Green Chemistry

At a glance

	Content summary	National Curriculum links	Activities
Lesson 1	12 principles of green chemistry; making glue, then revising the procedures	Aspects of working scientifically	**Activity A:** Introducing green chemistry **Activity B:** Making glue
Lesson 2	A case study of an industrial process – making crisps	Environmental impact of chemical processes and a product's life; viability of recycling	**Activity C:** An industrial process – making crisps

Background and National Curriculum links

The activities are intended for two Year 10-11 lessons on green chemistry. Green chemistry is a way of doing chemistry that reduces and minimises the impact of chemical processes on the planet's resources.

Lesson 1

The first lesson presents twelve agreed principles of green chemistry. To introduce these, students make glue from everyday substances using instructions that are deliberately wasteful and overly complex. They must improve the procedure using green chemistry principles.

National Curriculum

- evaluating associated personal, social, economic and environmental implications;
- making decisions based on the evaluation of evidence and arguments;
- evaluating methods and suggesting possible improvements.

Lesson 2

In lesson 2, students apply green chemistry principles to a case study about the industrial production of potato crisps.

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National Curriculum

- life cycle assessment and recycling to assess environmental impacts associated with all the stages of a product's life;
- the viability of recycling of certain material.

Teacher subject knowledge

- Basic knowledge of chemical processes;
- Awareness of green chemistry principles.

Cross-curricular links: green chemistry, sustainability and climate change

The phrase 'green chemistry' was first defined by Paul Anastas, a Yale University scientist who became known as 'the Father of Green Chemistry'. The US Environmental Protection Agency defines green chemistry as 'the utilisation of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products'. Green chemistry is a philosophy that ensures that products are made in sustainable, environmentally friendly and efficient ways. 'Green chemistry' is accepted internationally and is independent of politics. Minimising climate change, enhancing sustainability and reducing environmental impact of humans on the planet's resources are current priorities. Green chemistry principles can be applied to everyday processes, so there are opportunities to introduce local settings.

Many domestic items rely on chemical and physical processes for manufacture. Soap, cosmetics, ceramics, leather goods, jewellery, metals and fabrics such as denim, cotton and linen have been produced and used for centuries. Manufacturing processes developed over time, depending on links to economics of production, profits, costs and availability of raw materials. Industries produce sulfuric acid, ammonia, nitric acid, paints, pharmaceuticals, petrochemicals, aluminium, iron and steel, among other substances, which are processed further to make items that we use. Life cycle analysis studies items' use over time, how long they last and how they can be recycled.

The topic connects to waste management. Recycling technology is being continually improved: twenty years ago plastics and paper were sent to landfill and not collected separately for recycling. Many items made from recycled plastics are now available. Key issues relating to waste recycling in the school community and local areas can be discussed.

Student background knowledge

Prior knowledge of atom economy is helpful.

Resources and timing

Two 50 – 60 minute lessons are required.

Technical requirements

Access to the internet is required.

Lesson 1

Activity A: Introducing 'green chemistry': making glue

A strong recommendation is to trial the method with resources available in school. The outcome is subject to variability.

Keep the glue for several days to allow some water to evaporate. Students can test the glue. Compare it with bought samples of glue, e.g. PVA, acrylic, wallpaper paste, glue stick, wood adhesive, etc.

Each pair or group of students will need access to:

- Tap water
- Skim milk powder (or similar ingredient that is not actually used, e.g. coke, flour, cornflour)
- Glitter (allow about 0.5 g per pair/group)
- Cleaning wipes, preferably with bleach or isopropyl alcohol

Each pair or small group of students will need:

- Tap water
- Glitter (allow about 0.5 g per pair/group)
- Cleaning wipes, preferably with bleach or isopropyl alcohol
- 15 cm^3 vinegar
- 3 slices cooked beetroot (Note: one instruction is to discard this)
- Sodium hydrogen carbonate (baking soda)
- About 200 cm^3 milk (Note: one instruction is to discard about half of this. The discarded milk could be collected for future use)
- 1 test tube
- 2 x 250 cm^3 beakers
- 250 cm^3 conical flask
- Splints
- Plastic teaspoon
- Spatula
- Thermometer
- Tongs
- Eye protection

Introduction

- Ask students to write down 5 – 10 words that they associate with 'chemistry': explosions, precipitates, fireworks, industrial processes, toxic gases, smells, hazards.
- If necessary, prompt products such as clothing (textiles), food, drinks, medicines, plastics, furniture, paints, cosmetics and jewellery.
- Explain why they chose 2 – 3 of these.
  Prompt discussion towards chemistry being about making new products.
- Using the words that they associate with chemistry, is chemistry good for the environment?
  Yes / No

  Explanations:
  Yes – we are healthier, live more comfortably, chemistry contributes to the economy, chemistry tests make sure that food, medicines, water, materials are safe to use.

