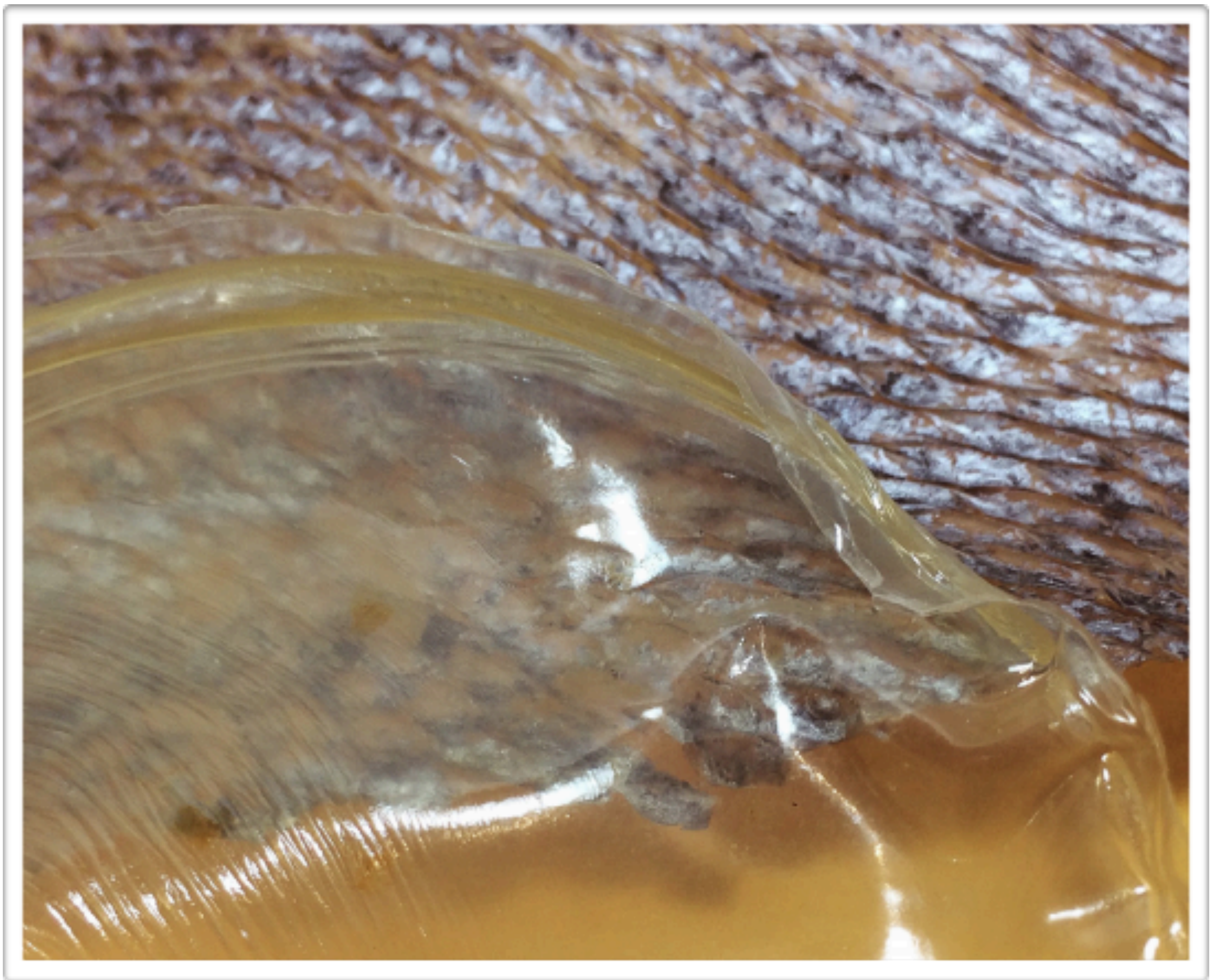


Converting Food Waste into Bioplastics for 3D printing in the North

Final Project Report, Students on Ice Micro-grant

Project team: Alysia Garmulewicz, Andrew Xu, Cassandra Elphinstone

5 July 2019

Cover image: gelatin plastic made from fish skin, LABVA

TO OUR SUPPORTERS:

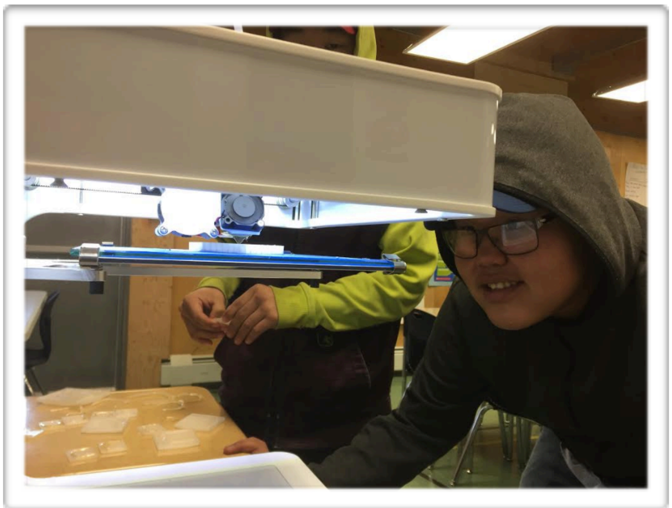
Thank you to Students On Ice and Parks Canada for the support of this project. Thank you to Nathan Curry, project mentor. Thank you also to our collaborators: Kaleb Milne in Hay River, NWT, Roman Mahnic and the students of Kugaaruk school in Nunavut, and LABVA in Valdivia, Chile.

- Alysia Garmulewicz, Andrew Xu, Cassandra Elphinstone

PART I. NARRATIVE REPORT

Project summary and key milestones

The aim of this project was to pilot the development of bioplastics made from food waste in the North, using 3D printing as an enabling technology for creating objects that can substitute for petrochemical plastic products. This required research and experimentation into the process stages of (a) identifying a viable source of food waste for bioplastics, (b) developing extraction techniques and recipes for transforming this waste into a bioplastic, (c) using 3D printing technology to design and print molds for the bioplastic. Each of these stages were completed through the following project phases.



3D printing in Kugaaruk, Nunavut

The first phase of the project involved research into and experimentation with available sources of food waste in Northern communities that can be transformed into bioplastics. Here we identified gelatin as a potential key ingredient. Gelatin can be isolated from the bones and skin of animals, and made into bioplastics that are moldable. In consultation with his students, Roman Mahnic, teacher in the school in Kugaaruk, Nunavut, identified fish skin as a plentiful waste source in the community: an estimated 5,000 Arctic Char are harvested annually, with the skin being disposed of after smoking the fish, and before the fish is consumed. This motivated our research into viable sources and methods of extracting gelatin directly from waste fish skin. This is key given the overall aim of the project is to develop bioplastics from local waste. We collaborated with LABVA, a biomaterials laboratory in Chile to experiment with low-tech ways of extracting gelatin from the skin of fish in the same genus as Arctic Char. We plan to replicate these experiments in Kugaaruk using Arctic Char in the future. Experiments in Chile resulted in successful extraction of a gelatin bioplastic that can be molded (Appendix A).

Glycerin was also identified as a key additive to gelatin plastic recipes, enabling one to make a plastic that is more or less flexible. Glycerin can also be made locally in the North from sources of animal fat. Experimenting with making glycerin in the North is a future project objective.

In the second phase we began experimenting with gelatin bioplastic recipes that can be molded with 3D printed molds. 3D printing can create an endless variety of molds, enabling the user to shape the bioplastic into a range of useful objects. This experimentation was done by Kaleb Milne, a 3D printing entrepreneur in Hay River, NWT (Appendix B). These recipes were then replicated by students in Kugaaruk, Nunavut

(Appendix C). In order to expedite experimentation and get students involved, this stage of the project used store bought gelatin and glycerin.

The third stage of the project involved developing Computer Aided Design (CAD) files for 3D printing molds of Inuktitut syllabic stencils. Roman Mahnic, teacher at the school in Kugaaruk, had identified the need to create syllabic stencils for students to learn to write in Inuktitut. The CAD files were designed by Andrew Xu, and sent to the students in Kugaaruk for 3D printing (Appendix D). The students then 3D printed molds for the stencil, and filled it with the gelatin bioplastic they had made to create a stencil for tracing. While the bioplastic recipe needs to be adjusted to create a more rigid stencil, the students successfully completed each step of the process (Appendix C). To empower the students to design their own molds in 3D software, Andrew Xu made online tutorials for designing Computer Aided Design (CAD) files of an Inuktitut syllabic mold and a bowl mold using Autodesk 360 software, available free for educational uses. These tutorials will be used by students in Kugaaruk in the months ahead (Appendix D).

