

# Sugar Content in Beverages

## Density Analysis

### Introduction

Nutritionists have recently raised concerns about the increasing popularity of sodas, fruit drinks, and other beverages due to their high sugar content. Do you know how much sugar is in your favorite beverage?

### Concepts

- Density
- Concentration
- Solution
- Calibration curve



### Background

The density of a *solution* depends on its *concentration*, that is, how much solute (solid) is dissolved in the solvent (liquid). If the density of a solution is plotted on a graph against the concentration of solute, a regular pattern is evident—density is proportional to concentration. The resulting graph, called a *calibration curve*, shows a straight-line relationship between the density of a solution and the concentration of solute. A calibration curve can be used to determine the concentration of solute in an unknown solution whose density has been measured.

The purpose of this cooperative class activity is to measure the densities of popular beverages and determine their sugar contents using a calibration curve obtained by plotting the densities for a series of reference solutions versus percent sugar. The experimentally determined percent sugar for the beverages will be compared against the information provided on their nutritional labels to evaluate the accuracy of this method.

### Hypothesis

How well does the sweet taste of a beverage correlate with the amount of sugar it contains? Based on your *memory* of their taste, predict the relative sugar content in the following beverages: cola, grape juice, and sports drink. (Rank the beverages from 1, highest sugar content, to 3, lowest sugar content.)

### Materials

Beverages (at room temperature)*	Graduated cylinder, 25-mL
Balance, centigram (0.01 g) precision	Thermometer
Beakers or plastic cups, 250-mL, 2	

\*Any carbonated beverages must be "flattened" to remove dissolved carbon dioxide before testing. This can be accomplished by pouring the beverage back and forth from one container into another several times until it stops fizzing.

### Safety Precautions

Although the materials in this activity are considered nonhazardous, follow all normal laboratory safety guidelines. Any food-grade items that have been brought into the lab are considered laboratory chemicals and are for lab use only. Do not taste or ingest any materials in the laboratory, and do not remove any food items from the lab after use. Wear safety glasses or chemical splash goggles whenever working with chemicals, heat or glassware in the lab. Wash hands thoroughly with soap and water before leaving the lab.

## Procedure

1. Place a clean 25-mL graduated cylinder on the balance and hit the “tare” or “rezero” button.
2. Fill the cylinder to the 10.0-mL mark with a beverage. Measure and record the mass of the beverage in the graduated cylinder.
3. Measure and record the temperature of the beverage.
4. Rezero the balance with the graduated cylinder containing 10.0 mL of beverage. Fill the graduated cylinder to the 20.0-mL mark with a second sample of the same beverage. Measure and record the mass of the second beverage sample in the graduated cylinder.
5. Calculate and record the density of each beverage sample. *Hint:* Since the sample volume is always 10.0 mL, the calculation should be easy—you don’t even need a calculator! Determine the average density of the beverage solution.

## Data Analysis

1. Plot the known density on the  $y$ -axis versus percent sugar on the  $x$ -axis for the following sugar reference solutions. Use a ruler to draw a “best fit” straight line through the data points.

Percent Sugar	1%	5%	10%	15%	20%
Density at 20 °C	1.002 g/mL	1.018 g/mL	1.038 g/mL	1.059 g/mL	1.081 g/mL

2. Use the graph to estimate the sugar concentration in the beverage: Locate the point on the  $y$ -axis that corresponds to the beverage density. Follow that point on the  $y$ -axis across horizontally to where it meets the best-fit straight line through the data points for the reference solutions. Draw a vertical line from this point on the best-fit line down to the  $x$ -axis. The point where this vertical “line” meets the  $x$ -axis corresponds to the percent sugar in the beverage. Estimate and record the percent sugar for the beverage.
3. Consult the nutritional label for the beverage—it should list the sugar content in grams of sugar per serving size. This value can be converted to percent sugar in the beverage by dividing the grams of sugar per serving size by the volume of the serving size (in mL), dividing this result by the measured density of the beverage, and multiplying by 100. Record the nutrition label information and the calculated percent sugar for the beverage.

*Sample calculation:* Measured density = 1.038 g/mL

Nutritional label = 42 g of sugar per 355 mL

$(42 \text{ g}/355 \text{ mL}) \times (1 \text{ mL}/1.038 \text{ g}) = 0.114 \text{ g sugar per g of beverage}$

Percent sugar =  $0.114 \text{ g sugar per g of beverage} \times 100\% = 11.4\%$

4. Calculate the *percent error* in the experimental determination of the sugar content using the following equation.

$$\text{Percent error} = \frac{|\text{Calculated value} - \text{Experimental value}|}{\text{Calculated value}} \times 100\%$$

5. This lab examines the relationship between the density of a beverage and its sugar content. What assumption is made concerning the other ingredients in the beverage and their effect on its density? Is this a valid assumption? Why or why not?

