OLLSCOIL TEICNEOLAÍOCHTA
BHAILE ÁTHA CLIATH

TECHNOLOGICAL
UNIVERSITY DUBLIN

Advanced Molecular Gastronomy

FINAL REPORT

May 2023

Prepared by:
Oscar ANDRADE
Student ID: D22126813

Instructors:
Róisín BURKE
Pauline DANAHER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction

"Molecular Gastronomy, since its first definition, has grown to encompass activities from the description and rigorous evaluation of highly traditional cooking and food preparation processes to the application of scientific principles for the design of highly innovative dishes and food products" (Burke, This and Kelly, 2016).

Indeed, innovation has underpinned Molecular Gastronomy (MG) aiming to be a connection to sustainability and product development linked with the foundation of food science for haute cuisine in the last couple decades since its formalization in 1988.

In the modern world, where mass consumption is part of the societies behavior and supply chains are still recovering from the damage the COVID-19 pandemic caused, this connection is more important than ever. Innovation must bring together sustainability into the food product development to avoid or, at the very least, diminish food loss and food waste, which is one of the greatest issues we are facing currently.

Mass consumption implies an even greater demand assuming that all food categories are prepared to meet consumption plus stocks, therefore, stands to reason that along the steps of this supply chain and even until the consumer purchase are losses and wastes that need to be addressed.

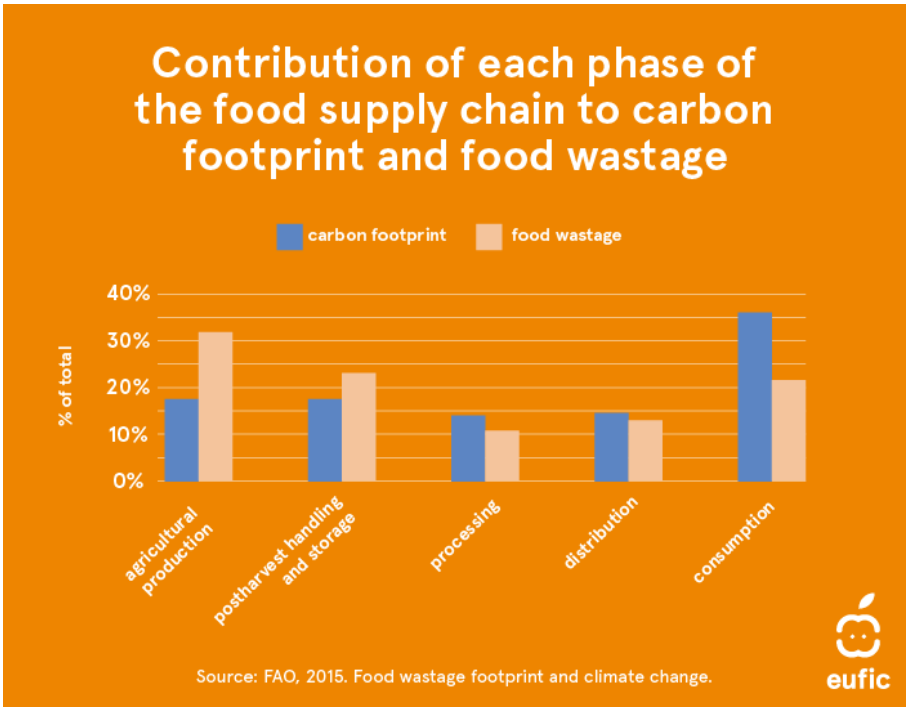


Figure 1. Contribution of each phase of the food supply chain to carbon footprint and food wastage in Europe (Food Facts for Healthy Choices, 2021).

As seen in Figure 1, agricultural production and postharvest handling and storage accounts for more than 50% of the food wastage in Europe, therefore, action must be taken to address this issue and a perspective to do so, could be through the tools that MG presents to us.

If we deep dive a bit more into the most common food waste products, we find on Figure 2. In terms of food wastage, cereals, vegetables, starchy roots, and fruits headline the graph having more than 15% of the total contribution to food waste each.

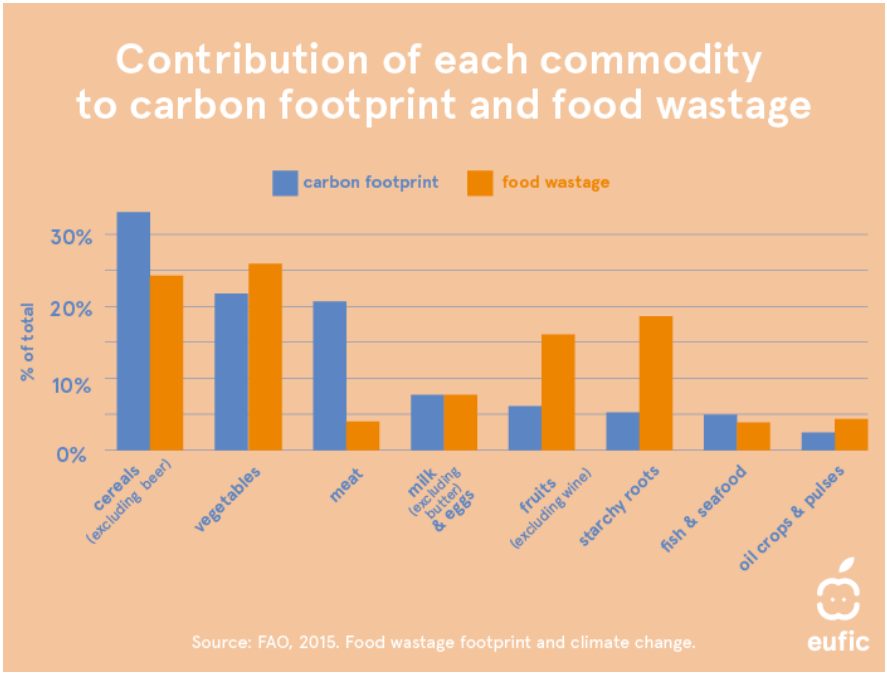


Figure 2. Contribution of each commodity to carbon footprint and food wastage in Europe (Food Facts for Healthy Choices, 2021).

It also stands to reason that the further a food product goes into the processing steps of the supply chain, the hardest it is to recover it or avoid its wastage since most probably would be an industrialized product made from several raw materials that needs specific storage and packaging conditions to be kept fresh.

Therefore, more effort could be invested into products that require little to no processing steps at all to try to avoid its loss, recover, and/or revalorize them into new products.

In Ireland, vegetables and fruits are the main food waste both in primary production and retail and distribution. These two steps in the supply chain account for the 9 and 8% of the total food waste respectively (Environmental Protection Agency, 2022), representing 130 thousand tones where 90 thousand tones are exclusively from vegetables and fruits.

Taking the example of fruits, where the natural flavors and colors, and complex matrixes would help to develop a wide variety of sub-products and avoid waste an academic, scientific-based work will be conducted to aim to revalorize the wasted fruits that are discarded either because of surplus in production or because it didn't meet the quality criteria in terms of appearance or slight damage to the surface.

Aim of the Report

Following the criteria of Note-by-Note cooking, the aim of the report will be to build a product using mainly pure or mix compounds based also on the idea of revalorizing fruits aiming to present an alternative to reduce food loss and waste.

In order to build on the concept for the product and looking at all the sugars that are naturally present on fruits, it was suitable to develop a snack for children based on the idea that whenever there's a decision to make in terms of nutrition for children, parents "will accept the natural sugar in fruit and vegetables given their other nutritional components but reject anything else as 'unhealthy'" (Osborne, 2020).

Regarding the product itself and seeing the amount of complex carbohydrates that are available on fruits one alternative is to produce jellies by extracting the natural sugars and complex carbohydrates such as starch and pectin to create a base for the jelly that will include the original color, flavor, and aroma (to some extent) from the fruit.

Aside from that, it is well known that children like something colorful and creative to happily eat it and even ask for more, therefore, this behavior must be also included in the product development because it won't be enough saying that it is made from fruits for the parents to accept the purchase, it must bring a playful experience for the children too.

To do this, the jellies can be made into different shapes to visually attract the children. Combining all these elements, the creative concept for the product development here discussed is ***play it! don't waste it***, since the Lego® shape will be used to encourage children to play with their food, creating different structures and figures while having a natural and delicious jelly snack.

Figure 3. Creative concept and mission for the product development.

In summary, this work aims to:

- Develop a fruit-based recipe that:
  - Is made mainly from pure or mixed compounds.
  - Complies with the EU regulation.
  - Is replicable and adjusted to the kitchen equipment and resources from TU Dublin.
- Perform quick sensory analysis on the samples to gather comments from fellow classmates onto the main product attributes such as: texture, flavor, color, and aroma.
- Estimate the cost of the product per 100g of jellies.

Materials and Methods

This product is composed by three main elements, each will be described in terms of ingredients and procedure to elaborate it.

- The jelly 95%
- The flavored sugar for coating 05%
- The sauce Optional/to taste.

