



Juice Balls: The Science of Spherification

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Experimental Procedure

Testing Spherification with Your Foods

In this part of the science project, you will test what spherification conditions turn several different foods into the best spheres. You will do this by measuring the pH of a sodium alginate and food test solution, adding increasing amounts of sodium citrate to the solution, and testing how well the solution makes spheres. You will *quantify* your results by measuring the longest and shortest dimensions (we will call them diameter and height in this project) of the balls you make using graph paper. You will calculate the ratio of both these measurements (diameter divided by height) to judge how spherical your popping boba is. In a perfect sphere these dimensions are the same, which means that the ratio of the diameter and height is 1. The closer your ratio is to 1 the more spherical your popping boba is. *Note:* In this science project, we will refer to the calcium alginate products as "balls," but this does not mean they will necessarily be spherical.

1. Prepare the graph paper you will use to measure the popping boba balls.
 - a. Cut a square (a few centimeters per side; the exact size does not matter) out of a sheet of graph paper so that the lines of the grid are right at the edges of the paper. You will use this to measure the height of the balls by holding it vertically (see Figure 6 for an example).
 - b. *Note:* You are cutting off the edge of the sheet of graph paper (and not using an uncut sheet of graph paper or an actual ruler) to measure the balls because most graph paper and rulers have a little bit of space before the "zero" mark. This means you cannot accurately measure the height of a small object sitting on a flat surface.
2. Before starting your tests, make sure that all test foods have been cooled in the refrigerator.
3. In your lab notebook, make a data table like Table 1 for each food you want to test. You will be recording your results in these data tables.

Total amount of sodium citrate added	pH	Ball	Longest dimension (diameter) [mm]	Shortest dimension (height) [mm]	Ratio (diameter/height)	Observations
0		1				
		2				
		3				
		Average				
1/8 tsp. (0.5 g)		1				
		2				
		3				
		Average				
1/4 tsp. (1.0 g)		1				
		2				
		3				
		Average				
3/8 tsp.		1				

Total amount of sodium citrate added	pH	Ball	Longest dimension (diameter) [mm]	Shortest dimension (height) [mm]	Ratio (diameter/height)	Observations
(1.5 g)		2				
		3				
		Average				
etc.		etc.				

Table 1. In your lab notebook, make a data table like this for each food you want to test. This means you should end up with at least three data tables. Be sure to label each data table with the food that you will be testing. You will be recording your semisolid ball measurement results in the data table. If no balls form, the diameter and height should be "0." *Note:* The "balls" may not be spherical.

4. Make the calcium chloride solution.

a. Add 1 cup (C) of water to a new, clean bowl.

b. Add 2.0 grams (g) of calcium chloride to the bowl.

i. To weigh out the calcium chloride and other chemicals used in this science project, cut a small piece of wax paper (around 8–10 centimeters [cm] on each side), place the wax paper on the scale, zero out the scale (so that it reads "0 g"), and then weigh out the chemical on the wax paper. Use a clean spoon to scoop the chemicals out of their containers. *Note:* You should use wax paper because it is harder for chemicals to stick to than normal paper.

ii. *Tip:* If the scale you are using does not have a feature to zero it out, you will need to first weigh the piece of wax paper so that you can subtract this mass from the total when you weigh the chemicals on it.

iii. Be sure to use a fresh piece of wax paper so no leftover calcium chloride contaminates your solution.

c. Stir the bowl using a clean spoon until the calcium chloride has completely dissolved.

5. Place a small piece of plastic wrap on a sheet of graph paper (for measuring the balls' diameters or longest dimensions). Make sure the plastic wrap is smooth, without any big wrinkles. Make sure the graph paper you prepared in step 1.a. (for measuring the balls' shortest dimensions or heights) is nearby.

