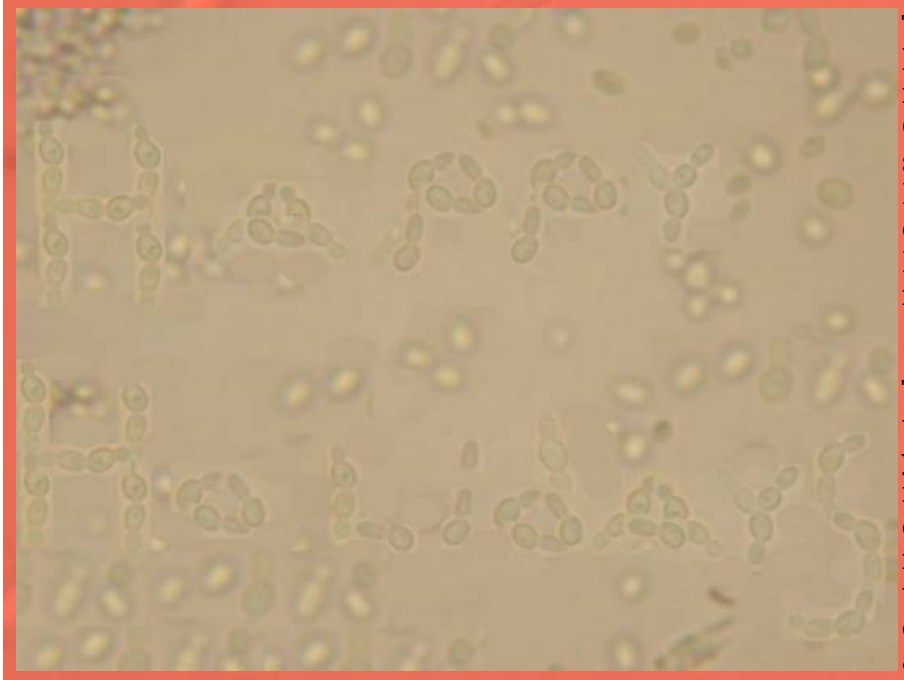
Tom Volk's Fungus of the Month for December 2002

by Tom Volk and Anne Galbraith

This month's fungus is *Saccharomyces cerevisiae*, the bakers' and brewers' yeast

For the rest of my pages on fungi, please click TomVolkFungi.net
For a special holiday treat, be sure to visit Fungi that are necessary for a merry Christmas



This month's fungus makes many of our holiday festivities even more festive in many ways, from the "spirits" of Christmas, to bread-making, to important scientific research. It's a very appropriate Fungus of the Month whether you're celebrating Christmas, Hanukkah, or Kwanzaa. Even its scientific name is festive, meaning ***"the sugar fungus of the beer."***

The term "Yeast" is a morphological term that refers to a one-celled fungus. Most yeasts, including *Saccharomyces* reproduce by budding, where the daughter cells bleb off from a small pore in the side of the mother cell, as shown to the left. Sometimes the buds do not completely split off from the mother cells, and chains of yeast cells can be formed, as if to communicate with us. A few yeasts, like *Schizosaccharomyces*, the "splitting sugar fungus," reproduce by simple fission, where the mother cell divides through the center into two more or less equal parts.

Although most fungi are multicellular, growing as filaments called hyphae, there are about 500 species of yeasts in 60 genera, or about 1000 species of yeasts or yeast-like organisms. Some fungi are called yeast-like because they exist in yeast form for part of their life cycle, but can be hyphal for a significant portion of it. Most yeasts and yeast-like organisms are affiliated with the Ascomycota, but there are a significant number of Basidiomycota yeasts, including *Cryptococcus neoformans* (teleomorph *Filobasidiella neoformans*). There are even a couple species of Zygomycota yeasts. There are also many species of single-celled Chytridiomycota, but these are mostly internal parasites of plants, animals and other fungi and do not reproduce by budding or fission. Thus these single-celled chytrids, including *Synchytrium, Batrachochytrium*, and *Physoderma* are not called yeasts.

The world's most important yeast, *Saccharomyces cerevisiae*, has been a very useful fungus for humans for many millennia. To the right are the ruins of an ancient bakery atop Masada, in Israel overlooking the Dead Sea. TJV visited Masada in 2000 on a fungi collecting trip with Karen Wikler, Matt Rademaker, and Dan Czederpiltz. This was one of our side trips-- We weren't looking for fungi on Masada.

Fermentation of sugar with *Saccharomyces* proceeds according to the (unbalanced) chemical reaction:

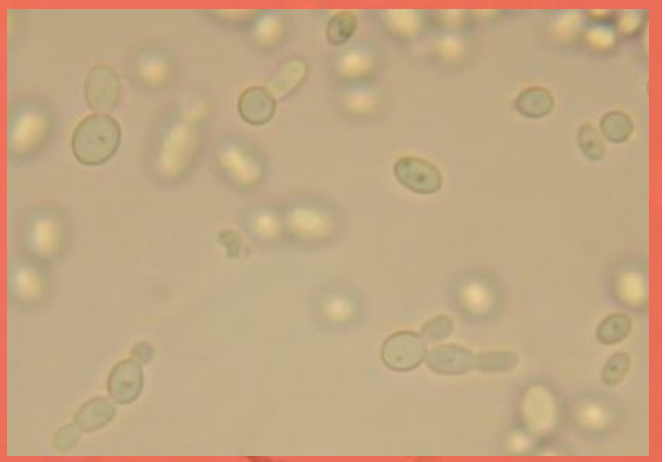
$C_6H_{12}O_6 + H_2O \rightarrow CO_2 + CH_3CH_2OH$ (or C_2H_5OH)

or

sugar (glucose) plus water yields carbon dioxide plus ethanol (ethyl alcohol)

