# Student Worksheet – part 1

## Synthesis of Bioplastic from Banana Peel

### Topics

bioplastics, natural polymers, starch

### Objectives

According to the Slovenian Chemistry Curriculum for Primary School (Chemistry Curriculum for Primary School, 2011).

* Students define polysaccharides as natural polymers.
* Students understand the importance and impact of organic oxygen compounds on everyday life and the environment.
* Students are encouraged to develop experimental-research skills.
* Students understand the interdependence of the structure, properties, and uses of chemical compounds.
* Students develop a responsible attitude towards use of chemical compounds and responsibility for health and the environment (chemical safety).
* Students are encouraged to observe systematically and use observations as a source of data.

### Introduction

Plastic materials (plastics) contain artificial polymers as their main component, which are characterised by high molecular weights. Due to the ease of processing and the numerous possibilities for manufacturing low-cost products that increase the standard of living, quality and comfort of life, polymeric materials have successfully penetrated the world markets. Depending on their origin, polymers can be divided into natural (e.g., proteins, polysaccharides, and DNA molecules) and artificial or synthetic.

Petrochemistry is a field of chemistry that includes technical processes and chemical syntheses for the industrial extraction of products from oil and natural gas. Currently, almost all polymeric materials are produced by the petrochemical industry i.e., they are produced from fossil (non-renewable) sources. Due to the mass consumption of disposable plastic products intended for very short-term use (e.g., plastic pots, plastic bags), the amount of plastic waste is increasing.

Some see bioplastics as an alternative option. The current definition refers to bioplastics as biodegradable plastics and/or plastics made from renewable raw materials. According to this definition, bioplastics also include plastics that are not biodegradable but are made from a renewable resource (e.g., polyethylene from sugar cane).

Depending on the raw material, bioplastics are divided into:

1. bioplastics from renewable resources
2. bioplastics from fossil resources
3. bioplastics from a mixture of renewable and fossil resources

Polymers based on renewable resources can be divided into three categories:

1. polymers extracted/removed directly from biomass: polysaccharides, e.g., starch and cellulose; proteins, e.g., casein and gluten
2. polymers produced by classical chemical syntheses using monomers from renewable raw materials (e.g., polyethylene)
3. polymers obtained with the help of microorganisms or genetically modified bacteria

Due to its wide availability, low cost, renewability and biodegradability, starch is often used to produce bioplastics. Many previous studies have been conducted using starch as a natural biopolymer. Starch consists of a long chain of two glucose units linked together, namely branched polymerised amylopectin and amylose, which give it a granular structure. Starch can behave like a thermoplastic in the presence of plasticisers and with the application of heat and mechanical treatment.

If not disposed of properly the amount of food waste from various sources can be a burden on the environment. Therefore, implementing a biorefinery platform for food waste is an ideal option (e.g., producing value-added products while reducing the amount of waste). It is expected that the implementation of such a process will reduce the production costs of biodegradable plastics (e.g., compared to traditional production routes using overpriced pure substrates (e.g., glucose)).

One of the most common starchy wastes is banana peels. In some parts of the world, the disposal of tonnes of banana peel is a problem, especially in industries that produce banana products such as banana cakes, banana crisps, banana fritters, and more. These industries use the banana flesh as raw material and dispose of the peels at the end of the process.

Banana peels contain a high percentage (about 18.5 %) of starch. As the banana peels ripen, the glucose content increases. Therefore, banana peels that are not too ripe can be proposed as a suitable resource to produce bioplastics.

### Lab equipment

* 100 mL beaker
* dropper
* glass rod
* petri dish
* spatula
* electric hot plate
* hand blender

### Chemicals

* 3 banana peels
* 60 mL water
* 0.2 M solution of sodium metabisulphite (sodium pyrosulphate), Na2S2O5
* 3 mL of 0.5 M solution of hydrochloric acid, HCl
* 2 mL glycerol
* 3 mL of 0.5 M solution of sodium hydroxide, NaOH

### Safety Information

Mandatory personal protective equipment: goggles, lab coat, and gloves. Before starting, it is necessary to carefully read the instructions for safe work. The waste must be handled properly / according to the description in the risk assessment or teacher instructions.



### Procedure

#### Preparation of banana peels

1. Cut the banana peels into small pieces and place them in 0.2 M solution of sodium metabisulphite for 45 minutes. This will increase the biodegradation period of plastic, as sodium metabisulphite is an antioxidant and preservative.
2. Transfer the ​​banana peels into boiling distilled water, and boil for about 30 minutes.
3. Drain the water and place the banana peels on filter paper and allow to air-dry for about 30 minutes.
4. Puree the dried peels into a smooth paste using a hand blender.

#### Preparation of bioplastics from banana peels

1. Weigh 25 g of banana paste into a beaker.
2. Add 3 mL of 0.5 M hydrochloric acid and 2 mL of glycerol to the beaker and stir.
3. Add 3 mL of 0.5 M sodium hydroxide and stir.
4. Spread a thin layer of the mixture onto petri dish and allow it to air-dry at room temperature for at least 24 hours.
5. When the mixture is dry, remove it from the petri dish.