6. Now make the sodium alginate solution with the first food you want to test. Try using liquids or foods with a low calcium content. Too much calcium interferes with the spherification process. We recommend starting with a soda (such as Coca-Cola).

a. In the cup part of a blender, add 1/2 C of the cold food.

b. Measure out the sodium alginate as you did in step 4.b. Weigh out 2 g of sodium alginate and add that to the food in the cup.

c. Add another 1/2 C of the cold food to the blender cup.

i. Adding the rest of the food now should help mix the sodium alginate and food a little.

d. You might want to ask an adult to help you use the blender to blend the food and sodium alginate together until the solution is completely smooth and well-blended. When you are done blending, the solution should look like the one in Figure 4.

i. Secure the blender cup lid tightly before blending so that nothing gets spilled.

- ii. *Tip:* It may be easiest to make the solution by blending the contents two or three times, for 5–10 seconds each time; if possible, shake the cup in between blending.



Figure 4. After blending the food and sodium alginate, you should have a solution that is *homogenous* (all of the solution's parts are now mixed together and the solution looks the same throughout). You may have more or less foam, depending on the food you are using.

7. Measure out 1/4 C of your sodium alginate and food solution and put it into a separate container, such as a clean cup or small bowl. Make sure not to scoop up a lot of foam. *Tip:* It is advised to leave the sodium alginate and food solution in the refrigerator for at least 1 hour or overnight to get rid of the foam. Too many bubbles in the solution can make it more difficult to form the balls in the next steps.
8. Test if you can make balls using your first food solution.
 - a. Make sure a timer, stopwatch, or clock that shows seconds is ready nearby.
 - b. Dip a pH test strip into the 1/4 C of food solution and match the color of the test strip with the color chart on its packaging to figure out what the pH of the solution is. Record the result in the data table in your lab notebook.
 - c. Using the syringe that came with the spherification kit, or a medicine dropper, suck up a small amount of the 1/4 C of food solution.
 - i. If there is still a layer of foam on the top of the solution, dip the syringe below that layer so you only suck up the liquid part.
 - ii. If there is any foam or excess solution on the sides of the syringe, carefully wipe it off on the rim of the sodium alginate container.
 - d. Practice releasing the sodium alginate solution very slowly back into its container. You want to get used to making one drop at a time.
 - e. Once you can make one drop at a time, drop a single drop into the bowl containing the solution of calcium chloride, as shown in Figure 5. You will need to make and quickly measure only one popping boba ball at a time, because the balls can change over time.
 - i. The tip of the syringe should be around 8–13 cm (3–5 inches) above the surface of the solution.



Figure 5. Drop a single drop of the food solution into the calcium chloride solution, as shown here.

- f. Let the drop sit in the solution for 60 seconds (sec); the timing is important.
- g. After 60 seconds, try to use a clean spoon to scoop the ball out of the solution, taking care to scoop as little of the solution out as possible without damaging the ball.
 - i. If nothing clearly formed, or whatever did form fell apart as soon as you tried to scoop it, make a note of this in your lab notebook. Do this by recording your observations and by recording the ball dimensions (diameter and height) as a zero in your data table. Skip ahead to step 8.j.
- h. Measure the longest dimension (or the diameter) of the ball by placing it on the plastic wrap on top of the graph paper and counting how many lines the ball spans. Note your findings in your data table.
 - i. Move the plastic wrap around a little until the edge of the ball lines up with one of the lines, as shown in Figure 6.
 - ii. Based on the number of lines the ball spans, calculate the ball's diameter in millimeters. If your graph paper has lines that are 2 mm apart, this means you will multiply the number of lines the ball spans by *two*.
 1. For example, if a ball spans about 2.5 lines on graph paper that has lines that are 2 mm apart, this means the ball has a diameter of 5 mm (since 2.5 times 2 mm equals 5 mm).
 - iii. *Tip:* If there is liquid around the ball, making it difficult to measure, you can carefully dab the liquid with a small piece of paper towel to remove the liquid. If you damage the ball when doing this, do not record the measurements for this ball and instead create a new ball in this solution (by repeating step 8.c.–8.h., and continuing from there). You may also want to record these observations in your lab notebook.