Formulation and Procedure

a) Jellies Formulation

*Table 1. Ingredient and Composition for Jellies Formulation. */**=depends on the color of the final Lego®*

	Ingredient	Quantity	Units	%
1	Water	500	g	82.44%
2	SOSA Gelling Agent	40	g	6.60%
3	Sucrose ($C_{12}H_{22}O_{11}$)	30	g	4.95%
4	Fruit Powder*	30	g	4.95%
5	Citric Acid ($C_6H_8O_7$)	6	g	0.99%
6	Food Coloring**	0.5	g	0.08%
	Total	606.5		100%

Table 2. Correlation between the fruit powder, natural flavor and color used in the final formulation.

	*Fruit Powder	**Food Coloring	***Natural Flavor
Red Legos	SOSA Strawberry Powder	Cake Decoration Red Color	MSK Strawberry Flavor
Blue Legos	SOSA Fig Powder	Cake Decoration Blue Color	MSK Blueberry Flavor
Yellow Legos	SOSA Mango Powder	Cake Decoration Yellow Color	MSK Mango Flavor
Green Legos	SOSA Apple Powder	Cake Decoration Green Color	MSK Granny Smith Apple Flavor

1. In a small metallic bowl, weight the gelling agent and add 100 grams of the total water to hydrate it in advance and avoid possible lump formation during the final cooking.
2. In a sauté pan, weight the sucrose and critic acid. Afterwards, add the fruit powder sifting it to avoid lumps. Mix all powders with a spatula to make the sugar and citric acid help as carriers.
3. With the help of a microscale, weight the food coloring and dissolve in 50 grams of the total water to avoid losses per changing containers.
4. Add the remaining water to the sauté pan and the color dilution and whisk immediately to avoid lump formation.
5. Place at low heat in the stove until starts to boil. Only then, add the hydrated gelling agent and whisk until combined.
6. With a large syringe, take some of the hot mixture and fill the molds to the top. To avoid spillage and easier the movement of the filled molds, previously place the molds in a tray covered with aluminum paper.
7. Let the molds set at room temperature for 15min, then place into the fridge to accelerate the temperature drop and therefore, the gelling process.

b) Flavored Sugar

As discussed in the logbooks (appendix), giving the characteristic flavor to the jellies was a challenge and different strategies were tried to test the best one. In the end, flavored sugar acting as a coating was the best option to enhance the flavor in the final product and use minimal quantities.

Table 3. Ingredient and Composition for Flavored Sugar.

	Ingredient	Quantity	Units	%
1	Sucrose ($C_{12}H_{22}O_{11}$)	50	g	59.52%
2	Maltodextrin	30	g	35.71%
3	Water	3	g	3.57%
4	Natural Flavor***	1	g	1.19%
	Total	84		100%

1. Weight the maltodextrin and sucrose in a plastic bag.
2. Dissolve the natural flavor into the water and spray into the bag with the maltodextrin and the sugar.
3. Shake vigorously until combined. A visual aid that the mixture is ready is not seeing any small drops of liquid lumped together among the powder. Should be uniform and highly aromatic.
4. Identify each bag to avoid confusion.
5. Sprinkle the flavored sugar in the set jellies at no more than 5% w/w ratio.
6. Let set for a few minutes, due to the hygroscopicity of the sugar and maltodextrin, water will migrate from the jelly into the powder making it unnoticeable at first sight. Only a granular surface will be recognized when looked in detail.

c) Sauce

The sauce is just a fun thick dip to add to the jellies if desired, this element is not mandatory for the concept, just a reminiscence of usual consumption habits in Latin America to add powders, sauces or dips when eating fruits. It's supposed to be mild spicy and sweet to compliment the fruit flavors.

Table 4. Ingredient and Composition for sauce.

	Ingredient	Quantity	Units	%
1	Water	50	g	55.25%
2	Sucrose ($C_{12}H_{22}O_{11}$)	35	g	38.67%
3	Chili Powder	5	g	5.52%
4	Cake Decoration Red Color	0.5	g	0.55%
	Total	90.5		100%

1. Weigh the sucrose and chili powder into a bowl and mix.
2. With the help of a microscale, weight the food coloring and dissolve in 10 grams of the total water to avoid losses per changing containers.
3. Add the remaining water and the color dilution and whisk until combined.

Ingredient Functionality

In this section, a brief but meaningful explanation for the ingredient functionality is displayed along with the pictures of the ingredients used in the experimental kitchen. Some properties will be further explored in the discussion section.

It is important to mention that three mixed compounds were used: SOSA Gelatin Agent, SOSA Fruit Powder and Chili Powder. Nonetheless, only SOSA Gelatin Agent has reported list of ingredients from the supplier, the other two did not contained a description of other ingredients mixed, therefore, it will be assumed that it's only fruit and chili powder respectively, neglecting carriers or anticaking agents since they are not declared.

The composition of SOSA Gelatin Agent is maltodextrin, gelling agent: carrageenan (E407), dextrose, stabilizer: potassium chloride (E508), acidity regulator: trisodium citrate (E331iii), gelling agent: carob bean gum. (E410) and sucrose. Another assumption that will be made is the type of carrageenan that is included in the gelling agent since it's not declared either. For this paper, κ-carrageenan will be assumed since a synergistic effect has been observed between κ-carrageenan and carob bean gum and the presence of the latter (Martins et al, 2012) may indicate that was the purpose of the supplier.

Table 5. Ingredient Functionality and pictures of the materials used.

Ingredient	Function	Picture
Water	Dissolving/hydrating agent	NA
SOSA Gelatin Agent	Main 3D network. Entrap water and other ingredients to form a firm gel using κ-carrageenan properties.	
Sucrose ($C_{12}H_{22}O_{11}$)	**In jelly:** Aid gel formation, higher concentration of sucrose helps a packed 3D structure and therefore a firmer gel. **In coating:** Flavor carrier **In sauce:** sweet taste, bulk ingredient.	
SOSA Strawberry Powder	Natural aromas, flavors, reducing sugars and gelling agents such as pectin and starches.	

Ingredient	Function	Picture
SOSA Fig Powder	Natural aromas, flavors, reducing sugars and gelling agents such as pectin and starches.	
SOSA Mango Powder	Natural aromas, flavors, reducing sugars and gelling agents such as pectin and starches.	
SOSA Apple Powder	Natural aromas, flavors, reducing sugars and gelling agents such as pectin and starches.	
Citric Acid ($C_6H_8O_7$)	Reducing pH and aid the formation of the helix structure in κ-carrageenan, also contributes to the acidic taste.	

Ingredient	Function	Picture
Food Coloring** **Brand:** Cake Decoration Red, Blue, Green and Yellow	General appearance	
Maltodextrin	Aids fluidity of the coating make it easier to spread through the jellies and avoids the caking effect on sugar.	
Natural Flavor*** **Brand:** MSK Strawberry, Granny Smith Apple, Mango and Blueberry	Taste release and overall liking	
Chili Powder	Taste release and overall liking	

Equipment and Utensils

For this development, besides the stove (ELECTROLUX brand) and the fridge (KBR brand) no special equipment was needed besides the ones mentioned in the procedure in the section above. Nonetheless, kitchen utensils were key to achieve the final product and those are mentioned in the following Figures 4 and 5.

