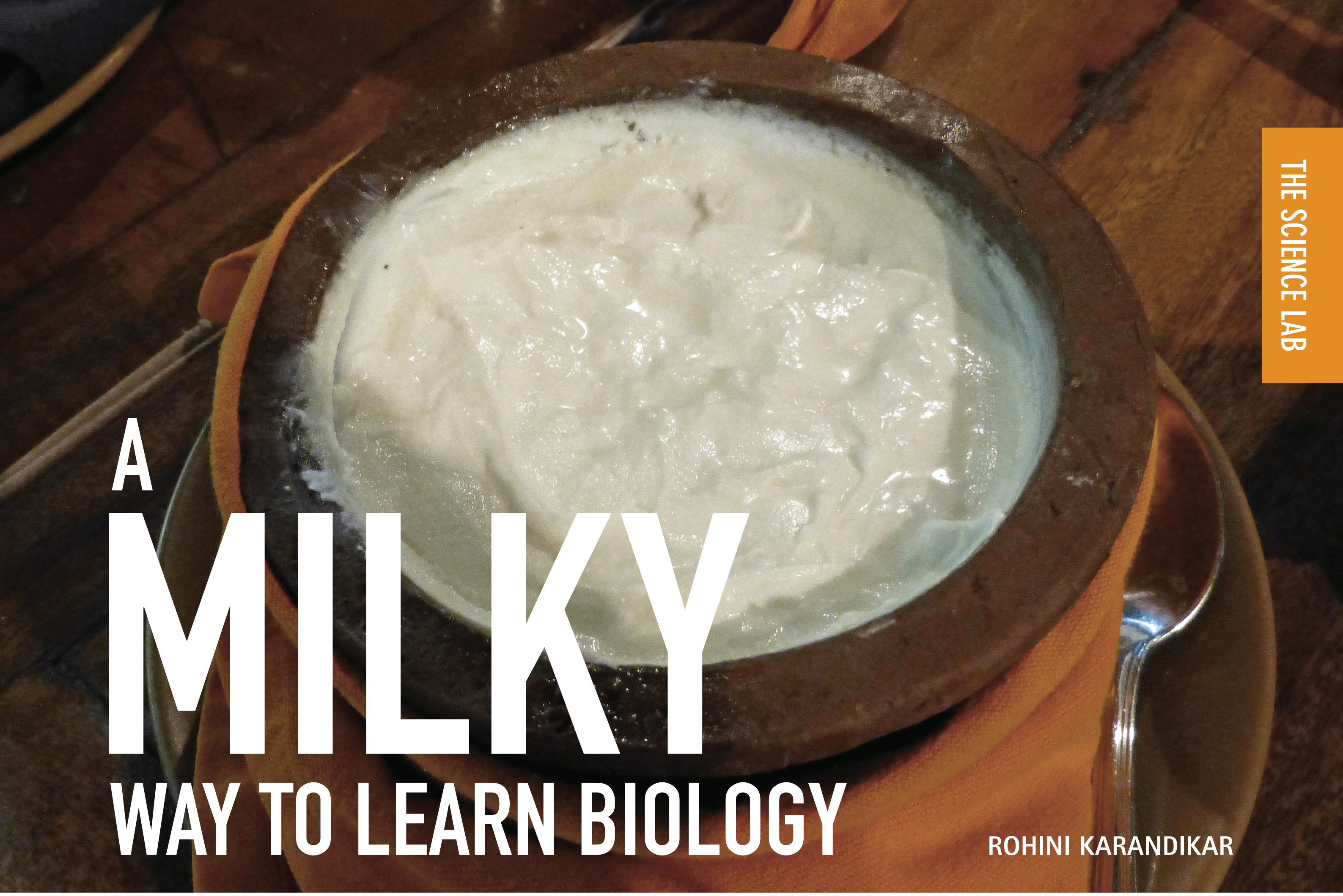


A MILKY WAY TO LEARN BIOLOGY

ROHINI KARANDIKAR

The simple and everyday practice of curd formation involves concepts taught in biology (microbial fermentation), chemistry (conversion of milk lactose to lactic acid) and physics (coagulation of milk proteins with acid). Can we use this process to offer a hands-on introduction to what it means to think like a scientist?

