The Science Behind Sauerkraut Fermentation

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I've been eyeball-deep in microbiology and ferments the past two weeks. I had just purchased some cabbage and was about to start my sauerkraut ferment when I first heard the theory mason jar ferments are less than ideal due to the lack of airtight seal.

Like many of you, I was scared I would be harming my family's health, yet unable to afford an expensive jar. I was confused that a familiar method was no longer safe.

I was totally out of my comfort zone on this one – I admittedly didn't have enough experience with microbiology to know if she was right. Some of it made sense, but surely she was wrong on other points. I didn't like this torn feeling in my gut. **I had to know**. Is mold really that scary? Is oxygen really a threat? Are mason jars really evil?

This post is born out of endless hours of research gained, sleep lost, and too many hours of my children parked in front of movies. I thought some of you might like to read what I have discovered.

What did traditional cultures use for ferments?

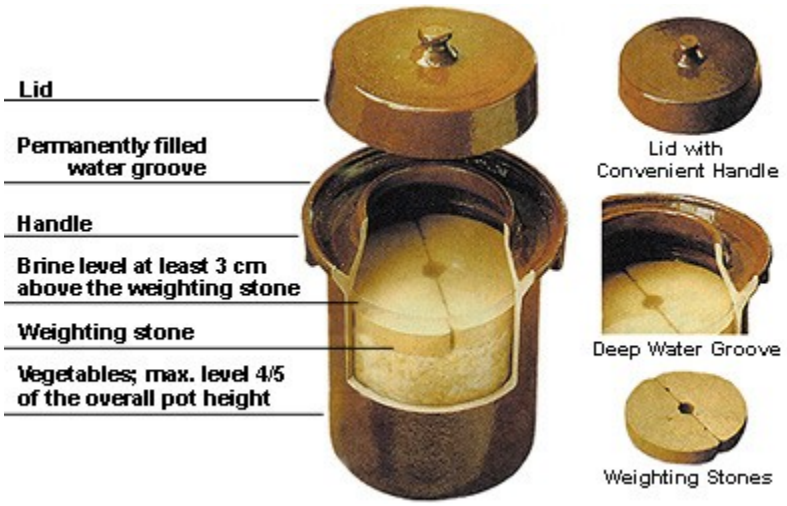
One of the first things I wondered was, "What did traditional cultures use?" Because certainly they didn't have an airlock like we have. Obviously, they also didn't use mason jars. So what did they do?

Traditional fermenting crocks were made of pottery or clay. Cabbage would be packed tightly in, a cloth large enough to drape over the crock and cover the top of the cabbage was placed next. Then, rocks were used to weigh down the cloth-covered cabbage. The brine would then be at or over the level of the rocks, providing a brine seal. If any mold did get on the top of the brine, it wouldn't reach past the rocks and cloth, and the cabbage below was safe.

Often, an additional step was created, similar to the current German and Polish designs of a "moat" around the lid where water would be filled, creating a barrier between the oxygen outside and the ferment inside. The small amount of oxygen left inside would be quickly pushed out with the help of carbon dioxide produced by the lactic acid bacteria. This method ensures air could be pushed out through the water, but none could make it in. Current German and Polish crocks like these were designed from these traditional crocks that were made and used hundreds and even thousands of years ago. They have been updated somewhat to provide for more consistent results.

Koreans had a similar method, but they would bury theirs in the ground, providing a barrier from the air that way. Other cultures used the stomachs of animals or other various organs that would allow for carbon dioxide to be released without allowing air inside.

So no, they didn't have a fancy airlock gizmo – but they did have an airlock system. They were clever enough to keep the oxygen out using a simple, yet effective method.



Benefits of Ferments that Traditional Cultures Experienced

The art and science of fermenting foods has been around for thousands of years. Even though traditional cultures may not have known the science behind fermenting, they did not have refrigeration and for them it was a practical way to increase the “shelf life” of their food supply.