Design for 3D printed Inuktitut syllabic

Project Objectives

The following states objectives that were met, amended, and are targets for future project steps.

Original objectives met

- Recipe book of bioplastics: see Appendix A and B for recipes developed for gelatin bioplastics.

Objectives met with amendments

- Report of imported plastic products: given our shift in geographic focus away from Cambridge Bay, we instead focused on a report of available sources of waste for making gelatin bioplastics in the community of Kugaaruk. Here we focused on available fish waste: the skin of harvested and smoked Arctic Char.
- Development of customized 3D printer: we had to revise this objective given our original aim was to modify one of the 3D printers at CHARS. Instead, we decided to support the school in Kugaaruk in purchasing a 3D printer that enabled them to 3D print molds for bioplastics instead of 3D printing the bioplastic directly. In parallel, we experimented with 3D printing gelatin directly using a modified extrusion process (see Appendix E); however, we found that a custom extruder with a heated print head was necessary, requiring more time than the project allowed.
- Engage the community: due to the move away from Cambridge Bay, we focused instead on engaging the students in Kugaaruk school. We focused on (a) providing 3D printable designs to the students of Kugaaruk for making Inuktitut syllabic molds, and (b) providing design tutorials for 3D printing software that

will enable the students to design their own objects for 3D printing.

Objectives planned to be met in future project steps

- Organize a community workshop: we plan to work with the school in Kugaaruk to set up a workshop with the wider community, either in Kugaaruk or Cambridge Bay to share the project.
- Develop a customized 3D printer: we plan to create a modified 3D printer for printing gelatin plastic directly in the next phase of the project.
- Set up the knowledge and technical capabilities necessary for having 3D printing technology available for the community of Cambridge Bay: we plan to work with the school in Kugaaruk to create a toolkit that can be used by future students and other schools in the North, including in Cambridge Bay.

Materials Produced

Material produced	Contributors	Contribution to project aims
Fish gelatin extraction methods (Appendix A)	Laboratorio de Biomateriales Valdivia, Chile	Developed viable methods of extracting gelatin from waste fish skin for making bioplastic.
Gelatin bioplastic recipes (Appendix B)	Kaleb Milne, Hay River NWT, Canada	Development of viable bioplastic recipes for molding objects using 3D printed molds. Used by students in Kugaaruk for stencil making.
Bioplastic experimentation with recipes developed by Kaleb Milne (Appendix C)	Kugaaruk School, Nunavut, Canada	Students experimented with making gelatin bioplastics using supplies bought by the project.
3D printed molds of Inuktitut syllabics (Appendix C)	Kugaaruk School, Nunavut, Canada	Students printed molds using their 3D printer that can be used to mold gelatin bioplastic (purchase of 3D printer supported by the project)
3D printable Computer Aided Design (CAD) files of Inuktitut syllabics (Appendix D)	Andrew Xu, Project team	Files used to make printable molds by students in Kugaaruk
Tutorials for designing Computer Aided Design (CAD) files of Inuktitut syllabic mold and bowl mold using Autodesk 360 software (Appendix D)	Andrew Xu, Project team	Enables students to design their own 3D files that can be printed, thus empowering students to make their own 3D printable molds
3D printed gelatin experiments (Appendix E)	Andrew Xu, Project team	Experimentation on the viability of 3D printing gelatin bioplastics

Unexpected Events and Challenges

Our initial intention was to develop the project in Cambridge Bay, in close collaboration with CHARS. Our project was delayed for 6 months after receiving notification that the 3D printing lab at CHARS was delayed. When this was delayed even further, we decided to alter our project focus, and instead work with a local 3D printing entrepreneur, Kaleb Milne in Hay River, NWT, and a school in Kugaaruk who were interested in purchasing a 3D printer and collaborating on our project.

We had also been intending to work with CHARS with their available laboratory and kitchen space for processing ingredients for making bioplastics. Given our lack of access to a viable place for experimentation, we had to find an alternative. We collaborated with a biomaterial lab in Chile in order to carry out experimentation of extracting gelatin from waste fish skin. Due to the time delay of the project, we were not able to experiment with other food waste sources.

In working with the school in Kugaaruk, we have had to be responsive to the availability of students who go onto the land in the summer months. This created a project delay during the summer months.

Reflection on improvements to increase project effectiveness

The project effectiveness could have been improved by greater attention to team development at the beginning of the project. We had a couple of key mentors and contributors who were not able to maintain support of the project, leading to unforeseen delays and changes in the project plan. If more attention had been given to building a larger team with more capacity at the beginning of the project, this may have been avoided.

Impact of the project

12 students (grade 9) were involved in the project from Kugaaruk school. During the next steps of the project, our aim is to share our work more broadly in the North, and engage students and community members in Cambridge Bay and Kugaaruk.

Project next steps

The next steps of our project are planned as follows:

3D design

- Mentor students in using the 3D design tutorials created by Andrew Xu, so that students can design and print their own molds for making Inuktitut syllabics, as well as functional objects such as a bioplastic bowl.

- Create a purpose-built 3D printer for printing gelatin plastics directly into useful objects. Initial research suggests adapting chocolate 3D printer designs for this purpose[1].

Local material development

- Help students develop a better gelatin bioplastic recipe that is more rigid and better for molding syllabics (current recipe was not rigid enough) using current stock of store bought gelatin.
- Work with Kugaaruk students in their sourcing of fish skin for making bioplastic. Fish skin is usually discarded after fish is smoked and eaten, making it a viable waste source.
- Work with Kugaaruk students to make bioplastics from fish skin waste that can be molded in 3D printed molds.
- Identify collaborators in Kugaaruk or Cambridge Bay to prototype making glycerin from animal fat, an ingredient additive that alters the flexibility of gelatin bioplastic.

Community engagement

- Research other uses of fish skin in the community, including historical and current uses that may compete with the use of fish skin for bioplastics. In collaboration with community members in Kugaaruk and Cambridge Bay, and local stakeholders such as Kitikmeot Foods Ltd., the Cambridge Bay fish processing plant, research the viability of developing a reliable source of fish skin for gelatin plastics in the North.
- Develop a knowledge sharing workshop with the wider community, either in Kugaaruk or Cambridge Bay to gather feedback on the project, and disseminate the knowledge of the project more widely.

[1] See example designs: https://www.open-electronics.org/syringe-heater-for-3drag-chocolate-printer/; https://www.instructables.com/id/Chocolate-Extruder-for-Ultimaker/