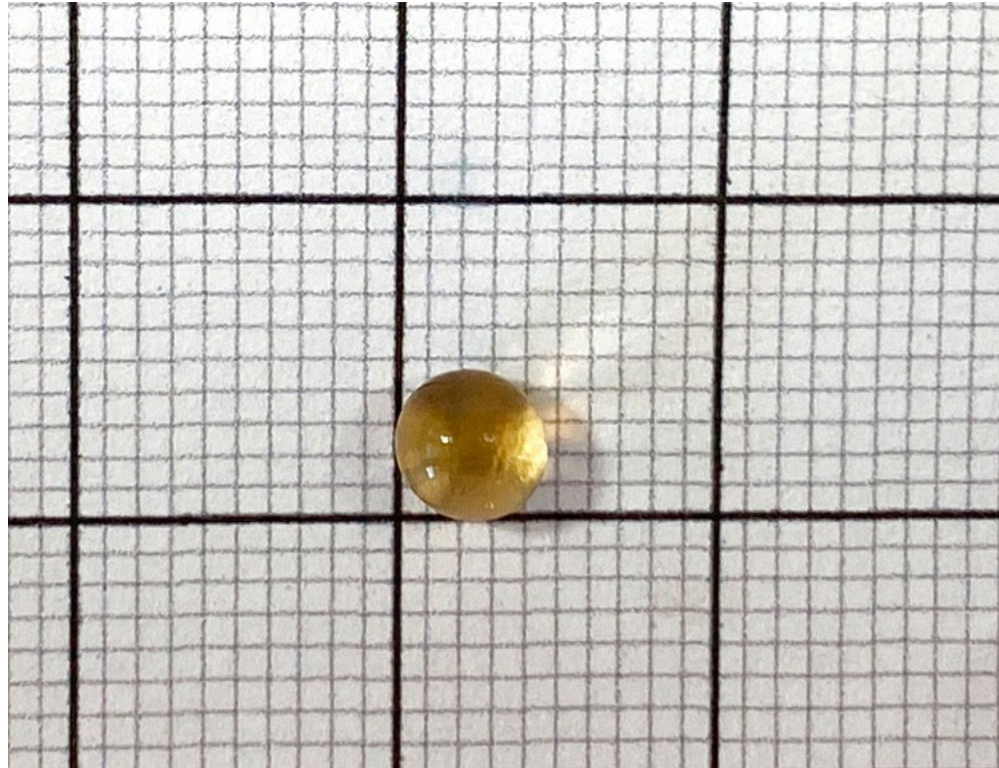


Figure 6. To measure the diameter of the ball, carefully move the plastic wrap so that one edge of the ball is lined up on a line, as shown here. Then count how many lines the ball spans. Measuring from the leftmost line, this ball spans about 4.5 lines, and since the lines in this graph paper are 1 mm apart, this ball has a diameter of about 4.5 mm.

- i. Measure the shortest dimension (or the height) of the ball by placing the graph paper you prepared in step 1.a. behind the ball, as shown in Figure 7.
 - i. Make your eye level with the ball and graph paper, such as by lowering your eye to the level of the counter or surface that you are using.
 - ii. Record the height of your ball (in millimeters) in the data table in your lab notebook. Be sure to account for whether you are using graph paper with lines every 1 mm or every 2 mm.