What traditional cultures experienced were the benefits of increased vitamins levels in the final product, and the ease of digestion a fermented food, like sauerkraut, gave them.

Although they couldn’t have realized naturally-occuring toxins were reduced and pathogens were destroyed, they saw the detoxifying effects of the acidity of sauerkraut by the fact that it did not spoil. What they had was a food full of lactic acid bacteria which has now been discovered to not only be probiotic, but is also effective in protecting one’s self from cancer.

What’s going on in a ferment, anyways?

Fermentation in general has been defined as “a biochemical change which is brought about by the anaerobic or partially anaerobic oxidation of carbs by either micro-organisms or enzymes.” This is distinct from putrefaction which is proteins being broken down.

In sauerkraut, the fermentation process has a very specific purpose: to quickly proliferate through the food by lactic acid-producing bacteria (LABs), primarily *Lactobacilli.* These *Lactobacilli* cause the pH to be reduced, making the environment acidic and **unsuitable for the growth of unwanted bacteria**. Since the goal of making sauerkraut is to provide the best environment for *Lactobacilli* to grow, it pays to get to know LABs and what makes them thrive.

What Are Lactic Acid-Producing Bacteria?

Lactic acid bacteria (LABs) produce lactic acid as the result of digesting carbs. LABs are vital

for fermenting cabbage into sauerkraut (as well as making sourdough and dairy kefir).

Although LABs in general are anaerobes, which make it very hard for them to live in the presence of oxygen, there are different sub-groups of LABs. One of these are the LAB Producers, and these include the microaerophiles *Lactobacilli* and *Leuconostoc,* which are vital for sauerkraut fermentation. By definition microaerophiles require small amounts of oxygen to function.

Now this isn't a free pass to not cover your sauerkraut. **The oxygen present in your jar and on your cabbage when you're packing the sauerkraut in your jar is sufficient**.

The three stages of sauerkraut fermentation

In order for sauerkraut to be a success, it must go through three specific stages of fermentation.

Stage One

***Leuconostoc mesenteroides* initiates sauerkraut fermentation.** Since *Leuconostoc mesenteroides* produce carbon dioxide, it effectively replaces the oxygen in the jar, making the environment anaerobic (oxygen-free). When lactic acids reach between .25 and .3%, *Leuconostoc mesenteroides* bacteria slow down and die off, although enzymes continue to function.

This stage lasts between one and three days, depending on temperature.

Stage Two

***Lactobacillus plantarum* and *Lactobacillus cucumeris* continue the ferment** until lactic acid level of 1.5-2% is attained.

High salt and low temp inhibit these bacteria, so I hope you didn't over-salt your cabbage – and be sure not to refrigerate yet.

This stage continues for 10-30 days, depending on temperature.

Stage Three

***Lactobacillus brevis* (some sources also include *Lactobacillus pentoaceticus)* finish off the ferment.** When lactic acid reaches 2-2.5%, they reach their max growth and the ferment is over.

This final stage lasts under a week. You will know your sauerkraut is ready for long-term storage (or to eat!), when no more bubbles appear on the sides or top of your jar. There is a nice image of the stages here.

What can affect the way my sauerkraut turns out?

Although the process is simple, and will complete well on it's own with the right amount of salt added, there are some factors that do influence how sauerkraut will turn out. These are: moisture, oxygen concentration, temperature, nutrients, and pH. Let's address these one at a time:

Moisture

Bacteria that love to spoil sauerkraut will have the upper hand if you have an insufficient level of brine. Too low a water/brine level and you're giving the undesirable aerobic (oxygen-loving) bacteria and yeasts the food they need to grow on the surface. This can cause off-flavors and discoloration at minimum, or even an allergic reaction to those with sensitivities to mold and yeast.

