

Plastics from potatoes and rubber from rice

Can plants solve the plastic problem?

Keywords

Polymers • Plastics • Starch • Biodegradable

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THE ROYAL SOCIETY
SUMMER SCIENCE EXHIBITION

The global production of plastic is around 100 million tonnes per year. (One tonne of plastic is equivalent to 20,000 two litre drinks bottles or 120,000 carrier bags). This is a difficult number to imagine but picture three plastic bags the size of the UK and that gives you an idea of the extent of our plastic addiction. Most of the plastic comes from oil and equates to about 4% of the world's production. After 2010 the production of oil will begin to decline as we use up this valuable resource. So where will plastic come from when the oil runs out?

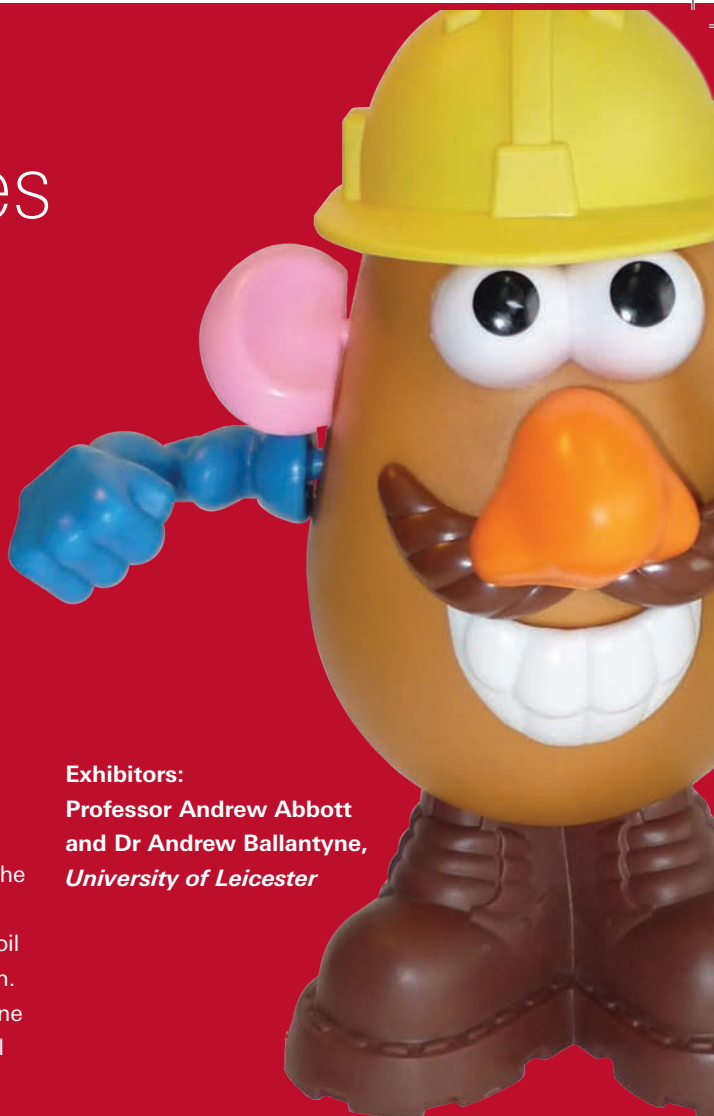
Another issue is what is happening to all the plastic that we throw away. Typically, petroleum-based plastics can take between 20 to 1000 years to biodegrade. It has been estimated that there are 46,000 pieces of floating plastic in every square mile of ocean and these kill up to a million sea birds and 100,000 sea mammals every year. Putting plastic in a landfill site is simply hiding a long term problem. We need to apply the 3 Rs; Reduce, Reuse, Recycle. We need to avoid using plastic where possible, reuse plastic articles when practical and when the item reaches the end of its serviceable life we should recycle it. Currently only 7% of the total plastic waste is recycled. Ultimately, there will always be plastic that we need to throw away and this needs to be biodegradable or, preferably, compostable. So we need to discover a natural, renewable source of polymers. A polymer is a large molecule composed of repeating structural units which can, in some cases, be used to form plastics.

Exhibitors:

**Professor Andrew Abbott
and Dr Andrew Ballantyne,
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Plants and animals have a wide variety of natural polymers, such as starch, cellulose, wool, silk and cotton. Clearly, most of these we already use but the issue we have is how to process them into useable plastics. It only takes 6 hours for nature to produce enough starch to fulfil worldwide annual plastic needs. Currently, the biodegradable plastics we use are mostly made from polylactic acid (PLA) which is derived from corn starch. This has a limitation due to its higher price than petrol-based plastics and it is often too rigid and brittle for many packaging applications. It would be very exciting if starch could be used directly as a biodegradable plastic due to its large abundance as a renewable source as well as its ability to break down quickly in landfill.

