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Measuring pH of Food Products

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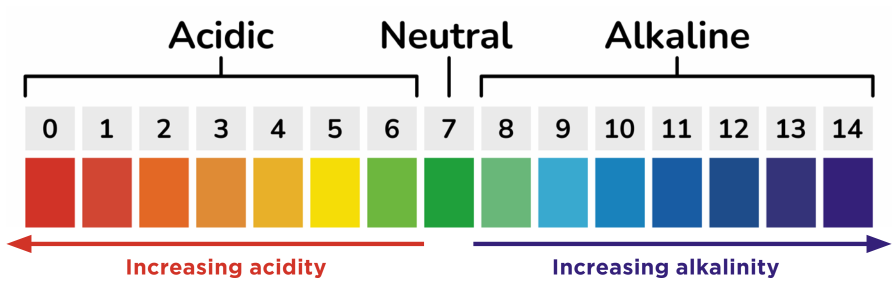
PH SCALE



Section 1: Introduction

pH is a measure of the acidity or alkalinity of a substance. It is expressed on a scale from 0 to 14, with 0 being the most acidic and 14 being the most basic. pH plays a crucial role in both food safety and quality. The pH level of food significantly influences its color, texture, flavor and shelf life, all of which contribute to its overall quality. pH also directly impacts microbial growth, food preservation and safety of foods such as canned (acid, acidified and low-acid foods) and fermented foods. The proper pH range may also be essential for facilitating various physical and chemical reactions during food production. For instance, maintaining the correct pH is required for achieving proper gel formation in jelly preparation and for successful fermentation in the production of cheese and pickles.

Whether testing the pH of the food product is for routine quality or safety evaluation, it is important to ensure that testing is done correctly. This publication will serve as a guide in selecting and using a pH meter to accurately measure the pH of various food products. While the Code of Federal Regulations for acidified foods (21 CFR Part 114.3) was referenced in the publication, the information and pH testing instructions can still apply to other foods that require pH testing.

Section 2: Definitions

Acid Foods: Foods that have a natural pH of 4.6 or below.

Acidification: Acidification is the process of lowering the pH for safety, preservation or flavor. Direct acidification involves adding acid(s) (e.g. vinegar, lemon juice, citric or lactic acid) directly to food. Indirect acidification uses microorganisms to produce acids naturally, as in yogurt, sauerkraut or sourdough, which also enhances flavor and texture. Some foods combine both methods for safety and taste, like certain pickles and cheeses.

Acidified Foods: Low-acid foods to which acid(s) or acid food(s) are added. They have a water activity greater than 0.85 and a finished equilibrium pH of 4.6 or below.

Canned Foods: A food is considered “canned” if it’s sealed hermetically (airtight) and heat-processed to prevent spoilage. Canned foods may be packaged in metal, glass or plastic containers.

Equilibrium pH: It refers to the stable pH value that a food reaches once all acid–base reactions have completed and no further significant pH change occurs. In food manufacturing, the equilibrium pH is the value monitored and recorded. Achieving equilibrium pH requires sufficient time for all reactions (such as penetration of acids into the particulates) to take place. The time needed to reach equilibrium pH depends on factors including the nature of the ingredients (e.g. porous vs dense structure), particle size of the solids and temperature. Determining the equilibrium pH involves repeating pH measurements periodically until no further change is observed. Most food products typically should reach equilibrium pH within 24 hours.

Fermented Foods: Fermented foods are low-acid products that undergo the action of desired microorganisms. These microorganisms produce acids during their growth, reducing the food’s pH.

Low-acid Foods: Foods, other than alcoholic beverages, with a finished equilibrium pH greater than 4.6 and water activity greater than 0.85.

Water activity (Aw): A measure of the availability of water for microbiological growth. Aw ranges from 0 (a completely dried product) to 1.0 (pure water). Water activity is related to the equilibrium relative humidity of air around the food product if sealed within a package. For example, a product with a water activity of ~0.98-0.99 (like freshly cut fruits and vegetables) when sealed inside a container will equilibrate with their surroundings and increase the relative humidity to 98 percent.

