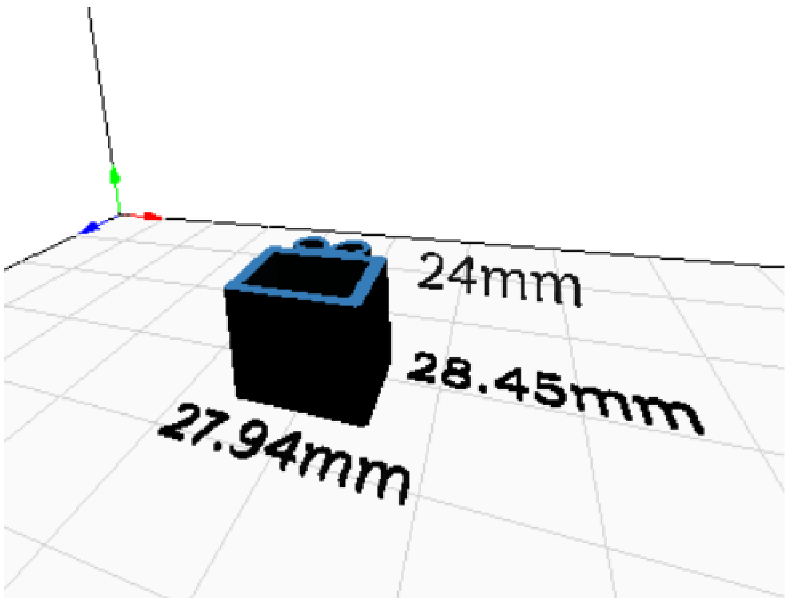

Figure 6. Side view of the 3D object "present 2"

Recipe 1 was put on a piping bag (Figure 7) and then in a syringe trying to avoid air holes. The syringe was introduced in the printer. Then in the printer programme the exported object was chosen to start the process. Since it was a chocolate template, the printer had an automatic pre-heating setting that it was skipped. Then, the 3D printer adjusted the printer head automatically but the configuration was not good and the heigh had to adjust manually to ensure the needle of the syringe was not too close to the printer floor.

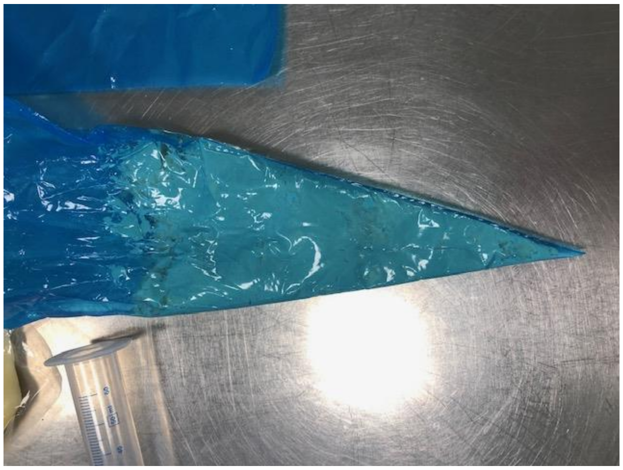

Figure 7. Piping bag with recipe 1

Then the printer started to print automatically but the recipe did not have a good texture to allow a good printing. The texture was lumpy and not like the texture of the first day that was made. This was mainly due to the sample storage conditions. A discoordination caused that the samples were not storage in the refrigerator but at room temperature. After 5 days at room temperature the samples did not maintain the right texture. Due to the amount of time left, only recipe 1 was tried to be printed.