Doing science may be a powerful way to understand the scientific method, and what it means to be a scientist. Applications of the scientific process extend beyond laboratories to our everyday life. One application of this process is in understanding curd formation (see **Box 1**).

Setting curd is an age-old practice, common to many parts of the world, that has undoubtably evolved through repeated observation, prediction and enquiry. This everyday practice offers plenty of learning opportunities to curious young students who may have just begun to explore the world of biology. For e.g., have you ever wondered why we always need a small amount of 'old' curd to get a batch of 'fresh' curd? Or, if it were possible to get curd simply by leaving milk undisturbed for long enough? Or, why the temperature of milk or the season of the year seem to affect the rate of curd formation? These, and many other such questions around curd formation can be answered through simple, cost-effective experiments. A small space, the motivation to observe, and the willingness to play around with milk and curd (and clean up later) may be all that is needed! Apart from introducing

Box 1. A quick look at the basics:

- The term 'curd' in this article (and in India) refers to the fermented product obtained by the addition of a small amount of curd (or buttermilk) to milk. This product is called yoghurt in some other parts of the world.
- Curd is formed due to several species of bacteria, like *Lactobacillus sp.*, *Lactococcus sp.*, and *Streptococcus sp.*, that convert the lactose in milk to lactic acid (which makes curd sour). These bacteria are collectively called **lactic acid bacteria** (or, LAB).

students to the scientific method, these experiments touch upon a wide range of topics in school biology (see **Box 2**).

How do people make curd?

This activity is ideally introduced a day before the other activities. Share the corresponding activity (see **Activity Sheet: How do people make curd?**) with students as homework. Introduce them to the idea of a 'science reporter' and ask what they expect to find.

Once students have completed this activity, encourage them to reflect on how they would go about testing the things they've learnt from it. This discussion could be used to introduce the concept of a hypothesis. In addition to the process of curd formation, this activity can also be used to discuss science–society relationships. For e.g., is science limited to labs? Are people with no professional training in science also capable of engaging with the scientific method in their everyday lives?

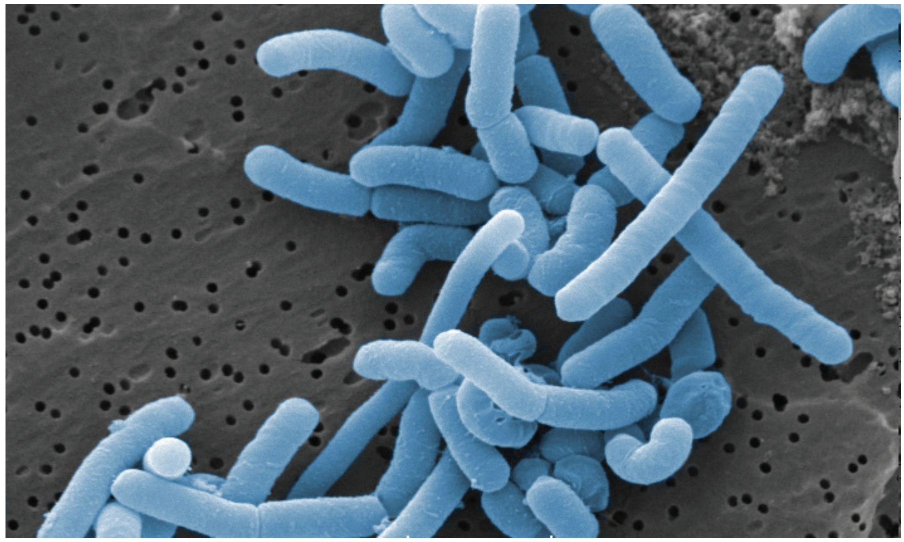
How is curd different from milk?