  No – chemistry uses the Earth's resources; produces pollutants; makes / uses plastics.

- What do they think is meant by 'green' chemistry?
  Using fewer resources; reducing temperatures for processes; ensuring that processes are efficient

Making glue

This activity makes glue from everyday substances. The instructions are intended to be wasteful of time and resources, so are not perfectly 'green'. Students should follow the steps precisely, noting which steps:

- work well and are essential;
- are essential but are wasteful so can be changed;
- are not needed and can be removed.

The glue will need time to dry out before testing. Compare the lab-made glue with a glue-stick and /or other glues / adhesives if these are available.

A completed version of the table provided to students is on the next page.

No.	Step	Essential	Wasteful	Not needed
1	Put on eye protection.	X		
2	Measure 200 cm3 milk into a beaker.	X	X	
3	Put 100 cm^3 of milk into another 250 cm^3 beaker. Do not use this.		X	
4	Choose the reddest slice of beetroot. Add this to the milk. Throw away the remaining slice.		X	
5	Stir the beetroot slice and milk mixture for 30 seconds using a plastic spoon.	X	X	
6	Remove the beetroot slice from the milk with tongs. Discard the beetroot. Your milk should be a pink colour.	X	X	
7	Measure 15 cm^3 of vinegar into a test tube. Place it in a fume cupboard (if available) for 20 seconds, or leave it to stand on the bench.	X		X
8	Warm the milk carefully to 45°C using a gentle blue flame.	X		
9	Add the 15 cm^3 of vinegar to the beaker.	X		
10	Gently heat and stir using the plastic teaspoon.	X		
11	As soon as it curdles turn off the heat. You should see solids in the beaker.	X		
12	Pour off liquid from the solid into the waste container. Recite the alphabet backwards while the solid cools.	X	X	X
13	The solid is casein. Wipe the casein with a cleaning wipe to remove any vinegar.	X	X	
14	Add 4.75 g sodium hydrogen carbonate and 0.5 g glitter. Stir with a glass rod.	X X	X	X (glitter)
15	Add 30 cm^3 of water. Stir. Leave to stand for a few days so water evaporates and the glue becomes sticky.	X		
16	Using wipes, clean your bench thoroughly.	X	X	

Ask students to rewrite the steps making the changes they have marked.
How is their process 'greener' than the original version?

Check for:

- Minimize waste (milk, beetroot).
- Reduce the heating temperature to the lowest required.
- Remove glitter because it's a plastic made from petroleum.
- Remove any ingredients not needed (milk powder or similar).
- Remove any unnecessary steps (e.g. reciting the alphabet backwards).

Next, see if they can make the steps even 'greener'.

Make available the twelve 'Principles of Green Chemistry'. Invite students to match their suggested improvements to the glue-making process with the principles. A completed version is provided showing possible outcomes. Use this to discuss changes that students may have missed. Phrases have been simplified to aid understanding.

Twelve principles of Green Chemistry

No.	Description	Application
1	Prevent waste rather than treat or clean up waste	Throwing away excess reagents (milk, beetroot) and other consumables. Using too much reagent. Using amounts of reagents needed to avoid waste.
2	Make sure all the materials used in the process are in the final product	Throwing away excess liquid once the casein has formed.
3	Use methods that are non-toxic to people and the environment	Avoid using the isopropyl alcohol /bleach wipes, which are toxic.
4	Ensure chemicals used are safe and non-toxic and that the product is non-toxic	Test how changes to the procedure affect the quality of the product – will the glue stay sticky?
5	Use the smallest amounts of solvents and added substances, and make sure they are non-toxic	Reagents were provided but not used. Is the beetroot necessary?
6	Recognise and minimise the energy requirements. Use room temperatures and pressures if possible.	What is the lowest temperature at which milk curdles? Does this amount of heat give the best result?
7	A raw material should be renewable whenever practicable.	Use laboratory items that are washable, e.g. glass stirring rod or a wooden spoon. Avoid using plastic items, e.g. the teaspoon.
8	Minimise steps that require additional reagents as these can generate waste.	The beetroot changes the properties of the glue. For red glue, a few drops of red food colouring could be added.
9	Use catalysts where possible.	The vinegar is a catalyst. Is there a way of recycling the vinegar?
10	Design products so they break down into non-toxic substances and do not stay in the environment.	Glitter is plastic made from petroleum. The glue is environmentally friendly without the glitter.
11	Develop methods to allow real-time, in-process monitoring and control prior to production of hazardous substances.	Reducing the number of steps simplifies the procedure. Less heat could be used; the amount of vinegar could be changed to reduce the temperature at which casein forms.
12	Choose substances and processes to minimise potential for accidents, including gas release, explosions and fires.	Eye protection and use of tongs minimises potential for accidents. Reducing the heating required minimises these risks further. The glue does not produce toxic gases and is non-toxic.

