



Popcorn - Cooking with Phase Changes

by Randy Landsberg



Introduction: Did you every wonder how a hard little yellow popcorn kernel becomes a soft, white, snack food? Whether you “nuke” your popcorn in the microwave, pop it in oil, or use a hot air popper the hard kernel is transformed in a similar manner. The key to popping corn is water. When the popcorn kernels are heated either via hot air, hot oil, or the microwave oven, some of the small amount of water contained inside becomes steam. This steam is then able to pop the corn by breaking the outer hull and blowing-up the starch inside (see the more detailed description

from the American Chemical Society below).

In this lab we will investigate popcorn and the water within it. We will determine how much water is in popcorn and how soaking or drying popcorn affects its “popability” (How well it pops and how much of it pops - volume change & percentage of kernels that pop).

CORNY BACKGROUND:

What is Popcorn? Popcorn, like all six types of corn, is a cereal grain and originates from a wild grass. Its scientific name is *zea mays everta*, and it is the only type of corn to actually pop. Popcorn is an ancient food with a long history. It is indigenous to the Americas and it was one of the many new foods that were introduced to the first Europeans who traveled to the New World in the fifteenth century. Source

<http://www.popcorn.org/frames.cfm?main=teachers/index.cfm&usernav=html>

According to the Popcorn Board, (Yes there is a popcorn board see www.popcorn.org), “Americans consume 17 billion quarts of popped popcorn annually [~1.2 billion pounds] or 59 quarts per man, woman and child...Major popcorn producing states are Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Missouri, Nebraska and Ohio... Each spring, farmers use a corn planter to place the popcorn seeds about 1 1/2 inches deep and 6 inches apart in the soil. That's nearly 28,000 seeds per acre.”

The Popcorn Board considers popcorn quality based on how big it gets, expansion ratio, and on how much of it pops expressed in percentage of kernels popped. “Processors consider the minimum expansion ratio for good popcorn to be 35 to 38 to one. However, some of today's improved hybrids will expand over 40 times...Good popcorn should provide at least 98 percent popped kernels with well under two percent ‘spinsters’ or unpopped kernels.”

Storage tip: do not keep popcorn in the refrigerator or freezer, both locations dry popcorn out and make it less “popable”.



How it Pops:

From “Popcorn” by Lynn Sibley American Chemical Society

http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=vc2\1rp\vp1_popcorn.html

Popcorn, a cereal grain like wheat or oats, is about three-fourths carbohydrate in the form of starch, with smaller amounts of protein, fat, minerals, and water. The water plays a critical role in the popping process. When heated, the moisture inside the kernel turns into steam. As the pressure increases, the starch expands and the kernel explodes. We like popped corn that is large and tender. This requires just the right amount of water in each kernel. Farmers harvest popcorn when the moisture content is [the correct amount] by mass. To ensure maximum popping expansion, the corn is then carefully cured or dried until the moisture content reaches [just the right amount for popping].

Like other cereals, popcorn kernels consist of three main parts: the pericarp (the hull or outer covering), the germ (the part that sprouts), and the endosperm (the starch that expands). [see dent corn figure on next page] Popcorn acts the way it does because of the special construction of the pericarp and the microscopic structure of the endosperm.

Popcorn has an extra strong pericarp. This tough, protective layer acts like a seal, holding in the steam until the pressure builds up high enough and the kernel explodes. If the pericarp has been cut or cracked during processing, the steam will be vented and the kernel will not pop properly.

Corn has two kinds of endosperm, translucent and opaque, which are named according to their appearance. The expansion, or popping, takes place in the tightly packed translucent endosperm. Popcorn contains mostly translucent endosperm, which is better at popping.

Where the action is

Before you start cooking popcorn, the pressure inside and outside the kernel is the same. As the kernel heats, the moisture turns to steam, and the internal pressure of the kernel rises. When the temperature inside the kernel climbs above 100 °C, you might expect that all the water would turn to steam. In fact, only a small amount vaporizes because the tough pericarp acts like a pressure cooker. The high-pressure steam penetrates the starch granules and transforms them into hot, gelatinized globules. Finally at about 175 °C, when the pressure inside the kernel is about 9 atm [\sim 132lbs/sq inch], the pericarp ruptures.

The steam and superheated water, now surrounded by normal-pressure air, become the driving force that expands the kernel. The gelatinized starch granules do not explode, but expand into thin, jellylike bubbles. Neighboring bubbles fuse together and solidify, forming a three-dimensional network much like a sink full of soapsuds. This is the white fluffy solid we eat. The moisture content of the kernel is now about 1-2% by mass, and the popcorn is transformed into a tender, fluffy morsel.