Discuss the difference between milk and curd with your students. Once they have arrived at some consensus, ask them if they could describe a method to distinguish between the two liquids without tasting them (tasting anything in the laboratory should be discouraged).

Box 2. Links to the school science curriculum:

The experiments around curd formation described here are linked to concepts of:

- Fermentation, food preservation, and microbiology from the chapter on 'Microorganisms: Friend and Foe' in the NCERT Grade VIII curriculum;
- Physical changes, reversible and irreversible changes from the chapter on 'Changes Around Us' in the NCERT Grade VI curriculum; and,
- pH, acids and bases from the NCERT Grade VII curriculum.



Encourage them to work in groups of 3-4 to try the corresponding activity (see **Activity Sheet: How is curd different from milk?**).

Students are likely to report that curd is not as runny as milk, has a sour smell, and a lower pH. A milk smudge is much smoother than that of curd (which appears clumpy) and milk tends to concentrate at the centre of the smudge. This activity may also be useful in provoking a discussion on the 'many senses' and 'extended tools' used for observation in science.

Turning milk into curd

Ask your students to describe how milk is turned into curd. Introduce the popular practice of adding a small amount of old curd to milk to get new curd — how many of them have observed this? What does the old curd contain that turns milk into a new batch of curd? Does the old curd change the chemistry of milk, or its biology?

Share the corresponding activity sheet (see **Activity Sheet: Curd formation**) with students. Encourage them to work in groups of 3-4 to design an experiment to determine the exact set of conditions required for curd formation. This activity is likely to take at least 5-6 hours for completion. If possible, it would be best to start the experiment at the beginning of the day, with incubations extending to the last period. The cultures need to be observed at regular intervals — the 3-4 students in each group can take turns to do this. Once students have completed this activity, discuss what they've learnt from it. Each group can be invited to share their design and results, and the class as a whole can be encouraged to identify similarities and points of difference.

Students are likely to report that even if it thickens, milk left to itself does not form curd. The thickening of milk, while similar in appearance to curd, is a result of spoilage by bacteria from the milk, air, the utensil in which the milk is stored, and/or handling. By adding 'old' curd to milk, we give the lactic acid bacteria in the old curd a chance to multiply, produce lactic acid, and inhibit the growth of food spoiling bacteria. This activity may also be useful in introducing a discussion on 'standardization' and its relevance to science.

What if you don't have 'old curd' to begin with?

There is a popular belief that if you don't have old curd, you could add some lemon juice or a chilly to milk to turn it into curd. Ask students to respond to this question with a show of hands: "*How many of you believe this could work?*" Share the corresponding activity sheet (see **Activity Sheet: Starter for a new batch of curd?**) with students, and encourage them to test this hypothesis in groups of 3-4. Once students have completed this experiment, ask for another show of hands to the question posed before. Encourage students to reflect on what convinced them to change their minds.

Students are likely to report that fresh curd is formed only by the addition of some old curd (source of lactic acid bacteria). Adding lemon juice or chillies to milk causes the precipitation of milk casein — resulting in the formation of *paneer* or cottage cheese, but not curd. Hence, what happens with these 'starters' is a chemical change — the precipitation of casein by acid. In contrast, the use of curd as a starter results in a biological change — the microbial fermentation of milk to curd. This activity may also be useful in introducing a discussion on 'controls' in scientific experiments (see **Box 3**).

Box 3. Experimental controls:

Controls help prove that an intervention (e.g., the addition of a small volume of curd to milk) causes the effect being studied (e.g., results in the formation of a new batch of curd). In this experiment, beaker 2 or the beaker where a small amount of curd is added to milk, is the 'positive control' because we have determined this as the optimum condition in our previous experiment, and we are sure that it will form curd. In contrast, beaker 1 or the beaker where nothing is added to the milk, is the 'negative control'. We know that the milk in this container will not turn into curd. An introduction to experimental controls can also lead to a discussion on questions, like: "*How important are these controls? How accurate is our inference from an experiment that does not involve controls?*"

Does the temperature of milk matter?