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Making a 'green' glue

How could we make non-toxic glue that minimises environmental impact?

- Examine labels of glues made by chemical processes, e.g. wallpaper paste, PVA, wood / ceramic adhesive, acrylic glues etc. What do we notice?
- Glues often have strong odours; can be very difficult to remove from the skin; may be toxic; are sometimes petroleum-based; and may need a lot of energy to make.
- Green chemists try to make new products with minimal impact on the environment. One way is to imitate nature, as most chemicals developed and used by living creatures are non-toxic, made from natural substances and are biodegradable.

  Look at the images of: A gecko A spider Blue mussels

What do these animals have in common?

- They are all able to stick to another surface or substance.
- The spider and mussel produce a sticky substance.
- The gecko has millions of tiny hairs on its feet, which become adhesive when pressed on a hard surface.
- None of these substances are toxic, yet they work as adhesives.

Apply 'green chemistry' to making a glue. Discuss what this might mean. For example:

- Not using toxic chemicals;
- Trying to mimic natural glues;
- Minimising energy needed to make a product;
- Using alternative energy sources;
- Minimising waste.

Emphasise that changing chemical processes to make them greener is now common practice in chemical industries.

Extensions

Calculate personal eco-footprints: Students can consider how their lifestyle relies on products such as clothing, technology, processed food and other items that place demands on the environment. Students can calculate their eco-footprints using an inventory available at http://www.footprintcalculator.org/. The results can prompt discussion about how changes to lifestyles may be needed to help resolve environmental challenges.

Visit a local waste management plant: Find out how recycling is managed in the community where students live. Find out what proportion of material sent for recycling is actually recycled, what the recycled material is used for, and what happens to the non-recycled waste. Discuss how we can reduce waste.

Resources

The website http://www.beyondbenign.org has an excellent range of activities featuring Green Chemistry. The glue-making activity is based on a lesson plan available from this site.

Lesson 2

Activity B: Making potato crisps

Students apply green chemistry principles to a case study of an industrial process: potato crisp production.

Short videos are available describing the manufacture of potato crisps in three factories.

Company	Website	Video of production process
Walkers Crisps in Leicester, UK	https://walkers.co.uk/.	https://www.leicestermercury.co.uk/whats-on/food-drink/look-inside-huge-walkers-crisps-1547323.
Kettle Crisps Norwich, UK	https://kettlechips.co.uk/.	https://kettlechips.co.uk/we-love-potatoes/ https://www.edp24.co.uk/business/watch-a-behind-the-scenes-look-at-how-kettle-chips-are-made-in-norfolk-1-5240668 (scroll down to find the video)
Frito-Lay Inc., Casa Grande, Arizona, USA	https://www.foodprocessing-technology.com/projects/pepsico-frito-lay/.	https://www.youtube.com/watch?v=ws_K9Cxs-uE.

Students are asked to consider positive and negative features of each factory.

- Think about how the factories already apply green chemistry principles.
- What changes could be made to increase compliance with green chemistry principles?
- To what extent does product quality influence how 'green' a process could be?

Discuss the outcomes.

Students may discuss: energy requirements and energy sources; water used to wash the potatoes; where the potatoes come from; what happens to waste materials; how the potatoes are cooked; any facts about packaging, transport, emissions from the factories.

Students may choose one factory over another – there is no 'right' answer. Frito-Lay boasts green principles, but uses a lot of resources; Kettle is small-scale using local potatoes so transport costs are reduced; Walkers fries at low temperatures.

Peer assessment can be used to assess students' presentations and judge the quality of their decision-making and recommendations.