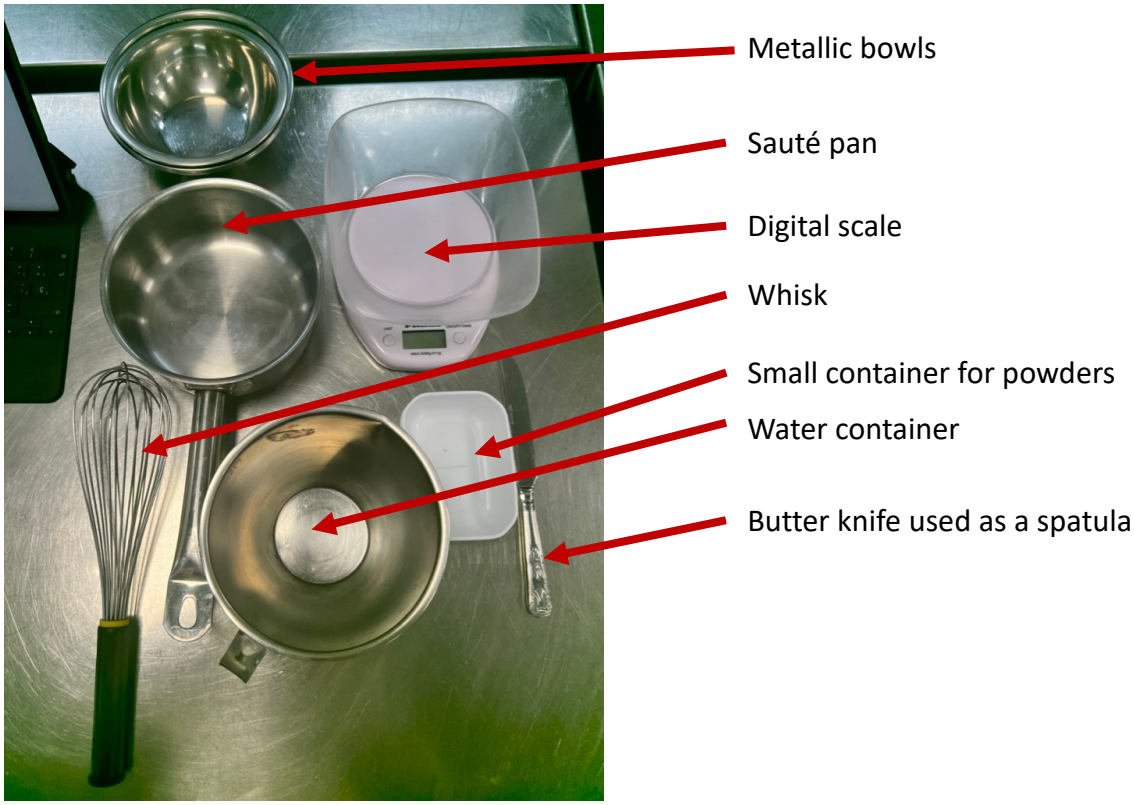
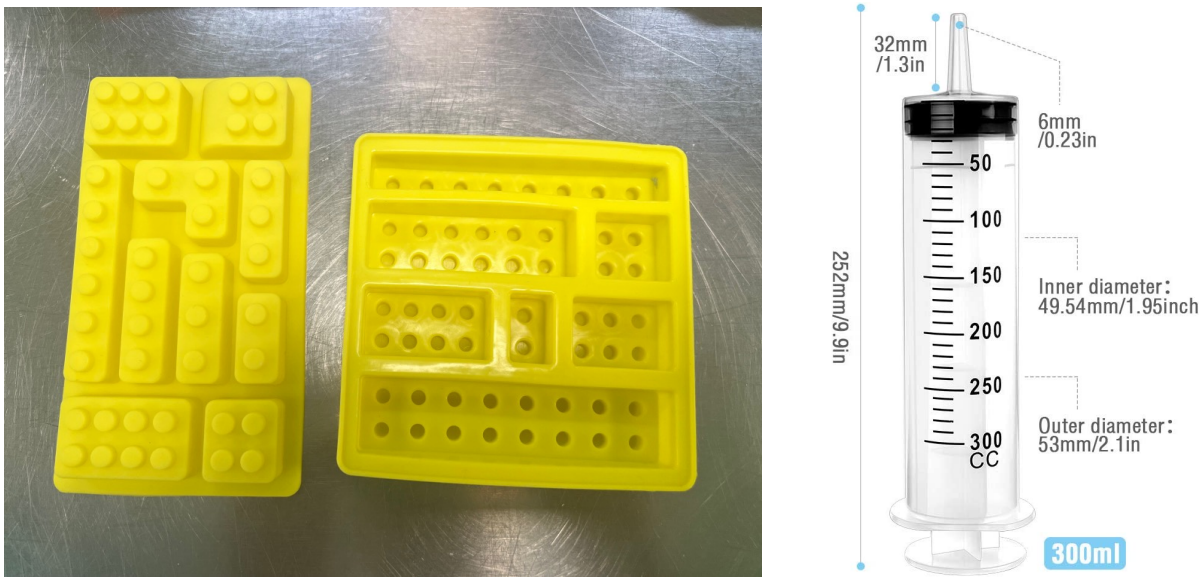


Figure 4. Kitchen utensils used for the product development.



(A) (B)

Figure 5. (A) Molds used to give the Lego shape to the jellies (B) large syringe used to inject the cooked mixed into the molds to avoid spillage.

Results

Final Product

After 3 sessions of product development on the experimental kitchen (plus a session to replicate and put together the dish), two main challenges were faced to deliver the final dish: gelling process in terms of how firm the jelly was to be able to obtain a defined Lego® shape and the flavor delivery. A detail into the changes in the recipe can be found in the Appendix.

The final presentation of the dish is intended to demonstrate that jellies can be obtained from different fruits and a good consistency and flavor delivery can be achieved, as well as a visual attractiveness into a snack-plate for children and even adults to enjoy. The quantity that is visualized in Figure 6 is considering as a sharing size, hence the various pieces of each flavor in the plate.

Figure 6. Final dish picture. In the center is a small container of sauce to dip the jellies that are surrounding it.

As stablished, one of the main challenges for this product was the right firmness of the gel to be able to demold it keeping the Lego® shape and not just a plain rectangle. This was achieved by the addition of 1% citric acid to the mixture to slightly lower the pH (6-7) to favor the formation of the double-helix in the carrageenan and, therefore, a stiffer gel.

It is also important to mention the addition of the sucrose as an agent to also favor the double helix formation by entrapping water and reducing the space between the helixes to be able to compact the structure altogether.

Figure 7. Individual figures exhibiting the defined Lego® shape.

For the flavor delivery, a coating of flavored sugar was used in a 5% (w/w) ratio that in the final product is almost indetectable due to the hygroscopicity of both the sucrose and the maltodextrin.

It is noticeable that the yellow figure has an appearance *wetter* than the other figures. This is due to being chilled in the freezer instead of the fridge and not having the setting time at room temperature. The hardening of the shape happened because of the freezing temperatures and not because of the actual gelling process, therefore, it can be concluded that the setting time must be followed to obtain defined shapes like the ones seen in blue, green and red.

Sensory Evaluation

For the sensory evaluation, a small analysis was conducted with 5-7 fellow classmates to taste the product and give comments about it using a hedonic scale of 5 levels (1 being *I don't like at all* and 5 being *I like it a lot*) for the main attributes of the product, these being:

- Size
- Color
- Aroma
- Texture
- General Appearance
- Flavor

Out of the four sessions available, only two sensory evaluations were conducted due to lack of time in the other ones and not-successful recipes that wasn't worth it to evaluate at all. The results of these two evaluations can be seen in Figure 8.

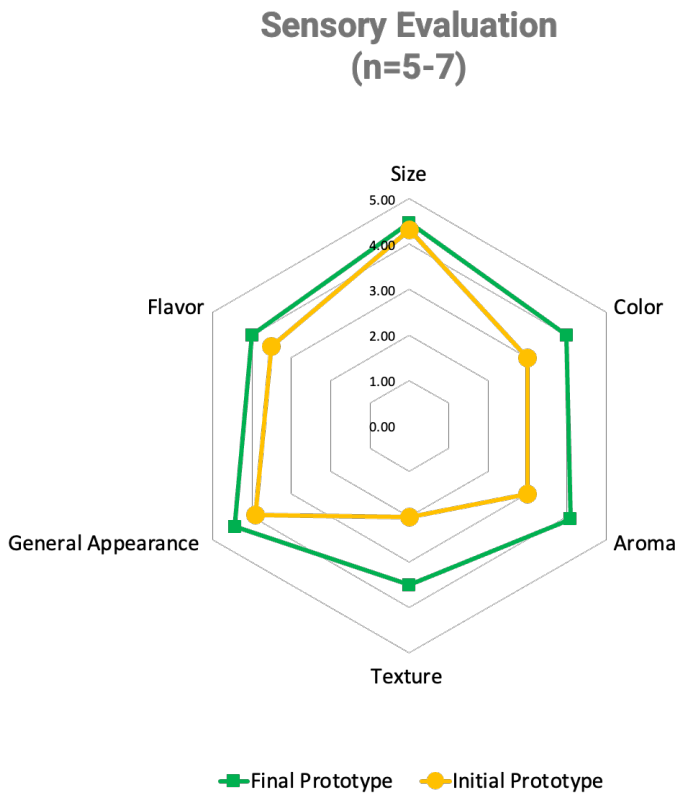


Figure 8. Sensory Evaluation for initial and final prototype.

The prototype was overall improved in almost all the attributes evaluated. Here's a summary of the findings per attribute:

- The color was improved with the addition of color before it only contained the color natural from the fruit powder and was considered too weak and not so attractive.
- In terms of aroma and flavor, the improvement was significative from one prototype to another since before the flavor was added during the cooking step, causing most of the volatile aromatic compounds to escape the matrix and, therefore, having a low performance in the finished prototype. With the use of the coating with flavored sugar, this improved significatively.
- In terms of texture, the improvement was also significative since the initial prototype didn't contain citric acid and therefore the gel formed was softer, more like a dairy dessert than an actual jelly. Afterwards, the gel became firmer and therefore the evaluation improved, especially the gels made with mango and strawberry. Nonetheless, this is the lowest score in the evaluation, being still an area of improvement to keep working on.
- Size and General Appearance were kept almost the same in both the attributes, which makes sense since the shape and size didn't change at all.

Cost Estimation

As seen in Table 6, an estimation of the cost of the prototype is given assuming the consumption of this product being 85% of jelly, 10% of sauce and 5% of the coating to deliver

flavor. Also, assuming this is a dish that will be consumed as served, and not pre-packaged, therefore no logistic costs were included (packaging, storage, modified atmosphere, etc.).