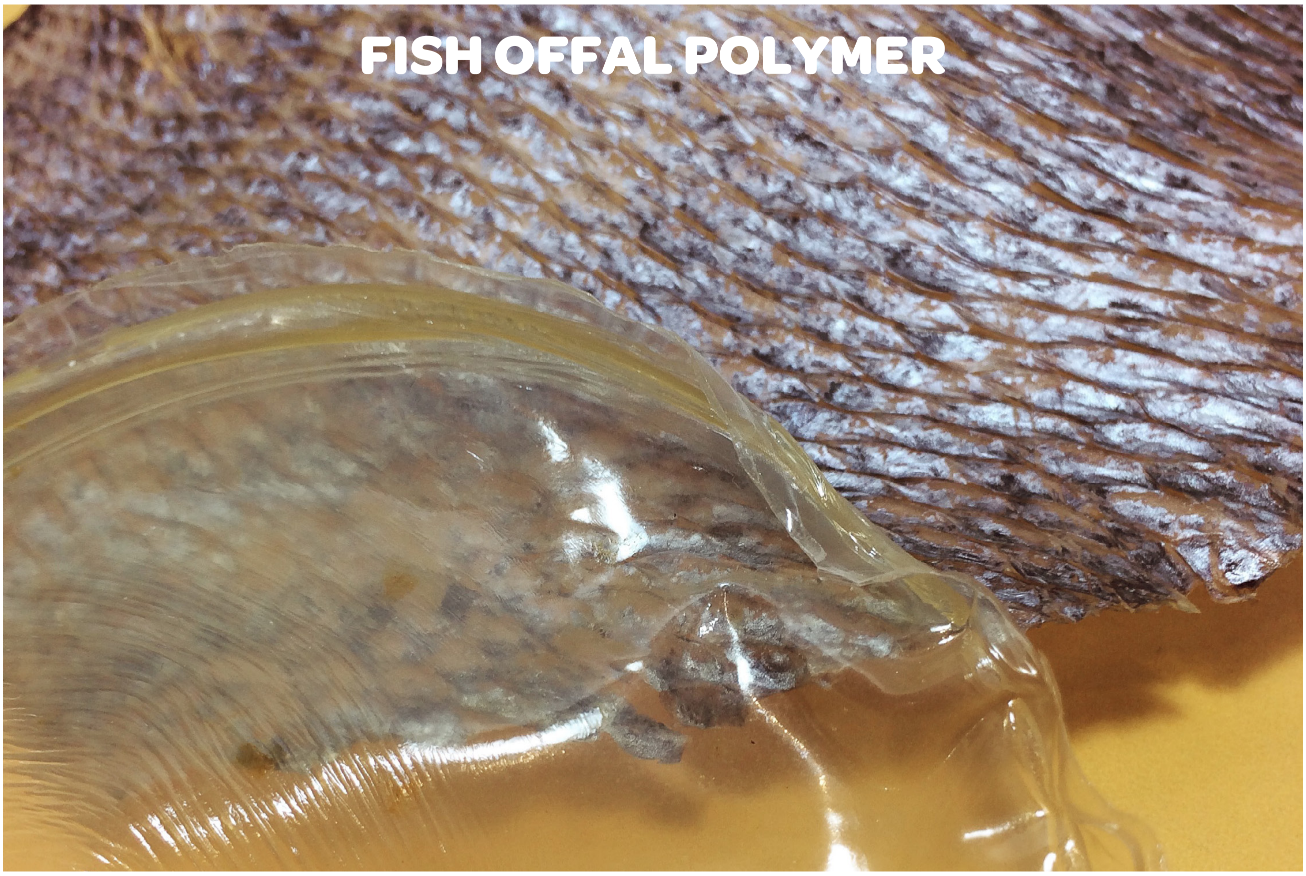
PART II: FINANCIAL REPORT

Expense Item/Description	Proposed amount (submitted in original proposal)	Actual amount (amount spent on this item)	Difference in amounts
3D printer	$3,000	$1,000	-$2,000
Material processing	$200	$251.99	$51.99
Costs of material collection	$1,000 (in-kind)	$0.00	$0.00
Design Challenge: community engagement workshop	$800	$0.00	-$800
Space for experimental work	$1,000 (in-kind)	$1,000 (in-kind)	$0.00
Travel expenses for team	$1,000	$0.00	-$1,000
Material costs Hay River	$0.00	$241.51	$241.51
Material and experimentation costs, Valdivia, Chile	$0.00	$1,000	$1,000
Interim grant total	**$5,000**	**$2,593.41**	**$2,406.59**
Interim in-kind total	**$2,000**	**$1,000**	**$1,000**
INTERIM PROJECT TOTAL	**$7,000**	**$3,593.41**	**$3,406.59**

Expense Item/Description	Proposed amount (submitted in original proposal)	Actual amount (amount spent on this item)	Difference in amounts
Custom 3D printer for gelatin plastic	$1,000		
Community workshop	$406.59		
Materials and processing tools for Kugaaruk	$1,000		
REMAINING PROJECT BUDGET TOTAL	**$2,406.59**		

APPENDIX A: FISH GELATIN EXTRACTION

By LABVA, Valdivia, Chile



This report resumes the experimentation to obtain different qualities and quantities of gelatin from fish offal, specifically Brama Australis (Reineta), a species abundant in Valdivia, and Oncorhynchus kisutch (Salmon) a family that's also present and available in the Artic sea. We reviewed different papers, resumed the procedures and then replaced some steps or ingredients in order to define a simple and artisanal way to extract fish polymer susceptible for biofabrication.

Client: Alysia Garmulewicz
Research: Extraction of fish offal polymer for biofabrication, Brama Australis and Oncorhynchus kisutch.
Researcher: María José Besoain (LABVA), Valdivia, Chile.
Date: May 2019.

PAPERS / REFERENCES

Herpandi , N. Huda and F. Adzitey, 2011. Fish Bone and Scale as a Potential Source of Halal Gelatin. Journal of Fisheries and Aquatic Science, 6: 379-389.

Abstract.
Fish gelatin is an important alternative gelatin which can be considered as Halal and acceptable by all religions. It is made from fish by-products of which fish skin is the most widely used part. The collagen and gelatin-like property of fish bones and scales coupled with their readily availability make it a potential source for development into gelatin products. This review discusses the potentials for the development and utilization of fish bones and scales in the production of gelatins. It also looks at the raw materials, processes, properties and the improvement of fish gelatins for future commercial use.

PROCEDURE a.
GELATIN FROM FISH BONES AND SCALES

Demineralization Treatment needed after the removal of non colagenous material prior to acid. It takes longer than acid treatment on skins

1. Removal of non collagenous material through salting NaCl.
2. Swelling Step low alkaline concentration 0.1-0.9% at 30^{0}C for 1-5 hr to process scales / 0.1 NaOH (Try CaCO3) in 1:8 (w/v) sample/alkali solution stirred for 6 hr.
3. Defatting step for bones w/ Butil Alcohol or Detergent.
4. Demineralization 3% HCl at ambient temperature 9-12 days.
5. Protease Enzyme at neutral PH and 20^{0}C-40^{0}C for 1-12 hr (High in Protease Pineapple, Papaya, Kiwi).

PROCEDURE b.
GELATIN FROM FISH SKIN

Breakage of cross-links and non covalent bonds of collagen can be done by THERMAL TREATMENT (HEATING AND AUTOCLAVING), ACIDIC OR ALKALINE PRETREATMENT or ENZYMATIC PRETREATMENT (Acid treated Collagen Type A gelatin)

1. Clean and Prepare the fish skin.
2. Swelling Step. Leave the fish skin in a low concentration of acid or alkali solution 1-5 hr. Could be different concentrations of Acetic Acid (1,2,3 and 4%).
3. Aqueous Extraction.
4. Gentle and Mild heating T^{0} 50^{0}C-90^{0}C for 1-6 hrs.
5. Separate Evaporate and Freeze Dry.

Ilona Kolodziejska, Elzbieta Skierka, Maria Sadowska, Wiktor Kolodziejski, Celina Niecikowska, 2007. Effect of extracting time and temperature on yield of gelatin from different fish offal. Food Chemistry 107 (2008) 700–706.

Abstract.

The aim of the study was to determine the optimal conditions for preparing gelatin from different kinds of fish offal: heads and back-bones of Baltic cod, skins of fresh and cold-smoked salmon, and skins of salted and marinated herrings. The yield of gelatin extraction at 45^{o}C was 71–75% for fresh salmon skins or cod backbones, and 86%, for smoked salmon skins. When heating marinated herring skinsfor 15 min or salted herring skins for 45 min, about 100% of collagen was converted to gelatin. For fish skins, 45^{o}C and 15–60 min. extraction time, depending on the kind of skins, were established as optimal conditions for preparing gelatin. The yield of gelatin extraction from the cod heads did not exceed 70%, even when a three stages process was used. In the case of backbones, 100% of collagen in theform of gelatin was isolated using this procedure. SDS-PAGE analysis showed that gelatin from fish skins was much less degraded than gelatin from pigskins.

Conclusions

The skins of semi-processed fish can be a valuable source of gelatin. The most suitable for this purpose are the skins of smoked salmon. This raw material is rich in collagen. Moreover, the collagen in skins after smoking of fish is still susceptible to thermal denaturation. Similarly to fresh salmon skins, about 80% of collagen contained in smoked salmon skins is converted to soluble gelatin after heating of raw material for 60 min at 45^{o}C. The obtained gelatin is less degraded than gelatins from skins of marinatedand salted herrings and its gelling temperature is alsohigher. On the other hand, collagen from herring skins iscompletely solubilised in these conditions. The yield ofextraction of gelatin from smoked salmon skins can be increased to almost 100% at 100 C. However, as a result of higher degradation of the main components of collagen, the gelling temperature of the obtained gelatin was lower than that from the process conducted at lower temperature. Heads and backbones can also be used as sources of gelatin. About 70% and 100% of gelatin were obtained, respectively, from cod heads and backbones in a three stage extraction procedure.