Starch in its native form exists as small particles (circa 2–20µm diameter – approximately 1/40 to 1/4 of the thickness of human hair). Each particle consists of two sugar-based polymers called amylopectin and amylose, both of which are chains of between 300 and 200,000 glucose units. Unlike conventional petroleum-derived polymers, these chains interact very strongly with each other through a network of hydrogen bonding which zips the chains together and tends to make the chains coil around themselves.



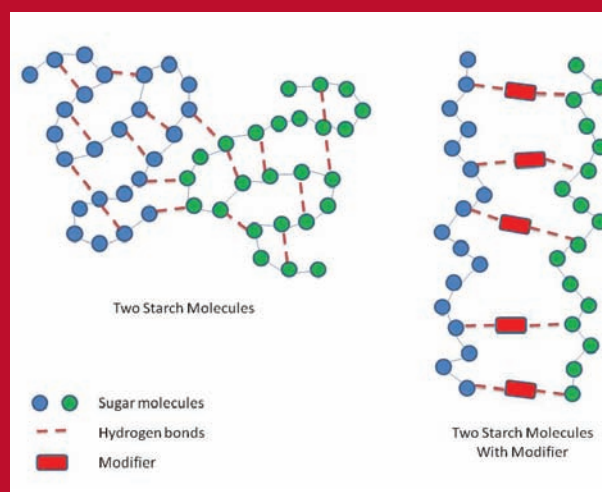
*Potatoes provide an alternative source to petroleum for plastics.
(Mr Potato Head ©2009 Hasbro. All Rights Reserved. Used with Permission)*

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The brittle nature of starch in its native form makes it unsuitable for use as a material in packaging or other conventional plastic uses. However, its properties can be modified through a combination of processing and incorporation of extra ingredients. The properties of the resulting material can be varied through the careful choice of additional ingredients. The additives unzip the long sugar chains of the starch granules promoting a more disordered, randomized molecular structure; they then allow them to be re-zipped in the required configuration. This disordered structure at a molecular level has a large impact on the respective physical and mechanical properties of the material. We have found that through incorporation of a number of compounds which contain hydrogen bond donating or accepting groups the properties of the starch can be greatly varied.

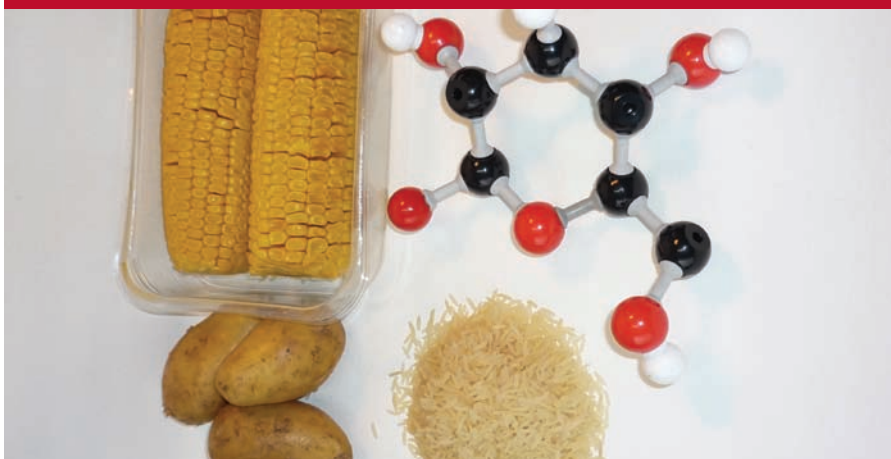
What we are doing is very similar to what you do at home when you bake bread, cakes or biscuits. Flour is the main ingredient, which is mostly starch, water unzips the starch and the other ingredients give the baked product its characteristic consistency. Accordingly, you can make everything from a ginger nut to baked custard (corn starch is the main constituent of custard powder!). The problem with all of these products is that the water is gradually lost and the food becomes 'stale' as the starch changes its structure.



We have emulated the baking process by substituting simple components that fulfil the role of the ingredients in your classic recipes but stop the material drying out and adopting its original structure. The starch, which was originally brittle, is transformed into a solid yet flexible material much like plastics that are used commercially as packaging materials. In addition, foamed material can be made with similar properties to the expanded polystyrene commonly used in things such as food trays and electronics packaging. This is possible by the inclusion of either a low boiling liquid or a solid that decomposes to produce an inert gas such as carbon dioxide. This is what baking powder and yeast do when you carry out your baking. As the temperature increases, gas pockets form in the sample which the starch then solidifies around. This means that a large portion of the sample is made of air pockets and the sample therefore has a very low weight while retaining a high proportion of its initial strength.

We have changed the properties of starch by incorporating strongly interacting modifiers in order to be able to form flexible yet strong materials which behave in much the same way as petroleum-based plastics. The other great advantage of our work is that our ingredients are biodegradable, cheap and simple to apply. The finished materials are fully compostable. This is an exciting development in the struggle to produce cheaper, greener plastics and packaging materials from renewable materials.

Our modification breaks down the internal bonding of starch (shown on the left) and helps the individual molecules interact more strongly with each other



Starches and cellulose from plants provide polymers for compostable plastics