Basic Formulations

S = starch; G = gelatin; AG = agar; A = alginate; P = pectin; Sorb = sorbitol

Starch - binary

CODE	Formulations	starch	gelatin	agar	sorbitol	water	1% glycerol solution	
SB-S4AG4	Starch- agar	0.4g	X	0.4g	X	X	30ml	
SB-S2AG8	Starch- agar	0.2g	X	0.8g	X	X	30ml	
SB-S8AG2	Starch- agar	0.8g	X	0.2g	X	X	30ml	
SB-S4G4	Starch-gelatin	0.4g	0.4g	X	X	X	30ml	
SB-S2G8	Starch-gelatin	0.2	0.8g	X	X	X	30ml	
SB-S8G2	Starch-gelatin	0.8g	0.2g	X	X	X	30ml	

Starch - ternary

	Formulations	starch	gelatin	agar	sorbitol	water	1% glycerol solution	
ST-S4G4AG4	Starch-gelatin-agar	0.4g	0.4g	0.4g	X	X	30ml	
ST-S4G8AG4	Starch-gelatin-agar	0.4g	0.8g	0.4g	X	X	30ml	

Pectin - binary

	Formulations	starch	gelatin	agar	Pectin	sorbitol	water	1% glycerol solution	
P-P8	pectin	x	x	x	0.8	x	x	30ml	
PB-S4P4	Starch- pectin	0.4	X	X	0.4	X	X	30ml	Difficult to mix well
PB-S8P2	Starch- pectin	0.8	x	x	0.2	x	x		
PB-G4P4	gelatin-pectin	X	0.4	X	0.4	X	X	30ml	
PB-G2P8	gelatin-pectin	X	0.2	X	0.8	X	X	30ml	
PB-G8P2	gelatin-pectin	X	0.8	X	0.2	X	X	30ml	

Alginate - binary

	Formulations	starch	gelatin	agar	Alginate	sorbitol	water	1% glycerol solution	
A-A8	alginate	x	x	x	0.8	x	x	30ml	v. thick – difficult to disperse
AB-S4A4	Starch- alginate	0.4	X	X	0.4	X	X	30ml	Difficult to disperse starch in alginate mixture - lumpy
AB-G4A4	gelatin-alginate	x	0.4	X	0.4	X	X	30ml	Difficult to disperse starch in alginate mixture - lumpy
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Sorbitol and Glycerol

- Sorbitol and glycerol act as plasticizers – too much will give a gum.

Potential problems

- Mould growth may occur if drying takes too long. If using petri dishes these should be cleaned with soap and water before use (if not the plastic kind).
- If there is a lot of water, it may appear that the bioplastic is not forming – some of these give thin brittle sheets rather than slabs after drying.

Possible variations

- the recipes given are starting points and can be modified in terms of proportions (e.g. more or less plasticiser – sorbitol, glycerol....). If you make changes, record what you did!
- Additives such as metal salts or other substances (e.g. alternative carbohydrates such as xanthan etc)
- In some cases the volumes of water are large and should be reduced for working on a smaller scale. This may cause a problem in drying.

Procedure

- ***LABEL ALL PETRI DISHES/ CONTAINERS FOR THE SAMPLES BEFORE YOU POUR THE MIXTURE IN FOR DRYING!***
- **NAME, DATE, MIXTURE COMPOSITION!**
- Wipe the surface of the petri dish with a piece of paper towel (Scottex) which has been dipped in oil to spread the oil over the surface.
- Weigh the powders and mix the ingredients well ***before*** adding liquid.
- Use a normal beaker of the correct size rather than a conical flask.
- Heat to 80^{o}C or to when it starts to froth (whichever comes first).
- Stir the mixture while you are heating it, and once it is at the right temperature (or starts to froth), remove the heat and keep stirring.
- Scoop out excess froth with a spoon, and make sure there are no clumps.
- Carefully pour the mixture into a drying pan (or a petri dish) placed on a level bench top. Dry under a flow of air (e.g. under a fume cupboard with extractor switched on).

Polymer Testing - Observations

Physical state

- slimy/ dry/ brittle/ flexible (bendy)/ elastic/ rigid / hard/ soft/ transparent/ opaque

Physical test of strength

Tomasetti test for residual solvent

CARE: do not burn the sample!

Place a sample between two microscope slides and place on a hot plate. Observe whether bubbles form as the sample heats up. Can you quantify the bubbles of solvent (water)?

Chemical tests

Lugol's reagent - a test for starch - a solution of iodine and KI.

In the presence of starch molecules the solution (or the polymer) goes dark blue-black. This happens because the iodine molecule reacts with iodide ion to give the linear I_3^- anion. Starch typically has regions where the sugar units are arranged in a helix like a spring, the I_3^- anion can fit inside these helices but in doing so, there is an interaction between the anion and the starch which causes the energy level spacings in the anion to change. The new spacings correspond to energetic jumps in the visible spectrum (particularly the orange part). This causes the dark blue colour.

Benedict's reagent - a test for reducing sugars (such as glucose).

It is an equi-volume mixture of aqueous solution of $CuSO_4$ and sodium citrate. If reducing sugars are present, the solution gives a yellow-orange-dark brown precipitate of CuO according to the amount of reducing sugar present. This is an example of a redox reaction.

Biuret test - a test for the presence of protein.

The **biuret reagent** is made of NaOH and copper(II) sulfate, together with potassium sodium tartrate which is added to stabilize the cupric ions. The test works by the protein complexing the copper ion in solution to form a tetradentate complex which has a characteristic purple colour.

Interaction with water, acids and bases

Observe what happens to a piece of sample in water, 1M NaOH, 1M HCl, ammonia, ethanol...

How hydrophobic / hydrophilic is the sample?

General references:

- http://green-plastics.net/posts/57/qaa-bioplastic-by-da-vinci/
- **E.S.Stevens, Green Plastics, , Princeton University Press, 2002**