PROCEDURE

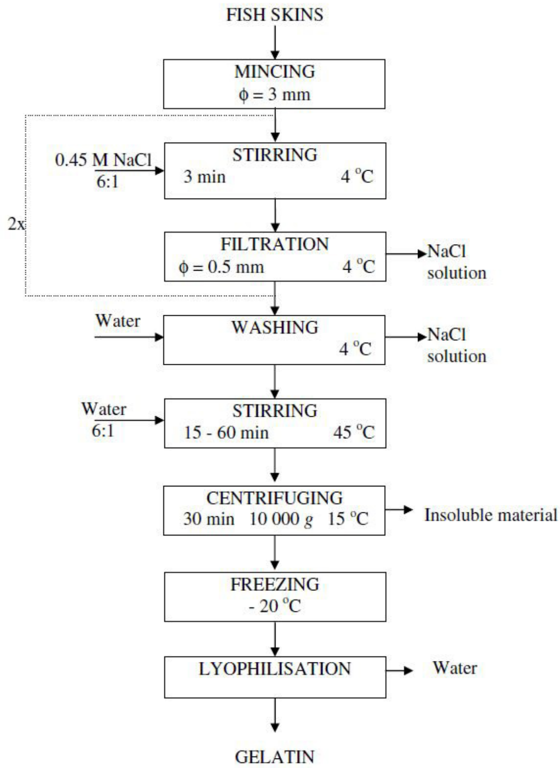


Fig. 1. Flowchart of the procedure used for extraction of gelatin from fish skins.

Koli, J & Basu, S & Gudipati, Venkateshwarlu & Chouksey, M.K. & Nayak, Binaya. (2013). Optimization of fish gelatin extraction from skins and bones: A comparative study. Ecology, Environment and Conservation. 19. 47-56.

Abstract.

Various reported methods for use in the extraction of fish gelatin from skins and bones were evaluated. Ten different methods were compared in order to select the most suitable method for the extraction of gelatin from the skins and bones of tiger toothed croaker (Oolithes ruber) and pink perch (Nemipterus japonicus). The method by Gudmundsson and Hafesteinsson (1997) was selected and further optimized based on gelatin yield and gel strength. The revised extraction process utilizes sodium hydroxide (0.20%), sulphuric acid (0.20%), and citric acid (1.0%) for pre-treatment of raw materials at a skin bone to water ratio of 1:7 for 40 minutes. The gelatin extraction was performed at 45^{0}C for 18h at a skin/bone to distilled water ratio of 1:3 followed by drying at 70^{0}C for 18h. The revised method as shown to increase yield and gel strength compa-rable to previous method described.

PROCEDURE

METHOD OF GUDMUNDSSON AND HAFSTEINSSON (1997).

The procedure described by Gudmundsson and Hafsteinsson (1997) originally used for extracting gelatin from the Cod skins (Gadus morhua). Following this method the skins & bones of TTC and PP were used for extraction of gelatin. Thawed skins & bones were thoroughly cleaned and rinsed with excess water to remove superfluous material and treated by soaking with 0.2 % (w/v) sodium hydroxide solution for 40 min. Then they were soaked with 0.2 % (w/v) sulphuric acid for 40 min. This was followed by soaking with 1.0 % (w/v) citric acid.
After each soaking treatment, the skins & bones were washed under running tap water until they had a pH of about 7. Each soaking and washing treatment was repeated three times with a total time of 2 h for each treatment. The ratio of skin to washing liquid used was 1 kg skin (wet weight) to 7 l of acid or alkali solution for each treatment. The skins were then subjected to a final wash with distilled water to remove any residual matter. The final extraction was carried out in distilled water at controlled temperature within the range of 45^{0}C for 12 h. The ratio used was 1 kg (weight of wet skin) to 3 L of distilled water. The clear extract obtained was filtered in a Buchner funnel with a Whatman filter paper (no. 1), followed by vacuum oven drying and made powder by pestle and mortar and packed in air tight container.

https://www.leaf.tv/articles/how-to-make-gelatin-from-animal-bones/

PROCEDURE
GELATIN FROM ANIMAL BONES

1. "Blanch" the bones by boiling them for five minutes, then changing the water and starting over.
2. Place bones with twice their weight of cold water and also try to keep them covered. Bring the pot to a simmer.
3. Skim off regularly as the proteins will rise to the surface.
4. Simmer 6-8 hours, refill w/ water keeping bones covered.
5. Remove the bones from the pot, and strain the liquid through several layers of cheesecloth to remove any solids. Skim off any fat that might be floating on the surface.
6. Return the liquid to the stovetop in a clean pot, and cook it at a low boil until it has reduced by half. Transfer to a smaller pot, and reduce by half again. Repeat twice more, until the quantity of liquid is 1/16th of its original volume.
7. Dehydrate

EXPERIMENTATIONS

Brama Australis (Ba)

The skin is retrieved at Valdivia's Fluvial market. While this fish geographic distribution considers the area between Bío Bío Region and Magallanes, it has an abundance peak between 41º S and 47º.5S with center at 43ºS Lat. (Galleguillos, 2015).
We chose this specie to start the experimentation because it's easy to find and also because they sell the fish without skin, so the skin is an abundant raw residue around the area.

Materials:
- Salt
- Vinegar
- Lemon
- Sodium Bicarbonate
- Calcium Carbonate
- Water
- Scissors
- Knife
- Bowls and Lids
- Strainer
- Coffee filter
- Pressure Cooker
- Dehydrator
- Molds
- Spatula

The experiments started freezing the skins to preserve them until we could start the experiment.

PROCEDURE 01
Skin + Scales Weight: 50 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Salting process: Put 250ml water + 25g salt in a bowl, stir until it dissolves. Put the skin and leave it soaking for 24 hrs at room temperature.
4. Clean under tap water.
5. Put the skin and 500ml of water in a pressure cooker for 30 min.
6. Once finished wait till it cools down.
7. Remove the skin and strain the liquid through a coffee filter and put in molds.
8. Dehydrate for 24 hrs, 41ºC.