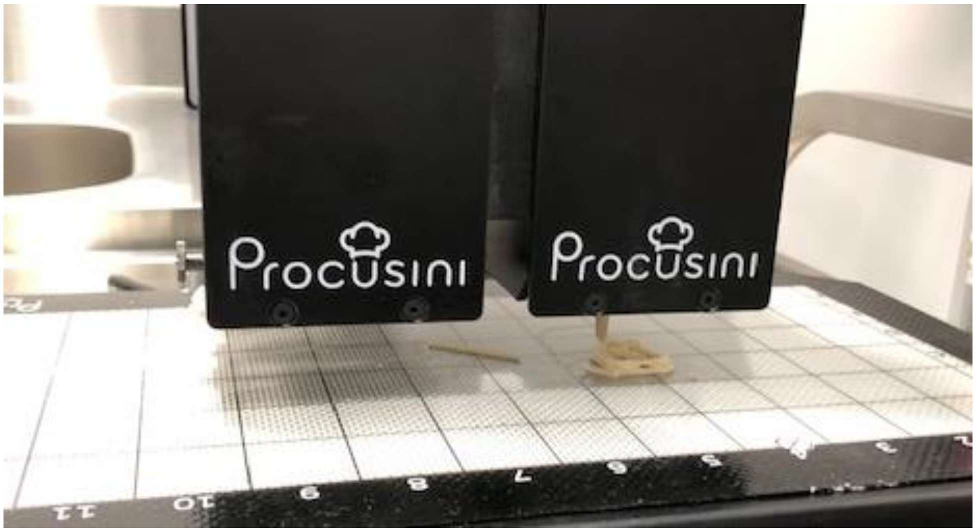

Figure 8. 3D printing of recipe 1

While the 3D printer was being set, the filling sauce was made. A note-by-note recipe of a tomato sauce "evocation tomato" was used as a base for this sauce (Róisín Burke et al., 2021). All the ingredients were dissolved in cold and then heated in a pan as described in the method part. Initially the recipe contained 40g of potato starch, but this quantity gave the sauce a paste texture more than a soft sauce (Figure 9). 4 different trials were made to achieve the desired texture. The quantity of potato starch was reduced to 15 g to obtain a soft sauce texture (Figure 10). Flavors used were Berthome and Conq from the Iquemusu company. Piovo flavour was not used because it was not available in the kitchen. Flavor of the tomato sauce was a little bland and needed more tomato flavor and glutamate to improve its taste.

Figure 9. Tomato sauce recipe with 45 g of potato starch

Figure 10. Tomato sauce recipe with 15 g of potato starch

4. Conclusions

- The 3D printer can only work with templates from the chocolate section and not from the marzipan section.
- Recipes for the pasta must be print the same day they are made to ensure the desired texture doesn't change.
- "Evocation tomato" recipe had to be modified to obtain a sauce texture that can be use in the dish. The flavor could be improved with the use of glutamate and another flavor.

5. Recommendations for following week.

- Prepare the pasta recipes and print them the same day.
- Focus on the development of the pasta recipe to ensure the dish success.

9.3. LOGBOOK WEEK 3

MODULE CODE: TFCS9025 2021-22 **FOOD PRODUCT: 3D Savoury Present**
MODULE TITLE: Advanced Molecular Gastronomy
STUDENT NAME: Maria Grazzia S. Peña Niebuhr
WEEK NO.: 3 **DATE: 04/04/22**

1. **Weekly Aims and Objectives**

1.1 Aim: To create and optimize the taste and texture, of a note-by-note savoury recipe that includes fibre and a dice shape through practical experimentation in TU Dublin laboratories.

1.2 Objectives of the week: To produce recipes with different protein sources that have the right texture to work in the 3D printer and bake it. To make a sensory evaluation of the proposed recipe.

2. **Materials and Method (Ingredients, Equipment and Method)**

2.1 INGREDIENTS

3D Savoury Pasta

Table 1. Ingredients for 3D printer pasta

Ingredients	Quantity (g)
Corn starch	60
Pea Protein	35
Dietary fibre	12.5
Vegetable oil	14.25
Caster Sugar	2
Salt	1
Water	116

2.2 EQUIPMENT REQUIRED

- Procusini 3D Printer
- Silicone mat
- Laptop with the 3D Printer programme
- Plastic syringe
- Plastic tips for the syringe
- Piping bag
- Scale
- Spoons
- Bowls
- Spatula
- Whipper
- Sieve

2.3 METHOD

3D Savoury Pasta

1. Weigh the dry ingredients
2. Mix with a spoon the dry ingredients and sieve it to ensure they are properly mixed.
3. Add the oil and mix with a whipper.
4. Add the water slowly and mix well with a whipper.
5. Introduce the paste to the piping bag and remove bubble airs.
6. Fill the syringe with the paste in the piping bag making sure to not include air bubbles.