$1.02 EUR per 100g of this product is rather cheap and could be further explored to make this into an industrialized process that, with the right branding and marketing strategy, could compete in the confectionery market for children and teenagers.

Analyzing the correspondence between the proportion and the percentage of the total cost of each element, is rather a consistent development. Where the element that weights 85% represents 78% percent of the cost, while the element that weights 10% and 5% represents a 15% and 7% of the total cost, respectively. As any project, optimizations can be made to lower the cost even more and increase profitability, this could be done in the sauce to change the chili powder for chili flavor.

Future Development

Based on all this information, several paths to improve this development can be followed if this project needs to be studied forward.

1. Sensory Evaluation
    a. The sensory process that was conducted in this work is not enough to determine the success of the product, therefore, a methodical analysis need to be done through quantitative research with fixed scales and in a controlled environment.
    b. The evaluation needs to be conducted with children to know if this is something they would be interested in. Same with the parents presenting them the overall concept of the product and nutritional profile of the product.
2. Scale-up and technology challenge
    a. It needs to be determined a process to obtain the fruit powder from actual fruits about to be wasted for the whole concept to work. One alternative is the lyophilization as current suppliers do it, which would increase the shelf-life of the product as well as the stability but require investment in terms of equipment and facilities to operate it. Another alternative could be the kitchen scale process of drying the fruit and then blend it to produce a powder, the question there would be the consistency and quality over the batches to be produced.
    b. The setting and cooling times also need to be optimized, especially if this product is planned to be produced in large quantities to avoid waste of time and knowing the freezing temperature won't help since we will be hardening the aqueous phase but not performing the gelling process as stablished in the Final Product section.
3. Product Optimization
    a. As seen in the sensory evaluation, there's still work to be done in terms of texture and the gelling process to obtain a firm gel that is stable at room temperature and it's manipulable for the final consumer.

Table 6. Cost estimation for 100g of product assuming the proportions per consumption.

	Composition (%)	Composition in Finished Product (%)	Content per package	Units	Price per package (EUR)	Price per Unit	Price in Finished Product (EUR)	% of cost
Jellies	**100%**	**85%**					**€ 0.797**	**78%**
Water	82.44%	70.07%	NA	ml	NA	€ 0.001	€ 0.070	
SOSA Gelatin Agent	6.60%	5.61%	500	g	€ 30.55	€ 0.061	€ 0.343	
Sucrose ($C_{12}H_{22}O_{11}$)	4.95%	4.20%	500	g	€ 1.45	€ 0.003	€ 0.012	
Fruit Powder*	4.95%	4.20%	400	g	€ 32.08	€ 0.080	€ 0.337	
Citric Acid ($C_6H_8O_7$)	0.99%	0.84%	1,000	g	€ 35.52	€ 0.036	€ 0.030	
Food Coloring**	0.08%	0.07%	100	g	€ 7.99	€ 0.080	€ 0.006	
Flavored Sugar	**100%**	**5%**					**€ 0.067**	**7%**
Sucrose ($C_{12}H_{22}O_{11}$)	59.52%	2.98%	500	g	€ 1.45	€ 0.003	€ 0.009	
Maltodextrin	35.71%	1.79%	500	g	€ 5.31	€ 0.011	€ 0.019	
Water	3.57%	0.18%	NA	ml	NA	€ 0.001	€ 0.000	
Natural Flavor***	*1.19%*	0.06%	30	ml	€ 19.99	€ 0.666	€ 0.040	
Sauce	**100%**	**10%**					**€ 0.151**	**15%**
Water	55.25%	5.52%	NA	ml	NA	€ 0.001	€ 0.006	
Sucrose ($C_{12}H_{22}O_{11}$)	38.67%	3.87%	500	g	€ 1.45	€ 0.003	€ 0.011	
Chili Powder	5.52%	0.55%	400	g	€ 94.00	€ 0.235	€ 0.130	
Cake Decoration Red Color	0.55%	0.06%	100	g	€ 7.99	€ 0.080	€ 0.004	
Lego Jellies		**100%**					**€ 1.016**	**100%**

NOTE: It was also assumed that the density of the natural flavors equals the one of water to consider 1mL = 1g for simplification purposes.

Discussion

For this section, mainly the jelly will be discussed in terms of the differences that can be found in the raw materials, the food structure in terms of the gelling process and aids that help to make it firmer and the regulatory section that will also include the coating and the sauce in the analysis.

Fruit powder

As stated on the Ingredient Functionality section, several assumptions were made regarding the raw materials used for this development. One of them, the most important one, is related to the fruit powder that was used, since the supplier didn't share nor the nutritional profile of the powder nor the composition to understand if there are carriers or other anticaking agents included or not.

To assess how valid this assumption was, data from raw fruit was collected from the USDA Food Data Central and then an estimation using simple mass balance equations was performed to simulate the nutritional profile of powder fruit that contains on average 10% of moisture.

Table 7. Estimation of nutritional profile using data from the USDA Food Data Central and simulating a concentration where all powders contain 10% of moisture.

Component	Units	Mango Powder	Fig Powder	Apple Powder	Strawberry Powder
Moisture	%	10.00	10.00	10.00	10.00
Total Ash	%	1.96	2.39	1.88	3.34
Protein	%	4.46	4.24	1.64	6.29
Fat	%	2.07	1.18	0.85	2.16
Dietary Fiber	%	7.07	12.60	21.26	30.46
Total Sugars	%	74.46	61.60	64.37	47.75
Total Carbohydrates	%	81.52	82.18	85.63	78.21
Calcium (Ca)	mg/100g	59.78	208.35	30.36	167.03
Iron (Fe)	mg/100g	0.87	2.61	0.43	2.55
Potassium	mg/100g	913.04	874.54	704.45	1581.88
Vitamin C (ascorbic acid)	mg/100g	197.83	1.54	NR	585.59

After reviewing the data, we can conclude that the data is consistent with the observed results since the gels that performed better in terms of texture were the ones that contained strawberry and mango powder, and this can be related to the amount of potassium that each of them have.

Rhein-Nudsen et al (2015) describe that the gelling mechanism for k-carrageenan is aided by monovalent cations such as potassium since they stabilize and aggregate the helixes

by binding to the sulfate groups without making a cross-link between the helixes, making a firmer and stiffer gel, as seen in Figure 9.

Although the concentration of calcium cations is not neglectable, the mechanism of gelation seems to work better with monovalent cations for k-carrageenan, while the bivalent cations help the gelation mechanism for ι-carrageenan, which also supports the assumption that the carrageenan present in the gelling agent is kappa instead of iota (Hotchkiss, 2016).

Analyzing now the carbohydrate content, it is possible to observe that is close to one another. Nonetheless, the content of sugars does change and it's an important parameter that will be discussed in the next section for the structure of the jelly.

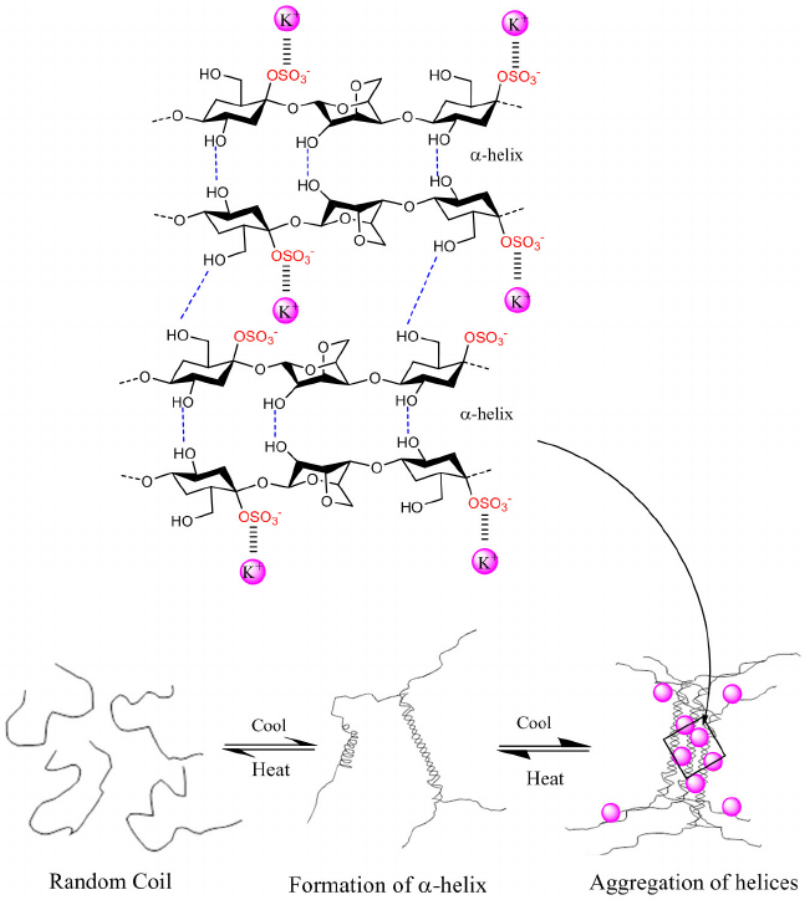


Figure 9. Gelation mechanism for k-carrageenan in presence of potassium cations (Rhein-Nudsen et al, 2015)

Food Structure

After reviewing the formula for jellies, it is possible to conclude that is rather simple and therefore, the structure should be easy to elucidate. Nonetheless, there are several factors playing along in the gelling mechanism and its final sensory characteristics, specifically the texture.

