# Pasteurisation

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Microbes, which are to be found everywhere in our environment – and particularly in the air – exist in greater numbers than any other living beings on planet Earth. Collectively, they also weigh more than any other category of being. Because of their size, however, we rarely notice them as we go about our daily lives. Observing and monitoring their effect on foodstuffs is a highly educational way for children to get to know them.

When studying the conservation of wine, Louis Pasteur made use of his knowledge of microbes. He had shown that these organisms – which are visible only under a microscope – were capable of feeding, and therefore of proliferating, by transforming food. "Good" microbes were used for transforming grape juice into wine, while "bad" microbes would make the same wine undrinkable. How could the "bad" ones be eliminated efficiently and the "good" ones allowed to develop unhindered? We are going to examine that problem in three successive phases:

– Producing food and drink through fermentation. Bread hot from the oven is so tasty! The production of wine or bread provides a creative opportunity to explore, to handle ingredients and to compare recipes and practices used in the home and by small businesses. It also allows room for experimentation, since various parameters – e.g. the presence or otherwise of yeast – can be modified and the results observed. Getting microbes to work for people is easier than one might think!

– Preserving food and drink. Once the food has been produced, we will look at how it can be preserved. If we leave a slice of fresh bread in a plastic bag for a week, it will be colonised by blue or green mould. It is no longer edible! How can the mould be avoided?

– Exploring an industrial preservation technique. The process developed and patented by Pasteur for eliminating undesirable microbes is particularly interesting. What are its characteristics and applications in the light of what the children have already studied?

The pupils test their hypotheses by examining the foodstuffs, conducting studies and discussing their ideas and findings in a logical manner. This ordered approach can also serve to develop civic-mindedness. The work performed individually and in groups – including diagrams and notes taken on sheets of paper – will be detailed in their experiment notebooks. The equipment used for the experiments, most of which can be readily found, will cost very little. The approach described here is merely a suggestion, and may be changed as desired.

Before going any further, a word about the term "microbe". This term, which comes from the Greek *micros* (small) and *bios* (life), is very general, and refers to living beings of different species, the essential common denominator of which is their small size (< 0.1 mm). Looking at the millimetres marked on a rule will give pupils an idea of how small this is.

Most microbes comprise a singe cell, and can be elongated, ovoid or roughly spherical in shape. Yeast cells measure approximately 0.01 mm, and have a nucleus containing DNA, in which genetic information is to be found. Bacteria are some ten times smaller than yeast cells (i.e. approx. 0.001 mm), and their DNA is not contained in a nucleus. Primary school is a little early to study the morphologies of microbes or to speak about DNA and nuclei, but the pupils can easily grasp the fact that, while all microbes are small, they are not all identical!

## Producing food and drink through fermentation

Since Antiquity, most civilisations have used fermentation to produce various types of food and drink, including bread, cheese and alcoholic drinks. However, it was not until Louis Pasteur that the scientific explanation for this natural phenomenon was first discovered. Pasteur demonstrated that the transformation of grape juice into wine was due to the action of the yeast – a type of microscopic fungus – found on the skins of the grapes.

The children are unlikely to know about Pasteur's work. They can first try to answer one or other of the following questions, which concern familiar products: "How is bread made?", "How is wine made?" and "How is yogurt made?". The aim is simply to see how something edible or drinkable can be produced. To begin with, each pupil gives his or her opinion and suggests ideas. They then discuss the subject among themselves, perhaps in groups, and the first review takes place. The class reviews what is clearly known (e.g. “To make bread, you need flour!”) and what is not yet known (e.g. “Have we forgotten any ingredients?”). Information and questions are written on a group poster and in the experiment notebook.

At this stage, if the discussion has gone far enough, the proposed recipes may be tested. Sooner or later, it may prove necessary for the pupils to ask questions at home, to visit a bakery or winery, or to do some research using books or the Internet. If someone mentions yeast or microbes, the meaning of those words may be discussed. If not, those items may be brought up as the need arises. It is a good idea to take photos of each session’s achievements.

## Producing wine

To give an idea of what pupils are capable of achieving, here is a report written by a class which had been visited by a wine producer before they conducted their experiment: “On 30 September, we picked the grapes. On 1 October, we pressed the grapes in a large salad bowl by crushing them with a fork. When we tasted the juice, it was very sweet! We covered the salad bowl with cling film. On 4, 5 and 6 October, we saw bubbles appearing, and the cling film began to rise. The grape must was floating on the surface. We tasted the liquid again, and it was less sweet than before. The taste and smell had changed. On 7 October, there were a lot of bubbles, and there was froth on the surface. On 14 October, we tasted the liquid again (without swallowing it!). The sugar was gone, and it contained alcohol. We had managed to make wine!”