Printing

7. Choose the template from the Procusini Club and scale it to the desired measures.
8. Export the template to the 3D printer programme.
9. Join the printer network and open the printer programme.
10. Introduce the syringe in the 3D printer.
11. In the printer programme choose the personalized template.
12. Skip the pre-heating process
13. Run the 3D printer
14. Press ok until product comes out.
15. Adjust the high of the printer head.
16. Run the 3D printer again.

Baking

1. Pre-heat the oven at 150°C
2. Put the 3D object in the silicon mat in a trail and put in the oven.
3. Bake the 3D object for 10 min

3. Results and Discussion

Due to time constrain, it was chosen to try only the recipe with pea protein in this session. Recipe chosen was the recipe 1 because it had less pea protein content, and the pea flavour might be too strong. Recipe with egg Albumin was not chosen because the texture of the pasta was a little stickier and it might require more time to achieve a formulation that worked properly. Recipe 1 had some changes in the quantities like a reduction on corn starch and dietary fibre (Table 2).

Table 2. Pasta recipe in percentage

Ingredients	Recipe 1 28/03/22	Recipe 1 04/04/22
Corn starch	27.2%	24.9%
Pea Protein	11.5%	14.5%
Dietary fiber	4.7%	5.2%
Vegetable oil	5.8%	5.9%
Caster Sugar	0.8%	0.8%
Salt	0.4%	0.4%
Water	49.5%	48.2%
Total	100%	100%

Right texture of the recipe was obtained as it was easily smashed with a fork and leave a patron like shown in Figure 1.

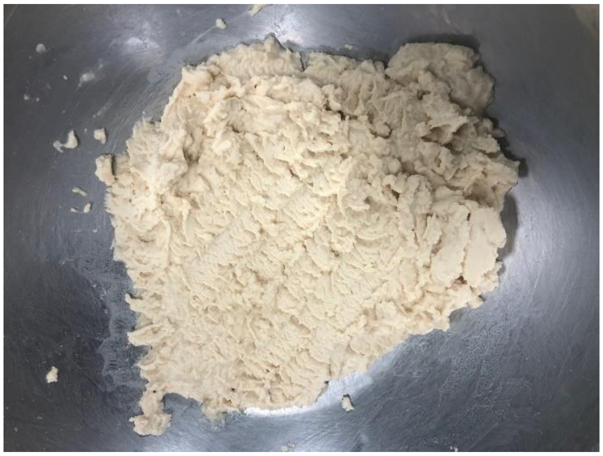

Figure 1. Texture of the pasta for 3D printer

In this session the printer programme could not be access for a long time despite following all the instructions. Finally, after some time, it was discovered that after opening the programme and press continue, the page must be refreshed.

The pasta was introduced in the syringe and the first trial was run. Figure 2 shows the first trial. Form of a present could not be achieved because the distance of the syringe tip and the silicone mat was too big and the pasta could not be correctly shaped.