Section 3: pH Testing Methods

There are several methods available for measuring pH, each with its own advantages, limitations and suitable applications. In this section, two common pH testing methods (indicator paper and a pH meter) will be explained.

Figure 1: *pH indicator paper*

Indicator paper: pH results measured using indicator paper (aka litmus paper) are based on a color change in dyes to indicate the sample pH. The FDA acidified foods regulations state that indicator paper may only be used if the product pH is less than 4.0 (21 CFR part 114.90(b)). A pH meter is required to be used for all USDA-FSIS regulated products. Although this method is inexpensive, the results can be inaccurate (due to the resolution of the indicator papers scale) or difficult to interpret since some foods may also stain the paper. Using this method, a paper strip treated with indicator dye(s) is dipped into the sample solution. Depending on the pH of the sample, the strip changes color, and an approximate pH is determined by comparing the pH strip with a standard color chart. For better accuracy, it is recommended to use pH strips that are close to the expected pH of the food sample with small increments of 0.5 or less. Make sure the expiration date of the strips is current, as the dye may not change color correctly if they are expired.

Figure 2: *Benchtop pH meter*

Figure 3: *Handheld pH meter*

pH meter: A pH meter electronically measures the hydrogen ion concentration in a solution by immersing an electrode (or probe) into the food product. Acids in the sample ionize when dissolved in water and release hydrogen ions into the solution. The higher the concentration of hydrogen ions in a solution, the greater the acidity and the lower the pH. A pH meter provides more accurate measurements than pH indicator paper. For this reason, acidified foods regulations require the use of **a pH meter when the sample pH is equal to or greater than 4.0** (21 CFR 114.80(a)(2)).

Section 4: Choosing a pH Meter

Resolution and Accuracy of the pH Meter

Accuracy and resolution are two key parameters to consider when selecting a pH meter. **Resolution** refers to the smallest detectable difference or increment in a measurement. For instance, if the pH meter has a resolution of 0.05 pH units, then it can detect the pH changes in increments of 0.05. Acidified foods regulations require a resolution of 0.05 pH units, but higher resolution will give more precise value. Generally, a resolution of 0.01 is recommended especially when processing acidified foods. A higher resolution meter will usually cost more.

Accuracy reflects how close a reading is to the true pH value. Lower-cost meters will typically have an accuracy of ±0.2 pH units. For example, if a pH meter with an accuracy of ±0.2 pH units measures a sample as 4.3, the actual pH of the sample could be anywhere from 4.1 to 4.5. In general, an accuracy of ±0.02 pH units or better is preferable.

Probe and Electrode Type

For a pH meter, the terms "electrode" and "probe" are often used interchangeably, even though they refer to slightly different components. **The probe** is the part of the pH meter that measures pH of the solution and consists of two main parts: glass electrode and reference electrode. The glass electrode is the part that interacts with the sample and is made of a special glass that reacts with hydrogen ions in the solution. The reference electrode ensures accurate pH readings by providing a stable reference voltage to compare against the voltage measured by the glass electrode. In short, the electrode is the component that directly interacts with the solution to measure pH, while the probe is the full unit, which typically includes the electrode and other necessary parts for proper functioning.

pH meters come with either a detachable (replaceable) probe or as all-in-one units with an integrated probe. Both options can offer comparable performance. The initial cost of the pH meter with detachable probe is usually higher. All-in-one units might look less expensive at first. However, it is important to note that all pH probes have a limited lifespan depending on their use and maintenance. Even with optimal care, a pH probe used to measure food samples will typically last between one to three years. With detachable probe units, the probe can be replaced when needed, while all-in-one units will require full replacement.

Temperature Compensation

Some pH meters/probes are available with a temperature compensation feature that attempts to "correct" pH readings for differences in sample temperature. However, for food samples, it is recommended to only measure the pH after the sample reaches room temperature (close to 77 F) even if the pH meter has temperature compensation. Measuring the pH of food samples at 77 F ensures the highest possible accuracy.