YIELD: 7.1 g
RATIO: 0.142

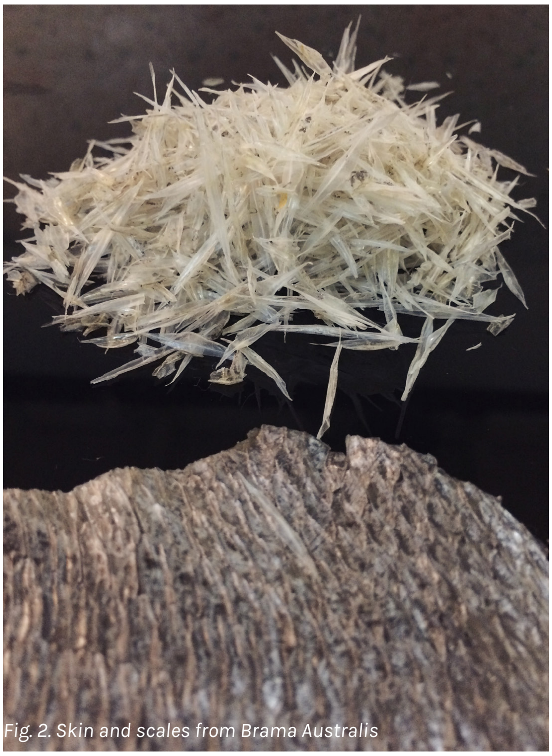


Fig. 2. Skin and scales from Brama Australis

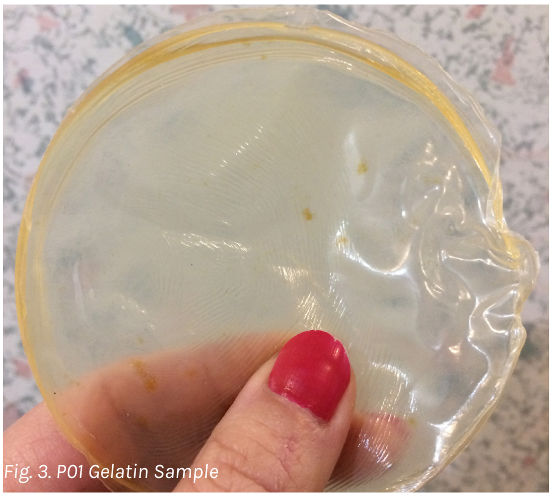


Fig. 3. P01 Gelatin Sample

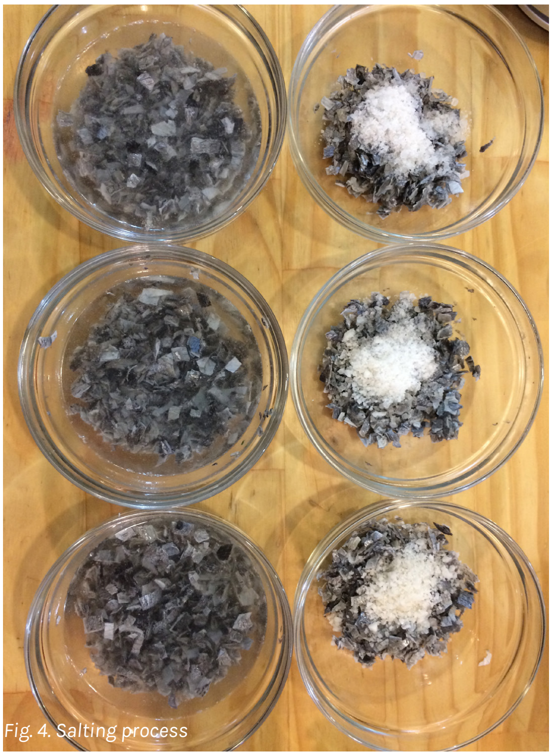


Fig. 4. Salting process

PROCEDURE 02
Skin + Scales Weight: 32 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Cut in 5mm squares.
4. Salting process: Put 150ml water + 15g salt in a bowl, stir until it dissolves. Put the skin and leave it soaking for 24 hrs.
5. Strain under tap water.
6. Acid swelling process: Put the skin in a 0.6 ml vinegar + 100 ml tap water solution. Leave it for 5 hr room temperature.
7. Strain under tap water.
8. Put the skin in a bowl with 100ml of tap water and a lid and heat at 70ºC for 6 hours in the dehydrator.
9. Strain the liquid through a coffee filter and put in molds.
10. Dehydrate for 12 hrs, 41ºC.

YIELD: 3.4 g
RATIO: 0.106

PROCEDURE 03
Skin + Scales Weight: 32 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Cut in 5mm squares.
4. Salting process: Put 150ml water + 15g salt in a bowl, stir until it dissolves. Put the skin and leave it soaking for 24 hrs.
5. Strain under tap water.
6. Acid swelling process: Put the skin in a 0.4 ml vinegar + 100 ml tap water solution. Leave it for 5 hr room temperature.
7. Strain under tap water.
8. Put the skin in a bowl with 100ml of tap water and a lid and heat at 70ºC for 6 hours in the dehydrator.
9. Strain the liquid through a coffee filter and put in molds.
10. Dehydrate for 12 hrs, 41ºC.

YIELD: 3.3 g
RATIO: 0.103

PROCEDURE 04
Skin + Scales Weight: 32 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Cut in 5mm squares.
4. Salting process: Put 150ml water + 15g salt in a bowl, stir until it dissolves. Put the skin and leave it soaking for 24 hrs.
5. Strain under tap water.
6. Acid swelling process: Put the skin in a 1ml lemon juice + 100 ml tap water solution. Leave it for 5 hr room temperature.
7. Strain under tap water.
8. Put the skin in a bowl with 100ml of tap water and a lid and heat at 70ºC for 6 hours in the dehydrator.
9. Strain the liquid through a coffee filter and put in molds.
10. Dehydrate for 12 hrs, 41ºC.

YIELD: 2.7 g
RATIO: 0.084

PROCEDURE 05
Skin + Scales Weight: 32 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Cut in 5mm squares.
4. Salting process: Put 150ml water + 15g salt in a bowl, stir until it dissolves. Put the skin and leave it soaking for 24 hrs.
5. Strain under tap water.
6. Alkaline swelling process: Put the skin in a 5 g Sodium Bicarbonate + 100 ml tap water solution.
7. Heat at 30ºC for 5 hr.
8. Strain under tap water.
9. Put the skin in a bowl with 100ml of tap water and a lid and heat at 70ºC for 6 hours in the dehydrator.
10. Strain the liquid through a coffee filter and put in molds.
11. Dehydrate for 12 hrs, 41ºC.

YIELD: 3.2 g
RATIO: 0.1

PROCEDURE 06
Skin + Scales Weight: 32 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Cut in 5mm squares.
4. Salting process: Put 150ml water + 15g salt in a bowl, stir until it dissolves. Put the skin and leave it soaking for 24 hrs.
5. Strain under tap water.
6. Alkaline swelling process: Put the skin in a 0.25 g Calcium Carbonate + 100 ml tap water solution. Leave it for 1-5 hr room temperature.
7. Strain under tap water.
8. Put the skin in a bowl with 100ml of tap water and a lid and heat at 70ºC for 6 hours in the dehydrator.
9. Strain the liquid through a coffee filter and put in molds.
10. Dehydrate for 12 hrs, 41ºC.

YIELD: 3.2 g
RATIO: 0.1

PROCEDURE 07
Skin + Scales Weight: 50 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Put the skin on a pan with 400 ml water and 4.5g Sodium Bicarbonate.
4. Heat on the stove for 15 min until the skin dissolves.
5. With the help of a spatula press through a strainer leaving only the scales in the strainer.
6. Separate and save the scales.
7. Cool down in the fridge to allow the oil phase separate from the rest.
8. With a spoon remove the oily phase.
9. Put in molds.
10. Dehydrate for 24 hrs, 41ºC.

YIELD: 9 g
RATIO: 0.18

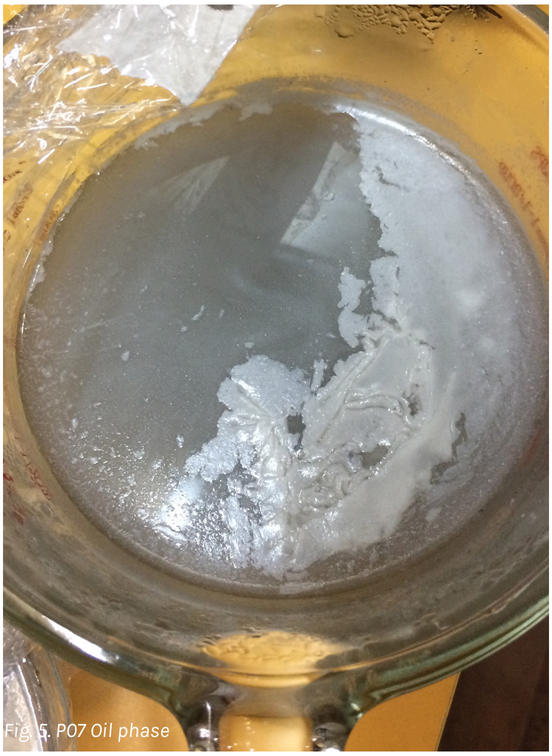


Fig. 5. P07 Oil phase

Fig. 6. P07 Result

PROCEDURE 08

Skin + Scales Weight: 25 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Alkaline Heating: Put the skin in a 0.2 g Calcium Carbonate + 200 ml tap water solution.
4. Heat at 70ºC for 3 hours.
5. Strain the liquid through a coffee filter and put in molds.
6. Dehydrate for 12 hrs, 41ºC.

YIELD: 1.1 g
RATIO: 0.044

P01 BIOPLASTIC
Ingredients
- 1.6 g Gelatin
- 0.6 ml Glicerine
- 40 ml water

Mix with boiling water to melt the gelatin and add the glicerine. Put on the stove and heat just until it boils. Put in a mold and dehydrate.

Result: Very stiky surface that doesn't dry. Glue like material. The gelatin appears to have less strenght and quality than the other samples.

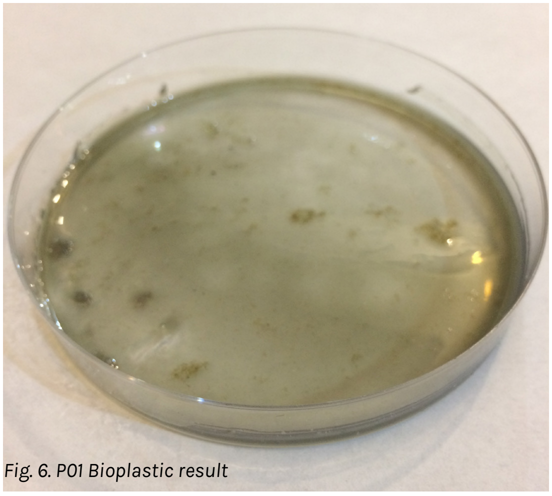


Fig. 6. P01 Bioplastic result

CONCLUSIONS

We can't draw any final conclusions because we need to perfect the procedures. These were planned based on the references in this report but also translating them in an easy and artisanal way in order to make it possible for anyone to extract these polymers. This translation was mainly intuitive and depending on LABVA's experience with other materials.
In the case of Brama australis the one that has the most potencial P07 was a mistake. This mistake ended up in a really easy way of liquifying the skin and making a skin biocomposite. It works with Ba but it didn't with Ok.