To adapt the activity for students of a range of abilities, students can:

- Work on one factory only, and compare their findings with others
- Watch the videos and read information from the websites
- Compare with a more complex process, e.g. car or cosmetics manufacture. Videos for these processes are readily available via the internet.

Extensions

Visit a chemical plant or a food factory: Find out what steps have been taken / are being planned to adopt greener processes and procedures.

Lesson 1

Activity A: Introducing 'green chemistry': Making Glue

- Write down 5 – 10 words you associate with 'chemistry'.
- Explain why you chose 2 – 3 of these.
- Using the words you associate with chemistry, is it good for the environment? Yes / No
- Explain your answer.
- What do you think is meant by 'green' chemistry?

Next you are going to make a sample of glue.

What you need:

- Tap water
- Glitter (allow about 0.5 g per pair/group)
- Cleaning wipes
- 15 cm^3 vinegar
- 2 slices cooked beetroot
- Sodium hydrogen carbonate (baking soda)
- About 200 cm^3 milk
- 1 test tube
- 2 x 250 cm^3 beakers
- 250 cm^3 conical flask
- Splints
- Plastic teaspoon
- Spatula
- Bunsen burner, heatproof mat, tripod and gauze
- Thermometer
- Tongs
- Eye protection

To make glue

Follow the instructions carefully. As you work through the steps, think about whether each step is:

ESSENTIAL WASTEFUL or NOT NEEDED

No.	Step	Essential	Wasteful	Not needed
1	Put on eye protection.			
2	Measure 200 cm3 milk into a beaker.			
3	Put 100 cm^3 of milk into another 250 cm^3 beaker. Do not use this.			
4	Choose the reddest slice of beetroot. Add this to the milk. Throw away the remaining slice.			
5	Stir the beetroot slice and milk mixture for 30 seconds using a plastic spoon.			
6	Remove the beetroot slice from the milk with tongs. Discard the beetroot. Your milk should be a pink colour.			
7	Measure 15 cm^3 of vinegar into a test tube. Place it in a fume cupboard (if available) for 20 seconds, or leave it to stand on the bench.			
8	Warm the milk carefully to 45°C using a gentle blue flame.			
9	Add the 15 cm^3 of vinegar to the beaker.			
10	Gently heat and stir using the plastic teaspoon.			
11	As soon as it curdles turn off the heat. You should see solids in the beaker.			
12	Pour off liquid from the solid into the waste container. Recite the alphabet backwards while the solid cools.			
13	The solid is casein. Wipe the casein with a cleaning wipe to remove any vinegar.			
14	Add 4.75 g sodium hydrogen carbonate and 0.5 g glitter. Stir with a glass rod.			
15	Add 30 cm^3 of water. Stir. Leave to stand for a few days so water evaporates and the glue becomes sticky.			
16	Using wipes, clean your bench thoroughly.			

Discussion

1. Note materials and equipment you did not use, and items that you needed but were not listed.
2. Suggest improvements that reduce the materials, energy and laboratory equipment required.
3. How could you make your process more environmentally friendly? Look at the 'Twelve Principles of Green Chemistry'. Did you miss anything?
4. Write down your improved instructions.
5. How could you use naturally occurring glues to make even 'greener' glue? Look at the images and think about how these animals stick to their habitats.

Student Sheet: Twelve Principles of Green Chemistry

No.	Principle	Description	Application to glue-making
1	Prevention	Prevent waste rather than treat or clean up waste	
2	Atom Economy	Make sure all the materials used in the process are in the final product	
3	Less Hazardous Chemical Synthesis	Use methods that are non-toxic to people and the environment	
4	Designing Safer Chemicals	Ensure chemicals used are safe and non-toxic and that the product is non-toxic	
5	Safer Solvents and Auxiliaries	Use the smallest amounts of solvents and added substances, and make sure they are non-toxic	
6	Design for Energy Efficiency	Recognise and minimise the energy requirements. Use room temperatures and pressures if possible	
7	Use of Renewable Feedstocks	A raw material should be renewable whenever practicable	
8	Reduce Derivatives	Minimise steps that require additional reagents as these can generate waste	
9	Catalysis	Use catalysts where possible	
10	Design for Degradation	Design products so they break down into non-toxic substances and do not stay in the environment	
11	Real-time Analysis for Pollution Prevention	Develop methods to allow real-time, in-process monitoring and control prior to production of hazardous substances	
12	Inherently Safer Chemistry for Accident Prevention	Choose substances and processes to minimise potential for accidents, including gas release, explosions and fires	

Imitating nature – how do these animals stick?