What happened to the sugar? Where did the alcohol come from? The children can observe the micro-organisms under a microscope, surmise that the sugar has been turned into alcohol and pursue their experiments on grape fermentation. Using an inexpensive winemaker’s tool – an alcoholmeter or hydrometer – they can see that, the more sugar is used (within reason – a few lumps per litre), the more alcohol is produced. To measure the alcohol content, the wine is poured into a graduated cylinder in which the hydrometer is then floated. The more alcohol the liquid contains, the higher the hydrometer will rise. The alcohol level corresponds to the graduations on the tube. The yeast causes so-called “alcoholic fermentation”.

## Producing vinegar

Producing vinegar is even easier. Simply half-fill a jar or demi-john with wine so that a large surface area of the liquid is exposed to the air, and wait. Two to four weeks later, the wine has turned into home-made vinegar. The taste changes this time, too! The liquid is acidic. The film on the surface contains microbes which need air in order to bring about so-called “acetic fermentation”.

The pupils may be asked where the microbes that make up the film came from. Did “spontaneous generation” occur in the wine, or did the microbes come from the air? This question was hotly debated by scientists during the 19th century. Using a very precise experimentation procedure which could not be followed in class, Pasteur finally proved that there was no such thing as spontaneous generation. The pupils may be told that, in well-equipped laboratories, the wine can be protected from contact with airborne microbes, and that, under such conditions, no film appears on top of the wine. However, there is no need to provide over-complicated explanations, since the main aim of the practical experimentation suggested here is to provide concrete examples of problems which will be solved later on in the children’s school careers.

## Making bread

Here is one account: “With 500 g of flour, 300 g of water, 20 g of yeast and 10 g of salt, we successfully made bread. You must mix the flour, water, yeast and salt until the dough no longer sticks to the bowl or to your hands. Then, you must let it rest for fifteen to thirty minutes. Next, you must divide the dough into smaller pieces (350 g for a baguette and 120 g for rolls) and roll it into balls. Then, you let it rest for fifteen more minutes. After that, fold the pieces several times, shape them as desired and place them on a clean tea cloth for an hour or two to let the dough rise. Then, place a container of water in an oven preheated to gas mark 7 or 8 (around 250 °C). The water will boil, giving off steam so that the bread stays moist and tender while being baked. Make some cuts in the dough with a knife before putting it in the oven. This will cause gas to escape. Bake for around half an hour, checking regularly.”

The children can experiment and try a variety of recipes: “When there are only water, flour and salt in the dough, it doesn’t rise, and the bread ends up all flat. And the taste isn’t great, either! The baker’s yeast, it makes a huge difference!”

When the yeast is cooked alone before the flour is added, the dough does not rise: “Of course! The heat kills the microbes, so they can’t work any more!”

Baker’s yeast, which is inexpensive, comes in little cubes that may be bought at the supermarket. Like wine yeast, it transforms the sugar in the flour into alcohol and gas (carbon dioxide, or $CO_2$). In the case of wine, it is the alcohol that is useful; in the case of bread, it is the gas, which makes the dough rise. The small quantity of alcohol produced in the dough evaporates during the baking process. This means that bread is safe for children, whereas wine is obviously to be avoided, since it can cause damage to the nervous system.

## Making yogurt

You have probably noticed that, unlike milk, yogurt has a slightly sour taste. Where does that taste come from? Yogurt is made using a yogurt maker, which is a sort of bain-marie (i.e. a water container incorporating a heating system) that maintains a temperature of around 38 °C. Using a litre of milk mixed with one tub of yogurt, it is possible to make eight tubs of yogurt in half a day. Why add a tub of yogurt to the milk when making yogurt? Simply to provide the microbes required (in the case of yogurt, it is bacteria, and not yeast, that do the work). The microbes grow by using the food found in the milk. During their development, they bring about so-called “lactic fermentation”, thereby transforming the sugar in the milk into acid (lactic acid). Lactic fermentation is different from alcoholic fermentation. Each type of microbe causes a different type of fermentation.