EXPERIMENTATIONS

Oncorhynchus kisutch (Ok)

The skin is retrieved at Valdivia's Fluvial market. This fish is an introduced specie that it's cultivated in the area between Araucanía Region and Magallanes. While it's semingly easy to find this fish is sold with it's skin so it's not easy to retrieve raw samples.

Materials:
- Salt
- Vinegar
- Sodium Bicarbonate
- Calcium Carbonate
- Water
- Knife
- Bowls and Lids
- Strainer
- Coffee filter
- Pressure Cooker
- Dehydrator
- Molds
- Spatula
- Syringe

The experiments started freezing the skins to preserve them until we could start the experiment.

STARTING PROCEDURE FOR THE 4 SAMPLES
Skin + Scales Weight: 192 gr.

1. Defrost the skin.
2. Clean under tap water and remove leftover meat
3. Salting process: Put 960 ml water + 96 g salt in a bowl, stir until it dissolves. Put the skin and leave it soaking for 24 hrs at room temperature.
4. Clean under tap water.


Fig. 7. Salting process

PROCEDURE 01
Skin + Scales Weight: 49.3 gr.

1. Put the skin and 500ml of water in a pressure cooker for 30 min.
2. Once finished wait till it cools down.
3. Remove the skin and strain the liquid through a coffee filter and put in molds.
4. Dehydrate for 24 hrs, 41°C.

YIELD: 13.4 g
RATIO: 0.271

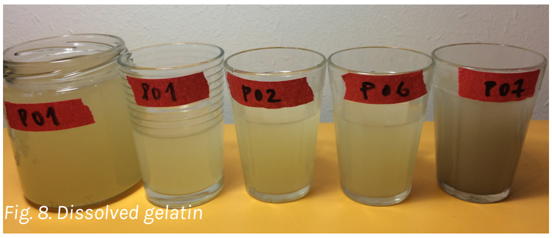


Fig. 8. Dissolved gelatin


Fig. 9. P01 Cooling down

PROCEDURE 02

Skin + Scales Weight: 46.4 gr.

1. Acid swelling process: Put the skin in a 0.8 ml vinager + 145 ml tap water solution. Leave it for 5 hr room temperature.
2. Strain under tap water.
3. Put the skin in a bowl with 100ml of tap water and a lid and heat at 70ºC for 6 hours in the dehydrator.
4. Strain the liquid through a coffee filter
5. With a syringe remove the liquid phase leaving the oily phase in the bowl.
6. Put in molds.
7. Dehydrate for 12 hrs, 41ºC.

YIELD: 5.3 g
RATIO: 0.114


Fig. 10 . P01 Straining liquid

PROCEDURE 06

Skin + Scales Weight: 37.1 gr.

1. Alkaline swelling process: Put the skin in a 0.29 gr $CaCO_3$ + 290 ml tap water solution. Leave it for 5 hr room temperature.
2. Strain under tap water.
3. Put the skin in a bowl with 100ml of tap water and a lid and heat at 70ºC for 6 hours in the dehydrator.
4. Strain the liquid through a coffee filter.
5. With a syringe remove the liquid phase leaving the oily phase in the bowl.
6. Put in molds.
7. Dehydrate for 12 hrs, 41ºC.

YIELD: 5.2 g
RATIO: 0.14

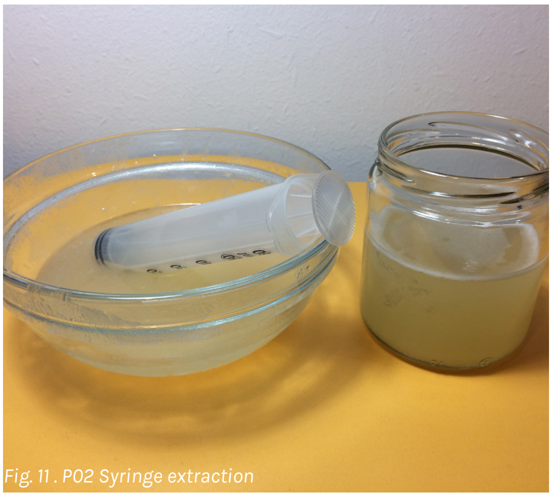


Fig. 11 . P02 Syringe extraction

Fig. 12 . P07 Coagulation

PROCEDURE 07

Skin + Scales Weight: 59.2 gr.

1. Put the skin on a pan with 232 ml water and 2.6 g Sodium Bicarbonate. (*There was a mistake while weighting the skin so the proportions were made for 29 g. of skin, and not for the real weight 59.2*)
2. Heat on the stove for 15 min until the skin dissolves. (*It didn't dissolved, not sure if it was because of the Sodium Bicarbonate proportion or because the skin is defferent)*
3. With the help of a spatula press through a strainer leaving only the scales in the strainer. (*Little scales came out and the skin didn't go through easily as the Brama australis).*
4. Cool down in the fridge to allow the oil phase separate from the rest. (*It coagulated and the phases didn't separate so we put it on a bowl with boiling water)*
5. Strain the liquid through a coffee filter.
6. With a syringe remove the liquid phase leaving the oily phase in the bowl.
7. Put in molds.
8. Dehydrate for 24 hrs, 41ºC.

YIELD: 6.8 g
RATIO: 0.115

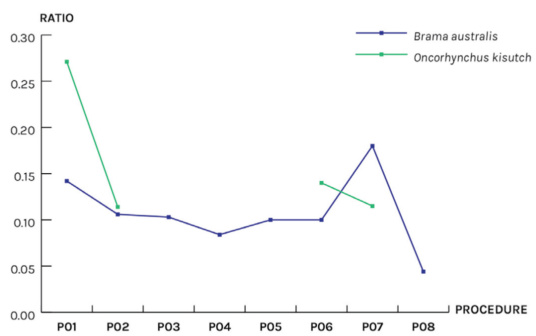


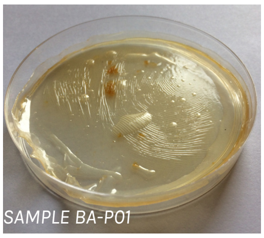
Fig. 13 . Ratio comparison

CONCLUSIONS

We took the most interesting results on Brama australis and repeated the procedures for Oncorhynchus kisutch. P01 procedure results in a less quality gelatin because the temperature of extraction is too high (over 100ºC) but it is an easy way of extracting glue like gelatin. P02 and P06 are the best results in quality and strenght. P07 didn't work as well as it did with Brama australis because the skin didn't liquify. It was another attempt of extracting gelatin with high temperature, and in that case the best are P02 and P06. We can't draw any conclusions between alkaline or acid extraction but for most of the procedures Ok yields more than Ba.