Gecko

image of green gecko on a wall - Bing images

Spider in its web

image of spider in a web - Bing images

Blue mussels

image of blue mussels on a rope - Bing images

Lesson 2

Activity B Case Study: Potato Crisp Production

A short history of the potato crisp

Potato crisps are one of the world's most popular snack foods. They were invented in the US in 1853 by George Crum, a chef at the Moon Lake Lodge, in Saratoga Springs, near New York. The lodge restaurant served chips, known as 'French fries'. One day, a diner complained his chips were too thick. George made a thinner batch. The diner that complained again. To irritate the customer, George sliced a potato into slices so thin they could not be picked up by a fork, fried them, and added a large amount of salt. The diner ate the lot. 'Saratoga Crisps' became so popular that George set up his own restaurant.

About forty years later, William Tappendon started manufacturing and marketing crisps in Cleveland, Ohio, in the US. Tappendon sold them to grocery stores in large bins. Grocers weighed crisps into small paper bags for sale. But crisps at the bottom of the bins became soft as they absorbed moisture from the air. This was solved in 1926, when Laura Scudder, a crisp manufacturer in California, invented a waxed paper bag. She made her staff use a hot iron to seal the bags closed, inventing the packet of crisps.

Crisps were first sold on a large scale in the UK from 1920 by Smiths Potato Crisps Company, based in north London. Mrs Smith washed, sliced and fried potatoes in the family's garage, while Mr Smith packaged the crisps into greaseproof paper bags, which were loaded on to his pony and cart and taken round shops to sell. The Smiths added a small blue bag of salt for flavouring. The Smiths' business expanded, becoming the UK's first large scale producer. After World War II, crisps started to be manufactured on a large scale in factories. The biggest factory in the UK today is the Walkers Crisps plant near Leicester, owned by PepsiCo. This makes five million packets of crisps every day from 675 tonnes of potatoes.

Making crisps

Crisp manufacture is a simple process that requires very large amounts of energy and water and produces a lot of waste material. The challenge is to use green chemistry principles to consider how crisp production can be made more environmentally friendly.

What to do

Three descriptions of the process for making potato crisps are provided. Each is based on a genuine factory that is working today.

1. Read about the three factories. If possible, watch the short videos.
2. Draw a flow chart of the crisp production process. Show on the chart:
   - The raw materials required
   - Any additional chemicals added or used
   - Where energy (heat, cooling, electricity) is required or occurs
   - Any waste products
   - Any possible hazards.

3. Analyse the three factories using the Twelve Principles of Green Chemistry.
4. Highlight the positive aspects of each factory and any that you think could be improved.
5. Rank the three processes from most to least 'green'. Give reasons for your ranking.
6. What recommendations would you make to crisp manufacturers to improve their processes in line with the principles of green chemistry?
7. Prepare a short presentation for your class that summarises your findings.

The Twelve Principles of Green Chemistry

No.	Principle	Description
1	Prevention	Prevent waste rather than treat or clean up waste
2	Atom Economy	Maximise the incorporation of all materials used in the process into the final product
3	Less Hazardous Chemical Synthesis	Use methods that are non-toxic to people and the environment
4	Designing Safer Chemicals	Ensure chemicals used are safe and non-toxic and that the product is non-toxic
5	Safer Solvents and Auxiliaries	Use of solvents and added substances should be minimised or unnecessary, and non-toxic if they are used
6	Design for Energy Efficiency	Recognise and minimise the energy requirements of processes for their environmental and economic impacts. Use room or ambient temperatures and pressures for processes if possible.
7	Use of Renewable Feedstocks	A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable
8	Reduce Derivatives	Minimise steps that require additional reagents and produce temporary changes to physical and chemical processes, as these can generate waste
9	Catalysis	Catalysts are superior to stoichiometric reagents (that is, those that appear in a chemical equation for a reaction)
10	Design for Degradation	Design products so they break down into non-toxic substances and do not persist in the environment
11	Real-timeAnalysis for Pollution Prevention	Develop analytical methods to allow for real-time, in-process monitoring and control prior to production of hazardous substances
12	Inherently Safer Chemistry for Accident Prevention	Choose substances and processes to minimise potential for accidents, including gas release, explosions and fires

Walkers Crisps, Leicester, UK

History

Walkers Crisps was founded by Leicester butcher Henry Walker in 1948. Post-war meat rationing meant that Henry needed another way of making an income. He set up as a crisp manufacturer. Today, the Walkers factory processes 280 000 tonnes of potatoes each year, making 80 000 tonnes of crisps. The factory employs 866 people on two sites.