Understanding that k-carrageenan has two main steps for gelation (formation of a double helix and aggregation of helixes), the ingredients that are added play a key role in the

enhancement of said mechanism, one was already explained regarding the cations available in the fruit powder, let's analyze now the sucrose and the citric acid.

According to Yang et al (2018), the addition of sucrose on a k-carrageenan solution enhances the gelation process, resulting not only on a stronger 3D network but also a higher gelation and melting temperatures which makes the gel less susceptible to syneresis for the thermos-reversibility of the gel due to changes in temperature.

Structurally speaking, FTIR (Fourier Transformed Infrared) analysis conducted by Yang et al (2018) demonstrated interactions between k-carrageenan and sucrose when the percentage of addition was above 20%. These interactions are believed to be hydrogen bonding between the hydroxyl groups, causing aggregation and junction by *covering* the negative charges of the k-carrageenan, overcoming the repulsion between the helixes, compacting the structure, and significantly improving the gel strength.

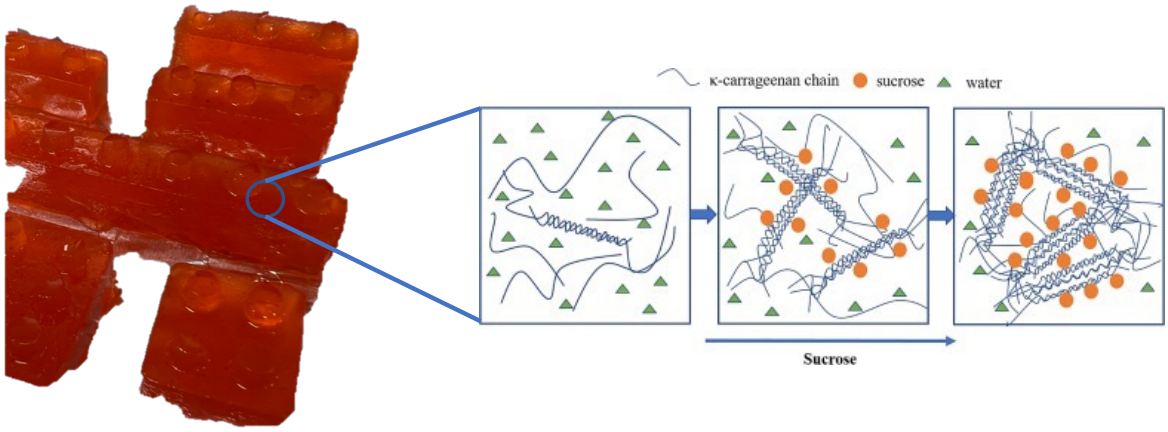


Figure 10. Representation of the effect of sucrose in a k-carrageenan gel by causing aggregation and compacting the structure to increase the gel strength (Yang et al, 2018).

Finally, in terms of the citric acid, Rinanda et al (2017) ran a study in systems containing sugar, carrageenan, and citric acid, demonstrating that the tensile strength of the gel due to the crosslink between the citric acid and the sugars present in the structure, consequently, also reducing the elasticity of the gel. Therefore, the citric acid, besides helping to taste and overall flavor delivery, also helps to increase the firmness of the gel by interacting with the sugars, both naturally present and added.

Regulatory

There are some components of this development that need a double check in terms of regulation to make sure that there's no maximum limit established for use, or in case there is, that the formulation is compliant with the regulation. These components are gelling agents (carrageenan and locust bean gum), food colorings and flavors.

- Additives: In accordance with Regulation 1333/2008, Annex II the status for the ingredients that are included in the formulation have the following status.

    - Carrageenan: *quantum satis* (Not possible to use on jellies mini cups)
    - Locust Bean Gum: *quantum satis* (Not possible to use on jellies mini cups)
    - Red Color (Allura Red AC):
        - Limit: 300mg/kg
        - Formula: 800mg/kg → **exceeded**
    - Blue Color (Brilliant Blue FCF): 300mg/kg
        - Limit: 300mg/kg
        - Formula: 800mg/kg → **exceeded**
    - Yellow Color (Curcumin): 300mg/kg
        - Limit: 300mg/kg
        - Formula: 800mg/kg → **exceeded**
    - Green Color (Green S): 300mg/kg
        - Limit: 300mg/kg
        - Formula: 800mg/kg → **exceeded**

In each of the colors, was detected an excess of coloring agent since the amount allowed is 300mg/kg and the formula contains 800mg/kg assuming each drop of the coloring gel is pure colorant, which we don't know since the raw material didn't specify concentration. To comply with regulation the addition of color must be lowered more than half its current value. The change can be seen in Table 8.

Table 8. Modified formulation for jellies to comply with Regulation 1333/2008, Annex II.

	Ingredient	Quantity	Units	%
1	Water	500	g	82.49%
2	SOSA Gelatin Agent	40	g	6.60%
3	Sucrose ($C_{12}H_{22}O_{11}$)	30	g	4.95%
4	Fruit Powder*	30	g	4.95%
5	Citric Acid ($C_6H_8O_7$)	6	g	0.99%
6	Food Coloring**	0.17	g	0.028%
	Total	606.17		100%

With this change, the colors are compliant with the regulation with 280 mg of color/kg of finished product.

- Flavorings: In accordance with Regulation 1334/2008, flavorings are used to improve or modify the odor and/or taste of foods and are not considered as additives.

To further comply with the regulation, it would be necessary to see the declaration of ingredients for each case and compare with the Annex III and IV of said regulation to make sure there are not certain substances that aren't allowed. For the purposes of this work, it will

be assumed that the flavorings used from MSK are compliant with the regulation since no other information has been provided.

Conclusions and Recommendations

Molecular Gastronomy, especially the Note-by-Note cooking technique, allows innovation to thrive by building imaginative dishes from the foundation of science itself while helping with pressing world issues, such as food waste and loss.

In this report, a product was developed from a concept to recover or revalorize fruits that otherwise will be discarded and wasted to create a snack for children: jellies Lego® shaped with different colors and flavors. The result was a bright and attractive dish that received good marks in terms of sensory evaluation.

The challenges that arose from this product were the gelling mechanism and the flavor delivery. The first one was tackled through food science by adding aiding agents that favor the gelling process and form a firm gel as explained in the discussion section, while the second one was tackled down through a technique that involved the spray of flavor (liquid) into a mix of maltodextrin and sugar (solid) to give the jelly a final outer coating.

Once doing the final analysis of the formula, this author realize that the color was exceeded in the amount allowed per Regulation 1333/2008, therefore, a significant reduction must be made to be compliant with the regulation. This is not expected to represent a big issue since the obtained colors are quite bright and intense already.

Overall, the product is feasible, and the cost estimation gave a very attractive price per 100g (1.02 EUR, Table 6) which could allow the development to continue through further steps. To do so, some considerations that I would recommend would be:

1. Sensory evaluation must be conducted in a more rigorous manner and must include both the children and the parents in said evaluation to see the comments from both sides, from the perspective of the final user and from the perspective of the one that will actually buy it.
2. Technology challenges must also be addressed since the process to obtain the powder fruit from the discarded or potential fruits to be wasted is still not clear, as well as the setting temperatures and time to avoid frozen conditions since it won't do any favors to the jelling matrix.
3. In terms of product optimization, there are some alternatives that can be explored such as the inclusion of other polysaccharides that help the gelling mechanism to produce a firm and stable gel, examples of this could be pectin or even agar. Also, to explore the food colorants that can que used *quantum satis* in case there's a need for brighter colors, a good alternative could be the carotenes family, paprika or beetroot extract, or even anthocyanins.

With that being said, still there is a good chance and opportunity to continue this project and improvement from many perspectives.