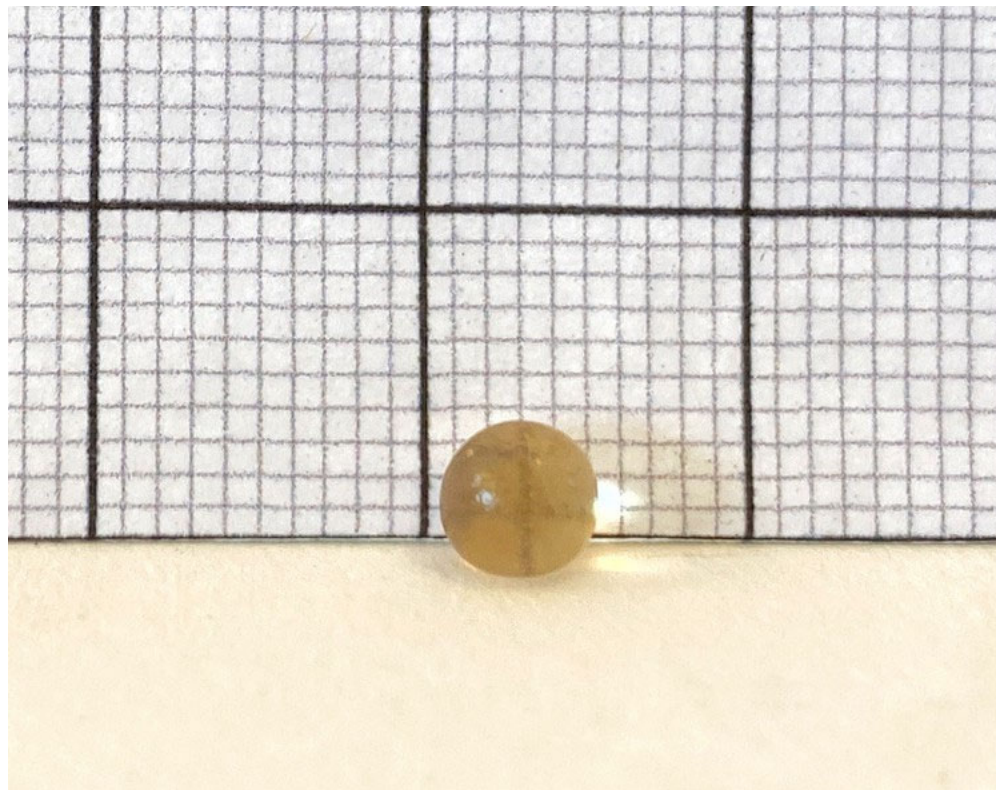


Figure 7. To measure the height of the ball, place the graph paper you prepared in step 1.a. behind the ball. Make your eye level with the ball and the graph paper and read how high the ball reaches on the graph paper. In this image, the ball and graph paper are not completely level (the viewer would need to lower his or her head to be level and make an accurate reading).

- j. Repeat steps 8.c.–8.i. two more times so that you have made and measured a total of three popping boba balls using the food and solution of calcium chloride *Note:* Remember, what we are calling "balls" might not actually be spherical shapes, but they should count as "measured balls" in your total.
 - i. Make sure to record your data in the data table in your lab notebook.
 - ii. When you are done taking your measurements, make some general observations about the three balls. How do they look and feel compared to each other? Record your observations in your data table.
 1. If you have a camera, you may also want to take pictures of your results. You may want to take some from above and some from the side. Later, you could print your pictures and put them on your [Science Fair Project Display Board](http://www.sciencebuddies.org/science-fair-projects/science-fair/science-fair-project-display-boards) (<http://www.sciencebuddies.org/science-fair-projects/science-fair/science-fair-project-display-boards>).
- k. Add 1/8 tsp. (0.5 g) of sodium citrate to the 1/4 C of sodium alginate and food solution. Mix in the sodium citrate with a clean spoon and let the mixture sit for 60 sec; this will let bubbles you added from mixing settle out of the mixture. Then repeat steps 8.c.–8.j. (using the food solution that you just added sodium citrate to).
 - i. Make sure to record your data in the data table in your lab notebook.
- l. Repeat step 8.k. until you see the balls no longer form spherical shapes (as additional sodium citrate is added). Note that if the balls did not form spheres *at all* to begin with (before adding sodium citrate), they might start to form spheres as you add sodium citrate, and then stop forming spheres again as you add even more sodium citrate. After the balls are no longer spherical (i.e., they are flat and do not hold a round shape), repeat step 8.k. one more time.
 - i. If your first attempt to make spheres was successful, be sure to repeat step 8.k. until the balls stop forming spherical shapes. You may end up

