Sculpting with milk

Keywords: 2017, Biology, Casein, Chemistry, Ethanoic acid, Filtration, Milk, Milk Curdle, Precipitation, Protein

Meta Description

A very easy experiment to create hard shapes simply by curdling milk with ethanoic acid.

Learning Objectives

To learn about the composition of milk.

To understand the effect of an acid on the structure of proteins.

To apply the concept of milk curdling through the use of an acid, which mimics the natural souring of milk by the presence of bacteria.

To become familiar with the importance of curdling in the production of other dairy food products.

Key Terms

Agglutination
Particles attaching together to form a clump.

Curdling
The liquid starts to get thicker and develops lumps.

Enzyme
Large chemical structures which are produced by living organisms, also known as proteins, that speed up a specific biochemical reaction.

Lactic acid
An acid that is formed in spoiled milk, which gives it a sour taste.

Lactose
A type of sugar present in milk.

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Micelles
Molecules which cluster together. The formation of such clusters depends on their solubility within their surrounding liquid medium, also known as a ‘solvent’.

Protein denaturation
This is when the proteins lose their structure due to stress, such as heat, acidity, or introduction of heavy metal ions.

Method

Step 1
Measure about 250 mL of milk in a measuring cup.

Step 2
Pour the milk into a glass bowl and warm the milk. It is important not to boil the milk.

Step 3
Add 4 tablespoons of ethanoic acid to the milk.

Step 4
Stir the milk with the spoon for about two minutes. Solid clumps should be observed.

Step 5
Pour the milk through a sieve to collect the solid clumps formed.

Step 6
Collect the clumps and transfer them to a piece of paper towel in order to dry the white solid as much as possible.

Step 7
Arrange the white solid clumps into different shapes and leave them for a day or two untouched to dry.

Alternative Method

To make it more appealing, add some food colouring to the white solid obtained and construct different shapes with different colours.

Precautions

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1. Use ethanoic acid with caution as it causes severe skin burns and eye damage. Therefore, avoid direct contact as much as possible. Additionally, use this acid within a sufficiently ventilated area since it is a flammable liquid and may cause respiratory irritation.

Narrative

Let's compare the structure of the paper clips with that of casein, which is one of two major milk protein components. When the paper clips are placed individually in water, each paper clip is free to move around. Upon heating these paper clips to high temperatures, one would quickly observe each clip to weaken and loosen up until they start unfolding, and some might also entangle together which would result in a reduction in free individual movement, creating clumps. This is the same process that occurs in casein protein molecules, where milk starts forming clumps upon the addition of ethanoic acid in a process known as agglutination.

Questions

Why was the milk needed to be heated?
When heating, curdling occurs at a faster rate.

Can you tell if milk is sour by a pH test (test for acidity)?
Yes. Check its acidity by litmus paper. If it is acidic then it is sour.

Are there other ways to curdle milk?
Adding other types of enzymes (as rennet or chymosin)

What causes protein denaturation?
Strong acids and bases, high temperatures and the presence of strong metals

What does milk consist of?
Proteins, fats and sugars. Proteins include casein and soluble whey proteins.

What is casein?
It is a major protein present in milk, giving milk its white colour.

Name a purpose for curdling milk.
*Milk curdling is the first step to produce cheeses and*yogurts*.*

Brief Explanation

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As milk mixes with ethanoic acid, white clumps are formed. This occurs because the casein protein structure loses its charge and becomes neutral. Therefore, it can no longer mix with the acidic milk as a result. Because of this, these structures become insoluble in milk and start forming solid clumps through agglutination, where they can be easily be removed from the milk by filtration.

Detailed Explanation

Milk is a mixture of proteins, sugars and fat. These constituents normally repel each other and remain barely dissolved in the solution, since they prevent each other from settling. The proteins present in milk can be divided into two major categories. One of which is the casein family, having phosphorus as an element in their composition which enables agglutination at a pH of 4.6 or lower. Casein is a slow-digesting protein, which is a major constituent of proteins in milk that exist as micelles, meaning that they are individual units stabilised in the solution. The other category of the protein consists of whey proteins, which are absent of phosphorus and remain in solution even at high acidity.

The addition of ethanoic acid, which lowers the pH, causes the proteins in the milk to no longer remain stable. The lowering of pH increases the number of hydrogen ions present in the milk. These positively charged hydrogen ions attach themselves to the casein protein molecules**.** This causes casein micelles to become neutral, which implies that they will start losing solubility and begin entangling together. The coagulation process as described is observed as a visible white solid structure. Such process happens slowly at room temperature but curdling occurs much faster when heat is applied.

The coagulation of milk performed by ethanoic acid mirrors the same process that occurs when milk spoils. The bacteria present in milk feed on lactose to release lactic acid as waste, which accumulates and lowers the milk's PH. This causes casein to precipitate out and forms clumps in the same manner.

Applications and Research

Curdling of milk is used for the production of various dairy products, such as butter, cheese, yoghurt and other fat-based dairy products, that are valuable in the industry. Investigating this process is important because different milk curdling parameters will cause the formation of different products. This is why Mozzarella is different from the typical cheeses, such as cheddar.

Carrying out research on the structural and physicochemical properties of milk proteins may cause enhanced health-promoting effects and unexplored discoveries for food and drug applications.

Investigation

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- Keep everything the same as mentioned in the method described, but do not heat the milk. Does curdling take longer to occur, or not?
- Ethanoic acid is used because it is acidic. Make use of different acids, such as lemon juice or orange juice (citric acid), wine (tannic acid), or soft drinks.
- Try to different types of milk and see if the result obtained is the same. For example, use whole milk, skim milk, soy or almond milk (lactose-free milk), and unpasteurized milk.



Subjects

Biology
Chemistry

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Education

Preschool
Primary
Secondary
Informal

Time Required

1 day or more
Preparation: 5 minutes
Conducting: 1-2 days
Clean Up: 5 minutes

Cost

0 – 10 €

Recommended Age

3 – 6
6 – 9
10 – 12

Number of People

1 participant

Supervision

Required

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Location

Indoors
Outdoors
Laboratory

Materials

Glass bowl

Measuring cup

Milk

Paper towel

Sieve

Stove-top oven and pan/ microwave

Tablespoon

White vinegar/ ethanoic acid

Contributor

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Author

Sources

Milk Protein

Nutritional Biochemistry (Book)

Science Fair Projects: Chemistry (Book)

Additional Content

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Using Bacteria to Make Cheese and Yoghurt (Beginner)

Dairy Researchers Identify Bacterial Spoilers in Milk (Intermediate)

Microbiological Spoilage of Dairy Products (Advanced)

The Determination of Lactic Acid in Milk (Advanced)

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