If left exposed to the air for too long, yogurt can go bad. If this happens, it must not be eaten, because it could be dangerous. Bad yogurt also has quite an unpleasant taste. “Useful” ferments are used for making food, whereas “undesirable” ferments can cause food to become inedible. Let’s try to see how we can protect ourselves from the latter.

## **Food conservation and protection** against undesirable microbes

A discussion can be organised based on the children’s life experience. Are there any special rules for food conservation? Are all types of food kept in the same manner?

### The children observe how food reacts, and express their opinions concerning food conservation

A variety of foods (fruit, cakes, etc.) are left at room temperature in the classroom. These can be made by the children, found in the wild, or brought from home or from the school canteen. “When food is not kept properly, it goes mouldy, it rots, it goes off, it’s spoilt, wasted. There are bacteria, viruses, hairs and microscopic fungi. It’s old and smelly. It can be used to make compost, but it’s bad for the health! That’s why you must take care to store food correctly”[1].

When storing food, certain precautions must be taken. What are they? The children outline their ideas: “You must keep it cold, in the fridge or freezer, leave it in a closed can, salt it a lot, cook it in sugar like jam”, etc.

### The children compare various means of conservation

The next day, some of the children’s ideas can be evaluated. Various means of conserving different types of food compared. Each day, the children make drawings or take photos, and note their observations in their experiment notebooks. Meat, milk and pears behave differently when left at room temperature, preserved in salt, boiled, left wrapped or unwrapped, put in a sealed jar or in alcohol, frozen, refrigerated or stored in a cellar. After getting together in small groups to discuss the protocols to be used, the children change the food-storage conditions. Each day, any changes in shape, colour or smell are noted in detail in the experiment notebooks.

After a time, it is concluded that not all means of conservation suit all types of food: “The pear keeps for a long time at room temperature, whereas the milk curdles! To be conserved successfully, the milk must not only be boiled; it must then be cooled quickly and kept at around 4 °C.”[2]

Does the food keep better with or without air? “The containers of milk left exposed to the air undergo changes. Gas appears, and mould can also grow after a few days. The containers that are sealed and heated in a pressure cooker do not undergo such changes. The milk that they contain keeps for longer.”

On the basis of their experiments and of reading, the children determined that two parameters were important when keeping food at room temperature – prior heating and absence of contact with the air.

### The children try to determine the conditions in which mould develops

Mould, which is caused by fungi, spoils food. In the environment (e.g. in the ground), these fungi are often active prior to the decomposition proper of the food. With few exceptions – e.g. blue cheeses such as Roquefort – mouldy food is inedible.

In the air, mould exists in the form of spores, which are basically microscopic capsules. When they find the appropriate conditions and nutrients, they develop into filaments. Which conditions are favourable for the development of bread mould? The pupils give the question some thought, and suggest possible answers: mould needs water and light; it develops better in the cold, etc. They conduct experiments. This investigation has several methodological advantages, including the fact that it teaches the children how to change parameters one by one. They put a slice of bread into each of a number of plastic containers, which are then closed. For the first experiment, all of the containers are left at room temperature in the light. Some contain a large quantity of water, others a little, and yet others none at all (some desiccant may be added to these). The children notice that the dry bread does not go mouldy – mould therefore needs moisture.

To investigate the temperature parameter, all of the containers are placed in the dark with the same quantity of water, some being left in the classroom at room temperature, while the others are put in a fridge. The children note that the mould grows more quickly at room temperature.

During the next stage, some containers are left exposed to daylight, while the others are kept in the dark (e.g. in a classroom cupboard). The experiments show that, in order to grow, the mould needs heat and humidity, but not light.

The main purpose of these experiments on mould is to show the children how experiments are conducted. The stages include initial hypotheses, proposals for a protocol (what we are going to do in order to test the hypotheses), implementation (adding and removing things), comparison of results (observation and drawings in the science copybook), interpretation (saying what we understand) and conclusion (possible criticism and, perhaps, new hypotheses to be tested through further experimentation). Without wanting to draw naive parallels between the work of scientists and that carried out by the children, it could be said that the above provides an introduction to research practices not unlike those used by Louis Pasteur when he developed pasteurisation.

## Pasteurisation

The packaging of some of the foods that the teacher asked the pupils to bring to class – e.g. milk and fruit juice – features the word “pasteurised”. Where does that term come from? What does it mean?

The pupils find the dictionary definition of “pasteurisation”. It is a process which consists in heating a liquid for a few minutes to a temperature lower than 100 °C and then cooling it rapidly. Pasteurisation is therefore different to sterilisation, which can be performed by heating a liquid for a few minutes in a pressure cooker at a temperature higher than 100 °C (see below).

