Instructor Guide

Learning Objectives

1) ***Appreciate the power of waste valorisation to create useful products***
2) ***Obtain an understanding of the process of transforming sour milk into a bioplastic***
3) ***Use a systems thinking approach to identify other applications of this process and discuss associated ethical implications.***

Introduction

This demonstration will find utility in introducing students to waste valorisation in the context of making a bioplastic from sour milk. The resource uses totally benign reagents and hence can be implemented in remote locations where reagents and equipment may be scarce. In valorising sour milk and forming a bioplastic, there is an opportunity for students to consider where materials come from, how they are transformed and used, and what happens at the end of their life span. There is scope for students to align the principles of the demonstration to relevant United Nations Sustainable Development Goals (UN SDGs) but also, through considering the entire system, for students to consider the ethical implications of making a bioplastic from milk when the same process is used to make paneer, an important foodstuff, especially in the Indian subcontinent for providing nourishment. This demonstration could be applied with students studying general chemistry, food science, natural sciences and chemical engineering topics. Associated literature, an equipment list and discussion questions are included to support implementation of the demonstration.

Recommended Literature

There is a wide range of literature available to support learning at differing levels. This demonstration has been created to be used with high school students or as an introduction to chemistry but can be amended to accommodate multiple audiences at more advanced levels.

General texts include:

Stevens, E. S. *Green Plastics: an introduction to the new science of biodegradable plastics,* Princeton University Press, USA. 2002.

Thielen, M. *Bioplastics: basics, applications, markets*, Polymedia Publisher GmbH, 2012.

Chemical and Equipment List

Skimmed milk (5-10 days passed the expiry date)
Lemon juice
Food coloring (optional)
1 x 50 mL measuring cylinder
1x 100 mL beaker
1x hot plate
1x thermometer (0-100 °C)
1x 5 mL pipette
1x glass rod
1x Petri dish
1x oven
1x shape cutter
1x mass balance (interactive extension)

Considering the necessary safety implications, this demonstration can be conducted in a classroom-type environment without the requirement of a fumehood. Similarly, bespoke glassware can be substituted for equivalents that are readily available (e.g. paper cup for beaker, wooden coffee stirrer for glass rod etc)

Procedure

1. Using a measuring cylinder, measure 50 mL of sour skimmed milk and then pour the milk into a 100 mL beaker.
2. Using a stirrer hot plate, heat the milk to 60 °C. Use a thermometer to check the temperature whilst heating the milk, continuously stirring it with a glass rod. If you wish to add color to the bioplastic, add a small volume (~ 5 mL) of food coloring now.
3. Whilst the milk is heating, measure 3 mL of lemon juice into a 5 mL measuring cylinder.
4. Once the milk has reached 60 °C, remove the beaker from the hot plate and place it on a desk.
5. Add the lemon juice and stir the milk and lemon juice mixture using a glass rod for about 5 seconds.
6. Using a spatula, scrape out the solid from the beaker onto a paper towel. Use a paper towel to dab the white solid to help dry the surface. Do this until as much water has been removed from the solid as possible.
7. Flatten the solid on a desk and use a plastic shape cutter to cut out the desired shape.
8. Place the shaped bioplastic in a petri dish and put the petri dish and plastic into an oven (set to 65 °C) for 4 hours.
9. Remove the bioplastic from the oven, allow to cool and distribute to the class.

Opportunity to extend

The demonstration can be made more active by asking students to participate through varying parameters and measuring the mass of bioplastic produced.

This can be most easily done by sequentially varying the amount of lemon juice added in aliquots of 1 mL from 0 mL to 5 mL.

Discussion points

- Formation of the bioplastic
- Effects of increasing addition of lemon juice (see extension)
- Systems thinking to make links to UN SDGs and discussion
- Ethical considerations of making paneer via the same process including making a link to additional (2nd) UN SDG. Discussion points could include:
  - Benefits of bioplastics as a substitute for petroleum-derived plastics (societal, economic, sustainable)
  - Does the existence of the process outlined for creating a foodstuff necessarily preclude use to make an ornamental bioplastic?
  - Does the former depend on the availability of the reagents (milk/lemon juice)?
  - Does the availability of the reagents depend on geographic location? In which case, can it be justified for ornamental bioplastics to be made via this process in some parts of the world and not others?
  - Should an alternative system be considered? Can you identify some examples that have been or could be explored?
  - Are some UN SDGs more important than others?