#### Questions for discussion

1. What is bioplastic?
2. List other plant resources that could be used in synthesis of bioplastic.
3. What is the role of glycerol in the synthesis of bioplastic?
4. List at least three factors that could affect the properties (e.g., biodegradation, strength, elasticity) of synthesized bioplastic.

### Results and Discussion

Organize, interpret, and communicate your experimental results using tables, graphs and/or charts.

### Conclusion

Summarize your findings presented in the Results and Discussion phase.

# Student Worksheet – part 2

## Evaluation of experimental work with green chemistry metrics

Evaluate the experiment *Synthesis of bioplastics from banana peel* using green chemistry metrics. In this activity you will

1. determine the hazards of the substances used in the experiment, thereby you will learn how to obtain and use safety data sheets and develop a practical understanding of hazard (H) and precautionary (P) statements
2. determine the value of perceived greenness of the experiment, thereby you will be introduced to the 12 principles of green chemistry
3. construct the green star of the experiment, thereby you will present the data obtained using graphical means to get a better overview of greenness of the experiment.

 Follow the instructions below and use appendix 2–4 to help with the activity.

### 1. Determine the hazards of the substances used in experimental work

1. In table 1, insert the names of the chemical compounds included in the experiment in the first column.
2. For each chemical used, consult the safety data sheets you can obtain via the QR code in the risk assessment and write the hazard codes of each chemical in the second column.
3. Use "Criteria to classify the hazards of substances” (appendix 2) to obtain scores\* (1–3) attributed to health, environment, and physical hazards for each chemical used in the experiment. Insert the obtained scores in the appropriate (third/fourth/fifth) column. If no hazard code is assigned for a chemical, assign a score of 1.

Table 1: Hazards of the substances used in experimental work. In this example: Synthesis of bioplastic from banana peel.

|  | Hazard code | Scores (S) attributed to hazards\* |
| --- | --- | --- |
| Health | Environment | Physical |
| **Stoichiometric reagents** |
|  |  |  |  |  |
|  |  |  |  |  |
| **Solvents and Auxiliary Substances** |
|  |  |  |  |  |
|  |  |  |  |  |
| **Product** |
|  |  |  |  |  |
|  |  |  |  |  |
| **Waste** |
|  |  |  |  |  |
|  |  |  |  |  |

\* Scores (S) attributed to hazards on a scale from 1 (low hazard) to 3 (high hazard)

### 2. Determine the value of perceived greenness

1. To fill table 2, see the appendix 2 “Green chemistry principles and assessment criteria for the value of perceived greenness (V)”.
2. Decide the number of principles (e.g., 6 or 10 principles) that provides the most meaningful evaluation of perceived greenness of the experiment.
3. The value (V) of perceived greenness can be derived from appendix 2. V ranges from 1 (minimum) to 3 (maximum). Write NA when non applicable.

Table 2: Green chemistry principles and the value of perceived greenness to construct the green star of the experimental work. In this example: Synthesis of bioplastic from banana peel

| Green Chemistry Principle | Value of perceived greenness (V) | Explanation (optional) |
| --- | --- | --- |
| P1 – prevention |  |  |
| P2 – atom economy\* |  |  |
| P3 – less hazardous chemical synthesis\* |  |  |
| P4 – designing safer chemicals\*\* |  |  |
| P5 – safer solvents and auxiliary substances |  |  |
| P6 – increase energy efficiency |  |  |
| P7 – use renewable feedstocks |  |  |
| P8 – reduce derivatives\* |  |  |
| P9 – catalysts\* |  |  |
| P10 – design for degradation |  |  |
| P11 – real-time analysis for pollution prevention\*\* |  |  |
| P12 – safer chemistry for accident prevention |  |  |

\* Applicable when using 10 or 12 Principles. \*\* Applicable only when using all 12 Principles

### 3. Construction of the green star

With a construction of green star present the results of the greenness assessment of experimental protocol.

1. If you are constructing the green star on paper, colour the radar chart shown in figure 1. Colour the area corresponding to a specific principle (e.g., P1, P2, etc.) based on the determined value V in table 2.
2. If you have a computer, you can construct the green star in Excel and insert a copy of the green star in your worksheet.
	* Open appendix 1 (Excel file) and select “Green star (10 principles)”.
	* Use your results from table 2 to fill in the data in the green cells.
	* Copy the image of your green stars and replace the images below.


Figure 2: Greenness assessment of the experimental work.

### 4. Reflect on the results of the evaluation of experimental protocols with green chemistry metrics

### References

Ribeiro, M. G. T., Costa, D. A., & Machado, A. A. (2010). “Green Star”: a holistic Green Chemistry metric for evaluation of teaching laboratory experiments. *Green Chemistry Letters and Reviews, 3*(2), 149-159. <https://doi.org/10.1080/17518251003623376>

Ribeiro, M. G. T., & Machado, A. A. (2014). Green star construction. <http://educa.fc.up.pt/documentosQV/EV/Construction%20of%20Green%20Star_6_points_GSAI.xlsx>