Raw materials

Lorries loaded with potatoes from farms arrive at the factory and tip their loads into a receiver. A powerful hose pushes the potatoes into an open water flume (imagine a water park filled with potatoes). Non-potato items are skimmed off by a 'de-wooder'. Stones fall to the base and are sieved out.

Peeling and slicing

Washed potatoes arrive into giant metal chambers. The chambers have abrasive internal surfaces. The potatoes spin round at high speed for 2 – 3 minutes, removing around 90% of the peel. It is difficult to skin potatoes perfectly and customers like the natural appearance that some peel creates on a crisp edge. Customers don't like green potatoes. These are removed by a computerised vision-inspection system, which examines each potato. Green ones are flicked out of the process by automated 'fingers'.

Potatoes pass into vertical metal cylinders about 40 cm diameter for slicing. Eight blades are evenly spaced around each cylinder. A spinning platform at the base of each slicer throws potatoes at high speed into the blades. Potatoes are cut into 20 – 30 curved slices about 10 potato cells thick. The curved slices allow outer surfaces to release more starch. The slices are washed in a water flume. The flume liquid is cloudy with starch. This is recycled to make Quavers. After a few metres, the flume fans out into a fishtail shape about 2 m wide. From here, slices move onto a conveyor belt for drying using air jets. Vacuum suction removes water droplets before they can settle back into place.

Frying the crisps

The potato slices are fried in sunflower oil in a continuous fryer, which is a covered metal tank several metres long. Oil is at 180°C where potato slices enter the fryer. Rotating paddles move crisps through the oil. Oil temperature drops along the fryer, corresponding to temperatures at which starch texture changes. Getting the temperature and timings right gives crisps their perfect crunch. At the exit point of the fryer, the oil temperature is 160°C. The high exit temperature drives off water vapour from inside the crisps. Oil is absorbed into the crisp on cooling. The final product is about 30% oil.

Seasoning, bagging and packaging

The crisps are laid on a conveyor belt moving at 3 ms^{-1} down a parabolic curve. This arranges them in a single layer. An automated vision system inspects each crisp, checking for golden yellow colour. Rejects trigger a puff of air that blows downwards as crisps fly over a horizontal gap about 10 cm wide. Flavours are added as solid powders as the crisps fall into giant tumblers. The challenge is to coat crisps evenly without breaking them. Flavoured crisps fall down a chute onto a metal plate shaped like a flower with fourteen petals. Each 'petal' funnels crisps into a weighing 'head'. Roughly once a second, any two heads tip their contents into a chute leading to the bagging area. Here, crisps drop into a tube of packaging material inflated by nitrogen. This is moving downwards at 0.25 ms^{-1}. A heat sealer and slicer create a filled crisp packet every 1.6 seconds. The bags fall on to a conveyor belt to be packaged into multi-packs or boxes.

Further information

Further information is available from the Walkers Crisp website at:
https://walkers.co.uk/.

A video of the Walkers Crisp factory showing some stages of the process is available at:
https://www.leicestermercury.co.uk/whats-on/food-drink/look-inside-huge-walkers-crisps-1547323.

Kettle Crisps, Norfolk, UK

History

Kettle Crisps was founded in 1987 by Cameron Healy, in a corner of an old converted shoe factory in Norwich. Cameron chose Norfolk to be close to potato farmers. Two years later, Cameron founded Kettle Foods with chef Chris Barnard. Kettle crisps are 'hand-cooked' with flavourings made from natural ingredients. Today the factory employs 443 staff and has 22 fryers. It processes 50,000 tonnes of potatoes each year, making 3.6 million bags of crisps.

Raw materials

Potatoes come from within 30 miles of the factory. On arrival at the factory, the potatoes are tipped from the trailer onto a hopper where they are graded. Six people work as graders, checking that the potatoes are the right size and shape to make Kettle crisps. Any that are green, too small or otherwise unsuitable for turning into crisps are removed.