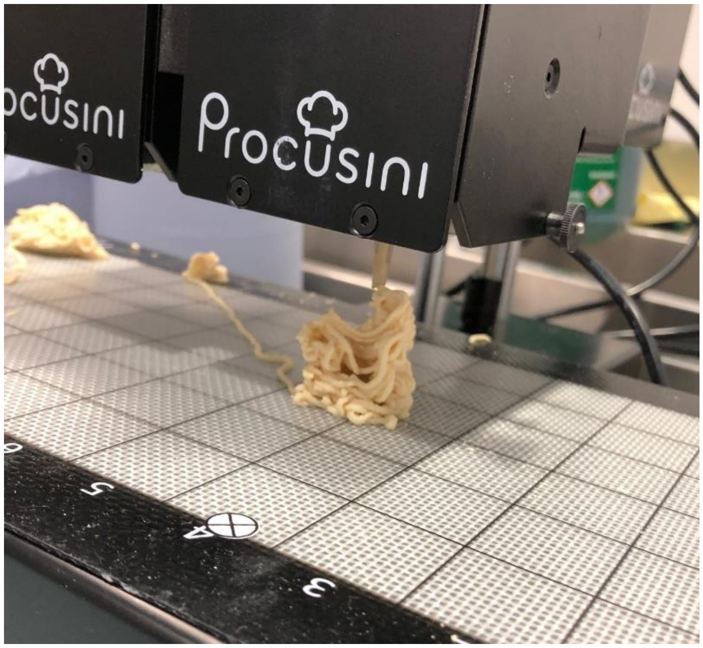

Figure 2. First trial of 3D printing the savory present

High of the syringe tip was adjusted to be closer to the silicon mat and a second trial was run. Figure 3 shows the pictures of the 3D object. The texture of the pasta was good and the present shape was obtained successfully. After this, a second 3D object was printed (Figure 4).

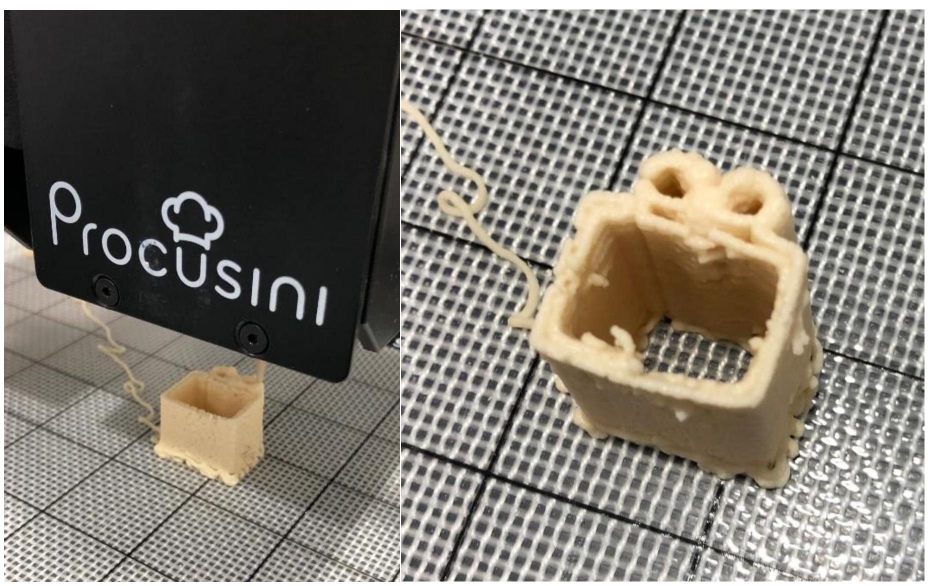

Figure 3. First trial of 3D printing the savory present

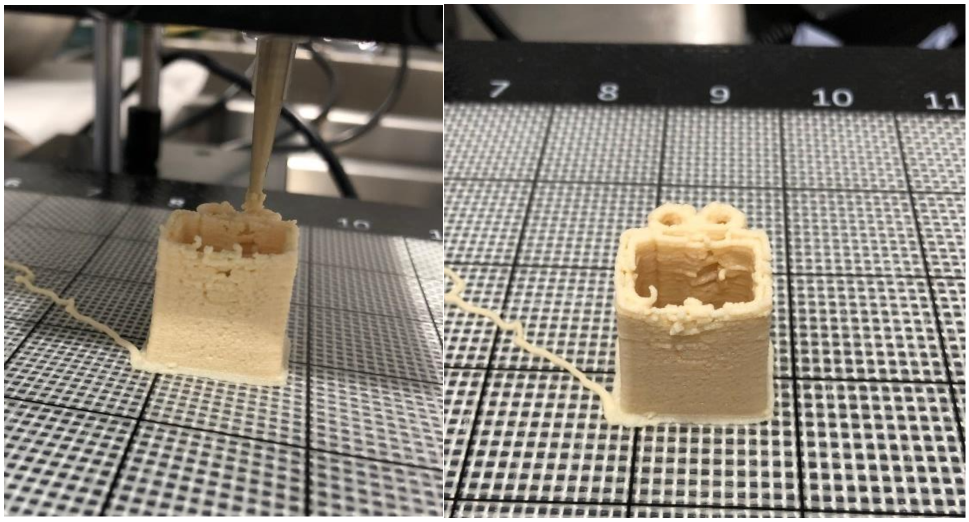

Figure 4. First trial of 3D printing the savory present

Both objects had some imperfections in their structure mainly due to air bubbles in the syringe. Air bubbles create holes and when the syringe pass again to keep printing in that area, it drags the pasta and create bigger imperfections. Nevertheless, in this case the air bubbles were so little than the shape could be maintained.