References

- Arltoft, D., Madsen, F., & Ipsen, R., 2008. Relating the microstructure of pectin and carrageenan in dairy desserts to rheological and sensory characteristics. *Food Hydrocolloids*, *22*(4), 660-673.
- Burke, Roisin, Herve This, and Alan L. Kelly., 2016. "Molecular gastronomy: an introduction." *Reference Module in Food Science* 1.
- Dominguez, H. ed., 2013. *Functional ingredients from algae for foods and nutraceuticals*. Elsevier.
- Environmental Protection Agency, 2022. *Food Waste Statistics for Ireland*. Available at: https://www.epa.ie/our-services/monitoring--assessment/waste/national-waste-statistics/food/ [Accessed 30 April 2023]
- Food Data Central, 2020. U.S. Department of Agriculture. *Apples, granny smith, with skin, raw*. Available at: https://fdc.nal.usda.gov/fdc-app.html#/food-details/1750342/nutrients [Accessed 04 May 2023]
- Food Data Central, 2020. U.S. Department of Agriculture. *Figs, dried, uncooked*. Available at: https://fdc.nal.usda.gov/fdc-app.html#/food-details/746768/nutrients [Accessed 04 May 2023]
- Food Data Central, 2020. U.S. Department of Agriculture. *Mangos, raw*. Available at: https://fdc.nal.usda.gov/fdc-app.html#/food-details/169910/nutrients [Accessed 04 May 2023]
- Food Data Central, 2020. U.S. Department of Agriculture. *Strawberries, raw*. Available at: https://fdc.nal.usda.gov/fdc-app.html#/food-details/2346409/nutrients [Accessed 04 May 2023]
- Food Facts for Healthy Choices, 2021. *Food waste in Europe: statistics and facts about the problem*. Available at: https://www.eufic.org/en/food-safety/article/food-waste-in-europe-statistics-and-facts-about-the-problem?gclid=Cj0KCQjwmN2iBhCrARIsAG_G2i48j-XMcuS9z9f-vF44VBBZzloC8TcqOD55vXNEZuo2xR6nmcUSXKMaAnEDEALw_wcB [Accessed 02 May 2023]
- Hermansson, A. M., Eriksson, E., & Jordansson, E., 1991. Effects of potassium, sodium and calcium on the microstructure and rheological behaviour of kappa-carrageenan gels. *Carbohydrate Polymers*, *16*(3), 297-320.
- Hotchkiss, S., Brooks, M., Campbell, R., Philp, K. and Trius, A., 2016. The use of carrageenan in food. *Carrageenans: sources and extraction methods, molecular structure, bioactive properties and health effects*, pp.229-243.
- Makshakova, O. N., & Zuev, Y. F., 2022. Interaction-induced structural transformations in polysaccharide and protein-polysaccharide gels as functional basis for novel soft-matter: A case of carrageenans. *Gels*, *8*(5), 287.
- Martins, J. T., Cerqueira, M. A., Bourbon, A. I., Pinheiro, A. C., Souza, B. W., & Vicente, A. A., 2012. Synergistic effects between κ-carrageenan and locust bean gum on physicochemical properties of edible films made thereof. *Food Hydrocolloids*, *29*(2), 280-289.
- MSK Ingredients. *Blueberry (Natural) Flavour Drops (Water Soluble), 30ml*. Available at: https://msk-ingredients.com/msk-0221-blueberry-natural-flavour-drops-water-soluble-30ml?search=blueberry [Accessed 05 May 2023]

- MSK Ingredients. *Granny Smith Apple (Natural) Flavour Drops (Water Soluble), 30ml*. Available at: https://msk-ingredients.com/msk-7942-granny-smith-apple-natural-flavour-drops-water-soluble-30ml?search=granny%20smith [Accessed 05 May 2023]
- MSK Ingredients. *Mango (Natural) Flavour Drops (Water Soluble), 30ml*. Available at: https://msk-ingredients.com/msk-7823-mango-natural-flavour-drops-water-soluble-30ml?search=mango [Accessed 05 May 2023]
- MSK Ingredients. *Strawberry (Natural) Flavour Drops (Water Soluble), 30ml*. Available at: https://msk-ingredients.com/msk-1489-strawberry-natural-flavour-drops-water-soluble-30ml?search=strawberry [Accessed 05 May 2023]
- Osborne, G., 2020. Bord Bia The Irish Food Board. *Children's Nutrition- Trends and Opportunities*. Available at: https://www.bordbia.ie/industry/news/food-alerts/2020/childrens-nutrition--trends-and-opportunities/ [Accessed 02 May 2023]
- Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008 on food additives, OJ L 354, 31.12.2008, p. 16
- Rhein-Knudsen, N., Ale, M. T., & Meyer, A. S., 2015. Seaweed hydrocolloid production: an update on enzyme assisted extraction and modification technologies. *Marine drugs*, *13*(6), 3340-3359.
- Rinanda, S. A., Nastabiq, M., Raharjo, S. H., Hayati, S. K., & Yaqin, M. A., 2017. The effect of combination of sugar palm fruit, carrageenan, and citric acid on mechanical properties of biodegradable film. In *Journal of Physics: Conference Series* (Vol. 909, No. 1, p. 012085). IOP Publishing.
- SOSA Cocineros. *Fresa liofilizada en polvo, SOSA*. Available at: https://www.cocineros.info/fresa-liofilizada-en-polvo-sosa [Accessed 05 May 2023]
- SOSA Cocineros. *Mango liofilizado en polvo (600g), SOSA*. Available at: https://www.cocineros.info/mango-liofilizado-en-polvo-600g-sosa [Accessed 05 May 2023]
- SOSA Cocineros. *Manzana verde liofilizada en polvo, SOSA (400g)*. Available at: https://www.cocineros.info/manzana-verde-liofilizada-en-polvo-sosa-500-g [Accessed 05 May 2023]
- Tsygankov, S., Grek, O., Krasulya, O., Onopriichuk, O., Chubenko, L., Savchenko, O., ... & Ochkolyas, O., 2018. Methods of determination of parameters of whey with food fibers. *EUREKA: Life Sciences*, (1), 69-76.
- Yang, Z., Yang, H. and Yang, H., 2018. Effects of sucrose addition on the rheology and microstructure of κ-carrageenan gel. *Food Hydrocolloids*, *75*, pp.164-173.

Appendix: Logbooks

Concept for Note-by-Note Cooking

DATE: March 20th, 2023

1. **Weekly Aims and Objectives**
    a. **Aim:** Production of Lego-shaped jellies using apple jam
    b. **Objectives:**
        a. Obtain jam from fruit powder
        b. Tint the soft jam different colours to imitate the real Legos
        c. Create jellies by carrageenan gelation in a Lego-shaped mould
        d. **IF POSSIBLE:** As the temperature decreases in the jelly, include strawberry spheres achieved by reverse spherification
2. **Materials and Method (Ingredients, Equipment and Method)**
    a. **Ingredients:**

Apple Jellies (Yellow Legos)

SOSA Apple POWDERED	15	g	4.05%
SOSA Gelatin Beef	50	g	13.51%
Water	300	g	81.08%
Apple Flavor	5	g	1.35%
Total	370		100%

Cherry Jellies (Red Legos)

SOSA Strawberry POWDERED	10	g	4.05%
SOSA Gelatin Beef	50	g	13.51%
Water	300	g	81.08%
Strawberry Flavor	5	g	1.35%
Total	370		100%

Spheres (inclusions in the jellies)

Alginate Bath

Water	500	g	99.30%
Sodum Alginate	2.5	g	0.50%
Sugar	1	g	0.20%
Total	503.5		100.00%

Strawberry Mixture (for the yellow Legos)

SOSA Strawberry powdered	100	g	46.51%
Water	100	g	46.51%
Calcium lactate/gluconate	5	g	2.33%
Caster Sugar	10	g	4.65%
Total	265		100.00%

Blackberry Mixture (for the red Legos)

SOSA Blackberry POWDERED	100	g	46.51%
Water	100	g	46.51%
Calcium lactate/gluconate	5	g	2.33%
Caster Sugar	10	g	4.65%
Total	265		100.00%

b. Equipment: Stove, stainless-steel pans, stainless-steel strainers, mason-jars, bowls, scale, spoons and trays.

c. Method:

For the jellies:

1. Rehydrate the fruit powders in a saucepan set on low heat with the water.
2. Add 100g of gelatin.
3. Mix until all dissolved and then remove from heat.
4. Add into the Lego mold.
5. Place in fridge overnight to cool and form or until solidified.

For the strawberry spheres:

1. Blend together the consistency is very important should be that of thick cream. If not, thick enough xanthan gum can be added.
2. Rest to remove excess air for 1 hour in the fridge or vac pack.
3. Using a dropper add the mixture to the alginate solution dropping a drop from the top of the solution. Cover gently with the slotted spoon to ensure the sphere is completely immersed.
4. Make sure the spheres don't stick together. After 2 minutes remove and rinse in a bath of water.
5. Remove and serve.