Curd formation requires certain environmental and physical conditions. Most students may be familiar with the idea that curd formation is faster when old curd is added to warm milk, and incubated in a warm place. Some students may suggest that the milk needs to be 'hot' rather than 'warm'. The teacher can then ask students to form a hypothesis, for e.g.,: "*Can we say that the higher the temperature, the faster the process of curd formation?*" Share the corresponding activity sheet (see **Activity Sheet: Does the temperature of milk matter?**) with students, and encourage them to test this hypothesis in groups of 3-4. Once students record their observations, ask students if they'd like to change their hypothesis. A discussion can then be conducted on: "*What is the temperature range in which curd formation was fastest? Why?*"

The LABs which ferment milk to curd also inhabit the human gut. They grow best at our body temperature (~ 37°C). Therefore, using milk warmed to this temperature helps provide these bacteria with conditions that are optimal for their growth and multiplication. On the other hand, using milk that is very hot (> 45 °C) will kill these bacteria — reducing the possibility of getting curd. Milk that is cold impedes bacterial growth, slowing the rate of curd formation considerably. Similarly, incubating milk with old curd in a warm place, like a hot water bath or incubator set at 37°C will speed up the process of curd formation by providing an environment in which LAB's thrive. Thus, this experiment helps demonstrate the significance of temperature in biological processes.

Here, the teacher may also ask: "*What would happen if curd was added in unequal amounts to all beakers?*" The answer is — we would not be able to determine if curd formation was an effect of the amount of curd added or the temperature. This also emphasizes the need to vary only one parameter at a time (here, the temperature). This is exactly how the scientific method works, by varying only one variable at a time, while keeping all the others constant.

Some parting thoughts

Each of these experiments helps highlight the role of various factors in curd formation. In doing so, they raise some interesting questions. For e.g., milk gets spoilt if not consumed within a day. But if turned into curd, it stays fresh for longer. So, isn't fermentation also a process of food preservation? Students begin to understand that fresh curd is a live source of bacteria, and turning milk into curd is akin to a process of breeding microbial 'pets'. Thus, performing these experiments will help students understand what these little creatures like or dislike.

Although the article provides experimental designs, it may be best to encourage students to come up with their own experimental designs, whenever possible (see **Box 4**). It is

Box 4. Experiments on sources of milk and effect of other additives:

Students could be encouraged to design and conduct experiments to check how curd formation is affected by using:

- Milk from different animals, like cow, goat, buffalo, sheep, camel, and horse etc.
- Milk subjected to different types of processing, like fresh, boiled, pasteurized, or milk stored in tetra-packs.
- Milk additives, like chocolate powder, nutrition supplements, etc.

likely that students might take some time designing their own experiments, but doing this will help them develop a hands-on understanding of the scientific method. Not only will this help students feel a sense of ownership towards their experiments, but it will also help them discover several ways of using simple resources, like milk and curd, as 'live educational tools'.

Key takeaways

- Practical applications of science provide a powerful lens to introduce students to the scientific method.
- Curd formation is one application of the scientific process in our day–to–day lives.
- Different aspects of the scientific method, such as hypothesis making, standardization and controls, can be introduced through activities around curd setting.
- These activities can also be used to discuss science–society relationships.

Acknowledgments: The author would like to thank Dr. Ritesh Khunyakari, Associate Professor, Hyderabad campus, Tata Institute of Social Sciences, for his valuable inputs during the development of this learning unit as well as the current article. She would also like to thank all the students who participated in field-trials, and teachers and members of the Vigyan Pratibha team who provided valuable inputs and feedback on the development of this learning unit.