(for the full article see ACS chemistry.org,

http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=vc2\1rp\vp1_popcorn.html)

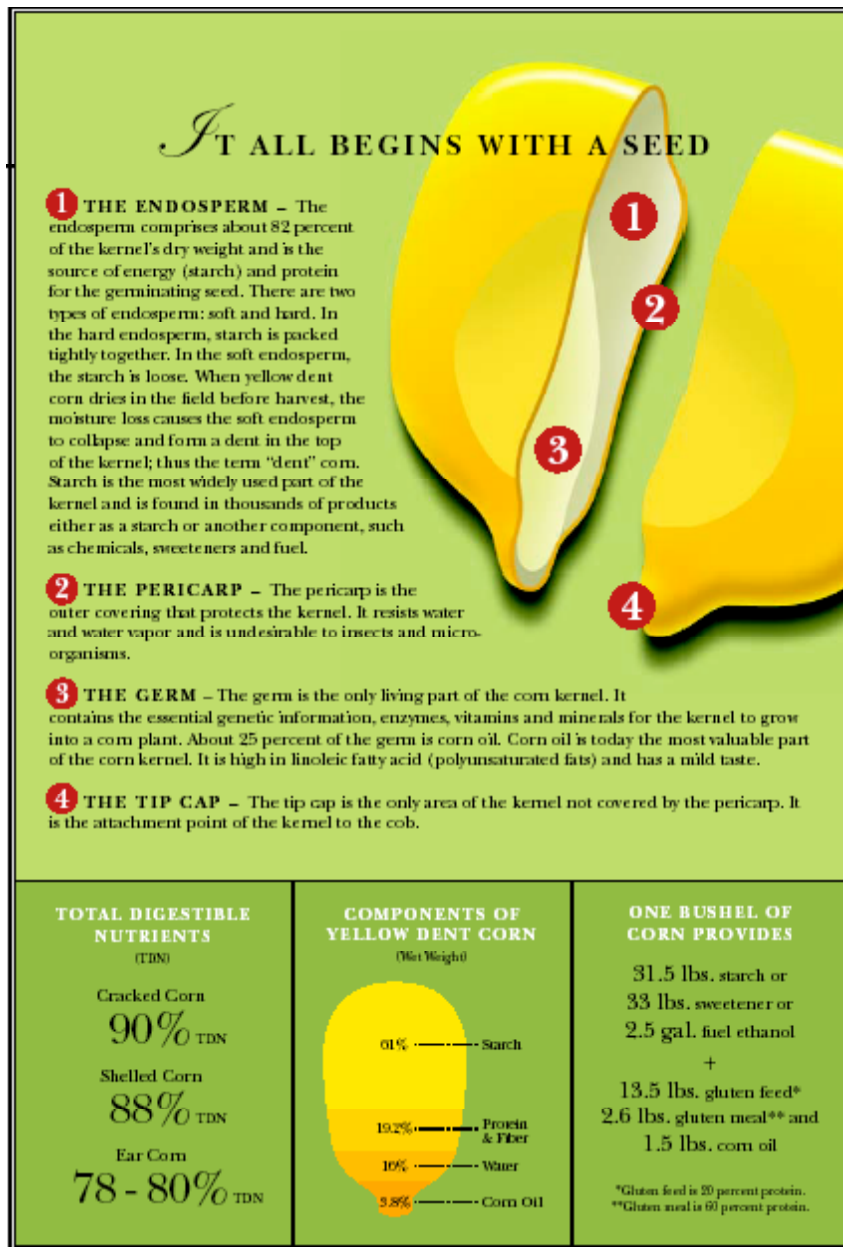


Figure Source:
The World of Corn 2003, p.3
 National Corn Growers Association (NCGA)
<http://www.ncga.com/03world/main/welcome.htm>



Laboratory Procedure



Percentage Water by Mass:

Percentage by mass is a practical and common way of describing composition.

It is defined as:

$$\text{Mass \% A} = \frac{(\text{Mass of A in whole})}{(\text{Mass of whole})} \times 100$$

For instance, if you had 100g of a breakfast cereal, say Post Raisin Bran[®], and 10 g of that was raisins, then the percentage mass of raisins would be:

$$\text{Mass \% Raisins} = \frac{(\text{Mass of raisins in whole})}{(\text{Mass of whole})} \times 100 = \frac{10\text{g}}{100\text{g}} \times 100 = 10\%$$

This is a logical way of characterizing things and has roots in chemical analysis and manufacturing. Instructions for making industrial sized quantities of breakfast cereal might naturally involve a ton of this and a few tons of that vs. a certain number of raisin and a certain number of bran flakes. In a sense percentage mass allows one to compare apples to oranges (e.g., if you had a fruit salad you could literally compare the amount of oranges to the amount of apples in a meaningful way by determining the percentage mass of each.)

SAFETY NOTE: Popcorn kernels that do not pop can be extremely hot, as can the plastic top of the popper. Use appropriate precautions when handling either e.g., wait for them to cool & use hand protection such as a potholder.

Materials:

- 500 Kernels (aprox. 1/3 cup) un-popped popcorn
- A few popcorn kernels cut in half (instructor will provide)
- Electronic balance (able to read to at least 0.1 gram, 0.1g)
- Hot-air popper
- Big bowl to catch popcorn
- Bag to collect popped corn & popcorn kernels for weighing e.g., plastic bag from green grocer section
- Potholder
- Magnifying glass or microscope (optional)
- Wax paper (optional)

Corn Study

Inspect a few kernels, and one of the bisected kernels.