Although white yeast "scum" on the surface can be scraped off without harm to you, mold is another story and will be addressed further in another section. Briefly, one way to eliminate the mold problem (because you certainly can't drain the moisture out of your 'kraut) is to make sure oxygen exposure is kept to an absolute minimum since molds need oxygen to survive. Which brings me to…

Oxygen Concentration

Lactobacillus plantarum, the primary bacteria responsible for Stage Two, works best without oxygen. Anaerobically (**without oxygen**), *Lactobacillus plantarum* does their job the way we want them to – **they cause fermentation of cabbage via lactic acid**. Aerobically (with oxygen), it will produce acetic acid (vinegar). Since we're making sauerkraut, oxygen must be avoided.

Sauerkraut that is allowed oxygen **will not contain any vitamin C** in the final product after just six days. It will also increase chances of mold forming. If you are regularly getting mold on the top of your cabbage, this is a visible sign you are allowing too much oxygen in. Oxygen also allows pink yeasts to grow and could result in soft 'kraut.

Finally, don't mess with your brine. When brine is stirred, you introduce air which make conditions more favorable for growth of spoilage bacteria.

Temperature

Micro-organisms are classified into three categories according to their temperature preferences. Since sauerkraut falls into the mesophilic category, the bacteria involved prefer a minimum of 50-77° F; an optimum of 86-104° F, and a maximum of 95-112°F. These are the temps that all bacteria prefer (non-pathogenic as well as pathogenic).

In the first stage of fermentation as described above, the *Leuconostoc mesenteroides* from

stage one likes a temperature range of 65-72° F. It's a little flexible, and built to resist some change in temp.

The second- and third-stage bacteria *Lactobacillus plantarum*, *Lactobacillus cucumeris*, *Lactobacillus pentoaceticus*, and *Lactobacillus brevis* prefer a temp of 72° F – 90° F.

It's important to keep these temps in mind, to be sure you provide the right environment for these bacteria to grow.

Temperature also affects enzymes, which are destroyed once the temperature has risen to 115 degrees.

Nutrients

Nutrients also affect the outcome of sauerkraut, salt being the primary nutrient of concern.

Salt should be added at a ratio of about 2-3%. Much more than this andthe *Lactobacilli* can't thrive. A good rule of thumb is one tablespoon of salt per two pounds of cabbage.

Be sure to add salt as evenly as possible – if you create pockets of cabbage that aren't salted, you are sending an open invitation for spoilage bacteria to invade and turn your cabbage brown, or for yeasts to turn it pink.

It is essential to use pure sea salt. Salts with added alkali may neutralize the acid, resulting in a failed sauerkraut.

pH

pH is a measure of hydrogen ion concentration. Foods with a pH above 4.6 are low acid and these foods won't prevent bacterial spoilage.

However, since sauerkraut has a pH of 4.6 or lower, it is termed a high acid food. **This acidic environment will not permit the growth of bacterial spores and thus is resistant to spoilage.**

Lactobacilli thrive in an acid environment, but so can molds and yeasts. So it's important to find out what the mold and yeast don't like that *Lactobacilli* can tolerate in order to prevent mold and yeast from growing at all. I discuss this next.

Keeping Sauerkraut Happy

	Helpful Bacteria (LABs)	Harmful Organisms (mold and yeast)
moisture	brine-covered	low (mold) to high (yeast)
oxygen	very little to none	moderate to high
temperature	65°-90° F	wide range
salt content	2-3%	wide range
pH	Less than 4.6%	2-8.5%

As you can see, both helpful and harmful organisms share some of the same preferences. All except oxygen. Helpful bacteria prefer very little to none, where harmful organisms require a moderate to high oxygen level. www.nourishingtreasures.com

Signs you're doing it right – or wrong

Okay, so now you know the particulars on moisture, oxygen, temperature, salt and pH. It's easy to tell if your brine is above your cabbage, and you can use a thermometer to check temperature. You've measured your salt correctly, and you can use pH strips to test the acidity. That leaves us with oxygen. **How do you know if you're keeping out enough?**

Fortunately, there are visible signs to help you figure out if your set-up is working.