3. Results and discussion

a. First, the beef gelatin was not available, so I had to change for the gelling agent that is carrageenan based. It is considered a good thickening and gelling agent, so should be fine the substitution.

b. After preparing the gels and let them set for a while, the consistency was not becoming firmer, therefore, it was better to pass it to the chill blast for 10min and then to the fridge to allow stabilization of the gel.

c. The results were underwhelming at best since the gel didn't properly got firm and it was very liquid-y, it broke at touch.
d. This can be result of not having hydrated the gelling agent prior to the cooking time and therefore, the effect was severely compromised.
e. Another factor is that the gelling process does not contain any other ingredient that helps packing the molecules together to form a firmer gel.
f. Doing a sensory analysis, the answers were quite obvious since the prototype didn't perform well

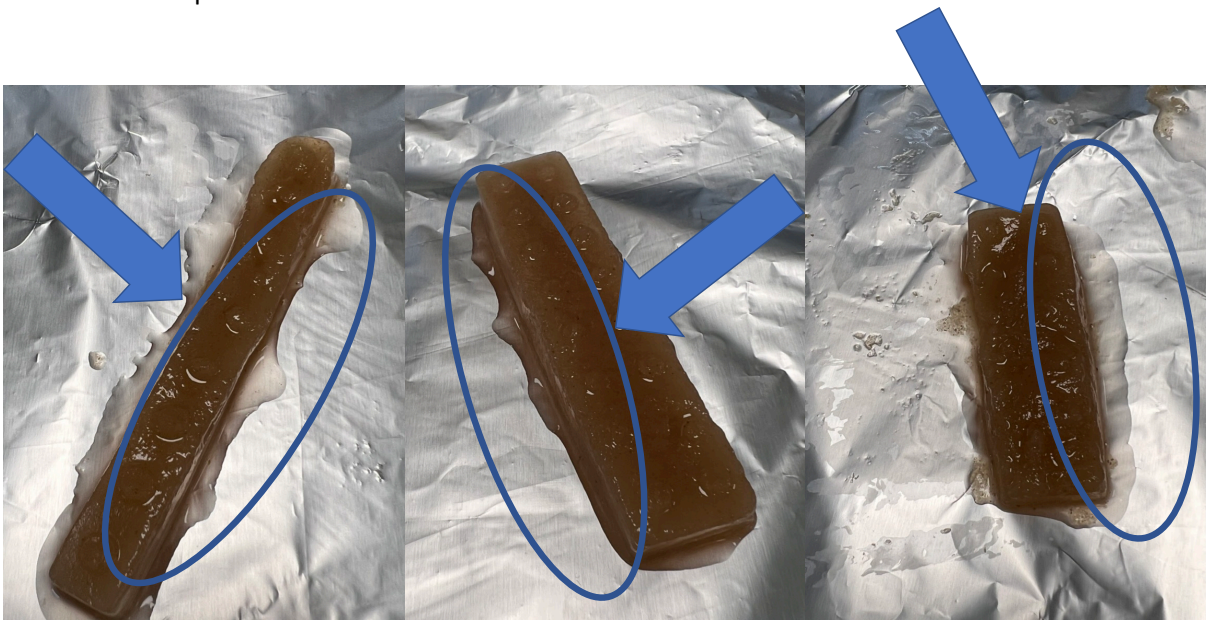
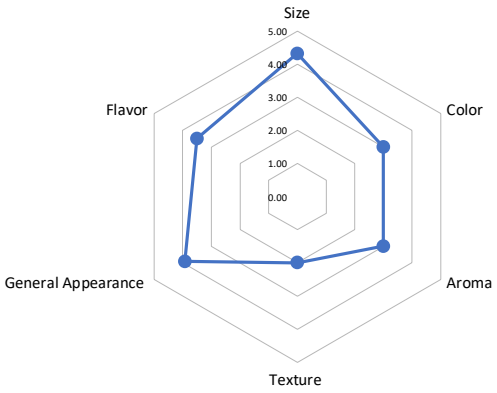


Figure 11. The structure seems to be swealing all over. The gelling process didn't occur very efficiently and all the entrap water is coming out of the matrix.

Sensory Evaluation



Size	4.32
Color	3.00
Aroma	3.00
Texture	2.00
General Appearance	3.92
Flavor	3.5

4. Conclusions

a. A reformulation is needed to include aiding ingredients in the gelling process.
b. The setting temperatures in the chill blast don't seem to help, but only one trial was done today, therefore it's too early to determine it.

5. Recommendations for following week

a. Hydrate the gelling agent prior to the cooking step, don't add until the water is already boiling.

b. Review what ingredients aid the packing of molecules to form stronger gels.

6. Ingredients required for the following 2 weeks

a. Same as here, I might just add citric acid, sucrose, or acidity regulators.

Concept for Note-by-Note Cooking

DATE: March 27th, 2023

1. Weekly Aims and Objectives

a. Aim: Production of Lego-shaped jellies using fruit powder

b. Objectives:

a. Make a jelly out of fruit powder and gelling agents
b. Use different colours to imitate the real Legos
c. **IF POSSIBLE:** As the temperature decreases in the jelly, include strawberry spheres achieved by reverse spherification.

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

a. Ingredients:

Apple Jellies (Yellow Legos)

SOSA Apple POWDERED	10	g	2.35%
Sucrose ($C_{12}H_{22}O_{11}$)	50	g	11.76%
Citric Acid ($C_6H_8O_7$)	10	g	2.35%
SOSA Gelling Agent (carrageenan)	50	g	11.76%
Water	300	g	70.59%
Apple Flavor	5	g	1.18%
Total	425		100%

Cherry Jellies (Red Legos)

SOSA Fig POWDERED	10	g	2.35%
Sucrose ($C_{12}H_{22}O_{11}$)	50	g	11.76%
Citric Acid ($C_6H_8O_7$)	10	g	2.35%
SOSA Gelling Agent (carrageenan)	50	g	11.76%
Water	300	g	70.59%
Strawberry Flavor	5	g	1.18%
Total	425		100.00%

Spheres (inclusions in the jellies)

Alginate Bath

Water	500	g	99.30%
Sodum Alginate	2.5	g	0.50%
Sugar	1	g	0.20%
Total	503.5		100.00%

Strawberry Mixture (for the yellow Legos)

SOSA Strawberry powdered	100	g	46.51%
Water	100	g	46.51%
Calcium lactate/gluconate	5	g	2.33%
Caster Sugar	10	g	4.65%
Total	265		100.00%

Blackberry Mixture (for the red Legos)

SOSA Blackberry POWDERED	100	g	46.51%
Water	100	g	46.51%
Calcium lactate/gluconate	5	g	2.33%
Caster Sugar	10	g	4.65%
Total	265		100.00%

b. Equipment: Stove, stainless-steel pans, stainless-steel strainers, mason-jars, bowls, scale, spoons and trays.

c. Method:

For the jellies:

6. Rehydrate the fruit powders in a saucepan set on low heat with the water.
7. Add 50g of sucrose.
8. Add 10g of gelling agent previously hydrated,
9. Mix until all dissolved and then remove from heat.
10. Add into the Lego mold.
11. Place in fridge for 30 minutes to cool and form or until solidified.

For the strawberry spheres:

6. Blend together the consistency is very important should be that of thick cream. If not, thick enough xanthan gum can be added.
7. Rest to remove excess air for 1 hour in the fridge or vac pack.
8. Using a dropper add the mixture to the alginate solution dropping a drop from the top of the solution. Cover gently with the slotted spoon to ensure the sphere is completely immersed.

9. Make sure the spheres don't stick together. After 2 minutes remove and rinse in a bath of water. Remove and serve.

3. Results and discussion

a. To aid the gelling process, I added sucrose and citric acid that are chemically reactive with the chains of carrageenan and help on the packing. And indeed, it worked! The setting of the gels started at room temperature as expected per the science review (carrageenan should gel when cools down starting between the 50-60°C).

b. When trying for the spherification process, only half the mold was filled to then place the spheres on top. Nonetheless, the spheres went to the bottom of the mold and the figure was completely disrupted, also the water added by the spheres is not entrapped and therefore is swollen from the matrix.

Figure 12. On green, we have the right gelling process, obtaining a very nice and defined shape, on red we have the deformation caused by adding the spheres into the structure.

4. Conclusions

a. Because of the success in gelling the product this week, a step to let the gel chill at room temperature will be added, afterwards, the jellies will be moved to the fridge to finish up the gelation.

b. Another method would have to be developed to deliver flavor since bursting from spheres don't seem to be helping.

5. Recommendations for following week

a. Reduce the quantity of citric acid, in the sensory comments it was said that it was too acidic and there was no actual flavor of the intended fruit.

b. Try to add the flavor as a top note instead of a flavor inside the matrix.

6. Ingredients required for the following 2 weeks

Same ingredients, just add flavors to the matrix that are already available.

Concept for Note-by-Note Cooking

DATE: April 17th, 2023

1. **Weekly Aims and Objectives**
    a. **Aim:** Production of Lego-shaped jellies using fruit powder
    b. **Objectives:**
        a. Make a jelly out of fruit powder and gelling agents
        b. Use different colours to imitate the real Legos
        c. Deliver flavour within the matrix or as a top note.

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

Apple Jellies (Yellow Legos)

SOSA Apple POWDERED	30	g	4.90%
Sucrose ($C_{12}H_{22}O_{11}$)	30	g	4.90%
Citric Acid ($C_6H_8O_7$)	6	g	1.92%
SOSA Gelling Agent (carrageenan)	40	g	6.54%
Water	500	g	81.83%
Apple Flavor	5	g	0.81%
Total	611		100%

Cherry Jellies (Red Legos)

SOSA Fig POWDERED	30	g	4.90%
Sucrose ($C_{12}H_{22}O_{11}$)	30	g	4.90%
Citric Acid ($C_6H_8O_7$)	6	g	1.92%
SOSA Gelling Agent (carrageenan)	40	g	6.54%
Water	500	g	81.83%
Strawberry Flavor	5	g	0.81%
Total	611		100%

    b. **Equipment:** Stove, stainless-steel pans, stainless-steel strainers, mason-jars, bowls, scale, spoons and trays.
    c. **Method:**

a. Rehydrate the fruit powders in a saucepan set on low heat with the water.
b. Add 50g of sucrose and citric acid.

c. Add 10g of gelling agent previously hydrated,
d. Mix until all dissolved and then remove from heat.
e. Add into the Lego mold.
f. Let the jellies set at room temperature for a few minutes and then place into the fridge to finish up the gelation.