Section 5: Testing pH of Foods

Figure 4: *Colored pH buffer solutions*

Warming Up the pH Meter

Turn the pH meter on and allow the electronic components to warm up and stabilize. This may take 5 to 10 minutes, but it is important for accurate and repeatable measurements.

Calibrating/Standardizing the pH Meter

Although the terms calibration and standardization have slightly different meanings, they are often used interchangeably in pH measurement. For simplicity and since calibration is more commonly used in pH meter manuals, the term calibration will be used throughout the remainder of this publication. Proper calibration of the pH meter is essential for obtaining accurate pH readings. Calibration should be performed at least once per day or once per shift by following the manufacturer's instructions. A typical calibration procedure includes the use of standardized buffer solutions, often pH 4.01 and 7.00 buffer solutions. Some buffers are colored for easy identification of their pH value. Always use freshly dispensed buffers for calibration and check the expiration date on the buffers before use. Be sure to rinse the probe with deionized water and carefully blot it dry with a lint-free tissue between standards. Do not rub the probe when drying, as this may damage the electrode membrane or create a static charge that could affect its accuracy.

After calibration, testing the pH of a standard buffer solution (ideally one closest to the pH of the food sample) to verify the calibration accuracy is good practice. Maintain records each time the probe is calibrated and record the measured value of the standard buffer to document that the pH meter is providing the required accuracy.

Preparing Food Samples for pH Testing

Foods come in various shapes and consistencies. Some foods consist of both a liquid and solid portion that may differ slightly in acidity. Others are more homogeneous and/or semisolid in nature. Below are guidelines for preparing different types of food products for pH measurement.

a. **Homogeneous foods:** If the food sample is homogeneous (i.e. has a uniform consistency), the pH measurement from any portion may be considered representative of the entire product. Most barbecue sauces or salad dressings can fall into this category. No special preparation is needed for these products except allowing them to reach room temperature before measuring pH. Some products high in oil content may also need special preparation to achieve accurate reading. (For oily products, see section (b), (d) and (e) below). Dip the rinsed (and pre-calibrated) electrode into the center of a well-mixed sample at 77 F and determine its pH. Most meters will take some time to reach an equilibrium measurement; this is normal.

b. **Liquid and solid mixtures:** Some food products such as chunky salsas and pickled vegetables may consist of a mixture of liquid and solid portions that may differ in acidity. The following is the preparation procedure for this type of food product.

- Drain the contents of the container for 2 minutes on a U.S. standard No. 8 sieve inclined at a 17- to 20-degree angle. Record the weight of the liquid and solid portions and retain each portion separately. Sieves should be constructed of stainless steel and are available from scientific supply stores. A household stainless steel strainer with openings similar in size to 3/32" (0.0937 in) may achieve the same result.

Figure 5: *U.S. Standard No. 8 Sieve*

- If the liquid contains oil, it may cause fouling of the electrode. In such cases, separate the oil and water layers. One method is to use a separatory funnel Depending on the type of food, other approaches may also be effective such as decanting or skimming for liquids, freezing for solid or semi-solid mixtures, and sieving or straining for chunky foods.

Figure 6: *Separatory Funnel*

- To separate the oil phase from the aqueous phase in the food using a separatory funnel:
  - Close the stopcock of the separatory funnel. Place the funnel on a ring stand securely.
  - Pour the mixture into the funnel.
  - Insert the stopper at the top.
  - Let it stand until two layers form. The denser aqueous layer stays at the bottom and the lighter oil layer floats on top.
  - Remove the stopper, open the stopcock and carefully drain the bottom (aqueous) layer into one container.
  - Then pour out the top (oil) layer which may be discarded. Then determine the pH of the aqueous layer at 77 F.
- Remove the drained solids from the sieve or strainer, blend to a uniform paste and determine the pH of the paste at 77 F.
  - If the paste of the drained solids has a higher pH than the aqueous layer, this indicates that acidification is not yet complete and equilibrium between the solid and liquid phases has not been reached. In this case, allow additional acidification time and repeat pH measurements until both phases reach the same equilibrium pH value.