Notes:

1. This article is based on a learning unit – 'The journey from milk to curd' developed as a part of the Vigyan Pratibha programme of HBCSE. Vigyan Pratibha is a talent nurture program in science and maths for Grade VIII-X students from diverse backgrounds of Kendriya Vidyalayas, Jawahar Navodaya Vidyalayas and Atomic Energy Central Schools. The programme is aimed towards developing a deeper understanding of concepts and critical thinking skills by providing students with tasks which go beyond textbook-based classroom teaching. Teachers' Notes. (URL: https://vp.hbcse.tifr.res.in/wp-content/uploads/2018/12/The_Journey_from_milk_to_curd_teacher.pdf) and Students' Worksheets (URL: https://vp.hbcse.tifr.res.in/wp-content/uploads/2018/12/The_Journey_from_Milk_to_Curd_student.pdf) for this learning unit are available online. Teachers need to register for access to Teachers' Notes.
2. Image used in the background of the article title – Curd (Sri Lanka). Credits: Ji-Elle, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Curd-Sri_Lanka.jpg. License: CC-BY-SA.
3. Image used as a filler on Pg. 44 – *Lactobacillus paracasei*. Credits: Dr. Horst Neve, Max Rubner-Institut, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Lactobacillus_paracasei.jpg. License: CC-BY-SA.

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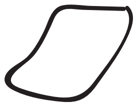
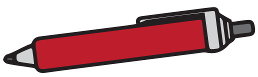
The Science Lab

HOW DO PEOPLE MAKE CURD?

You will need:



Paper



Pen

What to do:

1. Become a journalist for a day and ask your parent/grandparent/others how they set curd.
2. Do some research online to identify recipes and things to keep in mind while starting a new batch of curd.

Record: what you learn from your investigation in the table.

Some questions	What you've learnt
What should a good batch of curd smell, look, and taste like?	
What kind of milk (e.g., cow, goat, buffalo, pasteurised, full fat, skimmed, soy) is best for curd?	
Does the milk need to be treated in any special way (e.g., cooled, boiled, warmed) to set curd?	
What should we add (~ starter) to milk to get a new batch of curd?	
Can we get a batch of curd if we leave milk aside for 5-8 h without adding anything to it?	
How long does curd take to set?	
What environmental conditions make curd setting faster/slower?	
What kind of containers (e.g., plastic, stainless steel, earthen) improve the quality of curd?	
*	
*	

Note: use the rows marked * to include other questions on curd formation that you think may be useful to learn about.

Discuss: what you learn about curd formation in class. Can you identify 3-4 things about curd formation that all your sources (yours and your classmates') agree upon?

-
-
-
-

i wonder...
Rediscovering school science

Contributed by:
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Ritesh Khunyakari is an Associate Professor, TISS, Hyderabad.
Chitra Ravi works at Azim Premji University, Bengaluru.

Azim Premji University

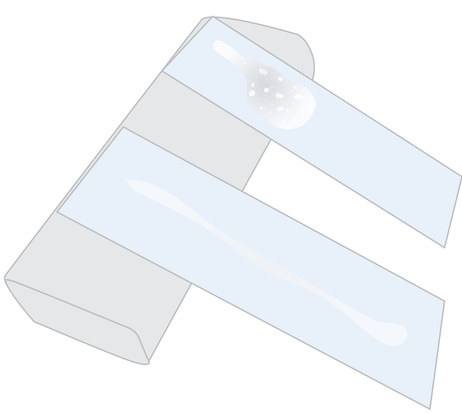
HOW IS CURD DIFFERENT FROM MILK?

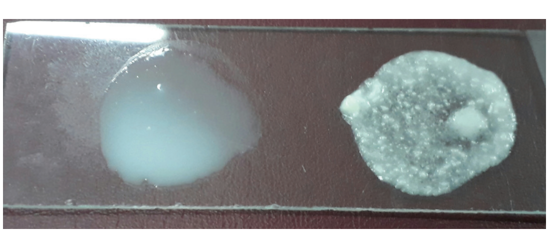
You will need:

Milk Curd Glass slides

What to do:

1. Compare the smell of the milk and curd. Can you describe the smell of each in one word? What words have your classmates used to describe each of them?
2. Place a drop each of milk and curd on separate slides. Hold the slides up and tilt to compare their runniness.
3. Place a drop each of milk and curd, side by side, on a single slide. Smudge each drop separately moving your forefinger over it in circular motion at least 5 times. Compare the appearance of the two smudges.
4. Put a drop of milk on the corner of a pH strip. Do the same with curd to compare the acidity of the two liquids.