Subsequently, the 3D objects were baked at 150°C for 10 min (Figure 5). Figure 6 shows the baking effect. After baking, the 3D object reduces its size because of water evaporation. Size reduction represents 27.13% of loss but the shape is well maintained. Figure 7 shows both 3D objects already baked, and Figure 8 shows the relative size of the 3D objects compared with a hand

Figure 5. 3D Savory Pasta in the oven

Figure 6. 3D Savory Pasta before (left) and after (right) cooking

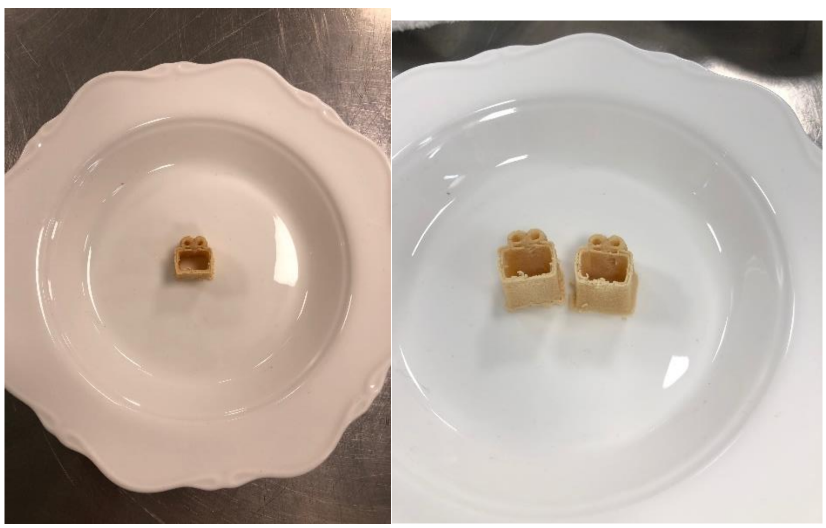

Figure 7. 3D Savory Pasta after cooking in a plate

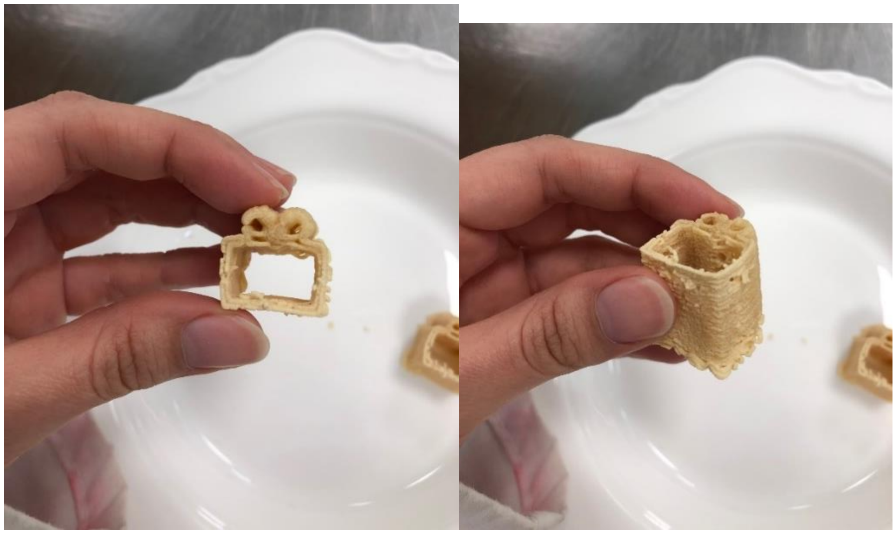

Figure 8. Relative size of the 3D Savory Pasta after cooking compared with a hand.