SAMPLES APPENDIX

Brama Australis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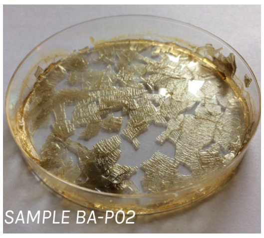
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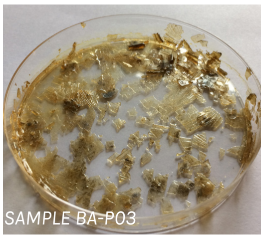
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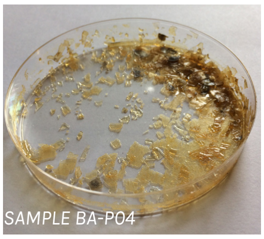
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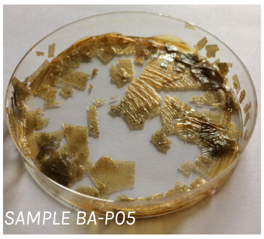
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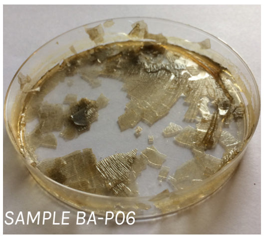
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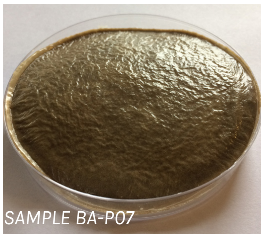
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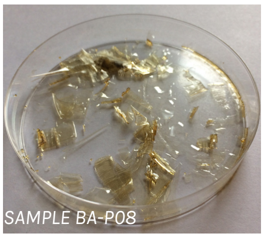
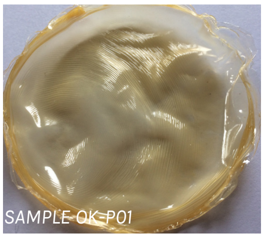
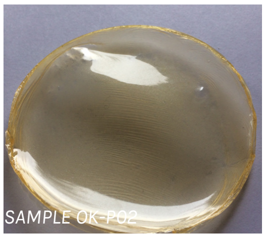

SAMPLE BA-P08

Oncorhynchus kisutch


SAMPLE OK-P01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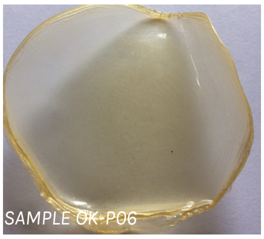
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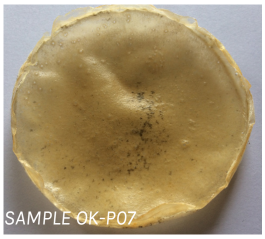
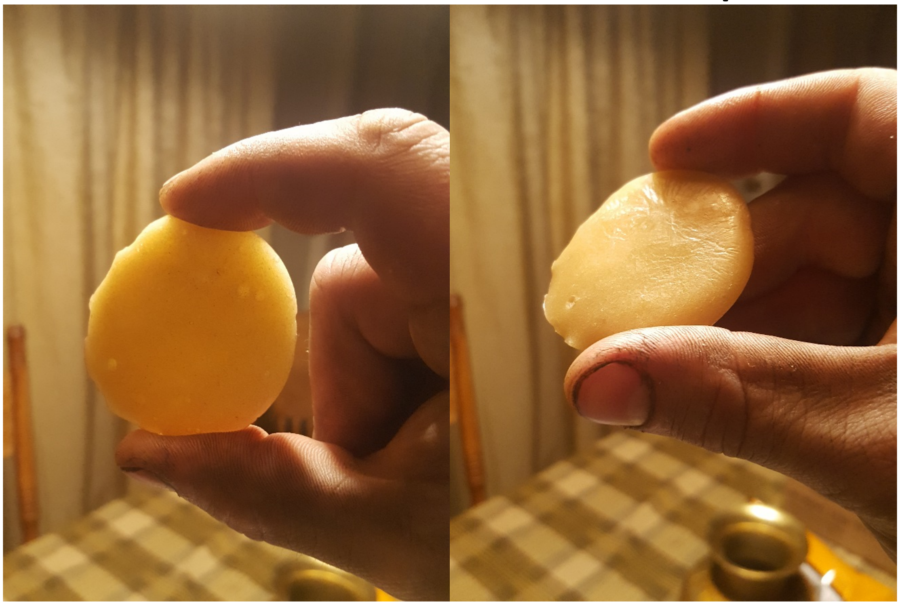

SAMPLE OK-P07

LABVA
LABORATORIO
BIOMATERIALES
VALDIVIA

APPENDIX B: GELATIN PLASTIC RECIPES

By Kaleb Milne, Hay River, NWT, Canada

Hard Reusable Gelatin Plastic Recipe



Ingredients: 50g of water
100g of gelatin

Step 1: Using a double boiling system as a heat source, slowly add layered amounts of water and gelatin powder into the heated vessel.

Step 2: Wait while the gelatin hydrates from the water and slowly melts under the heat. You should see the liquid gelatin pool around the edges of the apparent mound of dry powder.

Step 3: Using a fine tool, such as fork, gently turn and fold the semi molten sections of gelatin into the dryer sections. It will appear very un-mixed at first but after about 5 minutes the gelatin mixture will continue to break down into a plastic like semi liquid.

Step 4: Using forks, attempt to break down the solid blobs that remain in the solution to aid in the melt. You will know when the mixture is complete when it looks like this;

Step 5: (CAUTION! This mixture is extremely sticky when melted and is very hot, be sure to use protective gloves when handling it.)
Remove the vessel from the heat source and, while using a spatula or other tool, carefully coax the mixture into the desired vessel or quickly around the desired object and wait for it to cool.

Step 6: place all the utensils that have the contacted mixture on them in water and allow to soak, or alternately rinse them in hot water in order to clean them.

Flexible reusable gelatin rubber recipe.

Ingredients: 2 cups(450g) of hot water
4 oz(114g) of gelatin powder
12oz(340g) of glycerin syrup

Directions:

Step 1: Fill any vessel of your choice with water and bring it to boil

Step 2: In a cooking pot measure out the gelatin powder and the glycerin syrup and stir together thoroughly as to avoid dry patches of gelatin, the glycerin will naturally soak into the gelatin.

Step 3: Measure out 2 cups of hot water and gradually add it to the pot containing the glycerin/gelatin mix. Apply low heat on the pot if necessary but do not boil the mixture.

Step 4: Continue to patiently stir the mixture until it appears uniform with no lumps, then allow it to rest so the air bubbles have time to rise to the top.

Step 5: Pour the mixture into the desired container or around the desired object SECURELY FASTENED within the container and allow to cool. The mixture is freeze-proof and can be cooled off in a freezer and remain pliable.

Step 6: Soak all utensils in water or rinse with hot water in order to clean them.

APPENDIX C: 3D PRINTING AND BIOPLASTIC MAKING

By Roman Mahnic, Kugaaruk School, Nunavut, Canada

Project Summary Report

April, 2019

School: Kugaaruk School in Kugaaruk, Nunavut

Teacher: Roman Mahnic

Students involved: 12 students grade 9

Inuit Community in Canada's Arctic

The community: We are a community of about 1,000 people located in a fly-in community in the Kitikmeot Region. Many families still participate in traditional practices on the land and many people still speak Inuktut language. Increasingly, however, many young people are not learning the language to a level necessary for the language to continue to thrive in the future. We have one K-12 school of 380 students. There is a serious effort on behalf of the school and community to teach the Inuktut language to the youth.

Project overview: Students were introduced to the project idea in the spring of 2018. Originally, the plan was to source the product from animal bi-products. However, due to the temporary school set-up following the loss of the school two years ago due to a fire, we did not have the facilities to store the natural materials and lacked the facilities to prepare these materials for use in the bioplastics formula. This is a great idea and should be considered again when the new school opens in September.

The original plan was to use the bioplastics to create local plastics for everyday use. This could include 3D printing of practical and hard to access materials such as ski-doo parts, machine parts and other practical uses for home and traditional life on the land.

An alternative plan was to use gelatin and glycerol to produce the bioplastic material.

It was decided that the students would design Inuktut syllabics using 3D design software and create bioplastic syllabics stencils. These stencils would be used by students in clasroo9m projects as a means to use the syllabics to increase their writing skills. I had never worked with a 3D printer before and knew that the learning curve for the students and I would be very steep. In September of this year a 3D printer and filament materials were purchased. The students used an open-source 3D design program and this caused some delays in getting the syllabics designed due to limitations in the software.

With assistance from another member of the project team, we were able to receive a 3D designed syllabic as a prototype. In December, 2018, we received the gelatin and glycerin materials and were now ready to have the students begin experimenting with the bioplastic formula. We did run into another issue with a lack of a kitchen to bring the product up to required heat and were delayed until we received a camp stove in March 2019.

We experimented with the formula a number of times to create a product with enough elasticity to be flexible yet firm enough that students could lay it flat on a piece of paper and draw around the syllabic. As of April 2019, we are still trying to create a bioplastic that is just right for our purpose. It could be that trying to process the mixture on a camp stove when it's minus 30 degrees is causing us some issues with the final product. We will continue to experiment with the camp stove in warmer days to see if we get more success.

Overall, the project was a success for us. Without the project I am sure that we would not have purchased a 3D printer and would not have had the opportunity to experience 3D designing. We did learn that 3D designing is a complicated process and we believe that we learned that good quality software is important as we struggled with our software. Students were amazed to see that they could create their own bioplastic and were eager to experiment with alternative formulas to improve the product. We even had an Elder come in and provide a training session on how to safely operate the camp stove, a nice little bit of traditional learning on the side. The students thought that designing the Inuktut stencils was a good idea and can help to advance the local language. Students care about the environment and agreed that if we want to use actual animal by-products in the future, that we could get lots of animal products donated to the school. These are all important STEM skills, traditional learning skills and stewardship skills.