Photographic representation with milk (left) & curd (right)

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Azim Premji University

HOW IS CURD DIFFERENT FROM MILK?

Record: what you learn from your investigation in the table.

	Milk	Curd
How does it smell?		
How thick/runny is it?		
How uniformly does it spread? (Is the smudge even/clumped? Does it remain concentrated at the centre or does it disperse to the edges?)		
What is its pH?		
Others		

Discuss:

- Would you be able to identify a drop of curd by its:
  a. Smell?
  b. Runniness?
  c. Smudge pattern?
  d. pH?
- Which of these seems like a more reliable method to identify curd? Why?
- Can you think of other ways to tell milk and curd apart?

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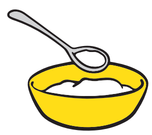
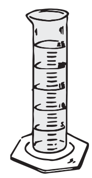
CURD FORMATION

You will need:

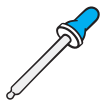
Milk



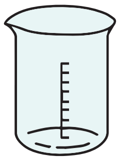
Curd



Measuring cylinder



Dropper



Beakers/bowls

What to do:

1. Design an experiment to determine conditions for curd formation within 6 h using:
   a. The lowest volume of milk.
   b. The lowest volume of curd.
   c. The ideal volume/volume ratio of milk/starter curd.
2. Set up the experiment and leave the beakers in a warm place.
3. Observe the contents of the beakers every hour and record the time point at which you notice the first change in physical consistency.
4. Continue observing the beakers every hour, recording changes in smell and pH.

Experimental set up:

Beaker no:	Volume of milk (ml):	Volume of curd (ml):	Incubation temperature:
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

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CURD FORMATION

Observe: Record your observations in the table below

Beaker no:	Change in physical consistency (runny/semi-solid/solid) and pH (with time point of change)
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

Discuss:

1. Can curd formation occur without adding any curd to milk? Why?
2. Why do you think some curd needs to be added to milk to get a fresh batch of curd?
3. What is the lowest volume of milk/volume of curd ratio that results in curd?
4. Which experimental set-up showed the fastest curd formation? How many hours did curd formation take in this set-up?
5. Which experimental set-up showed the slowest curd formation? How many hours did curd formation take in this set-up?
6. When did you notice the earliest signs of change:
   a. In physical appearance?
   b. In smell?
   c. In pH?
7. The aim of this experiment is to turn milk into curd. Do you think it is possible to turn curd into milk? Why?

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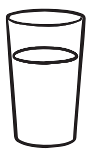
STARTER FOR A NEW BATCH OF CURD

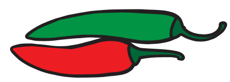
You will need:



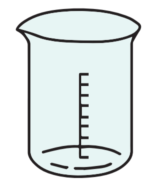
Milk

Curd

Lemon juice



Red & green chillies



5 beakers/bowls

What to do:

1. Distribute equal volumes (20 ml) of warm milk in 5 beakers.
2. Label the beakers 1, 2, 3, 4, & 5 respectively.
3. Add:
   a. A few drops (1 ml) of curd to the milk in beaker 2.
   b. 4-5 drops of lemon juice to the milk in beaker 3.
   c. 1 whole red chilly and its (separated) stalk to the milk in beaker 4.
   d. 1 whole green chilly and its (separated) stalk to the milk in beaker 5.
4. Mix the contents of beakers 2-5 well with separate spoons.
5. Leave all the beakers aside at room temperature.
6. Observe the contents of the beakers after 10 minutes, 6 hours and 12 hours respectively.