After baking, the product was tasted by 3 people. The consensus was that flavor was bland and the pea flavor was too strong. Also, near the bow of the present, it was not well cooked.

4. Conclusions

- Recipe 1 has the right texture for 3D printing.
- The distance between the syringe tip and the silicone mat is important to obtain the desired shape.
- The size of the 3D object is reduced after baking process.
- The flavor of the recipe needs to be improved.

5. Recommendations for following week.

- Improve the recipe reducing the pea protein content and use flavor and colorant to make it more attractive to consumers.
- Increase the baking time.
- Due to time constrains it is recommendable to not continue developing the tomato sauce.

9.4. LOGBOOK WEEK 4

MODULE CODE: TFCS9025 2021-22 **FOOD PRODUCT: 3D Savoury Present MODULE**
TITLE: Advanced Molecular Gastronomy
STUDENT NAME: Maria Grazzia S. Peña Niebuhr
WEEK NO.: 4 **DATE: 25/04/22**

1. **Weekly Aims and Objectives**

1.1 Aim: To create and optimize the taste and texture, of a note-by-note savoury recipe that includes fibre and a dice shape through practical experimentation in TU Dublin laboratories.

1.2 Objectives of the week: To produce the final recipe of the 3D savoury dice and make the sensory evaluation with panelist in the kitchen.

2. **Materials and Method (Ingredients, Equipment and Method)**

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2.1 INGREDIENTS

3D Savoury Pasta

- 61 g of corn starch
- 32 g of pea protein
- 17.5 g of dietary fibre
- 2 g od caster sugar
- 1 g of salt
- 3 drops of Conq flavour
- 4 drops of Berthome flavour
- 5 drops of red colour
- 2 drops of Onium flavour
- 127 g of water

2.2 EQUIPMENT REQUIRED

- Procusini 3D Printer
- Silicone mat
- Laptop with the 3D Printer programme
- Plastic syringe
- Plastic tips for the syringe
- Piping bag
- Scale
- Spoons
- Bowls
- Spatula
- Whipper
- Sieve

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2.3 METHOD

3D Savoury Pasta

1. Weigh the dry ingredients
2. Mix with a spoon the dry ingredients and sieve it to ensure they are properly mixed.
3. Add the oil and mix with a whipper.
4. Add the water slowly and mix well with a whipper.
5. Introduce the paste to the piping bag and remove bubble airs.
6. Fill the syringe with the paste in the piping bag making sure to not include air bubbles.

Printing

7. Join the printer network and open the printer programme.
8. Introduce the syringe in the 3D printer.
9. In the printer programme choose the personalized template.
10. Skip the pre-heating process
11. Run the 3D printer
12. Press ok until product comes out.
13. Adjust the high of the printer head.
14. Run the 3D printer again.

Baking

15. Pre-heat the oven at 150°C
16. Put the 3D object in the silicon mat in a trail and put in the oven.
17. Bake the 3D object for 15 min

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3. Results and Discussion

According to the recommendation of the previous session, recipe was modified (Table 1). Pea protein was slightly reduced to decrease the pea flavour. The reduction was meant to be 5%, which considered that a bigger reduction will impact the texture and it was replace by dietary fibre. However, during final mixing, the pasta was moister and pea protein and corn starch was added to finalize the texture. Flavours and colorant were added to improve the sensory characteristics of the pasta (flavour and colour) but these ingredients were in liquid form, which might be the cause of the water excess in the final recipe. Salt was slightly increased too.

Table 1. Pasta recipe in percentage

Ingredients	Percentage (%)
Corn starch	24%
Pea Protein	13%
Dietary fiber	7%
Vegetable oil	6%
Caster Sugar	1%
Salt	1%
Conq flavor	0%
Berthome Flavor	0%
Onium flavor	0%
Red colorant	0%
Water	50%
Total	100%

The 3D printer was set up and the paste was tried. In the first trial, the recipe did not work well as seen in Figure 1. The texture was too dry and it had several air bubbles. Also, the tip seem to be too wide for the pasta and it did not allowed it to have a defined shape.