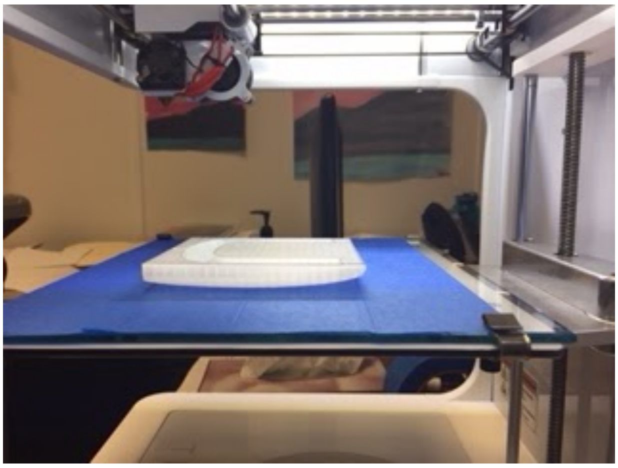
Although this was a success, we don't want to stop here. We are interested in a transfer of learning so that these skills and this project can be built upon moving forward. Some important follow up comments are shared below.

Did Andrew in Waterloo, construct a design that would permit the #D Filament printer to use the bioplastic? This would be a great addition and a better product could be produced directly printing from the printer rather than using a mould technique.

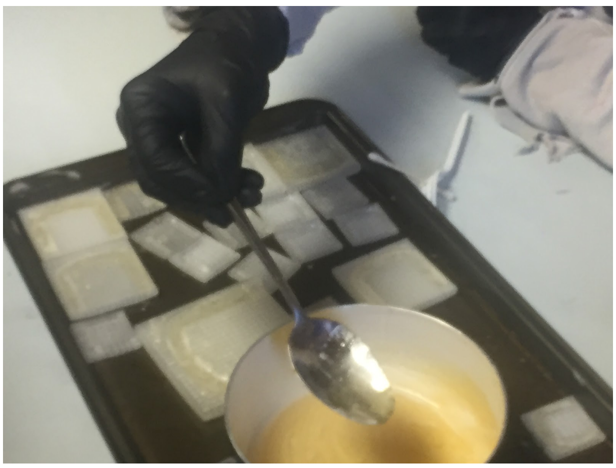
Also, it would be a great transfer of learning opportunity if the students could receive some 3D design workshops from a qualified instructor. I am in agreement that purchasing some good design software and arranging some sort of hands on design training for our students would lead a good transfer of learning plan. As part of the transfer of learning plan, students could be asked to continue designing more syllabics and adding some of the local additional syllabics so that the training connects directly with the project. Having the software available for subsequent years also boosts transfer of learning and on-going skills development for the student participants.

Many thanks to the team for all of the support our school received during this project. It has been a very worthwhile experience.


Making gelatin bioplastic



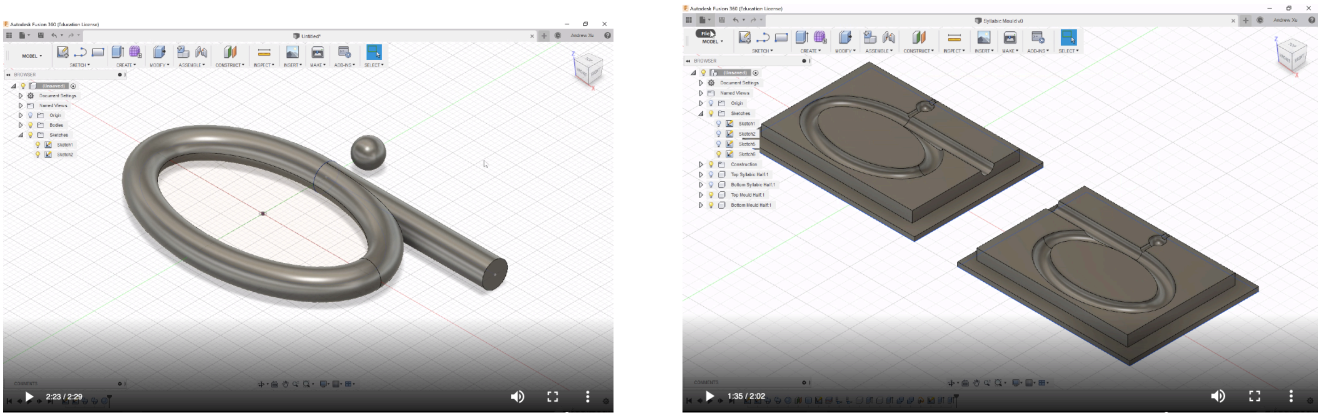

3D printing molds



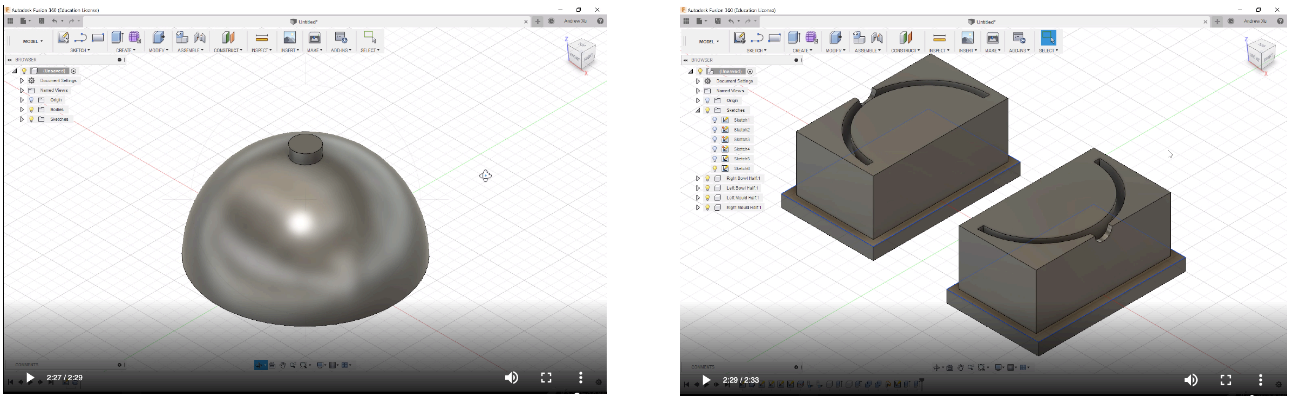

Preparing gelatin plastic syllabic stencils using 3D printed molds

APPENDIX D: 3D PRINTING DESIGN

3D printable mold for Inuktitut syllabic



Screenshots of design tutorial for a 3D printable mold for an Inuktitut syllabic



Screenshots of design tutorial for a 3D printable mold for a bowl

APPENDIX E: 3D PRINTING GELATIN

Recipe #	1	2	3
Given Recipe	Glycerin: 12g Water: 240g Gelatin: 48g	Glycerin: 340g Water: 450g Gelatin: 114g	Water: 50g Gelatin: 100g
Ratio	1:20:4	2.98:3.94:1	1:2
Actual Recipe	Glycerin: 4g Water: 80g Gelatin: 16g	Glycerin: 30g Water: 40g Gelatin: 10g	Water: 15g Gelatin: 30g
Immediate Comments	Mixture appeared to be liquid and non-viscous after it was homogenized	Mixture appeared to be liquid and non-viscous after it was homogenized	Insufficient water to extrude, added more water while heating on a stove top
Final Observation	Mixture exhibits jello like consistency. Consistency is homogeneous throughout	Mixture exhibits jello like consistency. Consistency is not homogeneous throughout, appears grainy	Mixture is rubber like, maintains it shape incredibly well. High tensile strength
Photo			
Comparison to other recipes	Compared to recipe 2, recipe 1 seemed more homogenized and exhibited a more yellow hue. Overall very similar to recipe 2		
Extrudability	As the solution cooled, there was no period of time in which the consistency was similar to that of silicone or any extrudable gel	As the solution cooled, there was no period of time in which the consistency was similar to that of silicone or any extrudable gel	There was a period of 10 seconds in which the gelatin solution had the proper consistency could be extruded. Current extruder system unable to maintain this temp