

Developing Science Savvy: Making a Recipe into an Experiment

**For more information on the actual Recipe and Experiment, check out our Chymosin Hands-on Exploration Activity
By Tom Zinnen

Consider this puzzle: **let's say you have some chymosin** but it's been out of the refrigerator for a week. You'd like to test if it's still works in making milk stiff. **What can you do?**

You could just do the recipe.

But even if the milk gets stiff, have you really **proven** that it's the chymosin that's making it stiff?

What if somebody asks: "**What else has the milk been exposed to besides the chymosin? Maybe it wasn't the chymosin but something else that made the milk stiff.**"

Using the "If, Then" Thinking Tool!

How can you **test** that it's the chymosin and not the plastic, the light, air, shaking, or heat alone that made the milk stiff?

If it's the chymosin that's essential, then can you test what happens when it's the **missing ingredient?**

If the plastic, the light, air, shaking, or heat alone can make milk stiff, then can you test that possibility by having a twin tube but without chymosin added?

What's the difference between a recipe with just one tube, and an experiment that compares two tubes side by side that differ by one thing?

Let's say you've done a two-tube test--the most basic of experiments--a fair comparison--and found **the milk is stiff in the tube that got chymosin but not in the tube that got no chymosin.**

What can you **conclude?**

It might be the chymosin.

Or it might just have been luck. How can you **test if it was just luck?**

If you flip a coin and it comes up heads, then does that mean it will always come up heads?

How do you test if a coin will come up heads all the time?

With the chymosin experiment, how can you test that it might not just be luck, but that it was the chymosin that caused the milk to turn stiff?

With a coin, you can flip it several times to test if it always comes up heads.

What can you do to be more sure that the chymosin made the milk stiff, and that it wasn't just

luck?

What if you had not just one tube with chymosin and one tube without chymosin, but you had three tubes with chymosin and three tubes without?

Let's say you tried three tubes with chymosin and three tubes without, and none of the milk turned stiff.

Does that **prove** that the chymosin doesn't work?

Or might it be that the chymosin would work if there were more chymosin--or maybe it would work if there were less chymosin.

Instead of trying just two levels of chymosin (none and 20 microliters), might you also try 10 microliters and 30 microliters?

Let's say you tried four levels of chymosin, each level with three tubes, and you lined the tubes up in a tube rack in order, with the zero chymosin tubes on the left.

Let's say the milk in the tubes on the left that got no chymosin did not turn stiff, while the milk in the other tubes away from the left edge did get stiff.

It could be the chymosin made the milk stiff.

Or, it might be that something about the left edge of the rack made the tubes stiff. How can you bypass that possibility that position or place on the rack affected milk stiffness?

In this parable, you've gone through four major transitions:

From recipe to experiment (from one tube to two tubes, two tubes that are a fair comparison and differ by only one thing);

From unreplicated experiment to replicated experiment (from having only one tube per treatment to three tubes per treatment)

From replicated experiment at **two levels of treatment** (the minimum) to replicated experiment with **several levels of treatment** (testing 0, 10, 20 and 30 microliters of chymosin, instead of just 0 and 20)

From a **well-ordered** arrangement of tubes to a **randomized arrangement** of tubes.

Does each step make your experiment **more reliable**?

Does each step reduce the **possibility of another explanation** for the milk being stiff?

Does designing an experiment involve **imagining possibilities**, and then including ways to test for those?

If you can see a possibility for making the milk stiff, then the idea isn't to "argue it away"; the idea is to design and test it away by making the possibility not an issue.