Firstly, you will see your cabbage darken. It will turn a brownish color. This also tells you your vitamin C content is tanking – or gone. If you have a pinkish color going on (and it's not from adding red cabbage) then you have a yeast issue. Finally, you could have mold.

All three of these are preventable. All three, like lactic acid bacteria (LABs), can survive in an acidic environment. But how do you kill off the yeast and mold without harming the vitamin C, and while keeping the lactic acid bacteria happy?

Keep the oxygen out.

Yeast and mold both need an oxygen source to thrive. Vitamin C deteriorates when exposed to oxygen after just six days.

The "Big Deal" About Mold

I know, I keep bringing up the mold issue. It's such a wonderful big red flag that I can't help but use it as a visible clue something is going wrong.

And you're asking yourself if mold is a big deal or not. After all, some cheeses mold and that's supposed to be a good thing – so what's the crime if sauerkraut molds? Can't you just spoon

it off and throw it away? Well let's check that out.

The first thing you need to know is that **moldy cheese is created on purpose**. Gorgonzola or blue cheese that has been cultured to create mold is different than moldy swiss cheese or even cheddar. Saying moldy sauerkraut is acceptable because some cheeses are meant to mold is like comparing cheese to sauerkraut 😀 On a microbial level, it's a whole other world.

Further, **scraping off the mold leaves it's roots behind**, and ingesting this can end up causing problems in the long run. Those already sensitive to mold can react immediately – they can tell you it's nothing to fool around with. Others may not get sick right away, but in the long run? I really don't want to take that chance, personally, but you are free to make that decision for your own family.

A Word on Yeasts

Yeast is another major inhibitor which requires an abundance of oxygen for growth. It's often one of the first signs that you're allowing too much oxygen near your sauerkraut. **In the presence of oxygen yeasts can be oxidized to form vinegar** - not something we want in our sauerkraut. Yeasts can also cause off-flavors and discoloration, visible signs you need a better seal on your sauerkraut. Pink sauerkraut (not from red cabbage) is a sign of yeast. This could be due to too much salt, or an uneven distribution of salt, or too much oxygen exposure. If you see a creamy film on top and/or one that smells yeasty, throw it out.

There is one yeast, however, that is helpful. *Saccharomyces cerevisiae*, a member of the ascomycetous yeast family (as opposed to the candida family) is probiotic and can help with candida overgrowth. Interestingly, *Saccharomyces cerevisiae* has the ability to shift its own metabolism from fermentive to oxidative. Do you know what causes it to make the switch? Oxygen. When present, oxygen will cause *Saccharomyces cerevisiae* to oxidize; **keep the oxygen out, and this friendly yeast can help your sauerkraut to ferment and provide you with delicious probiotics**.

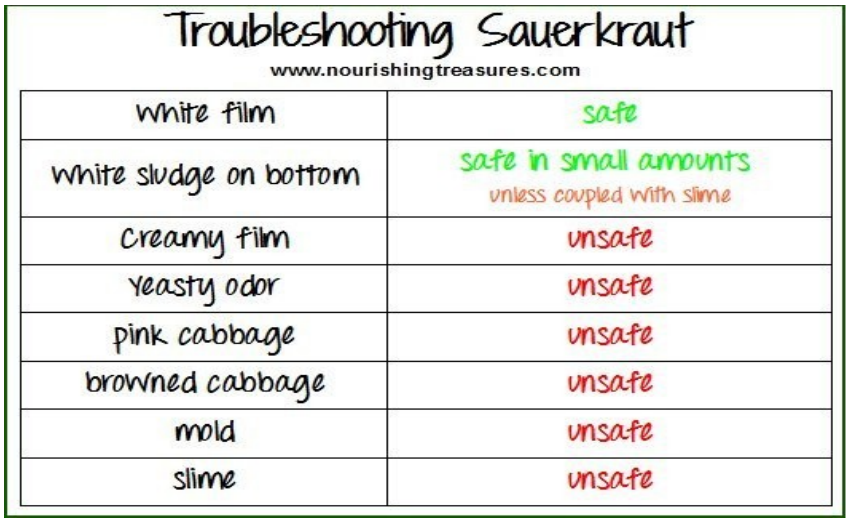
White Film, Slime, Sediment, and Starter Cultures