Beaker	Time	Did you get curd? (Y/N)	Other observations (smell, pH, etc)
1.  Warm milk only	After 10 min		
	After 6 h		
	After 12 h		
2.  Warm milk +  Curd	After 10 min		
	After 6 h		
	After 12 h		

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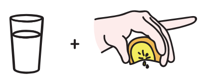
STARTER FOR A NEW BATCH OF CURD

Beaker	Time	Did you get curd? (Y/N)	Other observations (smell, pH, etc)
3.  Warm milk + A few drops of lemon juice	After 10 min		
	After 6 h		
	After 12 h		
4.  Warm milk + 1 whole red chilli & its separated stalk	After 10 min		
	After 6 h		
	After 12 h		
5.  Warm milk + 1 whole green chilli & its separated stalk	After 10 min		
	After 6 h		
	After 12 h		

Discuss:

1. Do the contents of beakers 2-5 have anything in common in their physical appearance, smell, or pH? If yes, what?
2. Are the contents of any of the beakers similar to that of 1? How, and till what timepoint in the experiment?
3. What are the main differences between the contents of beakers 2-5? When does this difference first become obvious?
4. Can we get a new batch of curd with any starter that increases the acidity of milk? Why?
5. Do you think adding a combination of curd + chillies, or curd + lemon juice, or curd + chillies + lemon juice alters the process of curd formation in any way? How, and why?
6. Can you design an experiment to test your prediction?

To ponder upon:

What do you think would happen if you:

- Use cold or boiling hot milk in Step 1?
- Use fresh/ 1-day old/ 2-day old/ 3-day old curd in Step 3a?
- Use some store-bought pasteurised yoghurt in Step 3a?
- Boil curd before adding it in Step 3a?
- Use double or triple the amount of lemon juice in Step 3b?
- Leave the stalks intact in 3c & 3d?
- Leave out Step 4?

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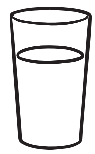
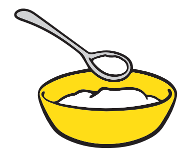
DOES THE TEMPERATURE OF MILK MATTER?

You will need:



60 ml milk (fresh)



3 ml curd

3 beakers/bowls

What to do:

1. Label the beakers 1, 2 & 3 respectively.
2. Pour 20 ml of:
   a. Refrigerated milk in beaker 1.
   b. Boiling-hot milk in beaker 2
   c. Milk that is warm enough to touch in beaker 3.
3. Add 1 ml each of curd to the three beakers.
4. Mix the contents of each beaker well with separate spoons.
5. Leave the 3 beakers at room temperature.
6. Test the contents of the beakers (for smell/runniness/smudge & pH) after 10 minutes, 4 hours, and 6 hours respectively.

1

Warm milk + curd
37 – 40˚C

2

Hot milk + curd
> 45˚C

3

Cold milk + curd
4–10˚C

4

Milk only

Observe:

Are the contents of the beakers different in any way? Record your observations in the table.

Beaker	Time	Did you get curd? (Y/N)	Other observations
1.	After 10 min		
	After 4 h		
	After 6 h		
	After 12 h		

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DOES THE TEMPERATURE OF MILK MATTER?

2.	After 10 min		
	After 4 h		
	After 6 h		
	After 12 h		
3.	After 10 min		
	After 4 h		
	After 6 h		
	After 12 h		

Discuss:

1. Is the initial temperature of milk important in curd formation? In what way?

2. Is the beaker with cold milk any different from the one with boiling hot milk after 6 h? How, and why?

3. Do you think you'd get different results if you increased the volume of starter curd you added to the beakers with milk in Step 3? Why? Can you think of an experiment to test your prediction?

4. Do you think you'd get different results if you incubated the milk in Step 5 at warmer (~37°C) or cooler (~4–12°C) conditions? Why? Can you think of an experiment to test your prediction?

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