- Record any observations.
- Sketch a typical kernel.
- Can you identify the different parts of the kernel: endosperm (clear & opaque), pericarp, germ & tip?



Challenge – working in small groups of 2-3, describe how you would use the resources listed above to determine:

- 1) The percentage of water by mass in popcorn
- 2) The percentage of the corn that pops

Write down your procedure, include the data you plan to collect and describe it to an instructor. Proceed with your experiment once an instructor has approved of your plan.

Tare Weight Note:

Sometimes it is possible to put something directly on a balance to weigh it. Often this is not possible (e.g., a liquid) or convenient (e.g., something with many little pieces like sand or popcorn). When this is the case one needs to place the stuff in question in or on something else. However, this means that your balance will actually measure the mass of your stuff and your container. The weight of the stuff and the container is called the **gross weight**, the weight of the container is called the **tare weight**, and the weight of the stuff in question is called the **net weight**. One can determine the weight of the stuff, the **net weight**, if one measures the weight of the stuff & the container, **gross weight**, and the weight of the container, **tare weight**.

$$\text{Net weight} = (\text{gross weight}) - (\text{tare weight})$$

Mass lost calculation:

$$\text{mass lost (g)} = [\text{mass un-popped (g)}] - [\text{mass popped (g)}]$$

Percentage mass lost calculation:

$$\text{Percentage mass lost (\%)} = \frac{\text{mass lost (g)}}{\text{Pre-popped mass (g)}} \times 100$$

Percentage popped:

$$\text{Percentage popped (\%)} = \frac{\# \text{ kernels popped}}{\text{original \# un-popped}} \times 100$$

Analysis: Compare your experimentally measured percent water by mass to the expected optimal popcorn percent water by mass – your instructor will provide this information.

- How do they compare?
- If different, offer possible reasons why they are different.
- *Can we assume all the mass lost when the popcorn popped was from water loss? Or that all of the water in the kernel was lost?*
- List any possible sources of error or uncertainty.

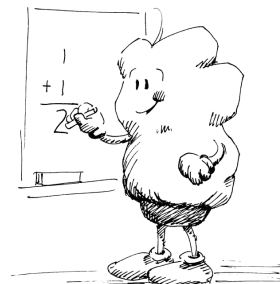
Pool the data with other the other groups in your session and from earlier sessions if available.



Other Challenges – pick your favorites as time permits

Additional Materials

- Un-popped Popcorn - that has been soaked in water overnight
- Un-popped Popcorn - that has been dried out overnight or longer
- Assorted Brands of Un-Popped Popcorn
- Large Volumetric Beaker (~3 L)



Altered States: How does soaking popcorn or drying popcorn effect how it pops? (500 normal kernels vs. 500 wet kernels, vs. 500 dried kernels)

- Volume changes
- Percentage that pop

Determine Percent Water by Mass of Dried Corn or Wet Corn (500 kernels)

Consumer Science

Compare percentage popped and volume change of different brands

Summing Up:

Write a description of what you investigated today in the laboratory. Describe how you went about it and include any new ideas or questions that have arisen.

Image Credits & References:

Fig 1 from <http://www.kidprintables.com/coloring/food/popcorn.gif>

Fig 2 NCGA www.ncga.com “World of Corn 2003” p. 3

Fig 3 <http://www.popcorn.org/images/coloring/poppin.gif>

Fig 4 <http://www.popcorn.org/images/coloring/mathpop.gif>

Popcorn Board website - <http://www.popcorn.org.html>

American Chemical Society website – www.acs.org

National Corn Growers Association website – www.ncga.com



INSTRUCTOR NOTES

(Not for students unless they are struggling in the time given)

Important data that you will need to record:

- 1) Mass Un-popped Corn
- 2) Mass Corn After Popping
- 3) Number of Kernels Prior to Popping
- 4) Number of Un-popped/Spinster Kernels After Popping
- 5) Type and Brand of Corn

1. Step one – select (~1/3 cup) of popcorn, count out 500 kernels, record your observations (Did you exclude any kernels? If so why?)
2. Step two – weigh the kernels & record the mass in grams
3. Step three – pop the kernels & record the number of un-popped kernels, and any observations (be careful to catch everything)
4. Step four – weigh the popped popcorn & record the mass in grams

Data table Columns:

- Mass 500 Un-popped Kernels (g),
- Mass Popped Corn (g),
- Mass Lost (g),
- Percent Mass Lost (%),
- # Pre-Popped Kernels,
- # Un-Popped Kernels
- Percent Popped (%)
- (Volumes Pre & Post Popping??)

Potential class demonstration: popcorn contains water – demonstrate that popcorn contains water by heating a kernel in test-tube e.g. with candle. Have students record observations and comment on if this does or does not demonstrate that there is water in popcorn.

Typical Percentage Water by Mass:

Un-popped – 13-14%

Popped - 1-2%