- repeating step 8.k. at least three more times before you see this change.
- ii. If you were unable to create spheres in your first attempt before adding sodium citrate, do not be discouraged. Note that it may take several additions of sodium citrate for the balls to start forming spheres, depending on the food you are using. Then you will continue adding sodium citrate until the balls stop forming spheres.
 1. You may end up repeating step 8.k. between three to nine times for the balls to become spherical.
 2. If the balls never become spherical, it is possible that this food cannot easily become spheres under these conditions. This is not necessarily an unexpected result. Try repeating step 8.k. 10 times with a food before recording it as being unable to make spheres. See step 5.d. in the "Analyzing Your Data" section, below, for ideas on how to make spheres using difficult foods.
 3. If you are concerned that your solutions are not working as they should, you can make a *positive control* test solution using water instead of food (in step 6) and repeat step 8 with it. Without adding any sodium citrate, the water and sodium alginate solution should create spheres in the calcium chloride solution.
 - iii. Keep in mind that the goal is to see how much sodium citrate you need to add to make the best spheres using your selected food.
9. Repeat steps 6–8 using the other foods you want to test.
- a. Be sure to use a separate, new table to record your results for each food.
 - b. If the calcium chloride solution gets dirty while you do your testing (such as by having sodium alginate and food mixtures dissolve in it repeatedly), make up a fresh bowl by repeating step 4.

Analyzing Your Data

In this part of the science project, you will analyze your data and come up with conclusions about how much sodium citrate is needed, and what the ideal pH is, to make the best spheres out of the different foods you picked.

1. For each data table in your lab notebook, calculate the average ball diameter (longest dimension) and height (shortest dimension) for a given amount of sodium citrate that was added. Record these numbers in your data table.
 - a. For example, if the diameters (longest dimensions) of the popping boba balls for one solution were 6 mm, 5.5 mm, and 6 mm, the average diameter would be 5.8 mm for that sodium citrate amount.
2. Next, calculate the ratio of your measured longest dimension (diameter) and shortest dimension (height) for each popping boba ball.
 - a. For example, if the longest dimension (diameter) of a popping boba ball was 6 mm and its shortest dimension (height) was 5 mm, the ratio would be 1.2 (6 divided by 5).
3. Then calculate the average ball ratio for a given amount of sodium citrate that was added.
4. For each data table (i.e., food tested) make two bar graphs of your data. One graph should include the calculated ball ratios for the different sodium citrate amounts. The second graph should show how the pH changed as more and more sodium citrate was added.
 - a. For both graphs, put the total amount of sodium citrate added (in teaspoons or grams) on the x-axis (the horizontal axis going across).
 - b. For the graph showing the ball dimensions, put the ball ratio on the y-axis (the vertical axis going up and down).
 - c. For the graph showing the pH, put the pH on the y-axis.
5. Look at your data tables, graphs, and observations and try to draw conclusions from your results.
 - a. For each food, how much sodium citrate did you need to add to make the best spheres?
 - i. *Tip:* Remember that your calculated ball ratio is a good indicator of how spherical your popping boba balls are. In a perfect sphere the longest and shortest dimensions (diameter and height) are the same. This means for a perfect sphere the calculated ball ratio should be 1. You probably could also tell which spheres looked the best based on observing them during your testing.
 - ii. What happened when there was too little, or too much, sodium citrate added?
 - iii. Were your results different for the different foods you tested?
 - iv. Can you explain your results in terms of the chemical reaction going on, which is explained in the Introduction in the [Background](#) (#background) section?
 - b. How did adding sodium citrate change the pH of the sodium alginate and food mixture?
 - c. For each food, what was the pH of the sodium alginate and food solution when the best spheres were made?
 - i. Do you see similarities between the different foods you tested?

- d. Were any of the foods you tested unable to make spheres no matter how much sodium citrate you added?
- i. If this was the case, it is possible that other factors, such as the amount of calcium in the food, is affecting the food's ability to become a sphere.
Check out the [Make It Your Own](#) (#makeityourown) section for a Variation to try to turn other foods into spheres.
- e. Based on your results, how do you think adding sodium citrate and changing the pH of a solution affects how well it can become a sphere using this molecular gastronomy technique?