c. **Semisolid products:** Food products of a semisolid consistency, such as applesauce, pureed fruits and vegetables, potato salad, etc., may be blended to a paste. If more fluidity is required, 10 to 20 milliliters of distilled water may be added to 100 grams of product without significantly affecting the pH. Determine the pH of the prepared paste at 77 F.

d. **Marinated-in-oil products:** Since oil does not affect the pH of a food product but can foul the pH electrode and can potentially interfere with accurate pH readings, the oil should be removed from the solid portion of the product. Oil separation may be achieved by first removing the solids from the oil, followed by blot drying with a paper towel to absorb any residual oil from the surface of the solids. Alternatively, measuring the pH of the ingredients before mixing with the oil may achieve the same result. Blend the solid into a paste using a blender. If necessary, add a small amount of distilled water (< 20 ml per 100 grams of product) to facilitate blending. A small amount of added distilled water will not alter the pH of most food products. Determine the pH of the prepared paste at 77 F.

e. **Special product mixture:** For special product mixtures such as antipasto, pour off the oil, blend the remaining product to a paste, determine the pH of the blended paste. If more fluidity is required, add 10 to 20 milliliters of distilled water to 100 grams of product. Determine its pH at 77 F.

Section 6: Cleaning a Dirty Electrode

Figure 7: *Sensing tip*

Occasionally, electrodes in the probe will become fouled with fats/oils or other food components which can negatively affect the meter's ability to measure pH accurately. If the meter is slow to respond or produces erratic readings, this is most likely the case.

- First, rinse the probe in tap water for several minutes to flush away any food residue.
- Check the sensing portion of the probe (the part in contact with sample that is usually a glass bulb, tip, or flat membrane on the bottom) for any visible debris and if found, remove the debris carefully and gently using a lint-free tissue.
- Immerse the probe in an electrode cleaning solution or 0.1 molar sodium hydroxide solution (0.1M NaOH) for one minute, then transfer the probe to a 0.1 molar hydrochloric acid solution (0.1M HCl). This cycle should be repeated twice, ending with the electrode in the 0.1M HCl solution. Both of these solutions can be purchased through scientific supply companies or online platforms at these concentrations, often for an affordable price. Some manufacturers provide general cleaning instructions using common household chemicals, such as laundry bleach and dishwashing detergent. A link to an example can be found in the Online Resources section of this publication.
- Always follow the specific cleaning instructions provided by the manufacturer.
- Rinse the probe tip for one minute with tap water.
- If visible oil remains, wipe the probe gently with a lint-free tissue soaked in acetone. Pure acetone can be purchased through scientific supply companies or online platforms at an affordable price.
- Rinse the probe tip with distilled or deionized water for one minute.
- Calibrate the probe to ensure the electrode is reading properly.
- After completing the measurement, store the pH probe's sensing tip in an appropriate pH electrode storage solution. This is often a potassium chloride (KCl) solution or a pH 7 or pH 4 buffer. Refer to the manufacturer's instructions to ensure you are using the correct solution. Replace the storage solution regularly to avoid contamination.

Section 7: Additional Information

For more information on pH measurement, please contact:

University of Tennessee
Food Science Department
2510 River Drive, Knoxville, TN, 37996
Email: foodsci_ext@utk.edu
Website: foodscience.tennessee.edu/food-science-extension/

Section 8: Acknowledgement

Some sections from the UT Extension Publication SP 747-A, originally published in 2012, have been updated and included in this publication. The publication mentioned is titled "Manufacturing Acidified Foods in Tennessee" and written by Faith Critzer, who then served as Extension Food Safety Specialist for the Department of Food Science and Technology.

Section 9: References

Food and Drug Administration, Title 21, Code of Federal Regulations, Chapter I, Subchapter B, Part 114. https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-114/subpart-A/section-114.3

McGlynn W. (2016). Choosing and using a pH meter for food products. Food Technology Fact Sheet (FAPC-117), Robert M. Kerr Food & Agricultural Products Center, Oklahoma State University.

Section 10: Online Resource

An example of cleaning instructions for pH electrodes: coleparmer.com/tech-article/how-to-store-clean-and-recondition-ph-electrodes

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