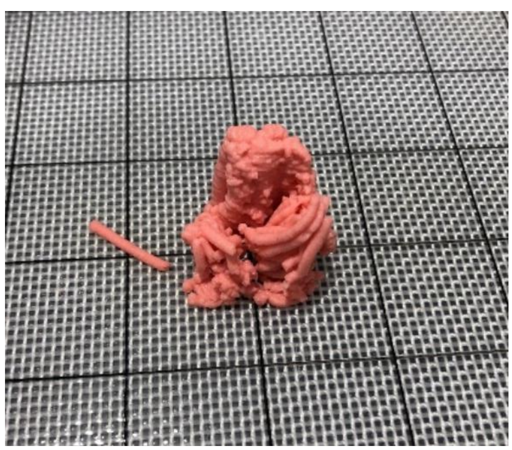

Figure 1. First trial of 3D printing the savory present

The recipe was then changed, adding 2 grams of water, and tried again. Figure 2 shows the start and end of the 3D printing process. A moister recipe and a change for a thinner tip, allowed to have a well-defined shape. The structure of the pasta was neat and smooth.

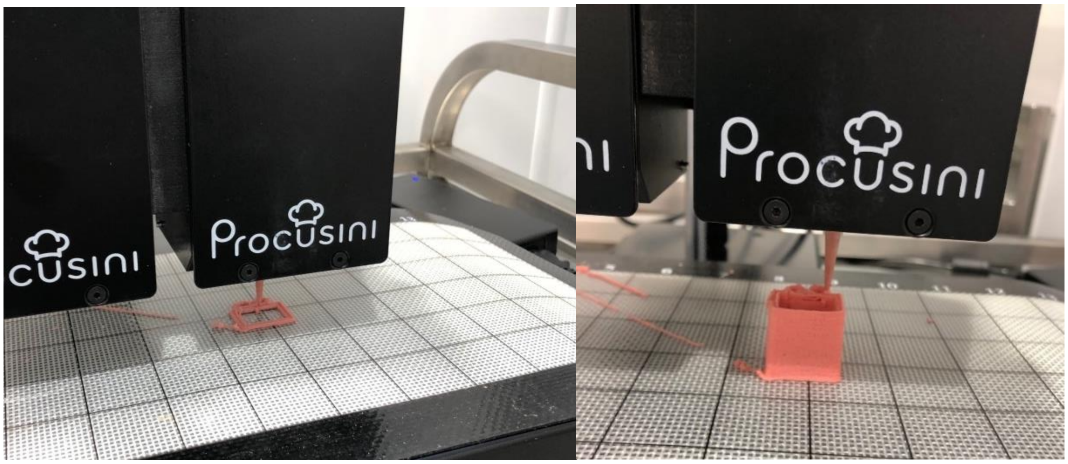

Figure 2. Second trial of 3D printing the savory present (left is initial step and right the final step)

Nevertheless, the 3D printer had an issue with the dossing connection. To make the product come out from the tip, it needed to press a lot the “ok” bottom and when it came out it had too much pressure and product were wasted. 3 times were tried to run again the 3D printer without success and the pasta in the syringe run out. The 3D printer had to be set to the initial mode what wasted time. A second batch of the pasta was introduced with the premise of adding 2 grams of water, but the product was already dryer from being expose to the environment and more water had to be water. 2 more grams of water were added but this was too much because the texture of the product was too soft. A defined shape was not achieved in 3 trials as seen in Figure 4. Then, the 3D printer did not allowed to dose more product because the dosing interface did not appear in the program and no more trials could be conducted.