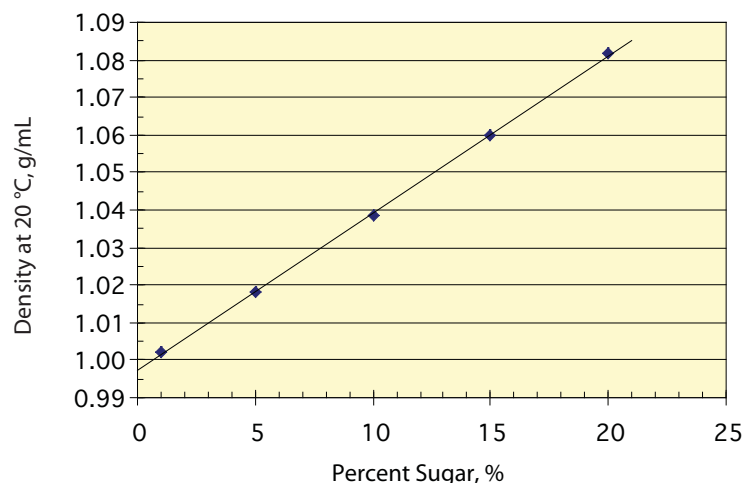
## Disposal

The beverage solutions may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b. Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste.

## Tips

- This experiment makes a great collaborative class activity. Make copies of pages 1 and 2 only for student use. Encourage students to bring in their favorite beverages for testing—this gives them “ownership” of their experiment and promotes friendly competition to determine the results of the testing. Try to obtain a variety of non-diet beverages. Carbonated beverages should be “flattened” first. If this is not done, the carbonation bubbles will interfere with the accuracy of the volume measurements.
- For greater precision in the density determinations, use volumetric or serological pipets rather than graduated cylinders to measure the beverage volume. This will allow 3 decimal places (four significant figures) in the density calculations.
- Fructose (“fruit sugar”) is the main sugar present in fruit juices, fruit drinks such as Snapple,<sup>®</sup> and most carbonated sodas. The literature density values for the sugar reference solutions are for fructose at 20 °C. For best results, the beverage samples should be at room temperature, as close to 20 °C as possible. (The sample results were obtained at 22 °C.) More accurate results may be obtained by preparing sugar reference solutions and measuring their densities at the same temperature as the beverages. The sugar concentrations are mass percent—a 10% sugar solution, for example, is made by dissolving 10 g of sugar in 90 g of water.
- Table sugar is sucrose, a disaccharide composed of one molecule of fructose joined with one molecule of glucose after loss of water. Both fructose and sucrose reference solutions were tested in this activity and both gave similar results and accuracy.
- Sports drinks such as Powerade<sup>®</sup> are the “exception that proves the rule” in this study. The working assumption in this experiment is that sugar is the main ingredient whose concentration determines the beverage density. This assumption may be true for sodas and juices, but not for sports drinks, which contain large amounts of salts such as sodium and potassium chloride to maintain electrolyte balance.
- Help students see (literally!) the amount of sugar in the beverage by weighing out the amount of sugar shown on the nutritional label.

## Sample Calibration Curve



## Sample Results

Beverage	Density	Percent Sugar (Experimental)	Nutrition Label	Percent Sugar (Calculated)	Percent Error
Grape Juice	1.06 g/mL	15.0	40 g/240 mL	15.7	4.5%
Cola	1.04 g/mL	10.2	42 g/355 mL	11.4	10.7%
Powerade <sup>®</sup>	1.03 g/mL	7.8	15 g/240 mL	6.1	28%

## Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

### *Unifying Concepts and Processes: Grades K–12*

Evidence, models, and explanation  
Constancy, change, and measurement

### *Content Standards: Grades 9–12*

Content Standard A: Science as Inquiry  
Content Standard B: Physical Science, structure and properties of matter  
Content Standard F: Science in Personal and Social Perspectives; personal and community health

## Acknowledgements

We are grateful to Bob Becker, Kirkwood High School, Kirkwood MO, for providing Flinn Scientific with instructions for this activity.

## Reference

This activity was adapted from the “Beverage Density Lab” experiment in *Introduction to Chemistry*, Volume 1 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor; Flinn Scientific: Batavia IL (2002).

## Materials for *Sugar Content in Beverages* are available from Flinn Scientific Inc.

Catalog No.	Description
OB2096	Flinn Scientific Electronic Balance, 210 g × .01 g
GP2010	Graduated Cylinder, Borosilicate Glass, 25-mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.