Peeling and slicing

The potatoes enter the factory at the point that workers call the 'wet end'. A de-stoner uses water to remove stones from among the potatoes, which then pass into a drum washer. Here, water is used to remove mud and peel. After this a de-wooder removes any straw, leaves and other non-potato material. The cleaned potatoes are sliced into 20 – 30 crisps. The wet slices are dried, then passed to the next stage.

Frying the crisps

The crisps arrive in the 'cook rooms'. Here, they are fried for about seven minutes in sunflower oil at 151°C in an uncovered metal tank. The frying is monitored by hand and eye. Rakes are used to turn the crisps as they pass through the oil. The same type of hand rake is used today as when the company started in 1987. The crisps are checked as they fry, ensuring each load of crisps is cooked perfectly.

Seasoning, bagging and packaging

The crisps pass along vibrating conveyors for seasoning. The company says vibrating conveyors are the best way to prevent crisps breaking. Quality control is carried out by eye. Each crisp is inspected by a controller who is trained to pick out and remove crisps that are not perfectly golden in colour. The crisps are seasoned. Seasonings are made from food prepared by a chef. The company believes this gives the best flavour. Food is converted to seasoning by spray drying, forming a powder. The powdered seasonings are added to crisps as they fall through a tumbler. From the tumbler, crisps are packaged in bags. Each bagging machine is supervised by one person. Every bag has a small amount of air sealed with the crisps to prevent breakage. The crisp bags are packed by hand into boxes for transport to Kettle's customers. The whole process takes about 30 minutes from potato to crisp packet.

Further information

Further information is available from the Kettle Crisps website: https://kettlechips.co.uk/.

Two videos are available showing the Kettle Crisps factory: https://kettlechips.co.uk/we-love-potatoes/ and https://www.edp24.co.uk/business/watch-a-behind-the-scenes-look-at-how-kettle-chips-are-made-in-norfolk-1-5240668 (scroll down to find the video)

Frito-Lay Inc., Casa Grande, Arizona, USA

History

Frito-Lay Inc. formed from two companies, Frito and Lay, in 1961. The Frito Company was started in 1932 by Charles Doolin in Kansas, who made corn chips in his mother's kitchen, calling them Fritos. The Lay Company was founded by Herman Lay in 1931, who sold potato crisps from the boot of his car. In 1965, Frito-Lay merged with Pepsi-Cola to form PepsiCo, the world's largest snack food company. The Casa Grande factory was built in 1984 and is the size of two football pitches. The factory makes about 68,000 tonnes of snack food every year.

Raw materials

The potatoes arrive from New Mexico. About 220 tonnes of potatoes are processed every day. The potatoes are tipped from trailers onto a conveyor belt and carried into the factory on an automated hopper-grader. At Casa Grande, 1 kg of crisps requires 3.6 kg of potatoes.

Peeling and slicing

The potatoes are washed then peeled using abrasion in a high speed centrifuge. As they move to the slicers, potatoes are inspected automatically by several vision systems for defects. Rejected potatoes are removed. Large potatoes are cut in half. Each potato is sliced into about twenty thin, wet crisps. Slices are washed to remove excess starch. The starch is recycled. Vacuum hoses are used to pull moisture from the slices. Water is recaptured and recycled. The drying process reduces the heat required to cook the crisps.

Frying the crisps

The factory has two fryers, which are enormous covered tanks. In each tank around 3000 kg crisps are fried every hour in hot oil. The oil is heated by steam, which is generated from a turbine that burns natural gas. The factory burns enough gas in a year to fuel 13,000 homes for one winter. After frying, crisps pass through an automatic vision system, which picks out under- and over-fried crisps and any other defects. Rejected crisps are recycled as animal feed.

Seasoning, bagging and packaging

The crisps pass on a vibrating conveyor belt into the seasoning area. Crisps are separated into two lines, one ready salted and the other for other flavours. Seasonings are sprayed on the crisps as a powder. Frito-Lay uses 'natural' seasonings. After this, crisps pass to the bagging area. Unused crisp bag film is recycled into other products such as handbags. Bagged crisps are packed by hand into boxes for transport to the consumer.

Further information

Further information about Frito-Lay is available at:
https://www.foodprocessing-technology.com/projects/pepsico-frito-lay/.

A video showing how Frito-Lay crisps are made is available at:
https://www.youtube.com/watch?v=ws_K9Cxs-uE.

Articles about the refurbishment of the factory to become 'net zero' are available at:
https://www.nytimes.com/2007/11/15/business/15plant.html and
https://www.foodprocessing-technology.com/projects/pepsico-frito-lay/.