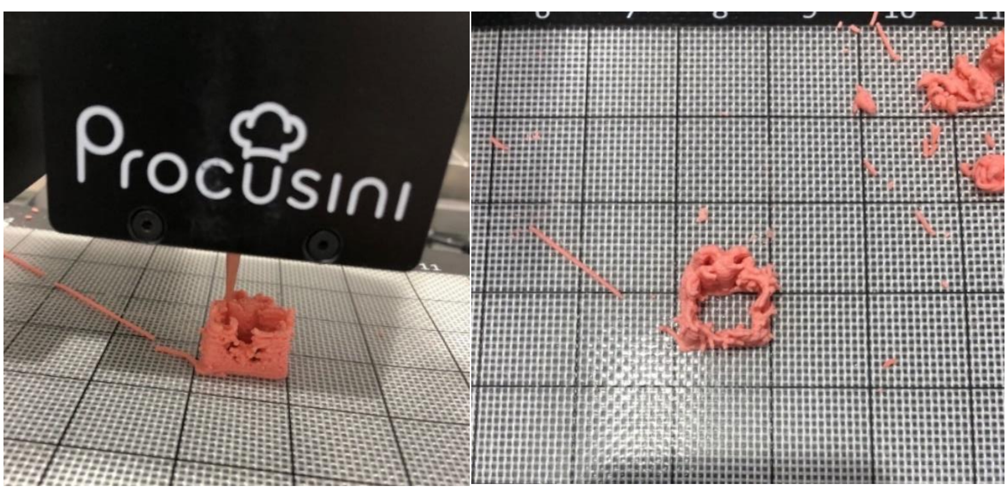

Figure 4. Third trial of 3D printing the savory present

The only 3D printed sample was baked following the recommendations of the previous session, at 150°C for 15 min.

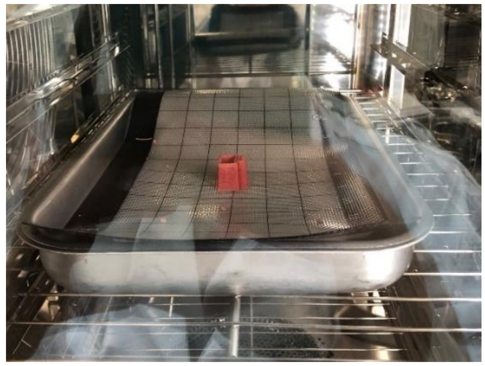

Figure 3. 3D savory present in the oven

The size of the 3D object was reduced, and the color changed to a lighter pink. Final sensory evaluation was made with 3 panelists that tasted the product. According to the consensus, pea flavor was still a little strong, but the saltiness was correct. Other flavors like onion and herbal were identified too. Pink color was extremely accepted for all the panelists.

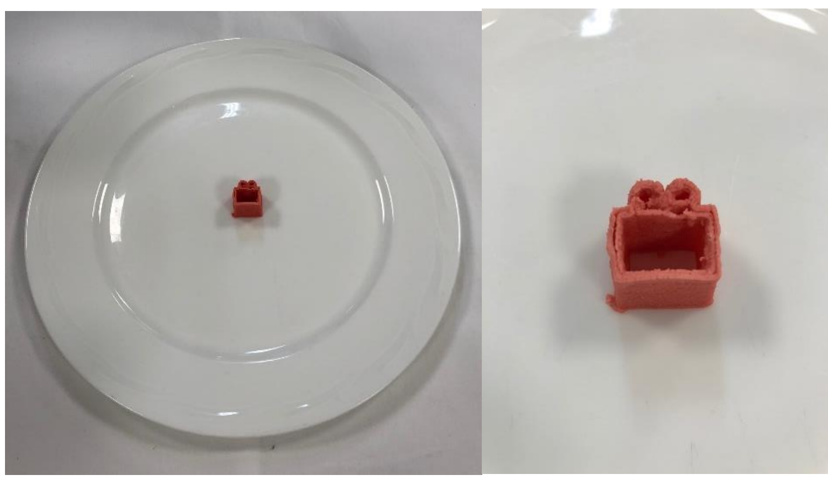

Figure 5. Final 3D Savory Present

4. Conclusions

- Small changes in the ingredients can make bigger changes in the texture of the final recipe and make it less manageable in the 3D printer.
- The pasta before printing loses moisture by being expose to the environment quite fast.
- Pink colours make the appearance of the dish more attractive.
- The inclusion of flavours improved the overall flavour of the recipe.

5. Recommendations for following week.

- Reduce the pea protein content and replace it with other protein with less bitter flavour like soy protein.
- Include a tomato sauce that can enhance the general flavour of the dish.

9.5. LOGBOOK REFERENCES

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10. APPENDIXES

10.2. 3D PASTA OF PROCUSINI