3. Results and discussion

a. After trying to add top notes and flavors into the matrix but failing due to the evaporation of volatile aromatic compounds during the cooking step, another technique was proposed by using a coating of flavored sugar.
b. This technique consists in spraying a liquid flavor into a sugar and shake vigorously until combined to latter sprinkle on top of the jelly. This allows to lower the quantity of flavor to be used and since the sugar has high hygroscopicity, the water from the matrix migrate to the surface and don't even look like there is sugar on top.

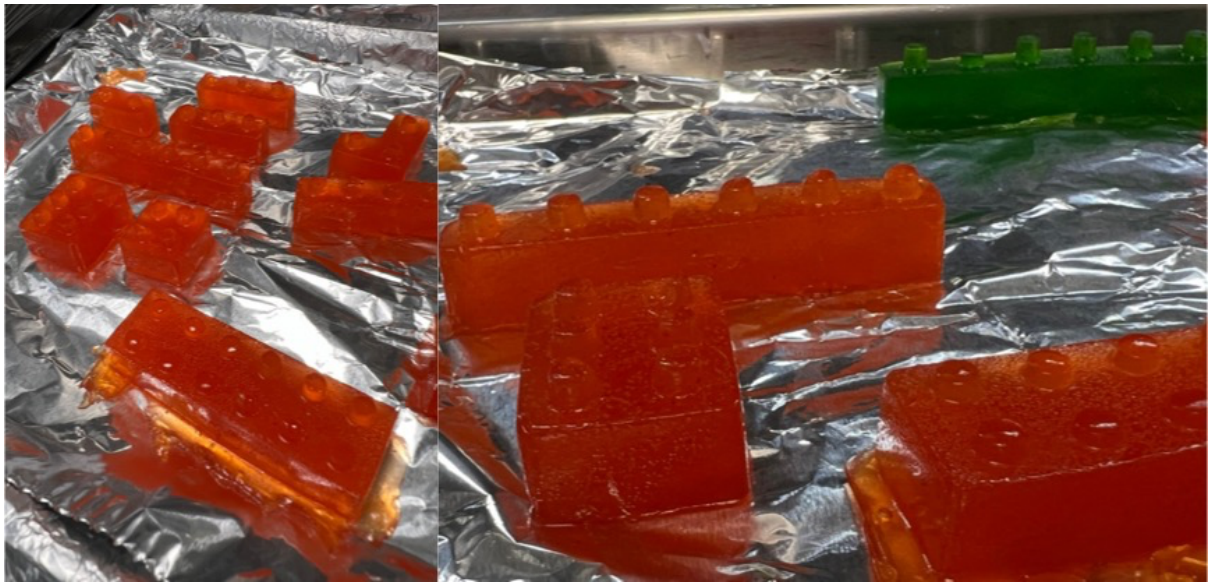


Figure 13. Coated jellies after a few minutes rest. Just a granular appearance on top but no white color from the sugar.

4. Conclusions

a. Repeat the process of coating, this time adding maltodextrin to the powder mix to aid the fluidity and avoid any lumping or caking of the flavor in the mixture.

5. Recommendations for following week

a. Repeat the process, but this time also dilute the color first since it was very difficult to weight the color directly into the pan and putting it into different containers creates losses in the process.

6. Ingredients required for the following 2 weeks

Same ingredients.

Concept for Note-by-Note Cooking

DATE: April 21th, 2023

1. **Weekly Aims and Objectives**
    a. **Aim:** Production of Lego-shaped jellies using fruit powder
    b. **Objectives:**
        a. Make a jelly out of fruit powder and gelling agents
        b. Use different colours to imitate the real Legos
        c. Put a coating on top of the jellies to deliver flavour.

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

	Ingredient	Quantity	Units	%
1	Water	500	g	82.44%
2	SOSA Gelatin Agent	40	g	6.60%
3	Sucrose ($C_{12}H_{22}O_{11}$)	30	g	4.95%
4	Fruit Powder*	30	g	4.95%
5	Citric Acid ($C_6H_8O_7$)	6	g	0.99%
6	Food Coloring**	0.5	g	0.082%
	Total	606.5		100%

	Ingredient	Quantity	Units	%
1	Sucrose ($C_{12}H_{22}O_{11}$)	50	g	59.52%
2	Maltodextrin	30	g	35.71%
3	Water	3	g	3.57%
4	Natural Flavor***	1	g	1.19%
	Total	84		100%

	Fruit Powder*	Food Coloring**	Natural Flavor**
Red Legos	SOSA Strawberry Powder	Cake Decoration Red Color	MSK Strawberry Flavor
Blue Legos	SOSA Fig Powder	Cake Decoration Blue Color	MSK Blueberry Flavor
Yellow Legos	SOSA Mango Powder	Cake Decoration Yellow Color	MSK Mango Flavor
Green Legos	SOSA Apple Powder	Cake Decoration Green Color	MSK Granny Smith Apple Flavor

b. Equipment: Stove, stainless-steel pans, stainless-steel strainers, mason-jars, bowls, scale, spoons and trays.

c. Method:

a. Rehydrate the fruit powders in a saucepan set on low heat with the water.
b. Add 50g of sucrose and citric acid.
c. Add 10g of gelling agent previously hydrated,
d. Mix until all dissolved and then remove from heat.
e. Add into the Lego mold.
f. Let the jellies set at room temperature for a few minutes and then place into the fridge to finish up the gelation.

3. Results and discussion

a. A final sensory evaluation was conducted to understand if there was perceived improvement or not, the results are showing in the graph.

b. Significant improvements are seen in almost all the attributes, just size and general appearance stayed about the same as the first evaluation.

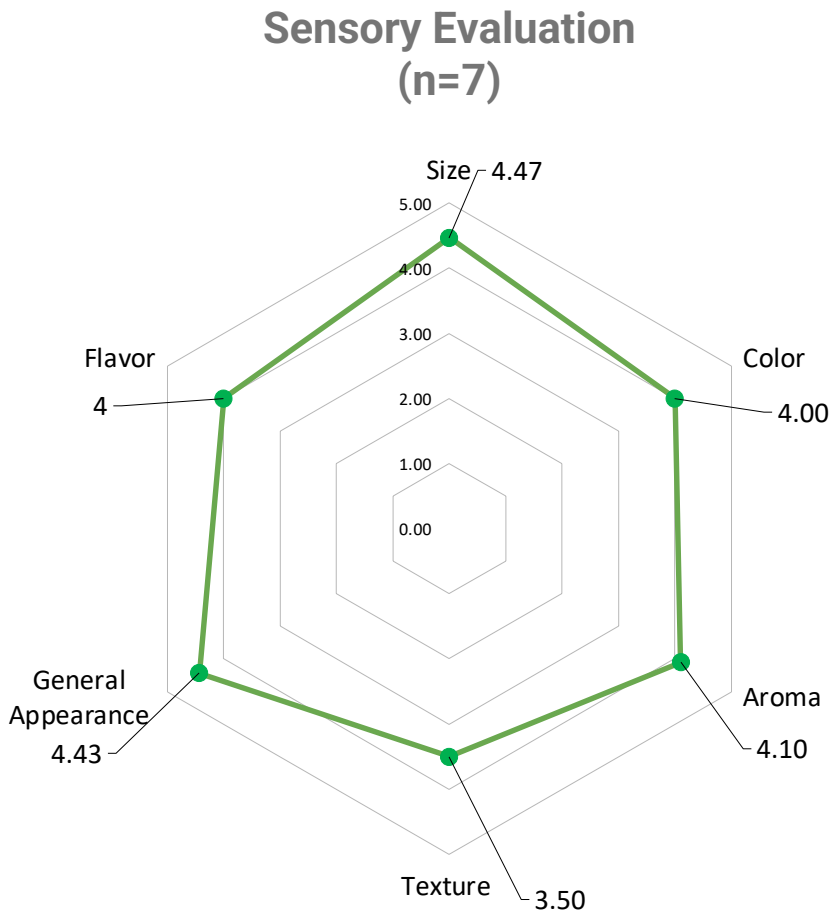


Figure 14. Final Prototype.

4. Conclusions

a. There are still things to work on regarding the texture of the jelly. Further experimentation could be done with other ingredients such as pectin or konjac.
b. The coating of the jelly with sugar is perceived as positive and the flavor is detected.
c. The attractiveness of the dish is good, and the comments are also positive, overall a good prototype.