In bread making, the carbon dioxide is the more important of the two products, with the evolving gas causing the bread to rise. There is alcohol production, but the alcohol quickly evaporates on baking. In beer and wine-making, the alcohol is the important product, although the carbon dioxide may be used in beer and champagne. The same species, *Saccharomyces cerevisiae*, is used in both processes, but different strains (varieties) of the fungus are used. The bread making strain, for example, is genetically selected to produce more carbon dioxide and much less alcohol, while the opposite is true of the spirit-making strains. Thousands of years ago, naturally occurring yeasts "contaminated" some flour or drinks, and the results were pleasant for the people using the contaminated products. Eventually, people learned how to cultivate these fungi on purpose (even before they knew what they were) and to select the strains that would work best in their process using whatever materials were common in that region. This fermentation was probably discovered and re-discovered many times and has resulted in a wide variety of leavened foods, as well as an even greater variety of alcoholic beverages. Some of these natural yeasts are still used in sourdough starter, which actually contains a number of ecologically balanced micro-organisms in its own micro-ecosystem. Many wineries still use yeasts, including *Saccharomyces ellipsoideus*, that occur naturally on grapes. In fact, each type of alcohol product and alcohol maker has its own proprietary strains of yeasts, specially adapted and selected for that product.

In the olden days, you had to keep a fresh supply of yeast on hand if you wanted to bake bread or ferment beverages. Now you can go to virtually any grocery store in most parts of the world and buy freeze-dried yeast that can be ready to ferment in just a few minutes. Just add some warm water, a little bit of sugar or some source of carbohydrate, and it's ready to go. Tom Volk's mother always added a pinch of ginger to the mix, just for good luck. Maybe the yeast wasn't so reliable back in the olden days?



Saccharomyces cerevisiae has also been a very important genetic tool. It has been used in genetic studies for many decades. Since it is very small and unicellular, large numbers of the yeast can be grown in culture in a very small amount of space, in much the same way that bacteria can be grown. However, yeast has the advantage of being a eukaryotic organism, so the results of genetic studies with yeast are more easily applicable to human genetics. It reproduces abundantly and quickly, producing more haploid cells. They can also mate with an appropriate strain, later undergoing karyogamy and growing as a diploid. The diploid can undergo meiosis to form ascospores, recombinant haploid progeny unlike either parent. Mitosis and meiosis can be more easily studied in these organisms. Lee Hartwell, from the Fred Hutchison Cancer Research Center in Seattle, won the Nobel Prize in Medicine in 2001 for his pioneering work on the mitosis genes in *S. cerevisiae*. He shared the prize with R. Timothy Hunt and Paul M. Nurse of the Imperial Cancer Research in London, who work on another yeast, *Schizosaccharomyces pombe*. The genes they discovered and characterized in the yeast as a model organism have led to some important discoveries in fighting cancer in humans. Read more about the genes they discovered and offshoots of their work here.

S. cerevisiae was the first eukaryote to have its entire genome sequenced. See this page from Stanford for more about the yeast genome.

Most yeast species are not harmful to humans, but a significant number can act as pathogens, causing mycoses. The most common of these is *Candida albicans*, the cause of up to 90% of yeast infections in humans. *Candida albicans* is part of the normal flora (mycota) of the human body, but is usually kept in check by other fungi and bacteria. When conditions are disrupted by antibiotics or other sorts of treatments, *Candida* can begin to overgrow and cause problems. *Cryptococcus neoformans* another pathogenic yeast, famous for causing diseases of the nervous system, especially cryptococcal meningitis. *Pneumocystis carinii* is a leading cause of pneumonia in AIDS patients. There are also three dimorphic pathogens, *Blastomyces dermatitidis*, *Histoplasma capsulatum*, and *Paracoccidioides brasiliensis*, that can change from a mycelium to a yeast form in the body, thus evading the immune system. There are also a few yeasts that can produce mycotoxins that harm people if ingested. One

such yeast is *Debaryomyces*, a yeast which you have probably seen, felt, and eaten. Have you ever taken hot dogs out of the freezer, and they felt slimy, but you ate them anyway? That's *Debaryomyces* causing the sliminess as it actually grows at freezing temperatures at high salt concentrations and produces a nasty mycotoxin that diffuses into the hot dogs. Better switch to macaroni and cheese...

This month's FOTM co-author is Anne Galbraith, one of my colleagues in the Department of Biology. She works on the genetics of cell division in *Saccharomyces cerevisiae*. Her research involves understanding the roles of two cell cycle genes, *CDC7* and *DBF4*, in yeast meiosis using genetics, molecular biology, cell biology, and biochemistry. It is known that these genes help initiate DNA replication in mitotic cells, but no one knows what they do in meiosis! For additional information, visit her home page You can learn more about her research here.

We hope you learned something about *Saccharomyces cerevisiae* today. You should be thinking about how the yeast helps you to enjoy the holiday season, whether it be in leavened foods or in beverages. We expect you to discuss this page and Fungi that are necessary for a merry Christmas at your holiday dinners and celebrations. Be sure to tell your friends to visit. :) Happy Holidays!

If you have recommendations for future FOTM's please write to me at volk.thom@uwlax.edu. Or maybe you'd like to be co-author of a FOTM?

If you have anything to add, or if you have corrections or comments, please write to me at volk.thom@uwlax.edu

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