Although mold is harmful, white film is not. This is just your friendly probiotic yeast at work. This happens more often when cabbage isn't properly submerged under the brine, or the container isn't sealed well.

Slime, however isn't to be tolerated. This is most often the cause of too little salt, or salt that wasn't evenly mixed into the cabbage.

What about white sediment on the bottom of the jar? A small amount is normal and a good sign. When coupled with slimy sauerkraut, it's a bad sign.

Starter cultures – are they bad? Although unnecessary, they aren't to be frowned on. Starter cultures can ensure consistency and speed up the fermentation process. Controlling a ferment in this manner can give consistent results.



The Bottom Line

If you're aiming to make sauerkraut, you want to be sure you do all you can to encourage the good bacteria to grow (correct salt ratio), and to keep the bad bacteria out (suffocate them!). It's part art, but mostly science.Since we know what environment the good bacteria prefer, and what the bad ones don't, it should be easy to get great results with sauerkraut.

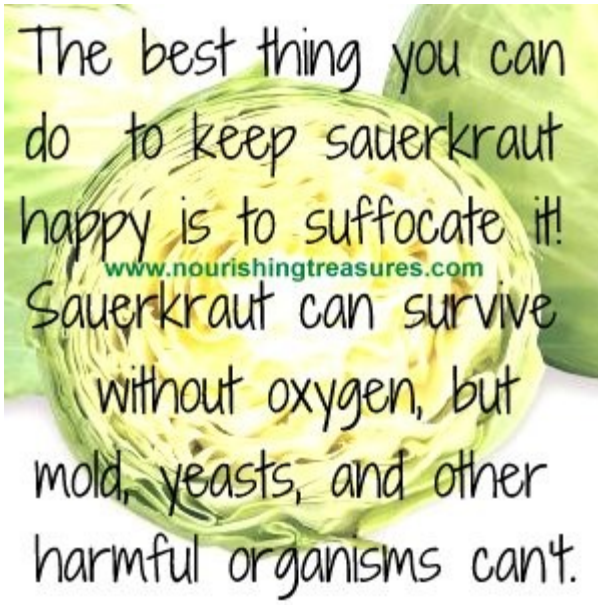
What I Learned

What I learned was oxygen IS a very important factor. Although I thought it was over-rated at first, I believe after educating myself that **it is one of the most important factors of all.**

I also learned how harmful mold can be – and more importantly, how to use it as a sign things are going wrong.

I learned we can't trust trends. Just because "everyone" has been using a certain jar set-up for the last decade, doesn't mean it's ideal. Accessibility and low cost are motivators, but we need to learn the science behind fermenting before we blindly trust a popular method.

At the same time, we can't dismiss new methods solely because they are modern. I love my dishwasher, and I like not having to do them all by hand. The end result is the same – clean dishes. Similarly, I love my "modern" jars, and since they gives the same results as a traditional method, I don't feel compelled to give them up.



After writing this post I began Sauerkraut Survivor - my little experiment to see just which jars provided a safe fermentation. If you're interested, in my final report, you can view it here:

http://www.nourishingtreasures.com/index.php/2012/07/03/sauerkraut-survivor-final-report/

You asked, we answered…

Sources: mold 1, mold 2, mold 3, mold 4, Micro-Organisms and Fermentation, Handbook of Fermented Functional Foods, sauerkraut fermentation stages, controlled fermentation of sauerkraut pdf, Fermented Fruits and Vegetables, a Global Perspective, pickle product problems pdf