### Research into Pasteur’s work

Pasteur’s notebooks are filled with drawings of small organisms, and with sketches, comments and diagrams of various items of equipment. They contain reports on countless experiments concerning each problem that Pasteur encountered.

The children read the description of Pasteur’s discoveries on fermentation (this may be found on the CD-ROM) and discuss questions – e.g. “where do wine diseases come from?” or “how can they be prevented?” – and note their conclusions.

The wine-conservation patent, which was filed on 11 April 1865, was the culmination of a lengthy and rigorous experimental demonstration involving a large number of stages which required strict hygiene conditions. Although much more complicated, the process was – as seen above – comparable to that followed when the children studied the conditions required for mould to grow. The children examine a facsimile of the patent, which is also included in the CD-ROM resources.

After using the microscope to see that the air contained micro-organisms (children – and, indeed, many adults – are under the impression that microbes are generated spontaneously in foodstuffs), Pasteur realised that certain microbes caused disease in, or damage to, wine. He discovered that, by heating the wine to between 60 °C and 100 °C without contact with the air, the microbes in question could be destroyed. This process prevented all types of undesirable fermentation in the wine, without having too severe an effect on its quality (the wine being heated just enough so that its taste would remain acceptable). The children can be told that this process is more suitable for other products, and that it is no longer used for wine, because it does take somewhat from the taste.

### Industrial applications of pasteurisation

Pasteur wrote the following about the wine experiment: “We heated 650 hectolitres in two days. The speed of the operation means that it is suitable even when very large quantities of wine must be supplied at short notice. These 650 hectolitres will be shipped to the West-African coast – where what our seamen drink is little better than vinegar – along with 50 unheated hectolitres of the same wine. If the trial is successful – i.e. if the 650 hectolitres arrive and can be stored locally in good condition, whereas the other 50 hectolitres go bad (and of this my laboratory experiments have left me in no doubt) – then the problem will be solved, and all wine sent to our navy will henceforth be protected from disease by the heating process.”

What is Pasteur’s initial hypothesis? What does he expect to find? What will the industrial ramifications be if his hypothesis is validated? Are the quantities mentioned similar to those currently produced by wine growers?

Looking at the industrial applications of pasteurisation can also provide an opportunity to learn from visits or documents, to conduct a study and to report back orally or in writing, with photos, a film or a wall chart.

### Pasteurisation and taste

Pasteurised orange juice does not keep for as long as sterilised orange juice. Certain children ask why pasteurisation is still used when the product must be refrigerated afterwards.

To find out why, all you have to do is taste different samples of orange juice. The pupils organise blind tests using numbered cups containing different samples of orange juice. During the tasting, they rinse their mouths between two samples. The children agree in general – but not always! – that the fresh juice tastes better than the pasteurised juice, which, in turn, tastes better than the sterilised juice[3]. In general, the less a product is heated, the less damage is sustained by its constituent parts, and therefore the less the taste is affected. This test provides an opportunity to learn vocabulary for describing taste sensations (sweet, sour, fragrant, etc.).

## Conclusion

In studying Pasteur’s work, the children discovered the strange and fascinating world of microbes. Do they know that microbes can also cause diseases in humans? This study can be followed up with a discussion and work on hygiene and health, which could involve simple experiments followed by a study and a visit. In a dairy, for example, the milk that arrives in refrigerated tanks is immediately pasteurised before being used for making other foods. Hygiene is strict, and the equipment is disinfected with bleach. The instruments are sterilised, and the staff wear white coats and caps. The same precautions are taken in hospitals.

These studies provide a better understanding of common practices such as disinfection, pasteurisation and sterilisation.

– disinfection (using chemicals) destroys pathogenic microbes, i.e. infectious agents. Alcohol is a relatively poor disinfectant, since it does not destroy all bacteria;

– pasteurisation, which involves heating a product to under 100 ° C, destroys active microbes – including the useful ones – but not spores;

– sterilisation, which kills all microbes and their resistance forms, is achieved through the use of chemicals or ionising rays (ultraviolet rays or gamma rays), or by heating to beyond 100 ° C for several minutes.

[1] From work performed by Sylvie Fremineur’s class in Le Chaumet-Évires.

[2] From work performed in Saint-Germain-et-Mons primary school.

[3] Work performed in the Bergerac school.